Drivers of change and their impacts on the WEFE nexus in the Mediterranean region

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This document should be cited as:
García-Vila, M., Rivera Ferre, M.G., Chfadi, T., El Kenawy, A., Branquinho, C., Lorenzo-Lacruz. J., Menichetti, E., Mohammed, S., Sanz-Cobena A., 2024: Drivers of change and their impacts on the WEFE nexus in the Mediterranean region. In: Interlinking climate change with the Water-Energy-Food-Ecosystems (WEFE) nexus in the Mediterranean Basin. [Drobinski, P., Rivera Ferre, M.G., Abdel Monem, M., Driouech, F., Cramer, W., Guiot, J., Gattacceca, J.C., Marini, K. (eds.)]. MedECC Reports. MedECC Secretariat, Marseille, France, pp. 57-139, doi: 10.5281/zenodo.13378622

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Chapter 2

Drivers of change and their impacts on the WEFE nexus in the Mediterranean region

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Executive Summary

The Mediterranean region faces a variety of drivers of change that operate at different spatial scales. These include climate change, land use changes, habitat alterations, air, soil and water pollution, population growth, industrialisation, urbanisation, lifestyle changes and conflicts (war). These drivers collectively impact the region's ecological and societal dynamics, including all the components of the WEFE nexus. Since the WEFE components follow complex hierarchical links and feedback, changes in one component can have cascading effects on other interconnected components, creating a complex web of interactions. To reduce the negative impacts of the drivers of change, the interlinkages among the WEFE components must be thoroughly evaluated at local scale, under a holistic view, to enable better-informed decisions and effective and more robust management policies. This chapter underscores the importance of recognising the interconnectedness of water, energy, food, and ecosystems in the Mediterranean region and the need for comprehensive assessment and management strategies to address the challenges posed by external environmental and social stressors.

Water security in the Mediterranean faces a multifaceted challenge stemming from a blend of factors, such as climate change, rapid population expansion in urban areas, unsustainable resource management and land use, and agricultural practices. The impacts of the drivers of change have negative effects on the availability and quality of water resources, but this effect will cascade, through a series of interactions, on the other components of the WEFE nexus, including crop yield reductions, alterations of agricultural commodity prices, reduction of electricity production and generation efficiency, desertification, habitat loss, and affecting vulnerable species.

Climate change, pollution, changes in diets, population growth, and urbanisation are inter-connected and contribute to the emergence of vulnerabilities through impacts on food availability, access and quality. There are substantial differences in terms of food security between Southern Europe and North Africa. Business as usual responses to address food security related challenges through industrialisation can lead to adverse effects on other WEFE components, such as increased soil and water pollution and GHG emissions, degradation of underground water resources, salinisation, loss of agrobiodiversity, and increase of energy demand and further greenhouse gas emissions.

The energy security of the Mediterranean region is significantly affected by a multitude of challenges from both the offer and demand sides. The escalating energy demands in the Mediterranean region are attributed to population growth, urbanisation and industrialisation. Moreover, addressing energy inequality is essential, as certain population segments have abundant energy access while others face deprivation. The dependence of the area on power generation methods that require significant amounts of water exposes them to the risk of decreased water availability and difficulties in managing water resources, due to the effects of climate change and the competition with other sectors. Similarly, competition for other resources to produce solar or wind energy, such as land for agricultural purposes and ecosystem services, further exacerbates the complex interplay within the nexus framework, showing the need to promote holistic analyses to address such challenge.

The pressures exerted on Mediterranean ecosystems impact their health resulting in ecosystem degradation, loss of biodiversity among others. These modifications disrupt the provision of multiple ecosystem services (namely, provisioning, regulating, and cultural) which subsequently have direct impacts on WEFE components as well as further cascading effects on other components of the WEFE.

2.1 The complexity of assessing the impacts of drivers of change on the WEFE nexus: the rationale of the approach

The ecosystems of the Mediterranean region provide many important resources and advantages, such as the ability to grow food for human consumption and industrial use, to enjoy the outdoors, and to foster artistic, cultural, and recreational pursuits. However, the physical parameters of the region, combined with the region's complex geographical (e.g. coastal vulnerability, water scarcity) and political issues (e.g. migration and refugee crises, territorial disputes), make it difficult to achieve environmental goals. Like other global ecosystems, the state of WEFE components and interdependencies between them serve as the defining characteristics of the Mediterranean ecosystem. Despite this, the spatial and temporal configuration of the WEFE nexus is undergoing substantial shifts linked to the drivers of change.

Drivers of change refer to all those factors that affect nature, anthropogenic assets, nature's contributions to people, and a good quality of life (Pörtner et al., 2021). A direct driver exerts immediate and noticeable impacts on the WEFE system, and can involve both natural change, such as earthquakes and volcanic eruptions, and anthropogenic factors like climate change, alterations in land and sea use, and air, water, and soil pollution (Sharif et al., 2020). On the other hand, indirect drivers of change are those that alter and influence direct drivers as well as other indirect drivers (also referred to as "underlying causes") and include, among others, demographic trends (population growth, urbanisation), technological innovations, lifestyle changes, and war (Odada et al., 2009). The impacts on the WEFE components are not isolated but are also the result of various interactions between two, three, or even all four WEFE components, such as water-food, energy-water, food-energy, ecosystems-water-food or water-food-energy interactions, among others. Within the WEFE system, cascading effects and interactions transpire across various temporal and spatial scales, ranging from local and short-term to regional, global, and long-term. Those interactions and cascading effects operate at a hierarchy of spatio-temporal scales. The complexity of this web of interactions is a big reason why the WEFE system in the Mediterranean changes in ways that are hard to predict. It should be noted here that, in the context of the WEFE system, the establishment of precise boundaries is of paramount importance to conducting a comprehensive assessment of the impacts of the drivers of change as well as of potential solutions. These 'boundary conditions' define the system's scope and spatial-temporal limits. The delineation of the system encompasses key parameters, including water resources, energy production, food systems, environmental ecosystems, and the geographic area or region under consideration. These boundary conditions may extend to include policy and governance structures that impact the WEFE system. In defining these boundaries, it is imperative to create a structured framework for understanding the interplay of drivers, components, and influences within the WEFE system, ensuring a comprehensive and contextually relevant evaluation. Also, understanding the complex interactions between the nexus components and how they can change and impact each other under different scenarios is crucial for identifying both positive synergies (e.g. sustainable land use and biodiversity) and negative trade-offs (e.g. hydropower dams and ecosystems) between these components. This approach makes it possible to design cross-sectoral adaptations, as shown by Kebede et al. (2021). Furthermore, it enhances our understanding of how these interactions impact the long-term health and productivity of ecosystems.

2.1.1 Drivers of change related to WEFE in the Mediterranean

2.1.1.1 Climate change

The Mediterranean is situated in a transitional zone between the mid-latitude and sub-tropics. The Mediterranean region has been labelled a "hotspot" for climate change due to its predicted warming and drying (Diffenbaugh et al., 2007; Giorgi & Lionello, 2008; Lionello & Scarascia, 2018). There is strong evidence that the twentieth century was marked by a general warming and by a more pronounced summer warming (El Kenawy et al., 2012; El Kenawy et al., 2019; Pfahl, 2014; Ulbrich et al., 2012). The observed rates of climate change are higher than global trends for most variables (*Figure 2.1*). Similarly, since 1950, heatwaves have become more frequent (Baldi et al., 2006; Ibrahim et al., 2021; Kuglitsch et al., 2010). Also, both the frequency and severity of droughts have increased (Cook et al., 2016;

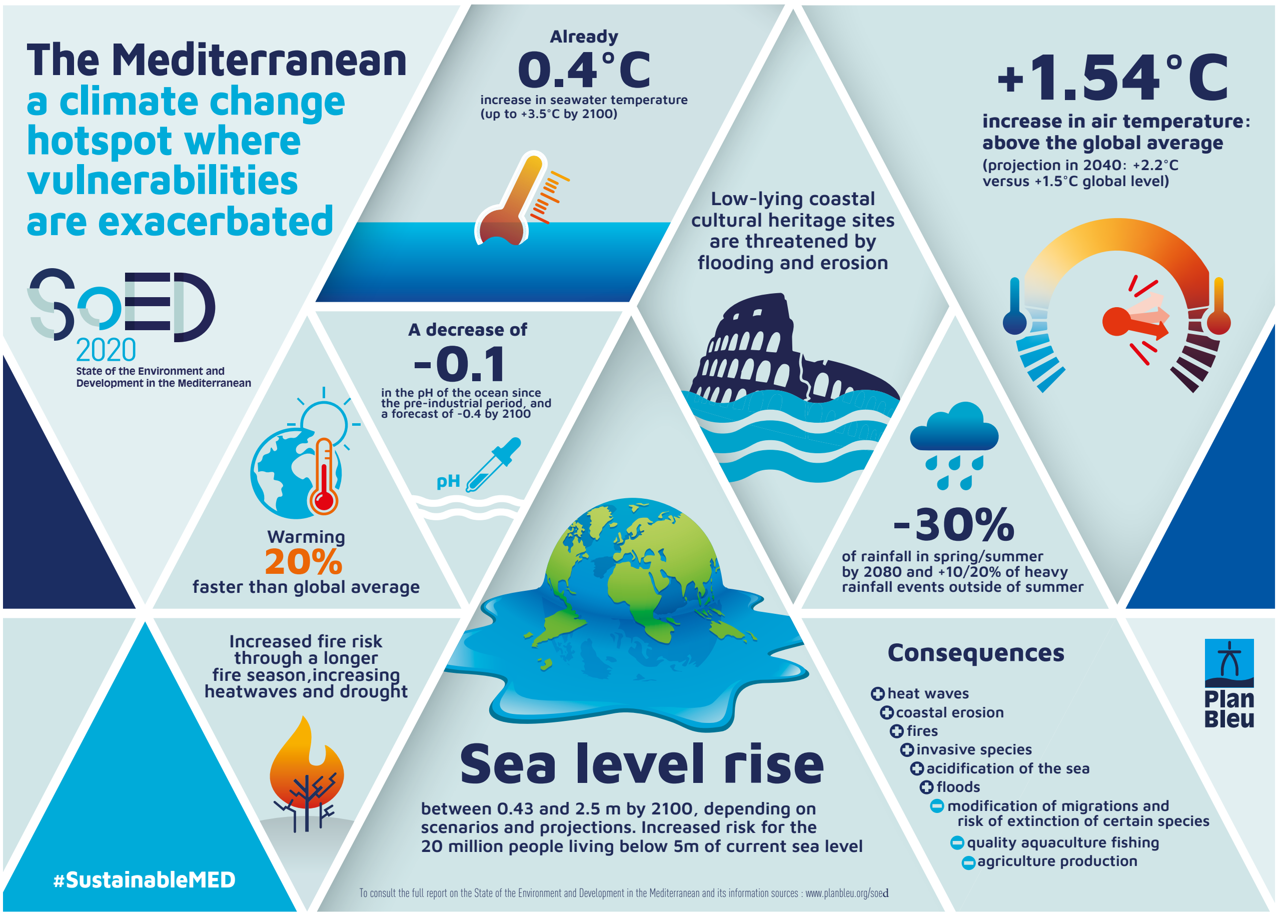

Figure 2.1 | Climate and environmental change in the Mediterranean.
Source: UNEP/MAP & Plan Bleu (2020).

Hoerling et al., 2012; Sousa et al., 2011; Tramblay et al., 2020a; Vicente-Serrano, 2007). These observed changes have been in line with global trends and can be attributed in part to decadal variability associated with circulation patterns like the North Atlantic Oscillation (NAO) (Meyssignac et al., 2011; Ozgenc Aksoy, 2017; Raymond et al., 2018; Tsimplis et al., 2013).

The Mediterranean region's climate will likely become warmer and drier in the twenty-first century (*high agreement; robust evidence*, especially for air temperature) (Drobinski et al., 2020b; Lionello & Giorgi, 2007; Nashwan et al., 2020; Planton et al., 2012; Taïbi et al., 2019; Zittis et al., 2019). The results show that future warming is expected to occur across the year, with the effects being more pronounced during summertime and on land, as opposed to the ocean (El Kenawy et al., 2013; Giorgi & Lionello, 2008). More frequent high-temperature events and heatwaves are thought to be linked to these increased temperatures (Jacob et al., 2014). Summer rainfall is expected to decrease by 10–15% in southern France, northwestern Spain, and the Balkans as a result of a global atmospheric temperature increase of 2°C and by as much as 30% in Türkiye and Portugal (Vautard et al., 2014). In recent decades, summer temperatures in the Mediterranean region have risen at a faster rate than those observed in the Northern Hemisphere and even more rapidly than the global mean, along with an increase in the frequency of intense heat waves. It is projected that future warming in the Mediterranean region will be 25% faster than the global mean, with summertime temperatures increasing 40% faster than the global mean (Lionello & Scarascia, 2018). The aforementioned consensus is established by taking into account multiple lines of evidence—observations, regional and global model projections, and an extensive comprehension of the underlying mechanisms—all of which contribute to a high level of confidence regarding observed and projected warming patterns in the Mediterranean region

(Doblas-Reyes et al., 2021). With respect to the pre-industrial period, average global warming of 1.5°C is predicted to reduce mean rainfall by 4% in much of the region, especially in the south, and increase the length of dry spells by 7% (Lionello & Scarascia, 2018). Reduction of precipitation will affect all seasons in central and southern Mediterranean areas, with maximum reduction for winter precipitation (-7% for the southern Mediterranean region). The length of meteorological dry spells (Schleussner et al., 2016) and meteorological, hydrological, and agricultural droughts is expected to increase significantly (IPCC, 2021; Kelley et al., 2015; Tsanis et al., 2011). In the same context, by 2100, the coast of southern Italy is predicted to be severely flooded (Scardino et al., 2022). Streamflow patterns are projected to shift, with spring's high flows diminishing earlier, summer's low flows becoming more intense, and winter's greater and more erratic discharge occurring earlier. Flooding is more likely to happen in most of the Mediterranean Basin because extreme rainfall is expected to get worse and happen more often (e.g. Drobinski et al., 2018; Tramblay & Somot, 2018). As stormwater management systems are generally not well planned in the Mediterranean, people who live in flood-prone areas are more exposed and vulnerable (Llasat et al., 2013).

Rising temperatures, coupled with drought and land-use change, are predicted to increase fire risk, lengthen fire seasons, and increase the frequency of large, severe fires (Gouveia et al., 2017; Santonja et al., 2017). It is also anticipated that future climate change will exert significant and diverse effects on marine ecosystems. Sea surface temperatures in the Mediterranean demonstrate a complex panorama of both regional and temporal variability with a prevailing warming tendency in sea surface temperature (SST), which is likely to continue under future warming scenarios (Axaopoulos & Sofianos, 2010; Pastor et al., 2018; Shaltout & Omstedt, 2014). In accordance with SST rise, a consistent decrease in pH in the Mediterranean Sea has been observed, signalling ocean acidification (Flecha et al., 2015; Kapsenberg et al., 2017). This phenomenon is attributed to the absorption of CO_2 from the atmosphere (Kapsenberg et al., 2017; Solidoro et al., 2022), with acidification particularly pronounced in the Western basin (Hassoun et al., 2015). Nevertheless, despite this acidification, the Mediterranean Sea remains highly supersaturated in calcium carbonate minerals (Hassoun et al., 2015). Projections indicate that acidification will persist, with the Eastern Mediterranean facing particularly acute effects (Reale et al., 2022a, 2022b). In the high IPCC emission scenario SRES-A2, nitrates are expected to build up in the seawater around the Mediterranean, but phosphorus does not seem to be changing. This means that low-phosphorus areas will increase (Richon et al., 2019).

Due to recent and future climate change, changes in the provision of ecosystem services may exacerbate social conflict and cause people to be forced to relocate (van der Geest et al., 2019). A representative example is found in the Egyptian Delta, where salinisation and erosion of agricultural lands forced farmers to relocate (Ahmed et al., 2014). Climate change and drought, in particular, have emerged as substantial contributors to the Syrian conflict, as they induced forced migration from the eastern to mainland regions of the country (Butler, 2018; Gilmore et al., 2018; Ide, 2018; Selby et al., 2017). When resources are scarce, attempts to mitigate one risk may weaken human communities or make other risks worse. The Mediterranean Basin has a long history of political and social unrest because of its complex cultural, geopolitical, and economic landscape. Extra climate-related stresses in the Mediterranean Basin increase human insecurity by making local communities there more susceptible to harm. As such, there has been an increase in vulnerability due to mismanagement and overexploitation of natural resources over the past century (Bremberg et al., 2022; Ide, 2018; Mycoo et al., 2022).

2.1.1.2 Land Use and Land Cover Changes (LULCC)

The high importance of Land Use and Land Cover Changes (LULCC) is recognised by the UN for fields ranging from biodiversity conservation to food security, disaster risk reduction, climate change, and sustainable development. The Mediterranean region has inherited a mosaic-structured landscape determined by heterogeneous topography, soils, water resources and vegetation (Lana-Renault et al., 2020). In this sense, there is a clear contrast in LULCC trends between the northern Mediterranean countries (225 million inhabitants) and the southern and eastern countries (335 million inhabitants). The land cover (LC) of an area is what is observed at the surface, with either vegetation and naked areas (e.g. from natural to agricultural ecosystems) or anthropogenic constructions (e.g. urban surfaces). Land Use (LU) is the management of those areas, to maintain or change their cover. One of the main drivers of LULCC is population dynamics, which show highly contrasting patterns in the Mediterranean: northern regions have seen population growth stabilised (FAO & Plan Bleu, 2018; PRB, 2019), causing diverging patterns of land use (i.e. land abandonment in low-productive mountainous areas and concentration of economic activity in valleys and coasts), and population growth in the southern and eastern regions has resulted in increasing demand for land for agricultural production and livestock pastures (FAO & Plan Bleu, 2018; Winkler et al., 2021).

A declining rural population in northern Mediterranean countries has led to the abandonment of crops and farmland, and to the reduction of livestock grazing, with the subsequent regeneration of forests and scrublands (Debussche et al., 1999; García-Ruiz & Lana-Renault, 2011; Moreno-de-las-Heras et al., 2019; Vicente-Serrano et al., 2019). Additionally, extensive afforestation programmes have been implemented in recent decades by northern countries' governments to enhance the environmental value of abandoned farmlands in the highlands and control hydrological and soil erosion processes (Ortigosa et al., 1990; Vallauri et al., 2002). Altogether, this has resulted in relevant environmental consequences, including changes in the water cycle (see *Section 2.3.1.1*), soil erosion and hydrological connectivity alterations, and biodiversity changes (see *Section 2.5.1.2*), among others. Moreover, revegetation processes have relevant implications regarding wildfire risks due to increased fuel load and biomass volume (Lana-Renault et al., 2020; Pausas & Fernández-Muñoz, 2012; Pausas & Millán, 2019). Intensive agriculture experienced significant growth in the more populated lowlands and coastal areas, with the goal of meeting the demand of national and international markets (Bellot et al., 2007; Serra et al., 2008). These changes have led to a significant expansion of irrigated areas in order to increase agricultural productivity and favouring the cultivation of new crops with higher requirements than the traditional Mediterranean triad (grapes, grains, and olives) (Tanrivermis, 2003). The most remarkable example of this process has been seen in Spain, where the extent of irrigated areas has doubled over the last six decades, from 1.8 million hectares in 1961 to 3.7 million hectares in 2019 (FAO, 2023). In the Southern Mediterranean, countries with higher demographic pressure have followed strategies based on land clearing, livestock breeding and wood gathering for heating (Barrow & Hicham, 2000; Johnson, 1996). These processes resulted in smaller forest areas than the ecological potential of southern and eastern countries (FAO, 1994; Lana-Renault et al., 2020), where high human pressure on forest ecosystems prevails in rural and mountainous areas, resulting in woodland degradation (Chebli et al., 2018; del Barrio et al., 2016; Nsibi et al., 2006). Still, intense urbanisation and associated expansion of agricultural areas are the main causes of deforestation in southern and eastern regions (Belaid, 2003; del Barrio et al., 2016).

Tourism development is another key factor in explaining LULCC trends. The Mediterranean region ranks amongst the world's top tourist destinations, accounting for 30% of global tourist arrivals (UNWTO, 2017). International tourists grew from 58 million in 1970 to 349 million in 2015, and these figures are expected to grow to reach 500 million by 2030 (UNWTO, 2017). The spatial pattern of tourism occupation is mainly concentrated in coastal areas, where strong urbanisation has occurred across the Mediterranean Basin (Shalaby & Tateishi, 2007; Sonmez & Sari, 2007), leading to significant forest regression and habitat fragmentation caused by urban sprawl (Hepcan et al., 2012; Jomaa et al., 2008) and a significant increase in water demand (see *Section 2.3.1.2*).

Past assessments and future predictions of LULCC involve a high degree of uncertainty (Anav et al., 2015). The future of forest cover in the Mediterranean is uncertain, with climate change and human activities posing significant challenges. Touhami et al. (2023) highlights the impact of the projected warming climate on forest ecosystems in Tunisia. Donmez et al. (2011) provides specific climate and productivity projections, providing estimations of net primary productivity in Turkish pine forests. However, numerous studies stress the need for mitigation and adaptation strategies to sustain forest ecosystem services in the face of changing land use and climate (e.g. Appiagyei et al., 2023).

2.1.1.3 Pollution

Industrial pollution is a major environmental concern in the region, as pressures from land-based sources remain high (EEA, 2014). Attention is given to key sectors: the production of energy, manufacture of refined petroleum products, treatment of urban wastewater, food packing, and manufacture of cement and metals. In particular, the manufacture of refined petroleum products is responsible for about 60 to 70% of nutrients and oxygen-depleting substances present in pollution. Southern and eastern countries are responsible for the largest share of biochemical oxygen demand measured in a water sample during 5 days of incubation at 20°C (BOD5) emitted by this sector for the whole Mediterranean. This means that while energy commodities are traded around the region, the adverse effects in terms of local pollution are concentrated in few areas. Chromium and cadmium emissions are also associated with energy refining processes (EEA & UNEP/MAP, 2014). Instances of industrial emissions, particularly in the Southern Mediterranean, have registered levels exceeding 100 µg m^{-3} of fine particulate matter (PM2.5), in stark contrast to the global average of 39.6 µg m^{-3} and the European Union's average of 14.2 µg m^{-3} (UNEP/MAP & Plan Bleu, 2020). Alarmingly, two-thirds of Mediterranean countries surpass the World Health Organization's recommended threshold for air pollution concerning both particulate matter and ozone (UNEP/MAP & Plan Bleu, 2020).

Disturbingly, nearly half (49%) of Mediterranean water bodies fail to achieve a good environmental status (EEA et al., 2020). The region generates a staggering 184 million tonnes of solid waste annually, characterised by low recycling rates. Additionally, the presence of emerging contaminants, such as pharmaceuticals, cosmetics, flame retardants, and plastic additives, poses a significant threat. These contaminants have poorly understood life cycles and impacts, and are potentially toxic and resistant to conventional wastewater treatment methods (EEA et al., 2020). Pollution in the Mediterranean is predominantly attributed to heavy metals, exacerbated by the continuous discharge of both treated and untreated wastewater. This pollution stems from various sources, including the production and processing of metals, energy production, pulp and paper manufacturing, chemical industry activities, and intensive farming and aquaculture practices (Ochoa-Hueso et al., 2017; Sicard et al., 2023). Heavy metals and mineral oils are responsible for approximately 60% of soil contamination in the region (Ballabio et al., 2018; Ferreira et al., 2022; Panagos et al., 2013). Nevertheless, the levels of heavy metals (cadmium, mercury, and lead) in coastal waters, assessed against Background Assessment Concentrations (BAC) and Environmental Assessment Criteria (EAC) through bivalves and fish, generally demonstrate an environmentally acceptable status (UNEP/MAP & Plan Bleu, 2020). On the other hand, the Mediterranean region stands as one of the most severely impacted areas globally in terms of plastics, with an alarming 50% of marine litter found on the seabed being composed of plastic. Microplastic concentrations on the surface of the Mediterranean Sea surpass acceptable limits, exceeding 64 million floating particles per square kilometre. Additionally, underwater noise pollution is a growing environmental concern with significant implications for marine life in the Mediterranean.

2.1.1.4 Population growth, industrialisation, urbanisation, migration, lifestyle changes, war

About 6% of the global population make home in the Mediterranean region (UNEP/MAP, 2016). According to World Bank data (*Figure 2.2*), total population growth in the Mediterranean region has remained at about 1% yr^{-1}, but with clear differences between regions and countries, a change over the decades, and a clear impact of the major conflicts that have affected the region (World Bank, 2021). In absolute terms, the Mediterranean population grew by 259 million inhabitants in fifty years (+84%), from 1970 to 2020, to reach 542 million people. Eighty-five percent of this increase (216 million inhabitants) occurred in the South and East Mediterranean, as a result of improved economic conditions and improved health services (World Bank, 2021). With current demographic trends, the Mediterranean population is expected to further grow by more than 100 million inhabitants until 2050 (UN DESA, 2022). Again, most of this increase will be concentrated in the South and East Mediterranean, in particular in the two densely populated countries of Egypt and Türkiye, which together represent more than one-third of the Mediterranean population. By

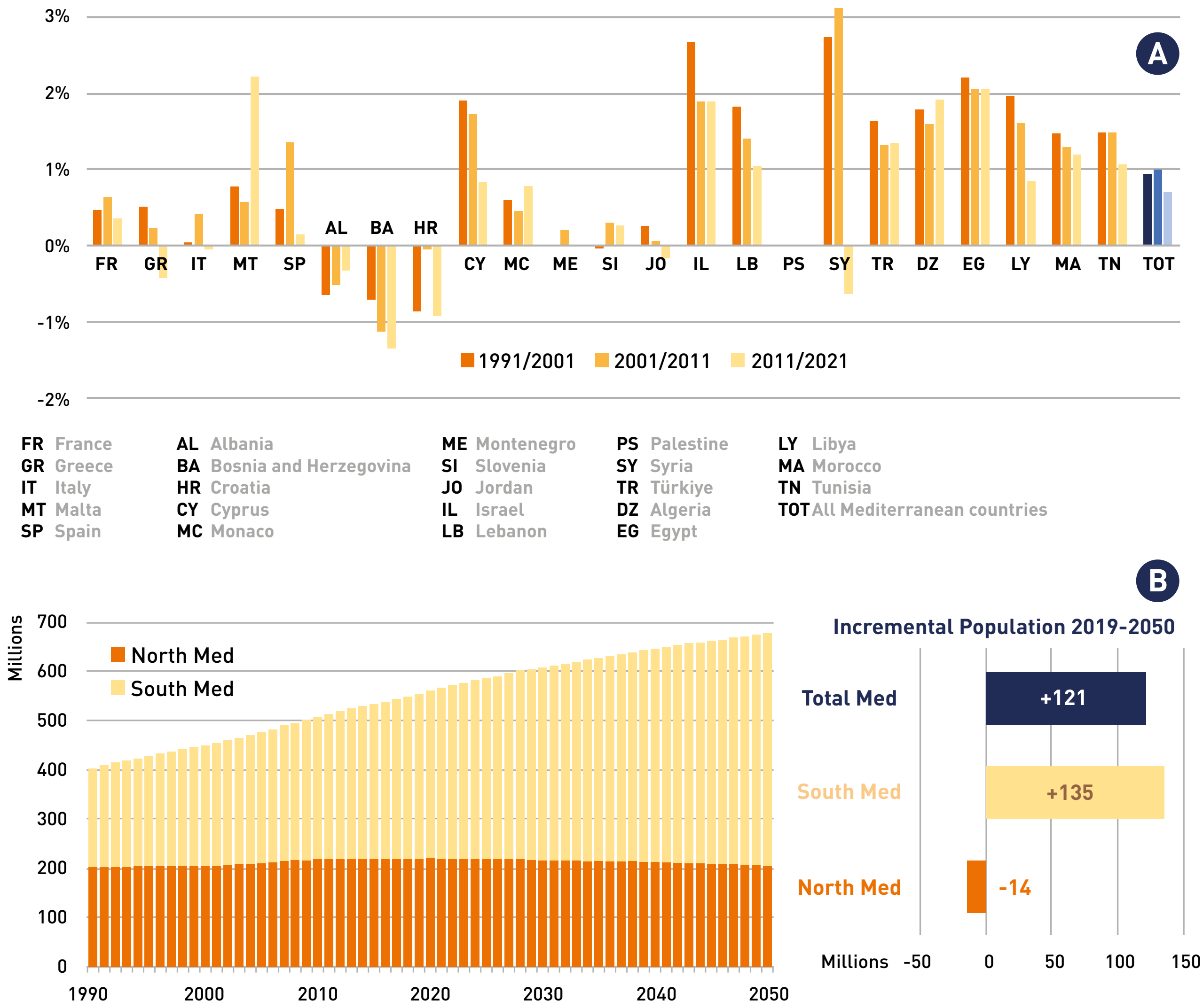

Figure 2.2 | (A) Population growth rates in the countries of the Mediterranean region in recent decades (based on World Bank, 2021) and **(B) current and projected demographic trends in the Mediterranean up to 2050** (OME based on UN DESA (2022).

2050, the southern Mediterranean's share in total Mediterranean population is projected to increase to 70%, while the northern Mediterranean will see its population ageing and its share decrease to 30%. In 2050 nearly half of the Mediterranean population is projected to be concentrated in three countries (Algeria, Egypt, Türkiye) (*Figure 2.2*). Since 1960, the rural population has increased at a lower rate in southern and eastern countries, with stabilisation expected by 2030, and considerably decreased in the northern countries (Lana-Renault et al., 2020; PRB, 2019). Population growth in southern and eastern Mediterranean countries is expected to develop through urban growth, mainly in coastal areas, reaching 75% of urban population share by 2050 (48% in 1960 and 68% in 2015).

Industrialisation and urbanisation are often analysed as sub-processes of modernisation, which is also accompanied by lifestyle changes resulting primarily from technological development. The Mediterranean region has witnessed rapid urbanisation over the past few decades, especially in the northern African and eastern Mediterranean regions, where data shows that the percentage of urban population in 2020 was almost 60% (still lower than the 75% for the Northern Mediterranean), up from slightly above 30% in 1960 (World Bank, 2021). By 2050, the urban population is projected to exceed 70% in both regions, and 80% in Southern Europe (World Bank, 2021). Taking into account increasing population and urbanisation trends, especially in coastal areas, southern and eastern Mediterranean countries will face a particular challenge in enabling sustainable urban development policies. Lifestyle changes have been accompanied by higher consumption of energy and materials. This increase, especially among affluent populations in the Global North, is accompanied by an increase in greenhouse gas emissions elsewhere, and evidence shows that luxury consumption can be more difficult to decarbonise than that of people living at sufficiency level (Millward-Hopkins, 2022). Rapid urbanisation in the Mediterranean region has led to several challenges, including inadequate housing, poor infrastructure, traffic congestion, and air pollution (Battarra & Mazzeo, 2022; Tourret, 2006). In addition, some urban residents in North Africa are living in informal settlements, and in the Eastern Mediterranean some urban areas have limited access to basic services such as water and sanitation (Mancuso et al., 2020). There is a growing awareness of the need for sustainable urban development and the adoption of smart technologies to improve urban infrastructure, transportation, and energy systems (Battarra & Mazzeo, 2022).

Migration plays a significant role in urbanisation in the Mediterranean region. Many people migrate from rural areas to cities in search of better job opportunities, education, and healthcare (Miftah, 2018). In addition to internal migration, many North Africans and sub-Saharans migrate to Europe, including cities in Southern Europe, in search of better economic opportunities (Schwan & Yu, 2018). Urban areas in eastern Mediterranean countries have been a major destination and transit point for refugees and migrants from conflict-torn countries like Afghanistan, Iraq, and Syria (Taghizadeh Moghaddam et al., 2017). Migration is also linked to geopolitical instability, which favours an increasing flux of immigrants from sub-Saharan Africa to Mediterranean countries, further stimulating the demand for energy, food, and water, and thus, further increasing the nexus challenges.

The period following the end of the Cold War has been marked by several wars and conflicts in the Mediterranean region, or in its direct vicinity, which have had very significant repercussions in terms of human lives, and serious effects on health, the economy, and the environment, all of them with close connections to the WEFE nexus. The Arab Spring had a major impact in the region, with effects ranging from constitutional reforms in Morocco and the overthrow of the regime in Tunisia and Egypt, to much more devastating effects in Libya and Syria (Muhammadsidiqov, 2015). The civil wars in Libya, in 2011, and then between 2014 and 2021, have cost thousands of lives and displaced hundreds of thousands of civilians (Müller-Funk, 2023). In Syria, the death toll from the ongoing conflict is in the hundreds of thousands, many of whom are civilians (Üngör, 2023). The war in Syria has also caused the destruction of the country's infrastructure and the displacement of millions of refugees to neighbouring countries, Europe and elsewhere. Finally, the Russo-Ukrainian conflict which started in 2022 represents another major challenge to regional and global peace, and a significant economic impact. Implications for the Mediterranean region include heightened uncertainty and the redirection of public spending towards security and rearmament (Fiott, 2022). WEFE is also impacted, for instance through ecosystems degradation, gas supply problems (see *Section 2.4.1.5*), especially for European countries, and food security challenges (see *Section 2.3.1.3*) for countries that depend on food imports from Ukraine and Russia (Liadze et al., 2023), particularly in the MENA region (Quagliarotti, 2023).

2.1.2 The cascading effects of nexus interactions on WEFE components

The WEFE nexus components and their spatio-temporal interdependencies behave as complex systems. These systems typically include multiple loops and feedback paths between many interacting entities – in this case, the nexus components – together with inhibitory connections and preferential reactions. The complex web of interactions between WEFE components can therefore result in feedback loops through which changes in one WEFE component, mediated by the impacts of drivers of change and associated responses, may result in changes in other WEFE components, as well as in the drivers of change themselves (*Figure 2.3*). For instance, changes in water availability due to climate change (or other drivers of change) can impact food production and energy generation. Reduced food availability may require increasing

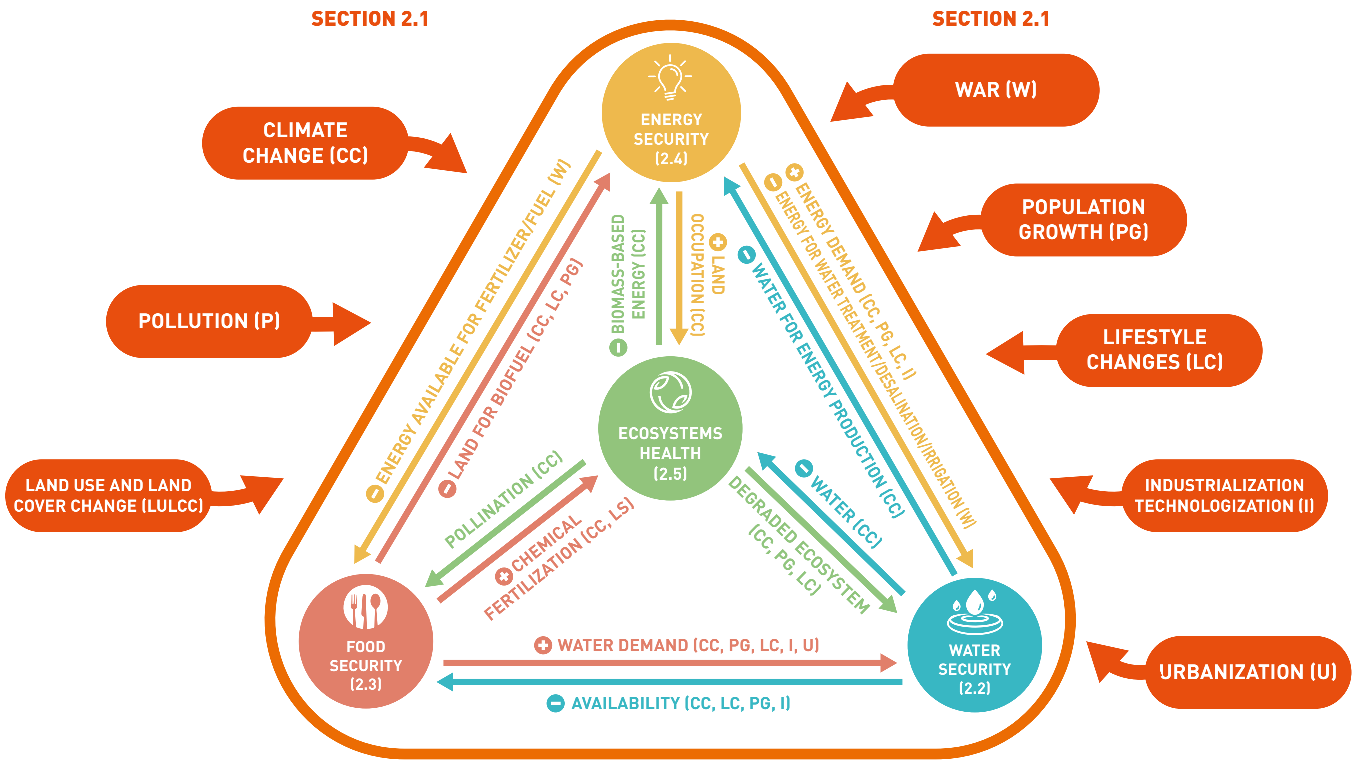

Figure 2.3 | Schematic figure of the rationale of Chapter 2.
Orange outer boxes represent the indirect (right) and direct (left) drivers of change (*Section 2.1*). Inside the box are the nexus components (WEFE) and examples of interactions between them, mediated through the drivers of change (in brackets). These interactions lead to feedback loops and cascading impacts through which nexus components become drivers of change for other nexus components (*Sections 2.2 and 2.5*).

yields, which then requires more water, further reducing the amount of water available for food, energy, ecosystems, and other uses. Furthermore, depending on the techniques used to increase yields, it may result in more greenhouse gas emissions and therefore reinforce climate change. It is important to bear in mind that drivers of change also generate those cascading effects between them. For instance, industrialisation or lifestyle changes contribute to climate change, while climate change may generate conditions that facilitate conflicts for resources, rural to urban migration and thus, increased urbanisation.

In line with this cascade rationale, in this chapter we describe, for each nexus component (water, food, energy, ecosystems), how the drivers of change described in *Section 2.1.1*, impact each WEFE component in particular (*Sections 2.2.1, 2.3.1, 2.4.1 and 2.5.1*). In a second step, we then analyse how those impacts can trigger different interactions and feedback loops between the WEFE components as well as the drivers of change themselves (*Sections 2.2.2, 2.3.2, 2.3.3, 2.4.2, 2.5.2, 2.5.3*). We call these interactions cascading impacts, that can occur downstream and upstream. Given the endless number of potential interactions between the drivers of change and WEFE components, for illustrative purposes and space constraints, we have assessed the mechanisms at play related to one or two drivers of change, for each component, with climate change common to all of them. *Figure 2.3* presents some examples of interactions between WEFE components which reflect the rationale of this chapter.

2.2 The WEFE cascade from the water change perspective

2.2.1 Impacts of drivers of change on water security

Water security in the Mediterranean is threatened by a combination of factors, including climate change, densely concentrated population growth, and unsustainable resource management and land use practices, among others (Daccache et al., 2014; Fader et al., 2020; Scheffran & Brauch, 2014). Climate change has caused an increase in temperature and more frequent and severe drought conditions in many areas of the Mediterranean region (García-Ruiz et al., 2011; IPCC, 2022; Samaniego et al., 2018). Population growth, economic development and lifestyle changes have led to increased water demand, resulting in water shortages and depletion of water resources (Labrousse et al., 2022; Rico-Amoros et al., 2009; Scheffran & Brauch, 2014; Schilling et al., 2012). Moreover, unsustainable resource management and inefficient irrigation practices (Bousbih et al., 2018; Martínez-Granados et al., 2011) have resulted in pollution of water resources (Lutz et al., 2016), groundwater depletion (Dalin et al., 2017; García-Ruiz et al., 2011; Wada et al., 2010). A combination of these factors has created many uncertainties regarding water security in the Mediterranean region that are set to increase during the coming decades in the context of climate change (IPCC, 2022; Malek et al., 2018).

2.2.1.1 Climate change

Some inherent characteristics of the Mediterranean climate (e.g. irregular spatio-temporal distribution of precipitation, very high evaporative demand in summer and high frequency of climate-related extreme events (droughts and floods) (Caloiero et al., 2018a; Deitch et al., 2017; García-Ruiz et al., 2011; Mateos et al., 2023) are being exacerbated by climate change, considerably reducing water security in the Mediterranean region on an increasing basis, with climate change impacts projected to continue occurring in the region with even more frequency and intensity (IPCC, 2022; Noto et al., 2022). Under a 2°C warming scenario, water resources in the Mediterranean region are expected to decrease by 2 to 15% (Cramer et al., 2018) with a likely increase in dry spell lengths (Noto et al., 2023; Raymond et al., 2019; Schleussner et al., 2016). For instance, the Water Scarcity Index is expected to be medium or high for a large portion of the Mediterranean region by 2050 (Caretta et al., 2022). Under future climate change scenarios, per capita water availability in Greece and Türkiye may drop below the generally accepted threshold for severe water stress of 1000 m^3 yr^{-1} in 2030 (Ludwig et al., 2010).

Decreasing water resources in the Mediterranean region has been attributed to changes in precipitation (García-Ruiz et al., 2011), especially in the southern region (Caloiero et al., 2018a), subsequently transmitted to other components of the hydrological cycle (i.e. runoff and river discharges, groundwater levels) (Dai et al., 2009; Finger et al., 2012; Kurylyk et al., 2014; Touhami et al., 2015), and to an observed and projected increase in atmospheric evaporative demand through rising temperature (IPCC, 2022; Noguera et al., 2021; Vicente-Serrano et al., 2018), leading to increasing evaporative losses (Cherif et al., 2020).

Decreasing precipitation trends are predominant in the Mediterranean region (García-Ruiz et al., 2011), with reductions in annual precipitation ranging from 10 to 20 mm per decade due to spatial variability (Achite et al., 2021; Noto et al., 2022; Vicente-Serrano et al., 2019). Decreasing summer trends are even worse, especially in the southern countries (Caloiero et al., 2018a), whereas dry spells have also become more intense, frequent, and protracted (Caloiero et al., 2018b). Future precipitation projections for the Mediterranean region forecast reductions ranging from 5 to 40%, depending on the emission scenario, with critical consequences for other components of the hydrological cycle and freshwater sources (IPCC, 2022). Under a 2°C warming scenario, the frequency and duration of meteorological droughts are projected to double in southern countries, and agricultural droughts are projected to be 150 to 200% more likely (IPCC, 2022). Furthermore, precipitation extremes have increased in specific northern regions, and future projections indicate a further rise in the north (for global warming levels surpassing 2°C), while there is no notable change indicated for the south (IPCC, 2022). This may potentially be linked to an increased occurrence of flash floods, exacerbating water insecurity through their impacts on water infrastructure.

General decreasing trends in precipitation have reduced runoff and river discharges in many river basins around the region. Moreover, revegetation processes and increasing evapotranspiration are exacerbating streamflow drought, rather than meteorological drought, characteristics (Peña-Angulo et al., 2021) (see *Section 2.2.1.2*). Future projections of declining precipitation, together with increased evaporation in the Mediterranean region, will likely cause a decrease in runoff, which, depending on the warming scenario, is expected to range between 5% (at 1.5°C warming) and 25% (at 2°C warming) (Droogers et al., 2012; Mariotti et al., 2015), resulting in a decrease of surface water resources especially in southern countries (Fader et al., 2020; Tramblay et al., 2018).

Groundwater is of vital importance for water security in many Mediterranean areas (Fader et al., 2020). Projections of climate change impacts on groundwater estimate reductions of around 12% for aquifer recharge in continental Spain over the coming decades (Pulido-Velazquez et al., 2018), reaching 58% in some areas (Pulido-Velazquez et al., 2015). Reductions range from 20 to 50% in western Türkiye (Ertürk et al., 2014), are projected to reach almost 30% in Tunisia by 2050 (Fader et al., 2020), and up to 25% in Morocco and Portugal by the end of the century (Stigter et al., 2014). Moreover, in coastal aquifers, salinisation created by seawater intrusion has become a first order issue for freshwater and agricultural supply (Guyennon et al., 2017; Pisinaras et al., 2021; Pulido-Velazquez et al., 2018).

The 1.5°C warming suffered in the Mediterranean, exceeding 2°C in summer (IPCC, 2022), has led to increased atmospheric evaporative demand with adverse consequences for water availability. Outcomes can be summarised as follows: (1) increased evapotranspiration by vegetation, with revegetation having a prominent role in explaining these trends in mountainous and rural areas (Labrousse et al., 2022; Lana-Renault et al., 2020; Llorens & Domingo, 2007); (2) increased evaporative loss from lakes and reservoirs (Martínez-Granados et al., 2011; Zhao et al., 2022); (3) increased severity of hydrological droughts caused by increased evaporative demand (Noguera et al., 2021; Vicente-Serrano et al., 2014); and (4) declining aquifer recharge due to increased evaporative rates and increasing water demand for crops (Bellot et al., 2007; Leduc et al., 2007).

Climate change affects not only water availability but also water quality through changing precipitation, temperature variability, frequency, and occurrence of extreme events (Nijhawan & Howard, 2022). Climate change may have an impact on nutrient and mineral exports. It could lead to a decline in nitrogen export due to a decrease in runoff and erosion (Lutz et al., 2016; Molina-Navarro et al., 2014; Serpa et al., 2017). In contrast, phosphorus exports could increase under some scenarios (Molina-Navarro et al., 2014), and copper should be little affected due to its strong immobilisation in soils (Serpa et al., 2017). Nevertheless, changes in water quality could vary markedly depending on the scenarios considered and land uses. Reservoir water quality may also be affected due to close coupling between the projected trend of decreasing streamflow and the risk of anoxia (Marcé & Armengol, 2010) and the direct implications on nutrient cycles, constraining future domestic water supply by water quality problems associated with phosphorus loads (Rocha et al., 2020). These effects could be boosted by a rise in water temperature (Sánchez-Arcilla et al., 2011), decreasing the amount of dissolved oxygen in the water and reducing the mass transfer between deep and surface waters. Other challenges to water quality in coastal areas will probably arise from salt-water intrusion driven by sea level rise and enhanced extraction by higher irrigation demand (Cramer et al., 2018).

With regard to extreme events, more frequent and intensive droughts can also affect water quality, because lower water flows reduce the dilution of pollutants (e.g. organic matter, heavy metals). Groundwater quality will also be affected by reduced water flows, conditioning stream-aquifer interactions, subsurface recharge and aquifer overuse, leading to a general modification of nitrate in the groundwater as dilution varies (Mas-Pla & Menció, 2019). Conversely, while augmented precipitation enhances dilution and contributes to enhanced water quality, the occurrence of floods poses a counterbalancing risk. Flood events have the potential to elevate the discharge of pollutants, resulting in the contamination of surface and groundwater bodies with untreated wastewater and leachate from solid waste (*Figure 2.4*).

2.2.1.2 Land Use and Land Cover Changes (LULCC)

LULCCs alter water balance and partitioning of precipitation between evapotranspiration, runoff, and groundwater flow (Foley et al., 2005). One of the most significant LULCCs observed in Mediterranean regions (especially in northern countries) is the revegetation process that has occurred in recent decades, following farmland abandonment in many mountainous and rural areas (see *Section 2.2.1*). From this perspective,

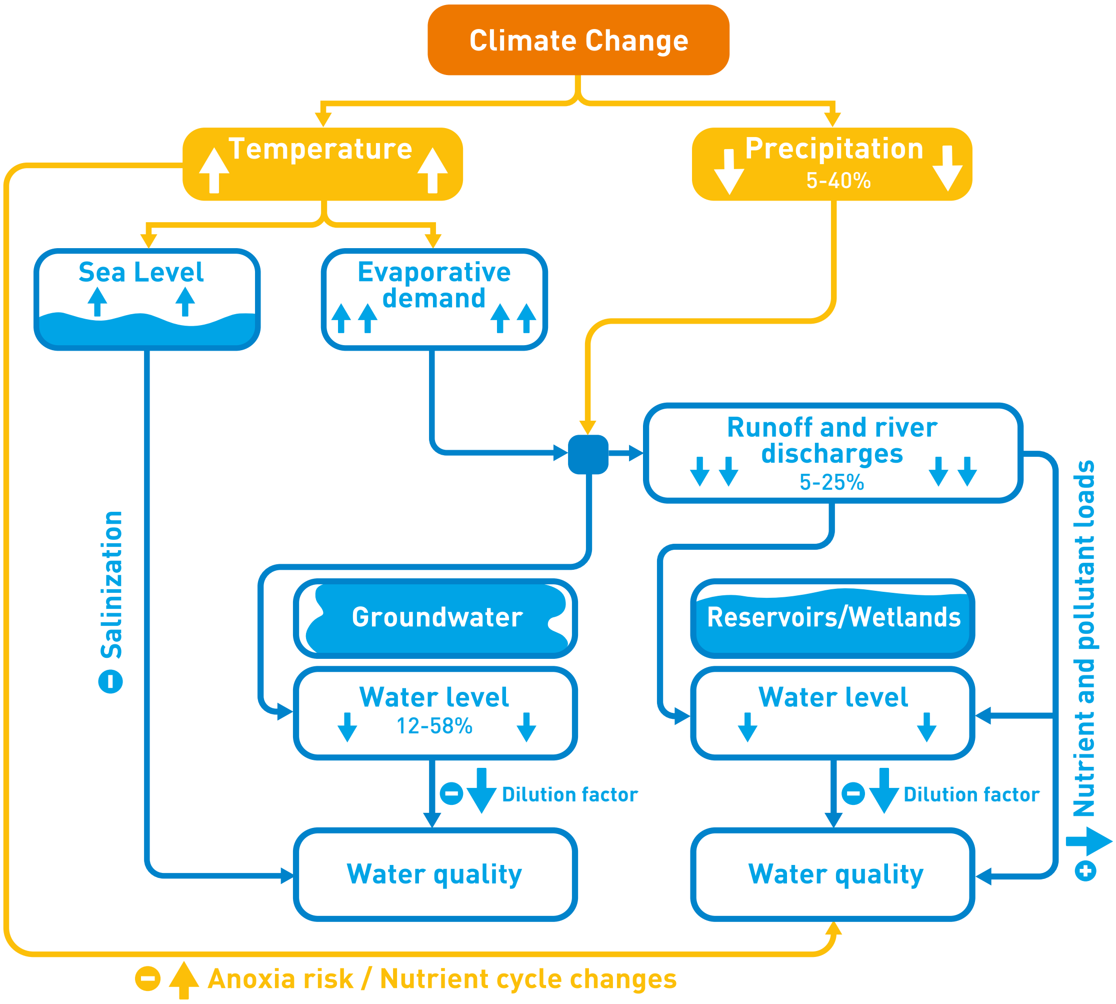

Figure 2.4 | Main impacts of changing mean climate trends on water availability and quality in the Mediterranean region. Up and down arrows indicate an increase and a decrease, respectively. The symbols + and – represent a positive and negative impact, respectively. The blue box represents a virtual water pool.

forest cover presents enhanced evapotranspiration and interception rates, increasing water consumption by vegetation, and water yield therefore usually increases when forests are transformed into systems with lower biomass, and decreases after revegetation processes (Andréassian, 2004; Bosch & Hewlett, 1982; El Hafyani et al., 2020; Lana-Renault et al., 2020).

Shrub and forest expansion processes, encouraged by farmland abandonment, are associated with decreasing river discharges in many areas within the Mediterranean region, including the Pyrenees (Beguería et al., 2003; Gallart et al., 2002) and the Ebro (López-Moreno et al., 2011) and Duero basins (Morán-Tejeda et al., 2012) in the Iberian Peninsula. Similar results have been reported in northwestern Anatolia (Albek et al., 2004) and southeastern France (Cosandey et al., 2005). In the Iberian Peninsula, trends toward higher frequency, duration and severity of hydrological droughts compared to the same characteristics for climatic droughts have also been registered, suggesting an increasing role for vegetation in hydrological control (Peña-Angulo et al., 2021).

Land cover also has a great impact on flood control and implications for flood risk management. Varied responses to extreme precipitation events were observed depending on the extent and density of vegetation cover (Lana-Renault et al., 2014), with longer runoff response times in more densely vegetated catchments, and very short responses with very steep rising limbs of the hydrographs (potentially catastrophic) in sparsely vegetated catchments

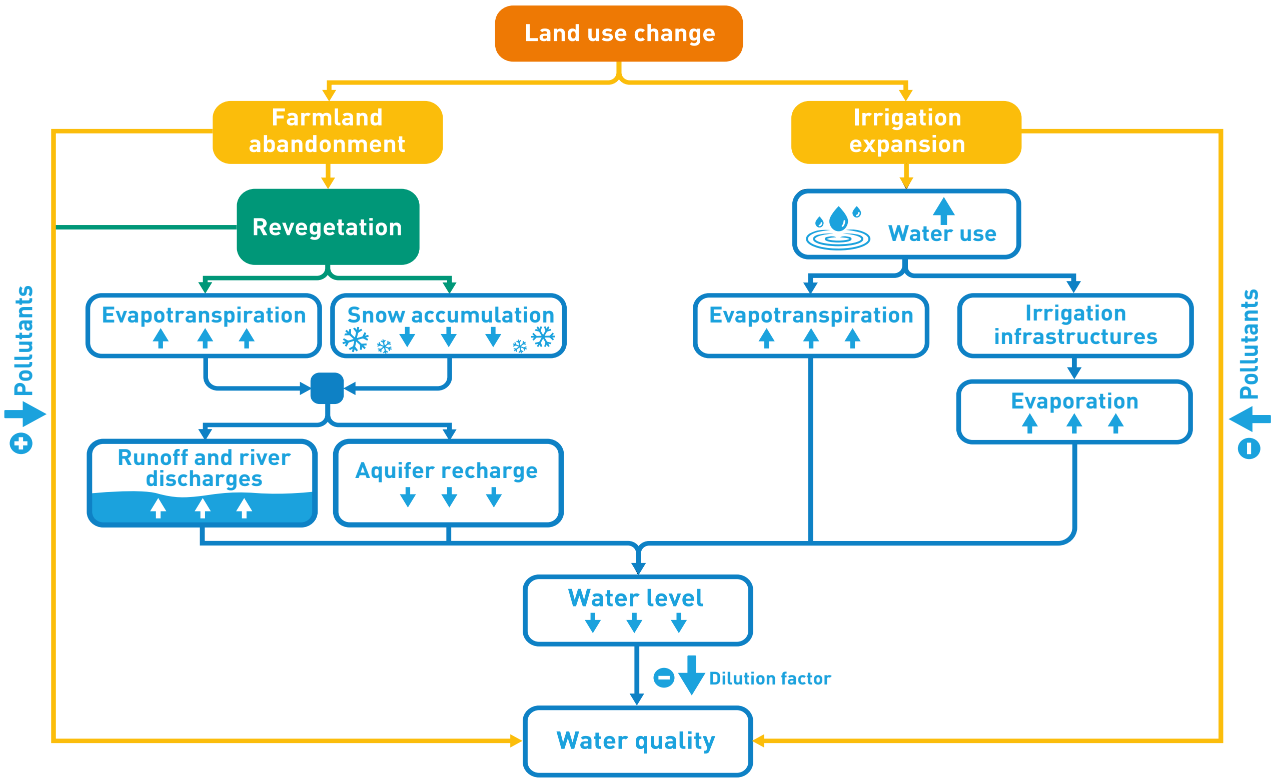

Figure 2.5 | Main impacts of land use change on water availability and quality in the Mediterranean region. Up and down arrows indicate an increase and a decrease, respectively. The symbols + and – represent a positive and negative impact, respectively.

(Camarasa-Belmonte, 2016; Delrieu et al., 2005; Lorenzo-Lacruz et al., 2019; Ortega & Garzón-Heydt, 2009).

In mountainous Mediterranean areas, where snow accumulation during winter plays a vital role for water availability during the dry season in the lowlands, it has been observed that forests reduce beneath-canopy snow accumulation (Lundquist et al., 2013), resulting in the reduction of the annual peak of snow-water equivalent and leading to earlier snowmelt (López-Moreno & Latron, 2008; Revuelto et al., 2016).

Increased irrigation is another LULCC responsible for large-scale impacts on water availability, since irrigation agriculture is the most water-demanding economic sector in the Mediterranean region (Lana-Renault et al., 2020), and usually involves unsustainable land use practices (Fader et al., 2020). The rainfed to irrigation conversion usually involves a change to higher market value crops with greater water requirements, like vegetables and orchards in Türkiye (Tanrivermis, 2003), or vegetables and citrus fruits in Morocco and Spain (Bekkar et al., 2007). Moreover, more frequent and abundant water supply is significantly increasing crop evapotranspiration (up to 20%) (Rodríguez-Díaz et al., 2011) and subsequent water consumption (Molle & Tanouti, 2017). The construction of huge reservoirs to feed irrigation produces greater water surface areas, causing increased evaporative losses (Martínez-Granados et al., 2011). Increasing demand for irrigated agriculture to stabilise market production and maintain food security exacerbates the general increase in water scarcity as a result of climate change (Iglesias et al., 2012). Depending on the warming scenario (2°C or 5°C), the need for irrigation in the Mediterranean is expected to rise by 4 to 18% by the end of the century. Increases of 22-74% are possible due to population growth and higher demand. However, it is not only the irrigated agriculture sector that is expected to increase its demand for an already strained resource. By the 2050s, industrial water demand in the Balkans and southern France is projected to increase by 50 to 100% (Forzieri et al., 2014).

The hydrological alterations caused by LULCCs are correlated with water quality (Stefanidis et al., 2016)

(*Figure 2.5*). Longer dry season flows concentrate contaminants, allowing the accumulation of detritus, algae, and plants, and fostering higher temperatures and lower dissolved oxygen levels (Cooper et al., 2013). Additionally, intensification of agricultural systems in recent decades in many Mediterranean areas has negative effects on water quality, particularly those associated with intensive and heavily irrigated and fertilised systems (Matono et al., 2019). In this regard, irrigated agriculture is one of the major diffuse sources of contamination of surface and groundwater bodies (mainly from pesticides and fertilisers) (Darwish et al., 2011; Martín-Queller et al., 2010; Re et al., 2014). A major issue for future decades is the multiplication of new contaminants from the active ingredients in agricultural products, which can be found in surface and groundwater bodies. The large number of these compounds, but also the cost of analyses, may explain the limited number of systematic surveys conducted (Leduc et al., 2017).

2.2.1.3 Population growth, urbanisation, industrialisation, lifestyle changes, war

Contrasting demographic trends have occurred in the Mediterranean region over recent decades (see *Section 2.2.1*), resulting in worsening of water security in northern Africa, where the greatest population growth has been seen. Moreover, both projected population growth and precipitation decrease will continue to threaten access to safe drinking water and availability for agricultural supply (Scheffran & Brauch, 2014). Inequalities in access to safe drinking water will likely occur in northern Africa, especially in Egypt and Morocco, where high water poverty indices caused by climate change have an impact on access to water as well as on social and economic life (Schilling et al., 2012). Nevertheless, Morocco has made significant efforts to improve water access, achieving 100% and 98% coverage in urban and rural areas, respectively, in 2021.

Population growth has led to rapid and intense urbanisation processes, especially in coastal areas (Cherif et al., 2020). The low-density urban sprawl model characteristic of northern countries has boosted water consumption. For example, in Barcelona, water consumption of single households is four times (100 l capita^{-1} day^{-1}) that of compact urban developments (multi-household residences) (March & Saurí, 2010). Water consumption is even higher for single houses with gardens or swimming pools, both common features of residential tourism (Hof & Schmitt, 2011; Rico-Amoros et al., 2009). Moreover, evaporative loss from swimming pools is not negligible (i.e. 4.8 hm^3 in 2015 in the Balearic Islands; Hof et al., 2018). Tourism alone is responsible for consuming 24% of total water resources in Mediterranean tourism hotspots (García et al., 2022). For example, in the Balearic Islands, water consumption in hotels ranged from 500 litres per guest and night in 3-star hotels to 700 litres in 5-star hotels (Deyà Tortella & Tirado, 2011). In Morocco, differences between hotel categories are similar, although the overall consumption is considerably lower (300 litres per guest and night in 3-star hotels and 500 litres in 5-star hotels). Leisure infrastructure associated with this type of tourism model has led to proliferation of golf courses in many coastal areas of the Mediterranean region, especially in northern countries. In southern and eastern countries, both urbanisation and tourism growth are also expected to increase water demand (Lana-Renault et al., 2020). For instance, golf courses and tourist areas near Agadir (Morocco) are expected to double by 2030 (Choukr-Allah et al., 2016).

Changes in dietary patterns generate crop strategy shifts to satisfy the market's demand for non-native cereals (Vanham et al., 2016), vegetables and fruit varieties that result in higher irrigation water demand, also impacting water security (Bekkar et al., 2007; Tanrivermis, 2003). The current diet in most European Mediterranean countries is far from the recommended Mediterranean diet, and a shift towards it (smaller amounts of proteins and fats and richer in fibre and micronutrients) would reduce the consumptive water footprint. For example, in Spain, this shift could lead to a reduction of approximately 750 litres per capita per day, based on data from the 2014-2015 reference period (Blas et al., 2019).

War in the Mediterranean has severe implications for water availability and security. Armed conflicts often result in the destruction of vital water infrastructure, such as treatment plants and pipelines, leading to water scarcity and contamination, which in turn poses risks to clean drinking water access and worsens food and economic insecurities (World Bank, 2017). In a region with multiple riparian states sharing critical water bodies like the Nile and Jordan River, conflicts escalate tensions over water-sharing

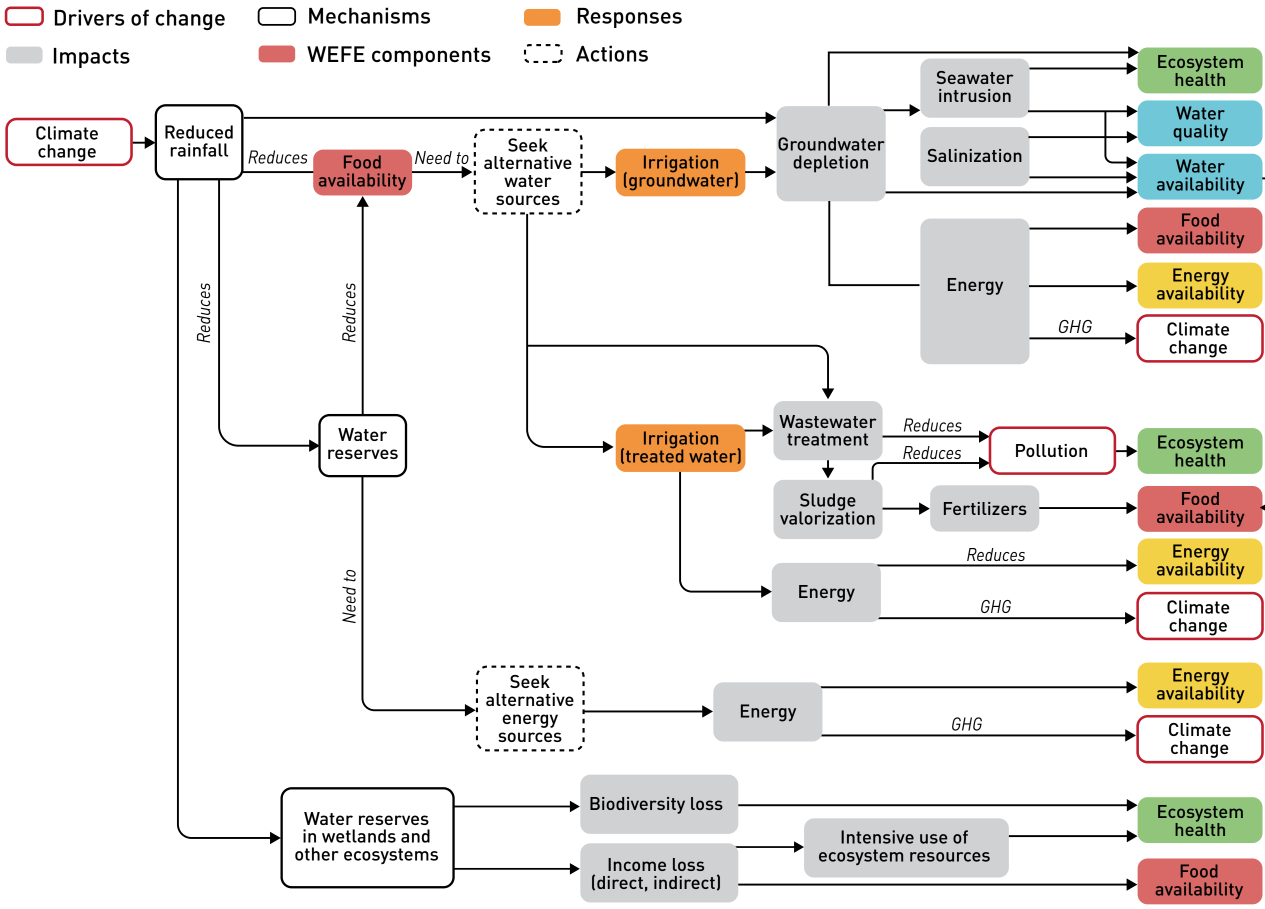

Figure 2.6 | Example of cascading impacts of climate-induced water changes on food, energy, and ecosystems.

agreements, potentially resulting in instability and disputes. Agriculture, being a major water consumer, suffers from war-induced disruptions, leading to crop failures and food shortages (Al-Muqdadi, 2022).

Population increases, particularly in coastal areas, and increasing urbanisation and dietary changes, also affect the quality of surface water and groundwater (high concentrations of nutrients, suspended solids, inorganic and organic chemicals, hydrocarbons, pesticides, heavy metals, potential endocrine disruptors, micro and nano plastics, microbial, etc.) (Chen et al., 2020; García-Nieto et al., 2018; Keshta et al., 2020; Papastergiadou et al., 2010; Salhi et al., 2021). In the Po River, the largest hydrological basin in Italy and the third tributary of the Mediterranean semi-enclosed basin, nutrient load projections for 2100 are strictly dependent on the resident population, which is responsible for a 61 and 41% increase for nitrogen and phosphorus, respectively (Copetti et al., 2013). Although sewage treatment plants play a crucial role in maintaining water quality, untreated wastewater discharges remain a challenge in the region (Llamas-Dios et al., 2021; Perrin et al., 2014). The Llobregat and Besós river basins (northeastern Spain) which supply water to the city of Barcelona, receive extensive urban, agricultural, and industrial wastewater discharges. Different studies have investigated the presence and effects of micropollutants, endocrine disruptors, metals and persistent organic pollutants in fish and invertebrates from these rivers (Barata et al., 2005; Fernandes et al., 2002; Solé et al., 2000; Teixidó et al., 2001).

2.2.2 Cascading impacts of climate-induced water changes on food, energy, and ecosystems

Climate change exacerbates the difference between water demand and the limited availability of renewable water resources, especially for countries located in the south and east of the Mediterranean Basin with a growing economy and population (Cramer et al., 2018;

Tramblay et al., 2020b). The effects of climate change in terms of reduced precipitation and frequent droughts have very negative effects on the availability of water resources, but this effect will cascade, through a series of interactions, onto the other WEFE nexus components (*Figure 2.6*).

Climate change impacts rainfall variability and infiltration rates directly affect groundwater recharge and water quality (Al Atawneh et al., 2021; Barbieri et al., 2023; Green et al., 2011). In countries with arid and semi-arid climates, groundwater resources are used more intensively to supplement water use in water supply and irrigation as an adaptation measure to climate-induced water scarcity (Iglesias et al., 2007; Kuper et al., 2017), leading, over an extended period of time, to a drop in groundwater levels in the Mediterranean (Hssaisoune et al., 2020; Schilling et al., 2020; Xanke & Liesch, 2022) (*Figure 2.7*). This, in turn, results, in the long term, in higher pumping water costs which can in turn reduce crop yields (Aw-Hassan et al., 2014). The reduction of the supply of local crops can lead to a higher demand for crops, hence affecting agricultural commodity prices and jeopardising food security (Dalin et al., 2019).

In addition, the consumption of non-renewable energy for irrigation leads to increased GHG emissions and carbon footprint in agricultural production (Daccache et al., 2014). In the case of some vulnerable environments, declining groundwater resources may also lead to a loss of ecosystem services (Bangash et al., 2013; Terrado et al., 2014). This vicious circle can be observed, for example, in the case of oasis ecosystems in southern Mediterranean countries, which have been strongly affected by climate change (Haj-Amor et al., 2020).

The decrease in aquifer recharge could also affect water quality, as a low recharge rate leads to an increase in water salinity (Hssaisoune et al., 2020; Mastrocicco et al., 2021; Velis et al., 2017), which can limit water uses, including in ecosystem services (Kath et al., 2015). In the case of coastal aquifers, overexploitation of groundwater can cause saltwater intrusion, which has even more negative consequences on water quality and can make resources unusable for irrigation and domestic use. Farmers are then compelled to abandon their wells, thus significantly reducing agricultural production (Agoubi, 2021; de Filippis et al., 2016; Mastrocicco & Colombani, 2021; Mazi et al., 2014). Saltwater intrusion can also be caused or exacerbated by sea level rise, another impact of climate change (Pisinaras et al., 2021; Sefelnasr & Sherif, 2014).

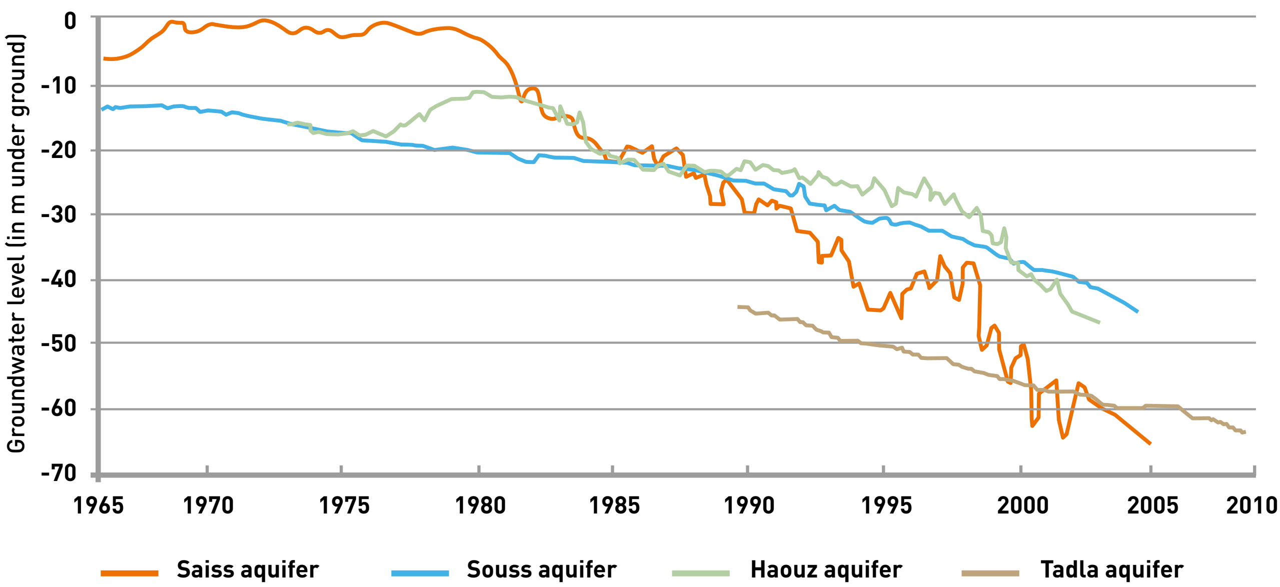

Figure 2.7 | Decline of groundwater levels in some important aquifers in Morocco.
Source: Hssaisoune et al. (2020).

In many Mediterranean countries a significant portion of the national energy mix is provided by hydropower plants that depend on water flows in rivers. Climate impacts on decreasing water availability – and altered periods of water availability – will cause hydropower plants to reduce their electricity production and affect their efficiency (Turner et al., 2017), which will also affect electricity prices (van Vliet et al., 2013) and thus, energy security. Water availability for hydropower generation is further threatened by the expected increase in extreme events such as droughts and heatwaves, and by competition from the agricultural sector (Fortes et al., 2022). Climate impacts on water availability can have other significant effects on the energy sector, especially in cooling and the production of steam in thermal power plants, and in cooling for nuclear power plants. According to IAEA (2022), 87% of global electricity generated from thermal, nuclear, and hydroelectric systems directly depended on water availability in the year 2020. Moreover, the IEA (2021) indicates that one-third of thermal power plants that rely on freshwater availability for cooling are located in areas of high water stress. This is also the case for 15% of existing nuclear power plants, a share that is expected to increase to 25% in the next 20 years. Furthermore, 11% of hydroelectric capacity is also located in areas of high water stress. Approximately 26% of existing hydropower dams and 23% of projected dams are in river basins that currently have a medium to very high risk of water scarcity. Looking at the Mediterranean region, the IEA analysis suggests that most oil refineries and thermal power plants are located in areas of high water stress.

The Mediterranean Basin is recognised as a freshwater biodiversity hotspot (Filipe et al., 2013), and inland waters, such as wetlands and riparian ecosystems, are among the most biodiverse areas in the Mediterranean, and play a key role in the global carbon budget. They also provide a wide range of ecosystem goods (e.g. food, drinking water) and services (e.g. water purification, climate regulation, flood regulation, coastal protection, etc.), which greatly benefit human well-being. The functionality of these systems relies heavily on water levels, and any alterations in the hydrological cycle, as a result of climate change, can significantly impact their structure and operation (Zaimes, 2020). Under future climate change projections, the Mediterranean Basin is one of the most vulnerable sites in this regard (Lefebvre et al., 2019; Xi et al., 2021). Climate change-related impacts on water reserves in wetlands and riparian ecosystems can lead to significant biodiversity loss, among other effects (*Figure 2.6*). The effects induced by water changes will lead to the worsening of ecological conditions, particularly for aquatic biota. They are sensitive to changes in water level, water quality, and disturbances. An increase in drought frequency is expected to affect inland water characteristics, and therefore reduce their suitability for aquatic biota. Additionally, inland waters represent isolated environments, limiting their ability to explore new habitats during unfavourable environmental conditions (Carosi, 2022). Changes in the hydrological cycle from climate change can also cause habitat loss for rich and dynamic riparian plant communities, which differ and are more diverse than those of temperate riparian areas (Zaimes, 2020). Mediterranean wetlands are also important migratory corridors and foraging hotspots. However, if water reserves decrease, it could severely damage the flyways between Africa and Eurasia, putting vulnerable waterbird populations at risk of decline during long-distance migration (Xi et al., 2021). The adverse effects on the goods and services provided by inland waters from reducing water reserves may also lead to potential loss of income. For instance, the tourism sector may suffer from such impacts (Molina-Navarro et al., 2014), and fishing and other related food provision sectors may also be adversely affected by the alteration of these fragile ecosystems.

2.3 The WEFE cascade from the food change perspective

Growing food demand linked to population growth and lifestyle changes (e.g. dietary change), under the combined pressure of climate change and urbanisation, increases dependency on food imports, making people more vulnerable to food prices. International trade largely contributes to food security in the Middle East and North African countries (Baer-Nawrocka & Sadowski, 2019). There are substantial differences in terms of food security between Southern Europe and North Africa. In both cases there are significant examples of very intensive agricultural systems but, in the latter case, agroecosystems are highly limited by the Sahara, leading to heavy exploitation of agricultural lands. Yet, contextual factors, such as population size, land area, employment in agriculture and precipitation,

Country	Land area (million sq km)	% Agricultural land (2018)	% Forest land (2018)	Agriculture (% of gross value added in 2020)	Employment in agriculture (in 2020)	Mean precipitation (mm yr^{-1} 1986-2016)	Population size (million people in 2020)	Human development index rank (2020)
Algeria	2.381	17.4	0.8	12.4	9.7	82	44	91
Egypt	1.002	3.9	0.1	11.5	23.3	31	102	116
France	0.551	52.3	31.2	1.8	2.4	839	65	26
Italy	0.302	41.7	31.8	2.2	3.6	914	60	29
Lebanon	0.01	64.3	13.9	3.3	13.4	536	6.8	92
Libya	1.676	8.7	0.1	0.9	18.8	42	6.9	105
Morocco	0.447	67.4	12.8	13.9	34.1	302	37	121
Spain	0.506	52.4	37.2	3.1	4.0	597	47	25
Syria	0.185	75.8	2.8	20.6	10.5	275	18	151
Tunisia	0.164	62.7	4.5	10.4	12.7	266	12	95

Table 2.1 | Examples of socio-economic and agronomic characteristics for some Mediterranean countries that can determine actions for food security.
Source: Bioversity International (2022).

need to be considered when assessing the capacity of countries to develop actions for food security (*Table 2.1*).

2.3.1 Impacts of drivers of change on food security

2.3.1.1 Climate change

Overall, climate change poses threats to food security in the Mediterranean region through impacts on food availability, access, and quality (*Figure 2.8*). It is expected that these pressures will be different across the region and its production sectors, creating further regional imbalances (Mrabet et al., 2020). In most Mediterranean countries, agricultural lands are arid and semi-arid, and crop productivity is highly susceptible to climate change. Climate change, and other stress factors, will likely decrease agricultural production (crops, fish, and livestock) in many areas due to reduced water availability and heat stress, making the region sensitive to food imports (Scheffran, 2020). A 17% reduction in agricultural productivity is expected in the Mediterranean (Mrabet et al., 2020), down to 9% in Southern Europe, taking into account autonomous adaptation actions (Kebede et al., 2021). Climate change also causes irregularities in the raw materials supply chain for crop production, leading to economic uncertainty and social insecurity (Petrović et al., 2023). In the Delta region in Egypt, extreme hydrological events like sea level rise caused by climate change may negatively affect crops and animals and cause deterioration of arable land productivity. These impacts will also be triggered by extreme weather events in the form of unexpected changes in the seasonality of temperature and precipitation, that affect the seasonality of crops.

With regard to crops, drought, heatwaves, frost or heavy rainfall during critical phenological stages may bring unexpected losses due to crop diseases, yield reductions and increased yield variability (Cramer et al., 2018) for many crops. Warming, associated changes in the phenological cycle, heat stress around flowering, and a lack of chilling accumulation, together with a change to pest infestation risks and increased risk of diseases will affect olives, grapevines, and fruit trees (Ponti et al., 2014). Yield losses in the Mediterranean region are projected at 5.4% for grapes, 14.9% for olives and 27.2% for almonds under a relatively hot and dry scenario (by 2041–2070) (Bezner Kerr et al., 2022). Fruit quality for high-quality wines will also be impacted (Cardell et al., 2019; Fraga et al., 2016, 2020a; Lazoglou et al., 2018; Resco et al., 2016). Furthermore, decreased yield in cereals is caused by inadequate precipitation that affects plant development and shortens the grain-filling period (Özdoğan, 2011) (*Table 2.2*). For vegetables such as tomatoes, projected yield reductions by 2050 vary between 18 and 81% depending on the availability of water for irrigation (Saadi et al., 2015). However, climate change can also have positive yield impacts for particular crops in some areas (e.g. wheat in Sardinia, Bassu et al., 2009). Sea level rise, combined with land subsidence, may significantly reduce the area available for agriculture in some areas, especially in productive delta regions such as the Nile delta (Link et al., 2013). The critical role played by agrobiodiversity in ensuring food is also threatened by climate change, especially in arid and semi-arid areas. Agrobiodiversity destabilisation by climate change affects plants, animals, and microorganisms used for food and other ecosystem services. Mycotoxins can also impact food availability and quality (Medina et al., 2017). The emerging issue of potential aflatoxin contamination of corn, almond, and pistachio crops is occurring in areas of Southern Europe due to the subtropical climate (EFSA, 2008). A shift in traditional occurrence areas for aflatoxins is to be expected, with more prevalent contamination during heatwaves and drought, which may stress the host plant, facilitating infection and leading to potential food safety issues in the Mediterranean (Battilani et al., 2016; Moretti et al., 2019).

For livestock production, impacts depend on whether the production system is intensive or extensive (Rivera-Ferre et al., 2016). Intensive farming systems will be mostly impacted by a decrease in feed crop availability or impacts on infrastructure and animal buildings. Extensive systems will suffer from a reduction of pasture, heat stress, fertility rates, etc. (Bezner Kerr et al., 2022). The magnitude of impacts depends on animal species, breeds, geographical location, and adaptive capacity. Goats, and particularly dairy farming based on indigenous breeds, are less affected by heat stress associated with climate change (Silanikove & Koluman (Darcan), 2015). Generally, direct impacts on animals arise from changes in behaviour, physiology, and health. Indirect impacts are due to lower feed quality and availability, and inappropriate feed composition. By 2050, the abundance and distribution of palatable plant species for grazing animals will be reduced due to climate change and increased grazing pressure (Louhaichi et al., 2019). Generally, besides decreased appetite, extreme heat stress reduces digestion efficiency and assimilation of feed and therefore leads to reduced growth rates, beef, milk, and egg production (Goma & Phillips, 2022). Overall, heat stress alters production and reproduction performance for all animal species, irrespective of the breed and production system. Local breeds are more adapted to heat stress than pure breeds, but they are nevertheless sensitive to it. In dairy animals, an increase in the temperature-humidity index of one unit over 69 decreases milk production by 0.41 kg per cow per day (Goma & Phillips, 2021). Heat stress also negatively impacts milk quality (Yerou et al., 2019). Key milk quality attributes significantly reduced by heat stress include protein content, butyrate, and total dry matter (Bernabucci et al., 2014). Moreover, extreme temperatures alternate the estrus cycle and may cause premature parturition (Goma & Phillips, 2022) and death in situations where animals fail to tolerate heat. In Syria, climate change caused a reduction of goat and sheep herds from −3.3 to −9.0% annually between 1999 and 2001 (Breisinger et al., 2011). By contrast, in other countries like Algeria, climate change could facilitate the expansion of farming alternative species, such as camels (Boudalia et al., 2023).

Oceans and Mediterranean Sea warming and acidification are among the most important factors impacting fisheries, with more than 20% of exploited fish and marine invertebrates expected to become locally extinct around 2050 in the Eastern Mediterranean due to climate change (Cramer et al., 2018). Projections for 2041–2060 are that 25 species would qualify for the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List, and six species would be extinct. By 2070–2099, 45 species are expected to qualify for the IUCN Red List whereas 14 are expected to be extinct (Ben Rais Lasram et al., 2010). Changes in temperature have reduced fishery landings (on average by 44%) for around 70% of the 59 most abundant commercial fish between 1985 and 2008, although increases were also found – mostly for species with short lifespans. For six out of eight of the fish species examined, catch per unit of effort is correlated with temperature (Tzanatos et al., 2014). In Türkiye, the fishing sector's high sensitivity to climatic stressors (temperature and storms) negatively affected its economic performance between 2018 and 2019. The rise in sea level and sea temperature affected survival

Crop	Region/Country	Yield variation (%)	Period	Climate scenario	Reference
Barley	Mediterranean Basin	-27 (dry scenario) to +8 (wet scenario)	2050	RCP4.5	Cammarano et al. (2019)
Maize	Egypt	-19 to -14 -40 to -47	2050	SRES scenarios 1.5°C rise in the future	EEAA (2016) Ouda & Zohry (2020)
	Portugal	-17	2061-2080	RCP8.5	Yang et al., (2017)
Olive	Mediterranean Basin	-28 to +36 -14 to +70	2071-2100	RCP4.5 RCP8.5	Mairech et al. (2021)
	Southern Europe	-17 to +4 -20 to +3	2041-2070 2041-2070	RCP4.5 RCP8.5	Fraga et al. (2020b)
Potato	Egypt	-11 to -2 -11 to -13	2050	SRES scenarios 1.5–3.5°C rise in the future	EEAA (2016) Ouda & Zohry (2020)
Rice	Egypt	-11 -26 to -47	2050	SRES scenarios 1.5°C rise in the future	EEAA (2016) Ouda & Zohry (2020)
	France	-6 to -5	2030, 2070	RCP2.6	Bregaglio et al. (2017)
	Italy	-20 to -12		RCP8.5	
Sunflower	Southern Spain	-80 to -10 -12	2070, 2100 2050	A1B	Abd-Elmabod et al. (2020)
Tomato	Egypt	-19	2050	SRES scenarios	Ouda & Zohry (2020)
	Italy	-9 -26	2030-2059 2070-2099	A2	Ventrella et al. (2012)
Vineyard	Mediterranean Basin	-11 to +4	2021-2050	SRES A1B	Ferrise et al. (2016)
	Southern France	-20 to +2	2031-2060 2071-2100	RCP4.5 RCP8.5	Naulleau et al. (2022)
Wheat	Egypt	-18 -11 to -12 -27 to -31	2050	SRES scenarios 1.5°C–3.5°C rise in the future	EEAA (2016) Ouda & Zohry (2020)
	Italy	+11 -8	2030-2059 2070-2099	A2	Ventrella et al. (2012)
	Portugal	-14 -27 to -17	2021-2050 2051-2080	RCP4.5 RCP8.5	Yang et al. (2019)
	Türkiye	-35 to -3	2030, 2050, 2070	SRES	Özdoğan (2011)

Table 2.2 | Expected yield variation of certain crops in the Mediterranean under future climate scenarios.

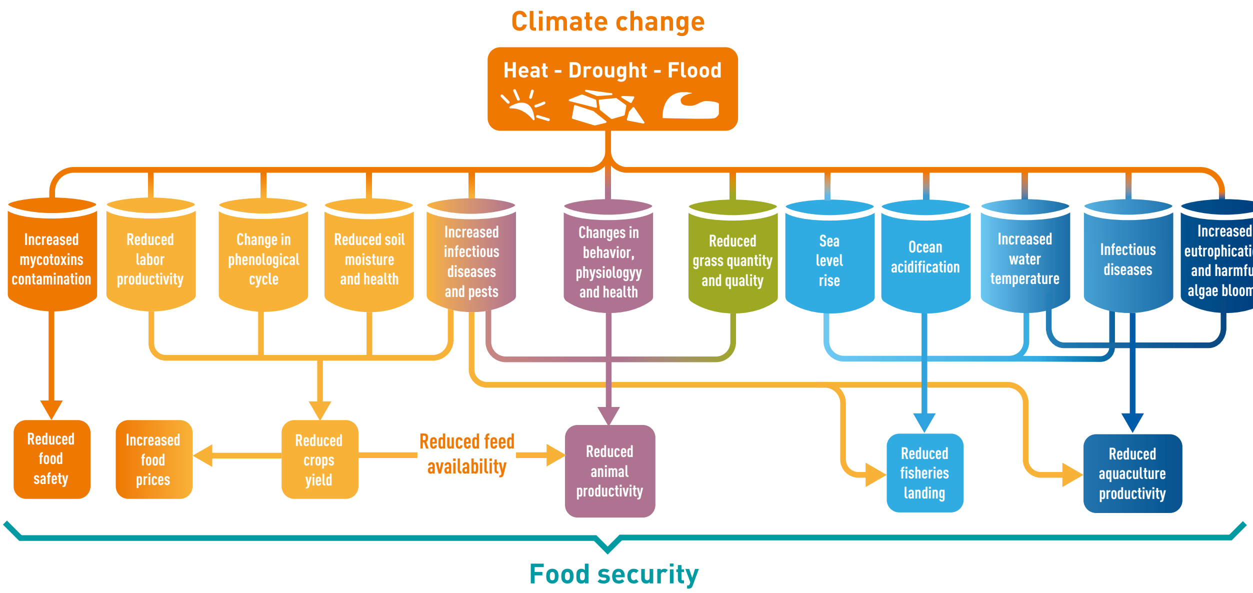

Figure 2.8 | Main impacts of climate change on food security.

of marine species (Gómez Murciano et al., 2021). In Italy, however, the temporal dynamics of total landings seem mostly driven by changes in fishing effort rather than by climatic factors (Fortibuoni et al., 2015), which illustrates the complex interactions in place between climate change and fishing effort.

Climate change is expected to impact aquaculture through an increase in temperature, eutrophication and harmful algae blooms, extreme events and water stress, sea level rise, acidification, and bacterial, viral, and parasitic fish diseases. Impacts of warming on aquaculture will depend on the production system, farmed species and country/ region (Rosa et al., 2012). Disease outbreaks for the three main fish species farmed in the Mediterranean are expected to increase due to higher water temperatures (Cascarano et al., 2021) (*Figure 2.8*).

Climate change is projected to also have severe impacts on rural livelihoods and farmers across the entire Mediterranean Basin. In the MENA region, it is estimated that rural livelihoods dependent on (declining) agricultural productivity will likely continue to contribute to migration flows, often to urban areas, and will also increase import dependency and therefore vulnerability to agricultural impacts well beyond country borders (Kjellstrom et al., 2009; Waha et al., 2017). Also, migration resulting in loss of agricultural labour could heavily impact exploitation of female labour in some countries of the Mediterranean Basin, both in the South (Medland, 2021) and in the North (Corrado et al., 2017). In Tunisia, the incapacity of farmers to adapt their cropping systems to soil salinity and water stress saw income drop by 45% (Souissi et al., 2018). In Morocco, climate change leads to recurrent and extreme droughts causing social inequality due to loss of animals and fodder, since pastoralism provides 38% of the jobs to the community (Schilling et al., 2012). Changes in temperature, together with other variables such as humidity, wind speed and solar exposure, also influence heat stress and reduce labour productivity. This is particularly relevant for outdoor activities such as agriculture. In Mediterranean Europe, it is expected that in the 2080s there could be 50 to 60 additional days of heat leading to heat stress, with an average associated labour productivity loss of 3% (Szewczyk et al., 2021). Climate variability poses a "contingent liability" to the economy since it affects livestock survival and production of critical food security crops, and consequently affects the agricultural trade balance (Verner et al., 2018). The combination of crop yield and agricultural labour productivity losses due to heat stress is particularly severe in the MENA region, which is also particularly vulnerable to associated higher import prices (de Lima et al., 2021).

2.3.1.2 Pollution

Mediterranean food systems are seriously affected by air, soil, and water pollution. The Mediterranean Basin can be considered an air pollution hotspot in terms of decreased air quality. The most widespread pollutant in the Mediterranean region, and the most studied and damaging for crops is ozone (O_3) (Cotrozzi et al., 2018; Kalabokas et al., 2023). Nevertheless, the long-term monitoring of ozone impacts on crops has been limited because of their usual annual growth cycle. Exposure to high levels of tropospheric ozone can result in phytotoxic effects, affecting yields and product quality. As such, visible injury has been reported with several sensitive crop species, causing 17–39% yield loss in crops such as wheat, bean, watermelon, and tomato (Fumagalli et al., 2001; González-Fernández et al., 2014), and 0–20% commercial biomass loss in spinach and Swiss chard (González-Fernández et al., 2016). With regard to grapes, traditionally cultivated in the Mediterranean region, ozone exposure can affect both the yield and quality (Blanco-Ward et al., 2021). Nevertheless, it should be highlighted that the predicted effects based on a model may be overestimating impacts on Mediterranean environments since most physiological mechanisms activated upon ozone exposure, such as stomatal closure, often interact with those triggered by drought and hyperosmotic stress, which are typical of these environments (Fagnano et al., 2009). On the other hand, although the Mediterranean area is among the least studied regions in terms of the potential impacts of nitrogen (N) as a pollutant, there is growing concern that natural systems limited by N availability are being affected by enhanced N deposition from the atmosphere. Decoupling of the peaks of N availability derived from the solubilisation of summer-deposited N with the onset of autumnal rains and the peaks of nutrient demand by plants in the spring makes Mediterranean systems more vulnerable to indirect effects of N deposition (Cotrozzi et al., 2018). Finally, special attention should also be paid to potential contamination from heavy metals due to atmospheric pollution in high-traffic areas, since urban agriculture is on the rise (Ercilla-Montserrat et al., 2018). In any case, air pollution can not only affect plant growth but also shift the market equilibrium of both agro-inputs and -outputs, indirectly affecting food security (Sun et al., 2017).

Soil pollution is also extremely important. This can reduce crop yields due to toxic levels of contaminants and make foods unsuitable for human consumption (Rodríguez Eugenio et al., 2018). In particular, excess heavy metals (such as arsenic, cadmium, lead, and mercury) in soils can impair plant metabolism, decreasing crop productivity and affecting pasture, before entering the food chain and becoming a hazard (Boudebbouz et al., 2023; Zergui et al., 2023). Local soil properties mean that the Mediterranean area is very sensitive to cadmium accumulation (de Vries et al., 2022). Compared to metals, organic contaminants (such as dioxins, furans, and per- and polyfluoroalkyl substances (PFAS)) are less present in soils, localised around industrial or urban centres. Other important pollutants in soils are nutrients and pesticides, which, when applied in excess, negatively affect yields (Rodríguez Eugenio et al., 2018). In addition, pollution derived from solid waste could threaten food production and security by negatively affecting soil, groundwater and surface water and crops, leading to increased health concerns for livestock, aquatic life, and humans (Chen & Chen, 2021).

Water pollution has historically impacted food safety, and today, specific attention is paid to seafood contamination. Mediterranean marine ecosystems present an idiosyncratic combination of characteristics, which make them sensitive to pollution (e.g. high temperatures, microtidal regime, oligotrophy, coastal morphology, biodiversity, anthropogenic pressure, etc.). Sewage and oil still pose the most significant and obvious problems (Danovaro, 2003). Different types of priority contaminants (heavy metals, toxic metals, organophosphate esters, polychlorinated biphenyls, polybrominated diphenyl ethers and polycyclic aromatic hydrocarbons) have been found in several food species (swordfish, bluefin tuna, sardine, anchovy, sardinella, and European hake) around the Mediterranean Sea (Anastasopoulou & Fortibuoni, 2019; Bencheikh et al., 2022; Harmelin-Vivien et al., 2012; Sala et al., 2022; Signa et al., 2017; Storelli et al., 2005). Of the wide range of pollutants contaminating the aquatic environment, heavy metals have been a major focus, mainly mercury, lead, cadmium, and arsenic. Before the prohibition of industrial wastewater being drained into the Nile was strictly applied, arsenic was found at higher levels among people consuming fishes more than twice a week, as well as among smokers (Saad & Hassanien, 2001). As for mercury levels, of 58 different species for human consumption from the western Mediterranean Sea, only thirteen species do not exceed EU thresholds for human consumption (0.5 μg g^{-1} ww) (Capodiferro et al., 2022). On the other hand, it is well known that plastics, microplastics, and nanoplastics threaten marine life by physical damage but also by chemical pollution from the plastic additives (e.g. plasticisers, flame retardants and colour pigments) or other adsorbed chemicals (Schmidt et al., 2018). Microplastics, in particular, can pose risks by entering the food web (Gedik & Eryaşar, 2020). 41% of all fish collected along the Mediterranean coast of Türkiye have microplastic in their intestines and 58% in either stomach and/or intestines (Güven et al., 2017). Additionally, increasing evidence exists that emerging pollutants such as pharmaceuticals and endocrine-disrupting compounds can be bioaccumulated by aquatic organisms (Ruhí et al., 2016). Novel substances with biological activity may have synergistic effects with classical pollutants. Biomagnification patterns along the hake food web differ by contaminants due to their physicochemical properties (Harmelin-Vivien et al., 2012). Chronic exposure to multiple pollutants affects aquatic organisms, even at low concentrations, explaining the deterioration of fish health and fishery production decline along the Mediterranean coastline (Bencheikh et al., 2022). Nevertheless, the human health risk associated with consuming these fish species should be analysed for each compound and species, since some pollutants do not pose a significant threat to public health (Sala et al., 2022).

2.3.1.3 Population growth, urbanisation, industrialisation, lifestyle changes, war

The adoption of modern lifestyles in agriculture and food has also led to major transformations in traditional agriculture characterised by the promotion of agricultural industrialisation and international trade, and changes in diets involving more consumption of animal protein and ultra-processed food. In fact, food production and consumption patterns are amongst the vital drivers of environmental degradation (Capone et al., 2014) and agrobiodiversity deterioration in the Mediterranean.

Industrialisation, urbanisation, and demographic changes together with political and environmental drivers are the main factors for agricultural land use change in the Mediterranean (*Figure 2.9*). Social and demographic drivers are shown to be particularly relevant for abandonment, which is frequently associated with intensification processes. Intensification dynamics are driven mainly by economic factors, which particularly affect annual crop production (Debolini et al., 2018). The industrialisation of agriculture that occurred worldwide during the 20th century aimed at increasing agricultural production to ensure the supply of food to the increasing population and to increase agricultural trade worldwide. During this period, countries in the Mediterranean Basin increasingly specialised in Mediterranean agricultural products for export (Duarte et al., 2021). It also had negative consequences, destroying agricultural employment and causing a loss of profitability for agricultural activity, the overexploitation of hydric resources, water pollution by nitrates and pesticides, high erosion rates, losses of soil organic carbon and an alarming loss of biodiversity. In the immediate future, this damage is expected to end up reducing production capacity (Aguilera et al., 2018; González de Molina et al., 2020; Harchaoui & Chatzimpiros, 2019; Vila-Traver et al., 2021). The intense expansion of Mediterranean virtual water exports between 1910 and 2010 that accompanied the construction of water infrastructure and enabled water-intensive crops to be grown in arid regions has exacerbated blue water stress (Duarte et al., 2021). The fertiliser consumption indicator gives an idea of the level of intensification of agricultural production. In the period between 2002 and 2009, average fertiliser consumption in 21 Mediterranean countries was 188 kg ha^{-1}, higher than the worldwide average (116 kg ha^{-1} of arable land). Over the same period, average fertiliser consumption in the MENA countries (91 kg ha^{-1}) was lower than the level of fertiliser consumption in the Mediterranean Euro area (180 kg ha^{-1}) and Mediterranean EU countries (156 kg ha^{-1}) (Lacirignola et al., 2014).

In the Southern Mediterranean, industrialisation of agriculture has often been accompanied by the development of export agriculture. In Morocco, export-oriented and industrialised agriculture contributes to 15 to 20% of its Gross Domestic Product (GDP). This change has transformed the nature of labour in agriculture, with the marginalised rural population being contracted as wage labourers (Bouchelkha, 2016). In Algeria, the agricultural sector plays an important economic role: in 2020 it contributed to

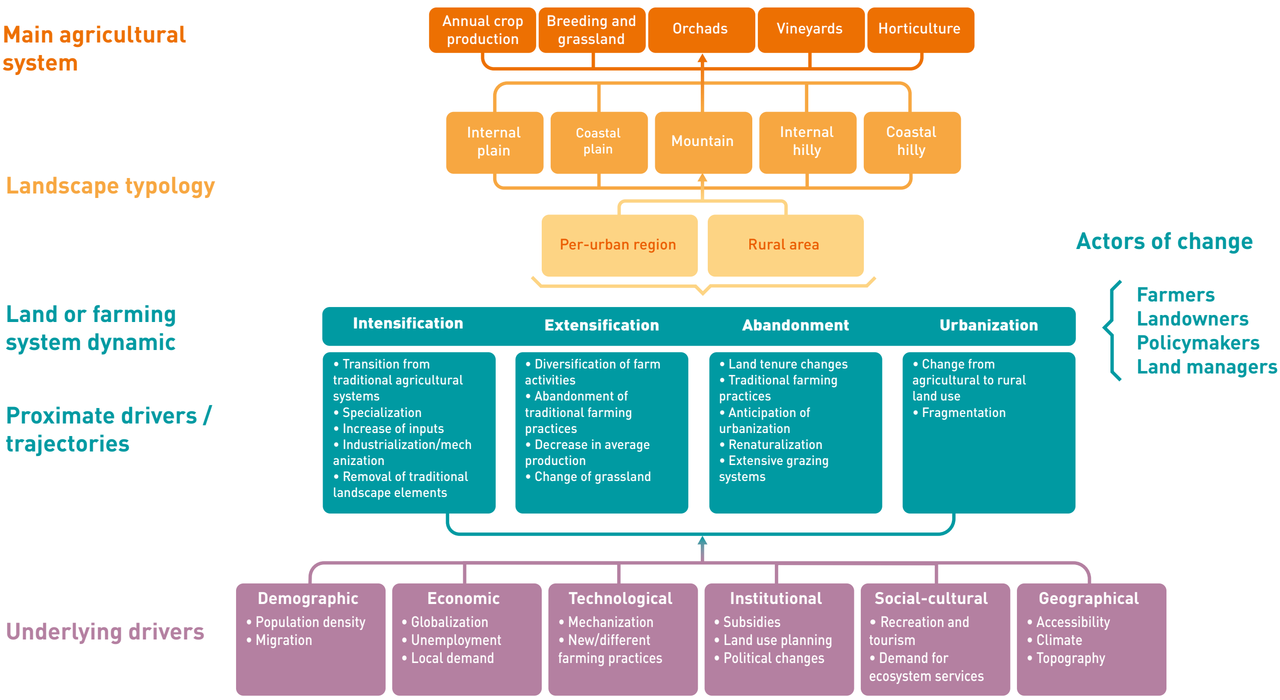

Figure 2.9 | Land and farming system dynamics in the Mediterranean.
Source: Debolini et al. (2018).

12.4% of the country's GDP and employed directly and indirectly around 13 million people. Yet, its agricultural area is prone to urban sprawl as a result of the growth of cities (Bellout et al., 2020).

Increasing urbanisation and industrialisation have also led to changes on the demand side, shifting food consumption patterns towards Western-style diets, characterised for being rich in energy and animal protein, and also linked to high levels of food waste. This nutrition transition has resulted in low adherence to the Mediterranean diet across the region (Grosso et al., 2014; Kyriacou et al., 2015; Marventano et al., 2018; Naja et al., 2019) with severe impacts on both human and ecosystem health. Dietary changes towards Western-style industrialised diets have been identified as drivers of the region's ecological deficit, including increased GHG emissions, changes in land use, energy use and water use. In Lebanon, dietary shifts towards diets with high environmental footprints among adolescents have been reported (Naja et al., 2020). An analysis of the ecological footprint (EFC) of consumed food in Mediterranean countries, i.e. the amount of land required to sustain their food consumption, showed the highest per capita values for Portugal, Malta and Greece (1.50, 1.25 and 1.22 global hectares (gha), respectively), while Slovenia, Egypt and Israel had the lowest (0.63, 0.64 and 0.79 gha, respectively). All in all, results show that all Mediterranean countries, except France, rely on the biocapacity of foreign countries to satisfy their residents' demand for food (Galli et al., 2017, *Figure 2.10*).

In general terms, the EFC in the Mediterranean is always higher than the EF of production, except for the case of Serbia (data for 2007; *Figure 2.11a*). Between 1961 and 2007, the ecological footprint per capita in the Mediterranean increased except in Albania, Jordan and Morocco, while biocapacity decreased, generating an ecological deficit. On average, the ecological footprint has increased by 47.4% while the biocapacity has decreased by 36.4%. The average ecological footprint in northern Mediterranean countries is at least 1.5 times the ecological footprint of MENA countries (Lacirignola et al., 2014, *Figure 2.11b*).

The Mediterranean food system is a traditional food system favoured by Mediterranean agroclimatic conditions, that involves commonly extensive, low-input farming, based on traditional knowledge

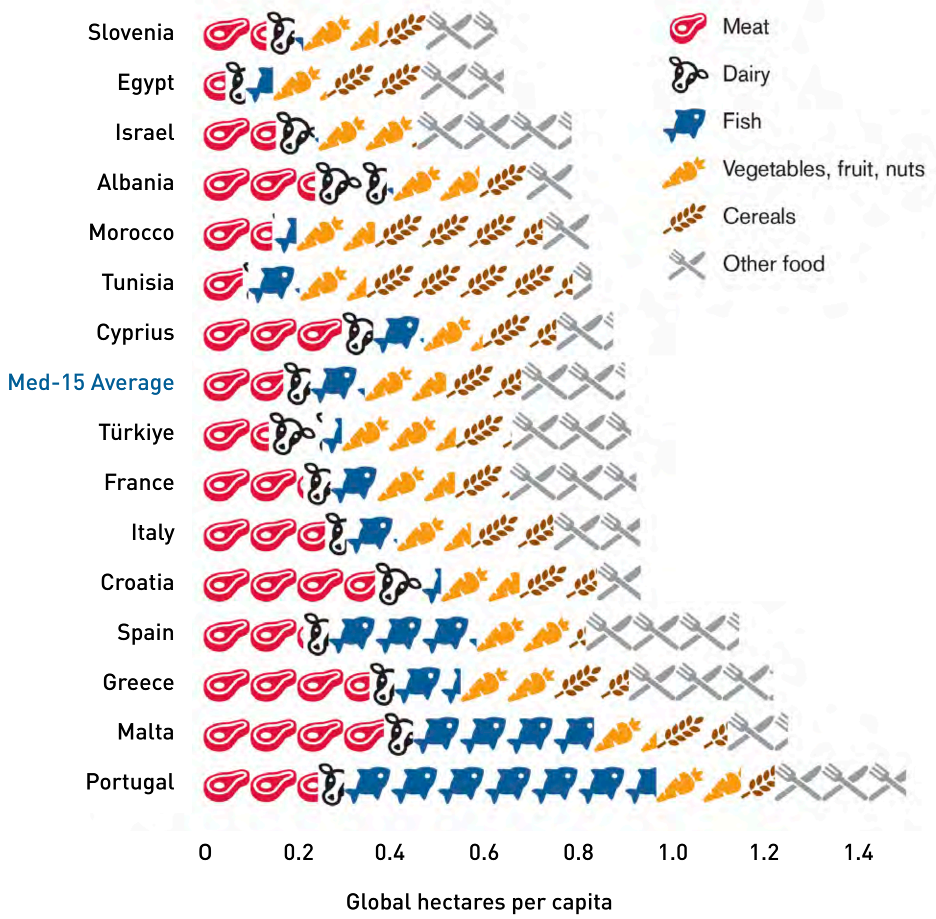

Figure 2.10 | Ecological footprint of per capita food consumption of Mediterranean countries in 2010, per type of food.

Source: Galli et al. (2017).

and using predominantly indigenous breeds, local crop varieties and wild foods. This has allowed the Mediterranean to be considered one of the world's eight "centres of origin", i.e. geographical areas where today's crops originated, and where, as a result, crop genetic diversity for wheats, barleys, forage plants, vegetables, fruits, spices, and ethereal oil plants, among others, is exceptionally high (Bioversity International, 2022). These plants have developed resilience traits that enable them to cope with the Mediterranean region's hot and dry summers. Agrobiodiversity Index status scores across ten Mediterranean countries as compared to global agrobiodiversity trends show that agrobiodiversity is well represented in some parts of Mediterranean food systems at the consumption level, indicating a high diversity of food contributing to healthy diets in markets and consumption. However, in production, the Mediterranean average is well below the global average, suggesting that production systems lack diversity (Bioversity International, 2022). Food systems in Mediterranean countries have undergone deep transformation away from the sustainable and healthy patterns that were predominant in the region until the mid-1960s. This transformation is evident across the whole food chain, from production to consumption, and has led to the erosion of a cultural heritage that maintained a sustainable balance between land and resource use, ecosystem conservation and healthy nutritional status. The industrialisation of agriculture and diets has significantly contributed to agrobiodiversity loss in the Mediterranean. Agricultural intensification has been shown to erode taxonomic and functional diversity in Mediterranean olive groves (Tarifa et al., 2021). Moreover, the erosion of Mediterranean food culture is accompanied by erosion of the plant and animal genetic diversity that characterises it, since the Mediterranean diet has also been linked with agrobiodiversity conservation (Renna et al., 2021). Agrobiodiversity loss from climate change, globalisation trends and urbanisation negatively

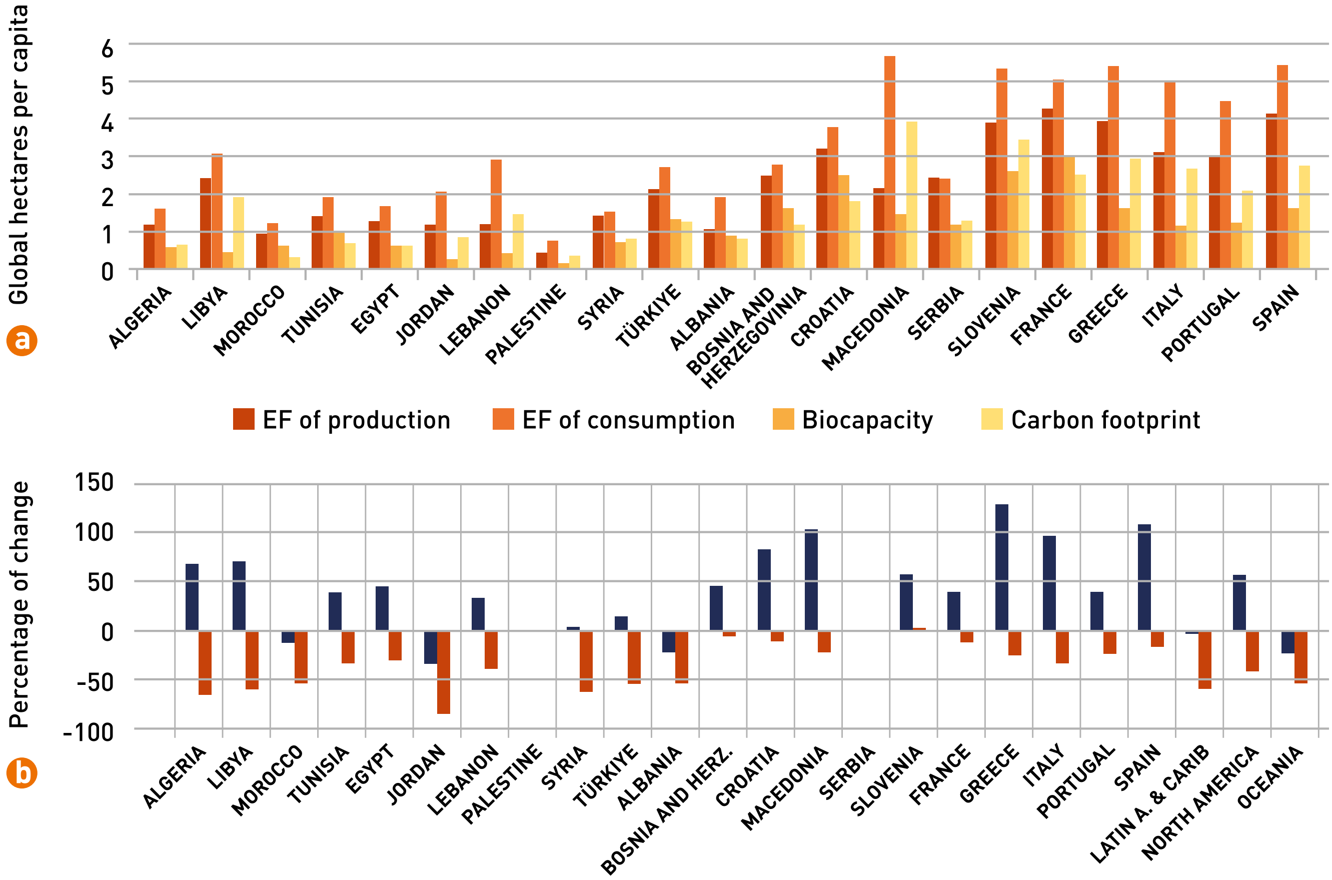

Figure 2.11 | a) Global hectares per capita (i.e. biocapacity), carbon footprint (CF) and ecological footprint (EF) of the production and consumption of food in the Mediterranean; b) Evolution of the EF and biocapacity in the Mediterranean countries from 1961 to 2007 (data shows change between 1992 and 2007).
Source: Lacirignola et al. (2014).

affects the livelihoods of populations inhabiting the region. Shrinking agrobiodiversity levels make farmers more vulnerable to climate risks in the Mediterranean, since less diversity in farming systems translates into reduced options for coping with change. Also, losing this diversity undermines the very survival of the Mediterranean diet and an opportunity to build a sustainable food system in the region. Transitioning back to the Mediterranean diet, including wild foods with high nutrition content, could contribute to counteracting the effects of climate change, malnutrition and biodiversity loss that are jeopardising food security in the region (Bioversity International, 2022; Borelli et al., 2022) (*Figure 2.12*).

Industrialisation of agriculture is also linked to increased food loss and waste. With regard to resources wasted associated to food loss and waste in the Mediterranean, Laricignola et al. (2014) estimated that from 294 (Palestinian territories) to 706 m^3 $capita^{-1}$ yr^{-1} (Portugal) of water is lost or wasted by Mediterranean people.

The war in Ukraine has had a clear impact on food availability and access across the Mediterranean, especially for those that rely on food imports, such as in the MENA region (Al-Saidi, 2023; Ben Hassen & El Bilali, 2022). In 2021, the Russian Federation and Ukraine together accounted for about 75% of the total wheat and wheat flour imports of Egypt and Lebanon, close to 40% in Tunisia, more than 30% in Jordan and around 20% in Morocco. In the southern and eastern Mediterranean group of countries, the proportion of imports to domestic availability of calories ranges from 37% (Morocco) to 84% (Jordan) (Rauschendorfer & Krivonos, 2022). The Russo-Ukrainian war impacts food security not only through disruption to food markets, but also to the

Figure 2.12 | Risks associated with low agro-biodiversity levels.

Source: modified from Bioversity International (2022).

fertiliser market, which may affect both food price and availability (Ben Hassen & El Bilali, 2022). The combined effects of war and climate change (e.g. droughts in Morocco) are also extremely relevant (Rauschendorfer & Krivonos, 2022). The climate–conflict link in Syria has also been examined for the 2006–2009 drought conceived of as a four-stage process, with various levels of scientific evidence and consensus existing for each stage: (1) climate change leading to the heavy 2006–2009 drought; (2) massive loss of agricultural livelihoods, significantly attributable to the drought; (3) massive rural–to–urban migration triggered by livelihood loss in combination with other factors; and (4) migration intensifying existing grievances and facilitating the onset of protests and the subsequent civil war (possible, but little knowledge exists) (Ide, 2018). Prolonged violence may also reduce the resilience capacity of households necessary to resist food insecurity, as observed in Gaza during the escalation of violence in 2014 (Brück et al., 2019). In that territory, the experience of food insecurity is associated with an approximate one-point reduction in dietary diversity as measured by food consumption score (Lin et al., 2022). The impact of the 2023 war on food security in the area cannot be assessed in this report due to lack of data at the time of the assessment. In sum, the high impact of war and conflicts on food security, combined with the significant dependence of many countries on food imports, unstable money exchange values, increasing trade uncertainty and future pandemics, is increasing the number of studies using a nexus approach to analyse the capability of countries to increase their food self-sufficiency, combining changes in food production and consumption, like Egypt (Fahim et al., 2013), France (Billen et al., 2018), Lebanon (Daher et al., 2022), Spain (Aguilera & Rivera Ferre, 2022), and South-East Europe (Brankov et al., 2021).

2.3.2 Cascading impacts of climate-induced food changes on water, energy and ecosystems

In the Mediterranean region, the effects of climate change are severely affecting the sustainable utilisation of resources to sustain human livelihoods. Climate change impacts on agricultural yield and therefore on food security, which can result in a series of cascading effects on other WEFE components, are mediated by the diversity of responses available to address the impacts of climate change (*Figure 2.13*). Cascading effects from food can be mediated by production (supply) and consumption (demand) trends. To produce food, agriculture requires indispensable resources like energy, soil, water, and then, of course, farmers. Food production also alters ecosystems, and it is expected to be the primary factor influencing Europe's future landscape changes (Kebede et al., 2021). The allocation of agricultural land and land use is frequently influenced by intricate cross-sectoral interactions that have cascading effects on other sectors, including forestry, biodiversity, energy, and water. Sustaining current levels of food production could be achievable under several climate and socio-economic scenarios, with strong impacts on biodiversity and water, particularly in Mediterranean Europe, where water stress is projected to increase by 26% in Southern Europe and 32% in Eastern Europe (Kebede et al., 2021). This raises questions about the long-

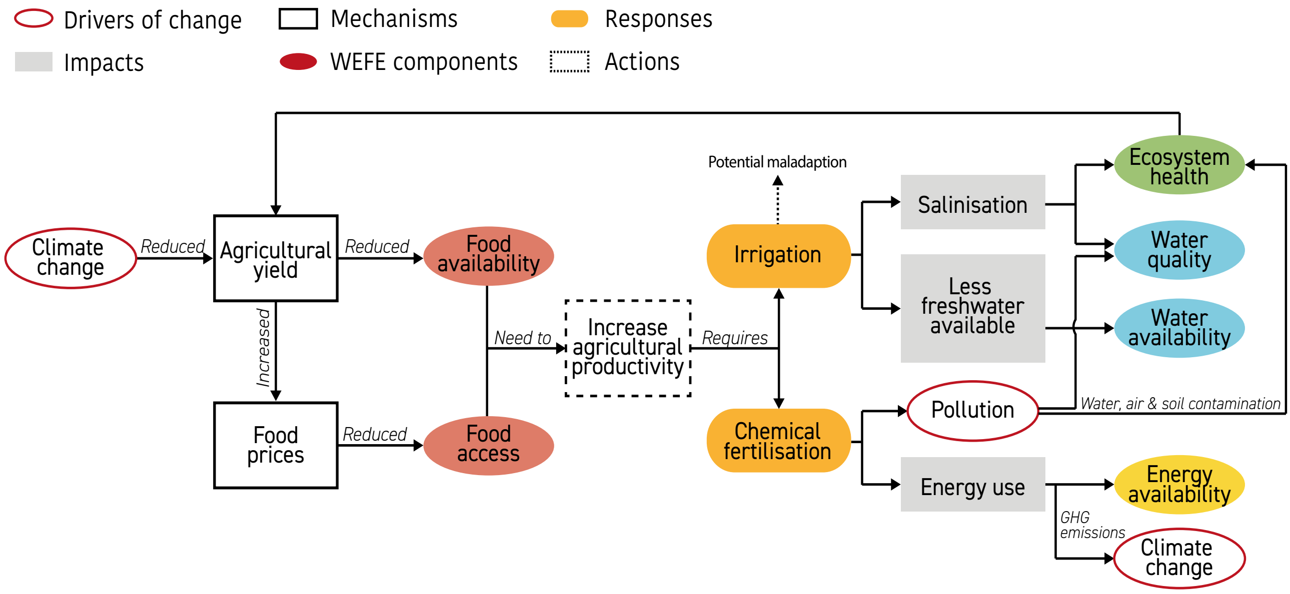

Figure 2.13 | Example of the negative cascading effects associated with climate-induced food security changes (access and availability) on water, energy, and ecosystems, initiated by the driving force "climate change" and followed by "business-as-usual" responses (see *Chapter 3*).

term sustainability of current production and consumption policies (Funes et al., 2021). Actions aimed at increasing agricultural yield through business-as-usual responses, such as increased irrigation or use of synthetic chemical fertilisers, can negatively impact water security, energy security and ecosystem health through a diversity of pathways. From a food perspective, reduced agricultural productivity due to climate change leads to an increase in water demand for irrigation, with impacts on water availability and ecosystem health through salinisation or changes in land use to expand the agricultural area and increase energy demand, also affecting ecosystems. In parts of Southern Europe, salinisation, which may result from drought and an increase in irrigation (see *Section 2.2.1*), is indeed a major problem. Soils in large areas of Spain and some regions of Greece and Italy are already salinised (Scheffran & Brauch, 2014). The degradation of ecosystems further affects soil quality and moisture, carbon cycle and local climate. Self-reinforcing consequences are lower air humidity and less precipitation. If this trend continues, it can lead to desertification, with land then being lost for future agricultural use (Scheffran & Brauch, 2014). In addition, agriculture depends on expensive external non-renewable energy inputs, which are imported. Currently, over 0.5 units of non-renewable energy produces a unit of crop energy. Moreover, in northern Mediterranean countries, the intensity of non-renewable energy is slowly declining (Aguilera et al., 2020). Increased food transportation to satisfy food security through imports raises energy demand and dependency, as well as GHG emissions. Globally, post-farm emissions contribute 5–10% of global GHG emissions (Mbow et al., 2019).

2.3.3 Cascading impacts of human-induced food changes on water, energy, and ecosystems

Cascading effects also arise from indirect drivers of change in food systems, such as population growth or lifestyle changes, and in particular, increased consumption of animal-based products associated with the promotion of industrialised systems (*Figure 2.14*). Production of large-scale industrial animal protein to satisfy current demand requires the cultivation of cereals and leguminous crops in third countries (Garrett & Rueda, 2019). Cultivation of feed crops for animal production in the Mediterranean is leading to deforestation in some countries in Latin America (Martínez-Valderrama et al., 2021). Deforestation increases CO_2 emissions, destroys ecosystems, and reduces

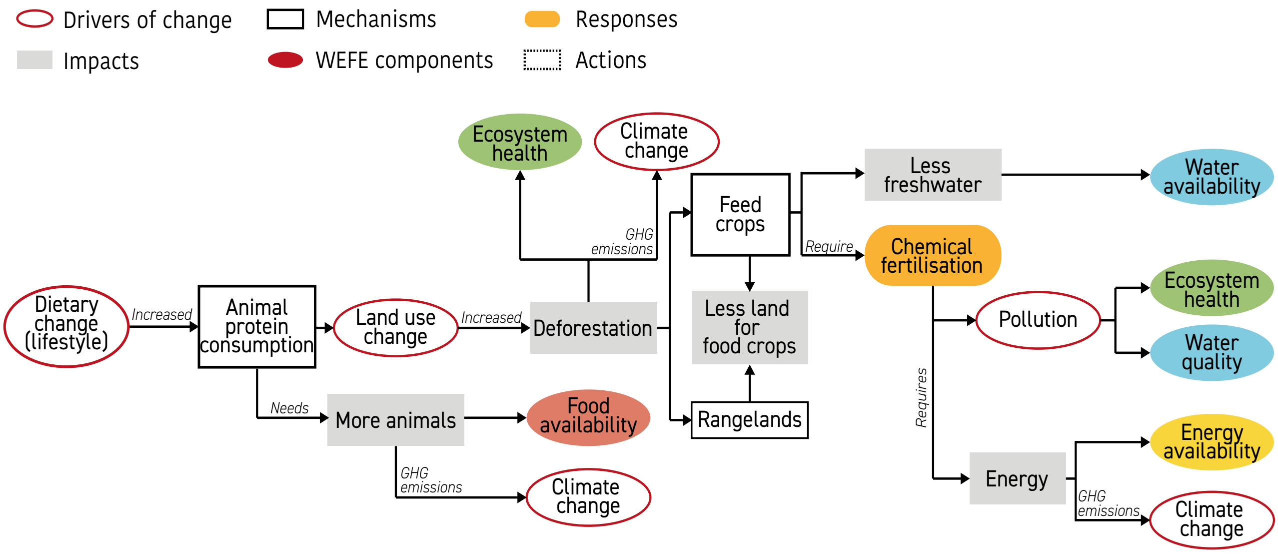

Figure 2.14 | Example of the negative cascading effects associated with lifestyle-induced food security changes on water, energy, and ecosystems, initiated by the driving force "dietary change" and followed by "business-as-usual" responses.

biodiversity. Deforestation also means less land for food crops for humans or alternative uses. For example, Spain's current food demand requires cultivation of 6 Mha in other countries, of which 5 Mha is for animal production (feed crops or pasture) (Aguilera & Rivera Ferre, 2022). In addition, the production of feed crops in deforested land has the same impacts on WEFE as those described above. Breeding more animals, particularly ruminants, also increases direct GHG emissions in the form of methane. With monogastric species, GHG emissions mainly occur indirectly, both upstream (e.g. production of feed) and downstream (e.g. through ammonia volatilised and further deposited). Furthermore, regions with over-abundant N have been identified in the region, mainly in EU countries where intensive livestock and cropping systems exist (e.g. Sanz-Cobena et al., 2023). Increasing amounts of reactive N entering these systems as N fertilisers and animal manures are triggering the emission of reactive N into the atmosphere, as well as into soil and water bodies, in the form of the air pollutant ammonia and oxides of N (NO_x and N_2O). Inefficient conversion of N in agroecosystems is making a significant contribution to this situation (Aguilera et al., 2021).

Box 2.1

Intensive livestock production systems and nitrogen cycle

On the basis of some intensive industrial farms in the Mediterranean, these farming systems, particularly for monogastric species, are characterised as:

- Being energy dependent
- Having external feedstock demand with a high energy cost (i.e. transport or synthetic fertiliser)
- Having enhanced reactive N losses into the environment – air (ammonia) and water pollution (nitrates) – with impacts on ecosystems
- Having increased GHG emissions, mostly indirect (upstream) due to land use change (impact on ecosystem health)

These livestock production systems are mostly focused on the export market (*Figure 2.15*). Nevertheless, they rely on (and support) an extended transition to unsustainable and unhealthy diets that has been occurring over the last four decades in Mediterranean countries, far removed from more "territorially appropriate" eating habits (e.g. Mediterranean diet).

Livestock systems sustained on imported feedstock/livestock are responsible for disrupting local and regional nitrogen cycles, thus triggering environmental losses in the form of ammonia (to the atmosphere) and nitrates (to surface and groundwater) (*Figures 2.15* and *2.16*). These reactive N losses are the result of high inefficiency in the use of nitrogen and are behind relevant impacts linked to both human and ecosystem health.

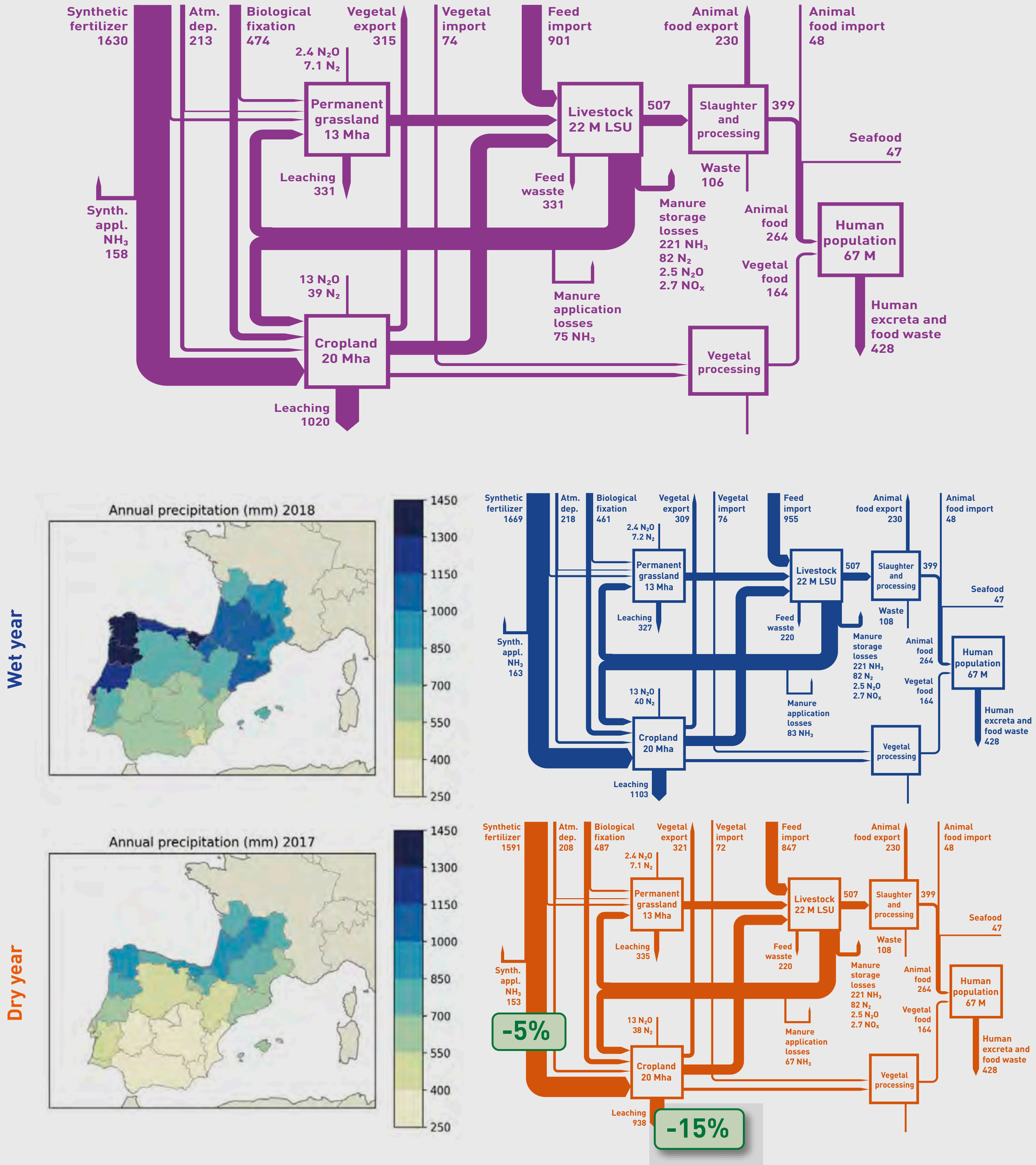

Figure 2.15 | Nitrogen dynamics for the entire SUDOE territory (southwestern Europe) shown through the GRAFS approach (Billen et al., 2014) with a distinction between wet and dry years. Interannual variations associated with the Mediterranean climate between dry and wet years could lead to reductions in synthetic N entering in the system (–5%) as well as N pollution in the form of nitrate leaching (–15%).
Source: AgroGreen–SUDOE project (https://agrogreensudoe.org/en/impact-visualizer/)

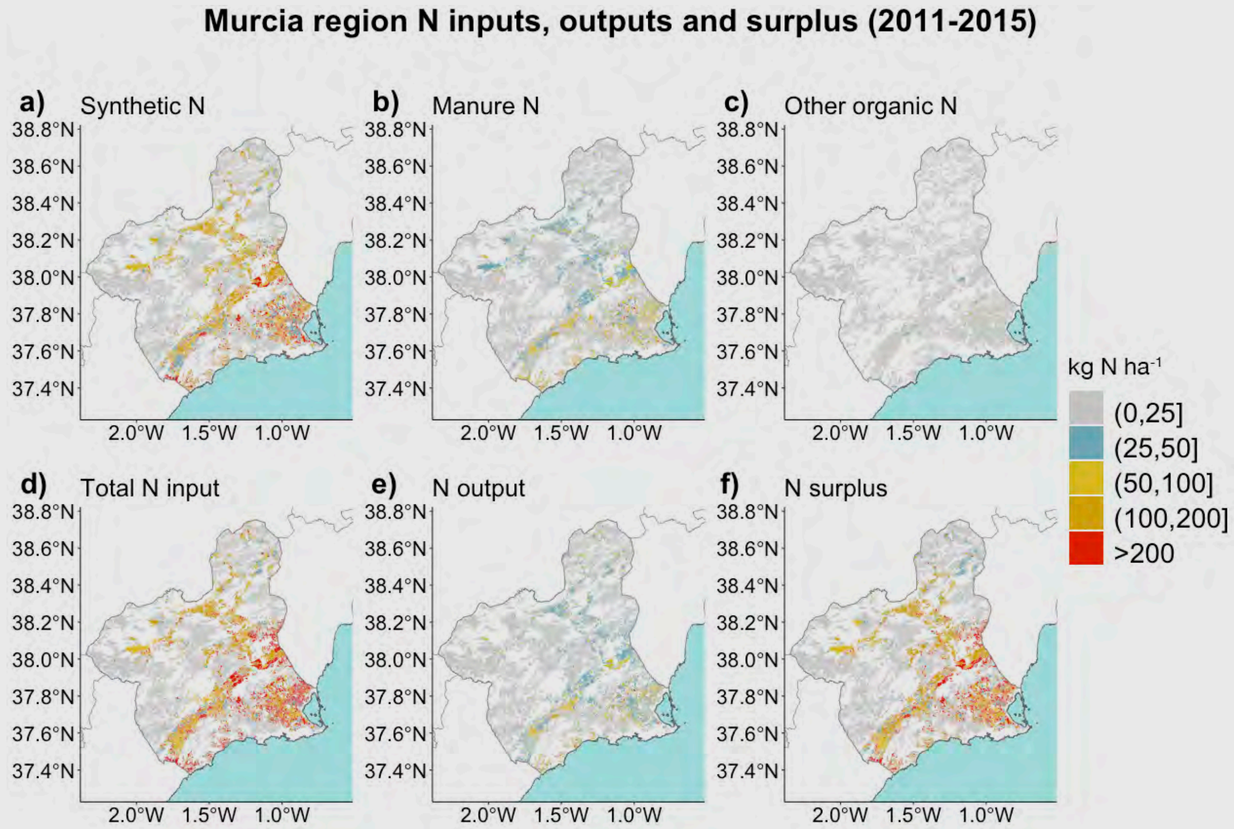

Figure 2.16 | N applied to agricultural soils in the Murcia region (kg N ha^{-1}): synthetic N (a), N in animal manure (b), N in other organic sources (c), total N input (d) and N output (e), and N surplus (f) (mean for 2011–2015).

Source: Sanz-Cobena et al. (2023).

2.4 The WEFE cascade from the energy change perspective

Energy is linked to all the nexus components through a variety of interactions (Sargentis et al., 2021). Regarding water, hydroelectric energy can only be generated if water is readily available in rivers or reservoirs, while the cultivation of plants for biofuel consumes significant amounts of water. Also, groundwater (the world's most extracted natural source) needs energy to be pumped; natural water, clean water, and wastewater need energy for treatment and transportation; and water distribution, and especially desalination, are energy-intensive processes. The extraction of fossil energy (conventional and unconventional) also requires water, as well as hydrogen. This is particularly crucial as the industry often operates in regions characterised by high temperatures and water scarcity. Regarding food, food production consumes 30% of total energy globally (harvesting, tillage, processing, storage) and the production of fertilisers is an energy-intensive process. On the other hand, there is competition between producing food grains for food, feed, or biofuel (e.g. corn, soya). And of course, through the consumption of food, energy is provided for our organs to function. Land is a central element that plays a key role in this context. The competitive relationship of land uses with the water–food–energy nexus is linked to ecosystems. Land is used for mining and extracting materials for energy production, cultivation of biofuel plants, creation of reservoirs in hydroelectric dams, ground-mounted photovoltaic (PV) panels and onshore wind turbines, creating competition with the cultivation of food. Biofuel plants use land and water to produce energy instead of food. Ground-based PV panels use land to produce energy without water. Using the land for reservoirs, hydroelectric projects produce energy using water (Sargentis et al., 2021). The related cascading effects mediated through the different drivers of change identified in *Section 2.4.1* need to consider all these interactions and identify potential synergies and trade-offs.

2.4.1 Impact of drivers of change on energy security

2.4.1.1 Climate change and climate policies

Energy production is the sector most responsible for climate change in the Mediterranean, accounting for 74% of total GHG emissions (Menichetti, 2021). This energy is later used by different sectors, like agriculture, building, industry, or transport. However, the energy sector is also impacted by climate change, with challenges to the stability and reliability of energy systems, both conventional and renewable (e.g. Solaun & Cerdá, 2019; WMO, 2022; Zapata et al., 2022). The main impact of climate change on energy is mediated through water scarcity (see *Section 2.2.3*). In Morocco, for the same installed capacity, the electricity produced in 2021 was about half the amount generated in 2011, and one third of the electricity generated in 2010. Yearly variations are significant and, despite some exceptions, depict a decreasing trend in electricity generation. The same can be observed for Tunisia (*Table 2.3*). The significant variations across the years are related to reduced rainfall, and to water management, which is prioritised as follows: (1) drinking water; (2) agricultural use; and (3) electricity generation.

Cumulative installed hydropower capacity in the Mediterranean stands at nearly 120 GW and represents 18% of total electricity capacity and 13% of electricity generation. If rainfall patterns drop drastically, energy availability in the region will be affected, with increasing energy security concerns. The decline in hydropower and thermoelectric power usable capacity is higher than global estimates (2.5–7.0% for hydropower in 2050 and 10–15% for thermoelectric power) (Drobinski et al., 2020a). Although solar photovoltaics and wind power are growing rapidly, thermoelectric power, together with hydropower, will most likely remain the dominant power-generating technologies throughout the twenty-first century (Drobinski et al., 2020a). In addition to hydropower electricity production, water stress is also an issue of concern for oil refineries and thermal power plants in the Mediterranean, most of which are located in highly water stressed areas (IEA, 2022). Moreover, nuclear power plants not only depend on water for cooling but are also often located in low-lying coastal areas and are therefore potentially vulnerable to sea level rise and weather-related flooding (*Figure 2.17*).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Morocco												
Capacity (MW)	1770	1770	1770	1770	1770	1770	1770	1770	1770	1770	1770	1770
Generation (GWh)	3631	2139	1816	2990	2033	2282	1662	1565	1998	1654	1290	1213
Load factor (%)	23	14	12	19	13	15	11	10	13	11	8	8
Tunisia												
Capacity (MW)	62	62	62	62	62	62	62	62	62	62	62	62
Generation (GWh)	50	54	110	60	56	70	45	17	17	66	46	28
Load factor (%)	9	10	20	11	1à	13	8	3	3	12	8	5

Table 2.3 | Annual production from hydropower over the last 10 years as compared to installed capacity.
Source: elaborated from ONEE[7] and STEG statistics[8].

7 http://www.one.org.ma/

8 https://steg.com.tn/fr/

It is expected that climate change will lead to decreasing mean wind, wind energy potential and strong winds in North Africa and Mediterranean regions as a consequence of the poleward shift of the Hadley cell in the RCP4.5 and RCP8.5 scenarios by the middle of the century or beyond, and for a global warming level of 2°C or higher (Ranasinghe et al., 2021). However, this is not the case for the whole Mediterranean and for all seasons. For example, EURO-CORDEX regional climate simulations at the 12 km grid resolution over the twenty-first century indicate a significant increase of Etesian wind frequency and intensity in the summer over the Aegean Sea, under the two emission scenarios, RCP4.5 and RCP8.5, implying that future wind power potential in the Aegean Sea will be significantly increased by the end of the century (Dafka et al., 2018, 2019). Furthermore, extreme events can cause damage to production and distribution infrastructures with disruptions in supply, transportation and storage, and potential contamination of the natural environment (Brown et al., 2014; Patt et al., 2013).

Despite these risks, the number of strategy documents (National Adaptation Plans, Long-Term Strategy or Nationally Determined Contributions) submitted by Mediterranean governments to the United Nations Framework Convention on Climate Change (UNFCCC) and which mention energy as a climate adaptation sector, is fairly low. In southern Mediterranean countries, Morocco and Tunisia have developed Carbon Neutrality Strategies for 2050. Achieving the Paris Agreement commitment (UN, 2015) to hold the increase in global average

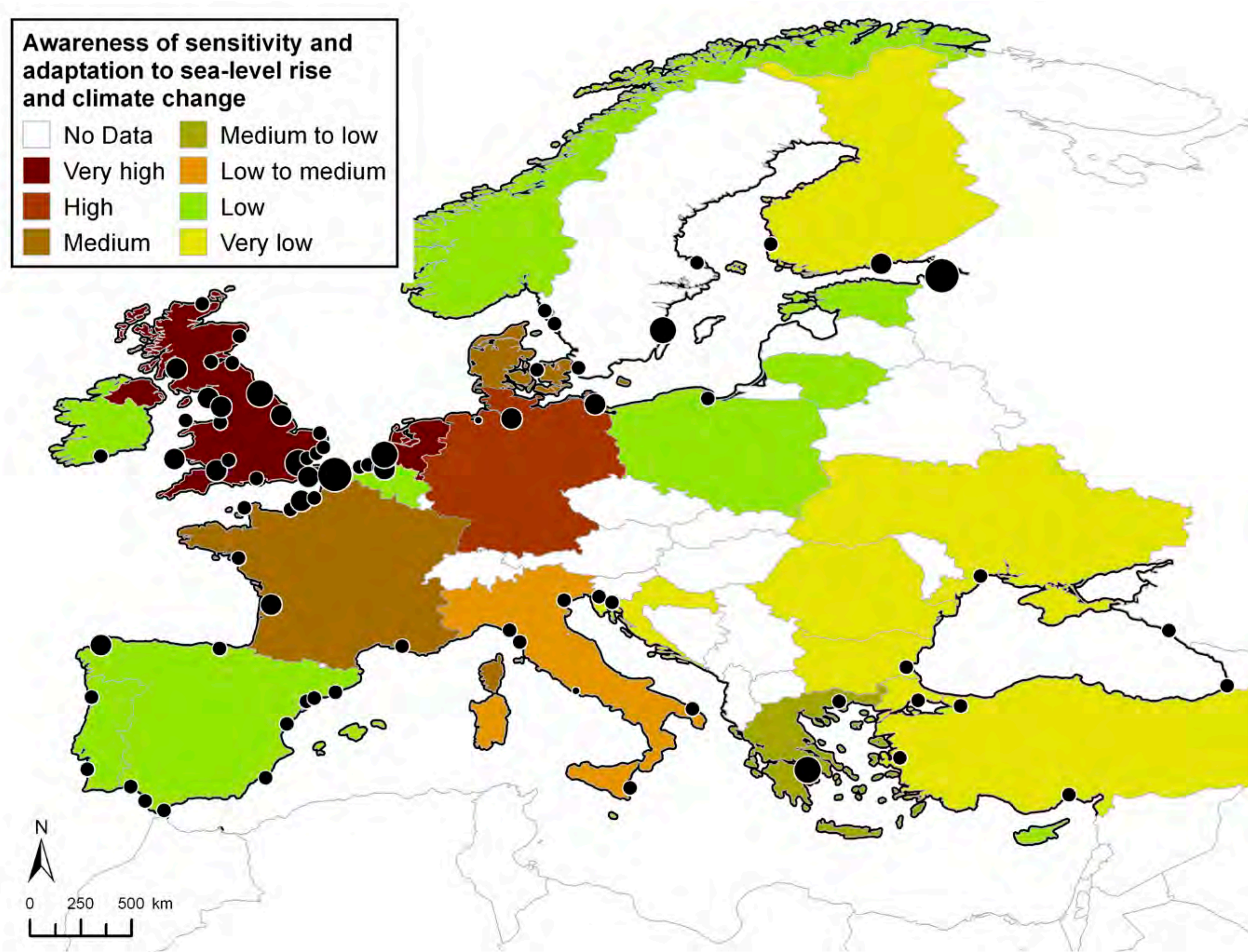

Figure 2.17 | Oil, gas, liquefied natural gas (LNG), tanker and nuclear terminals in Europe (where at least two facilities exist) with status of awareness of climate change and sea level rise.
Source: Brown et al. (2014).

temperature to well below 2°C above pre-industrial levels means reducing CO_2 emissions by approximately 50% between 2050 and 2100, alongside a reduction of emissions from other greenhouse gases linked to energy. Policies to reduce emissions associated with electricity production can be divided into three categories: carbon-intensity reduction, increase in energy efficiency, and reduction of consumption. For carbon-intensity reduction, cutting CO_2 emissions in half is equivalent to reducing the carbon content of energy by approximately 75% (Drobinski & Tantet, 2022). The Mediterranean is still a long way from decarbonising its energy system, and significant efforts are needed to accelerate the transition and meet climate mitigation goals. In practice, this means promoting renewables. Traditionally, the most exploited renewable energy sources have been biomass and hydropower. In terms of hydropower, dams all over the world produce a large amount of electricity, but a large part of the resource is already exploited (Grill et al., 2019), and they have considerable impact on ecosystems (Kuriqi et al., 2021). Biomass is heavily limited by the regeneration rate of forests, and can therefore hardly be considered carbon neutral (Sterman et al., 2018). Geothermal energy contributes in a few countries. In recent years, wind and solar solutions have entered the energy mix, for both electricity and heat production. Most southern Mediterranean countries lie in the so-called sunbelt, with global horizontal irradiance (GHI) values ranging from 1600 kWh m^{-2} yr^{-1} in coastal areas to 2600 kWh m^{-2} yr^{-1} in the desert, and direct normal irradiance (DNI) varying from 1800 kWh m^{-2} yr^{-1} to more than 2800 kWh m^{-2} yr^{-1}. They are therefore suitable for the development of both solar power (solar PV, concentrating solar) and solar heating and cooling technologies. Currently, the deployment status is far below the potential for both technologies (Resch et al., 2015). The potential is also very high for wind. While onshore wind has already reached a cumulative capacity of over 90 GW, the development of offshore capacity is rapidly accelerating and could lead to more than 20 GW and up to some 50 GW of additional capacity by 2035, according to national energy and climate plan objectives and market trends. In sum, despite quasi-stable oil-based energy production between 1995 and 2016, coal gradually decreased, primary energy production from natural gas doubled, while the contribution of nuclear energy and renewable energy sources increased by around 40%. However, promotion of renewables needs to take into consideration environmental protection and avoid conflicts with other land and sea uses through accurate maritime and land spatial planning, since this can have cascading impacts on other nexus components, particularly ecosystems and food (*Section 2.4.2*).

Finally, climate change impacts energy through changes in demand for heating and cooling buildings (temperature-sensitive energy demand). Overall, in continental areas, energy demand trends for heating and cooling were weak (under 10%) from 1941–1960 period to 1981–2000 period and increased (by more than 10%) from 1981–2000 period to 2021–2040 period. Increasing trends in cooling energy demand are more pronounced than decreasing trends in heating (Deroubaix et al., 2021). However, quantification of global warming impacts on future energy demand is still highly uncertain, despite being a key issue for accurate energy planning.

2.4.1.2 Population growth and lifestyle changes

Demographic trends and industrialisation (see *Section 2.1.1*) have a direct impact on energy systems. In a "Net Zero Carbon" scenario[9], energy demand in the South and East Mediterranean would increase by 2% in 2050 compared to current levels, as opposed to a 40% reduction in the North, as a consequence of contrasted demographic and economic trends (OME, 2022). In absolute values, this would translate into almost 19000 PJ in the South against some 15000 PJ in the North in 2050. Energy intensity would be higher in the South (1496 TJ k€$^{-1}$) than in the North (1373 TJ k€$^{-1}$) (OME, 2022), while per capita energy consumption would be higher in the North (76 MJ), than in the South (40 MJ), with a Mediterranean average of 51 MJ. These differences are linked to different lifestyles and currently, there are already high disparities between countries in per capita energy consumption. In 2022, according to OME

9 The « Net Zero carbon » or "ProMed" scenario has been developed by OME within the framework of its Mediterranean Energy Perspectives publication and with the co-funding of the European Commission. It assumes reaching carbon neutrality for the entire Mediterranean region to the 2050 horizon.

analysis (OME, 2023) per capita energy consumption was 108 MJ in the North Mediterranean (140 MJ in France, 53 MJ in Malta), against an average of 52 MJ in the South Mediterranean (25 MJ in Morocco, 18 MJ in Mauritania). Globally, 40% of current global energy use would be sufficient to provide universal decent living standards in 2050, while the energy consumption of a super-rich global 1% could equal that required to provide decent living standards (i.e. what is appropriate for sufficiency) for 1.7 billion people (Millward-Hopkins, 2022).

2.4.1.3 Urbanisation

Due to urbanisation trends, transportation systems are being redesigned to accommodate for a wider shift towards electric vehicles, biofuels, biomethane and other low-carbon technologies. In fact, the transport sector is currently, with power generation, one of the main players responsible for GHG emissions in the Mediterranean and is the sector with the highest growth in emissions in recent decades, especially in southern Mediterranean countries (UN DESA, 2022). It is also the sector with the highest energy intensity and the largest indirect contribution to primary energy imports - mainly oil, and associated energy dependence for non-producing countries. Under current trends, energy demand for the transport sector would increase by 35% and would still be heavily reliant on oil with an 84% oil share in 2050. To achieve carbon neutrality, the transport sector will need to be heavily decarbonised with oil dropping to about 8% of transport energy consumption by 2050. Sustainable transport (pedestrian and bicycle mobility) must also develop, and collective transport must be promoted.

Since the mid-1970s, waste management has become a major concern for Mediterranean countries. Waste represents an enormous loss of resources in the form of both materials and energy, and contributes about 5% of total GHG emissions. If not appropriately managed, waste can create a number of direct and indirect risks to both humans and the environment. Although significant effort has been invested by several Mediterranean countries, 58% of collected waste is disposed of in open dumps and 31% in sanitary landfills, while less than 10% of collected waste is recycled or composted (EEA & UNEP/MAP, 2014). Integrated waste management policies based on regional and international best practices can help rapidly improve the situation and turn a serious environmental issue into an opportunity for resource reuse and generation of sustainable energy.

The rapid urbanisation that occurred in Mediterranean countries also creates another impact in terms of energy consumption from buildings, accounting for 38% of energy consumption in the region (Plan Bleu, 2012). Despite the expected increase in demand for cooling services, due to rising average temperatures, as well as for other electrical uses, the building sector represents important potential for energy savings, integration of renewable energy technologies and emissions reduction.

2.4.1.4 Industrialisation and pollution

The industrial sector is the second largest energy-consuming sector in the Mediterranean after transportation, accounting for 28% of total final consumption in 2020. Under current trends, energy consumption in the industry is expected to increase by 60% in 2050, while the share of renewable energy technologies is set to grow by only 15% (OME database). Energy efficiency measures can curtail the increase in demand.

The case of Egypt highlights some of the most critical issues related to growing industrialisation, that hold true in other Mediterranean countries (EEA & UNEP/MAP, 2014). In the last decade, industry has developed rapidly in Egypt, and is expected to keep growing at a rate of about 7% per year. The continuous growth of industrial production has led to both human health and environmental stresses. About 60% of all CO_2 emissions, and 10% of SO_2 emissions originate from industry. Based on the 3rd Nationally Determined Contribution (NDC), estimated CO_2 emissions from industry were 23.4% for 2005/2006. The main source categories for CO_2 emissions respectively are cement, ammonia not used in the urea, iron and steel industry, and lime production (EEAA, 2016). To tackle this problem, an objective of decreasing the pollution loads generated by industries by at least 50% has been set.

2.4.1.5 War

The relationship of energy with conflicts has been described in three ways: (1) The energy system as an objective in conflict (linked to energy security, control system structures and competition for resources); (2) The energy system as a means in a conflict (linked to deliberate reduction of flow by supplier or user and disturbance induced by a third party); and (3) The energy system as a cause of conflict (linked to the resource curse/local abundance in a country, environmental degradation, reduced security of supply or interactions with food prices) (Månsson, 2014). When energy production and distribution infrastructure are damaged, it creates not only problems for energy access but also for the environment.

The 2010 Arab spring led to more serious conflicts in Libya and Syria, which are still heavily affecting their social, economic, and energy systems. When the social upheaval started in Libya in early 2011, the country was the largest oil producer in the Mediterranean. Annual production dropped from 90 to 26 Mtoe between 2010 and 2011, and after slightly recovering, it dived again as a consequence of the nationwide blockade (OME, 2022). There is a similar story with gas production. Syria's relatively modest oil production was already on the slide when war broke out in the country. Sanctions in December 2011 halted the operations of international companies. Most large oil fields and infrastructure are damaged or non-operational.

Besides the clear impact of war on fossil fuel production and trade, the current instability holds back the spread of energy efficiency and renewable energy projects. For example, the 60 MW Derna onshore wind farm in Libya announced in the early 2010s is still shelved. Of course, such a situation not only directly impacts the countries concerned, but indirectly affects the development of regional projects, thus slowing down the energy transition process in the region.

An additional point involves the increasing role of fossil energy supply in the Euro-Mediterranean dialogue. After the approval of REPower EU, Algeria has become the third biggest supplier of gas to the EU. Similarly, a Memorandum of Understanding between the EU, Israel and Egypt was signed in June 2023 to increase exports of natural gas to Europe from these two countries (Directorate-General for Energy, 2022). These agreements must not undermine the need to foster energy transition and sustainable development under a nexus approach.

2.4.2 Cascading impacts of climate-induced energy changes on water, food and ecosystems

The main impacts of climate change on energy are mediated through water scarcity, impacts on infrastructure or changes in demand, as well as the mitigation policies to which all countries are committed and that imply changing the energy production mix to increase the proportion from renewable resources (*Section 2.4.1*). However, introducing a nexus perspective shows that the development of renewable energies as low-carbon solutions is not as easy. Two major challenges affect the WEFE components in a low-carbon transition. First, the fluctuating nature of the capacity factor, which measures how often an energy production plant is running at rated power. In the Mediterranean region, the capacity factor of onshore wind energy sources ranges between around 20% in Italy and France to 25% in Spain up to nearly 30% for Portugal and Türkiye (Gönül et al., 2021), reaching 45% in Morocco (Bouramdane et al., 2020, 2021). Capacity factors of offshore wind energy resources can reach up to 50% in the region (Kalogeri et al., 2017; Nøland et al., 2022). For solar PV, the capacity factor drops to around 20% on both shores of the Mediterranean Sea (Bouramdane et al., 2020, 2021) while for concentrated solar power (CSP), it can reach 35% in Morocco (Bouramdane et al., 2020, 2021). Capacity factors of renewable energy sources in the Mediterranean are 3 to 4 times smaller than operational thermal power plants (which can reach 90%) (IEA, 2020). Therefore, for a given energy production, the installed capacities of wind or solar energies are 3 to 4 times higher than for conventional thermal production. Also, the space required per kWh is several orders of magnitude larger compared to conventional electricity production methods (van Zalk & Behrens, 2018), which is a problem, because land use change is one of the main causes of biodiversity loss (IPBES, 2019). According to Nøland et al. (2022), power densities of conventional thermal energy plants differ by a factor of between 50 and 500 (nuclear around 500 W m^{-2}, natural gas around 350 W m^{-2} versus around 1-10 W m^{-2} for wind, PV and biomass). Assuming that all areas are amenable to each source and that they face no limitations in terms of scalability other than their mean annual energy densities, the spatial requirements for the different power sources to meet 100% of the 2020 primary energy use for Europe, the

Middle East and Africa are shown in *Table 2.4* (Nøland et al., 2022). This shows that for renewable energy sources, the spatial requirements already necessary in the Mediterranean region to fulfill 100% of the primary energy use ranges typically between 1% for hydro or solar PV to about 10% for onshore wind in Europe and the Middle East and between 0.1% for solar PV to about 2% for onshore wind in Africa. For biomass, the spatial requirements already exceed 100% of Europe and the Middle East. By comparison, the spatial requirements for nuclear or natural gas never exceed 0.7%. With energy demand in MENA countries expected to double by 2040 from 2015 (Drobinski et al., 2020b, 2020a), the proportion of land dedicated to energy production could reach more than 10% of total land with potential consequences on land degradation or biodiversity loss.

In addition, the impact of energy on land occupation in transitioning to renewable energy can conflict with food production (Sargentis et al., 2021) (*Figure 2.18*). The growing availability of arable land in Mediterranean regions, as a consequence of the decline of cereal cropping systems and grain legumes, provides ample opportunities for performing successful feedstock production in unmanaged areas (Pulighe et al., 2019). Also, integrated approaches in which energy crops are introduced into the rotation cropping system for local use can reduce burdens on land (ranging from −32 to −8%) and improve environmental farming sustainability (Solinas et al., 2015). In Greece, the impact of diverting food crops to produce bioenergy shows strengths including the creation of direct and indirect jobs (biofuel production industry), diversity of energy supply, and a positive contribution to the greenhouse effect. Weaknesses include environmental impact, and dependence on land availability (additional need for arable land other than that required to grow food) (Paschalidou et al., 2016). Energy communities and multifunctional land use have proven to improve implementation possibilities and consensus at local level (Abouaiana & Battisti, 2022). Offshore wind energy production also requires careful consideration, as it can impact the marine environment through noise

	REGION		
POWER SOURCE	EUROPE (%)	MIDDLE-EAST (%)	AFRICA (%)
Nuclear	0.031	0.021	0.002
Natural gas	0.064	0.043	0.005
Hydropower	0.712	0.958	0.455
Solar (CSP)	1.181	0.787	0.093
Solar (PV)	2.422	1.615	0.192
Wave	3.023	2.015	0.239
Geothermal	4.918	3.279	0.389
Solar (rooftop)	6.486	2.508	0.110
Wind (offshore)	6.170	4.113	0.488
Tidal	8.451	5.634	0.669
Wind (onshore)	6.154	7.547	1.845
Biomass	184.615	123.077	14.615

Table 2.4 | Spatial requirements for the different power sources to meet 100% of primary energy use, normalised by land area.
Source: Nøland et al. (2022).

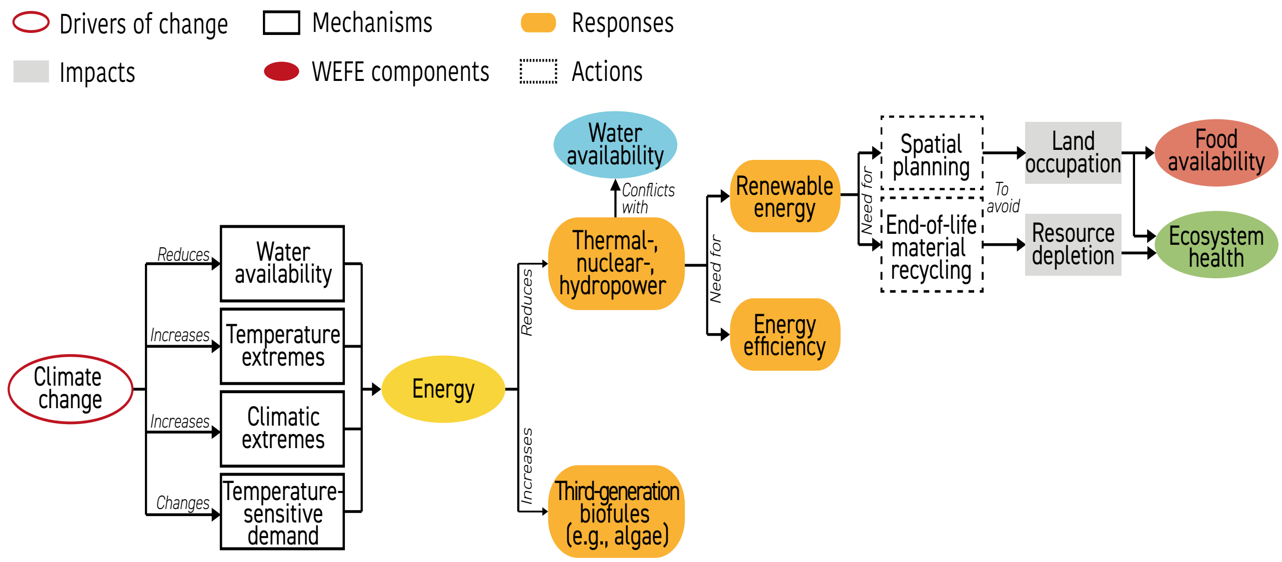

Figure 2.18 | Example of cascading impacts of climate-induced energy changes on water, food, and ecosystems.

emissions that affect marine wildlife. The Convention on the Conservation of Migratory Species of Wild Animals has published Best Available Technology (BAT) and Best Environmental Practice (BEP) for mitigating noise from this technology (Weilgart, 2023).

Finally, increasing energy production implies more water. In Europe, water withdrawals for energy are similar to those for agricultural irrigation. A small fraction is eventually consumed (6% for EU countries, nevertheless with large disparities between countries), and the remainder is returned to the hydrological system (Adamovic et al., 2019). In the MENA region, the share dedicated to irrigation is much higher (80%) (World Bank, 2018), as the climate is much more arid. But the energy sector still represents a significant proportion of withdrawals which could evolve over time due to improved technologies associated with the water–energy nexus.

In sum, accurate spatial planning is needed to avoid adverse effects such as loss of biodiversity and conflicts between different land and sea uses. If priority is given to system integration of renewable energies (building-integrated, industrial areas, non-arable land, mixed-cropping systems, etc.), potential conflicts between energy and non-energy use of soil can be avoided. This point is really crucial as the added value of renewable energies is their flexibility and modularity compared to conventional technologies. It is important for policymakers to adopt clear rules and regulations to prevent the deployment of renewable energy following the same pattern as conventional energies. Calls for tenders for renewables should, for example include the land occupation aspect, and in general more of a nexus approach to minimise conflicts with water, food and ecosystems. Reducing energy demand is also crucial considering the biophysical limitations for production.

2.5 The WEFE cascade from the ecosystems change perspective

2.5.1 Impact of drivers of change on ecosystem health and services

2.5.1.1 Climate change

The Mediterranean Basin is undergoing several climatic alterations that are transforming this previously biodiversity-rich region (Moatti & Thiébault, 2018). Rising temperatures, changes in rain patterns, more frequent and stronger extreme weather events (such as wildfires, storms, and droughts) and rising sea levels, can worsen the condition of sensitive Mediterranean ecosystem species, disturbing the already delicate balance (Cramer et al., 2018; Lange, 2020; Seneviratne et al., 2021). These changes can be seen through increased vulnerability of endemic and keystone species, shifts in vegetation, migration of fauna, phenological changes and ecological asynchrony, as well as the expansion of arid and semi-arid zones, among others.

Vulnerability of endemic and keystone species

Endemic species, uniquely adapted to the Mediterranean climate, face increased vulnerability. The restricted geographical ranges of these species leave them with limited options for migration or adaptation, rendering them susceptible to temperature-induced stress. This poses a considerable threat to the rich biodiversity that characterises Mediterranean terrestrial ecosystems (Médail, 2017). For instance, warmer temperatures can impact the Iberian lynx (*Lynx pardinus*), endemic to the Iberian Peninsula, by changing the lynx's preferred habitats and the abundance of its primary prey, the European rabbit (*Oryctolagus cuniculus*) (Fordham et al., 2013; van Hassel & Bovenkerk, 2023). The Atlas cedar (*Cedrus atlantica*), an endemic tree species in the Atlas Mountains of North Africa, faces increased vulnerability due to temperature-induced stress, especially as warmer conditions impact its distribution and growth. Elevated temperatures and altered precipitation patterns also have the potential to augment the proliferation of pests and diseases affecting this tree (Cheddadi et al., 2017). As trees are weakened by unfavourable environmental conditions, an increasingly large proportion is expected to become susceptible to pathogens. This has twofold implications: (1) many trees will die, reducing the standing biomass; and (2) the pathogen population will build up to the point of threatening trees that could, perhaps, resist a light attack but not a heavy infestation. Losses will probably be greatest for trees on the edges of their natural distribution, where a small change will make the environment unsuitable for them. Some forest diseases now considered minor may become serious (Resco de Dios et al., 2007).

Keystone species play pivotal roles in maintaining ecosystem structure and function. Whether they are dominant plant species shaping landscapes or top predators regulating populations, these keystone species are sensitive to changing climate conditions. Their decline or altered behaviour can trigger cascading effects throughout the ecosystem. holm oak (*Quercus ilex*), a dominant tree species in Mediterranean forests, plays a key role in shaping the structure and composition of these ecosystems. It provides habitat, influences nutrient cycling, and regulates water availability. However, changes in precipitation patterns and increased frequency of droughts associated with climate change pose threats to the health of Holm oak forests (Puig-Gironès et al., 2023). Reduced water availability can affect the distribution of this keystone species and impact the diverse flora and fauna dependent on these ecosystems, especially in less favoured microclimates (Principe et al., 2019). The pine processionary moth (*Thaumetopea pityocampa*) is a keystone species in Mediterranean pine forests, influencing vegetation dynamics and nutrient cycling. It also serves as a food source for numerous bird species. Warmer temperatures and altered precipitation patterns can affect the life cycle and population dynamics of the pine processionary moth. This, in turn, can impact the entire trophic cascade within the forest ecosystem, affecting both flora and fauna (Hódar et al., 2003).

Shifts in vegetation and migration of fauna

Rising temperatures are inducing significant shifts in the composition of plant and animal species within terrestrial ecosystems. As thermal conditions become less suitable for certain species, there is an observable migration of vegetation zones to higher altitudes, altering the dynamics of ecosystems traditionally characterised by distinct plant communities. Heat-tolerant and drought-resistant species may become more dominant, leading to changes in the composition of plant communities. This phenomenon poses a threat to endemic and specialised species adapted to cooler temperature ranges, leading to potential biodiversity loss, and impacting the overall biodiversity and structure of Mediterranean ecosystems (Peñuelas et al., 2017). In addition, if temperatures change as rapidly as predicted, then the reassembly of ecological communities will need to take place within the lifespan of individual trees. As communities are the result of interactions between organisms as well as between organisms and their abiotic environment, rapid climate change may be expected to alter species assemblage composition (Resco de Dios et al., 2007). Changing precipitation patterns, including altered rainfall amounts and distribution, influence the structure of terrestrial ecosystems. Wetland and forest ecosystems may experience changes in plant composition and distribution as species adapt to new moisture regimes. Species adapted to specific precipitation patterns may face challenges as their habitats change, potentially resulting in declines for certain plant species and impacting associated fauna (Erol & Randhir, 2012).

Examples of shifts in vegetation due to alterations in temperature and moisture regimes include Morocco's

Atlas Mountains. They are currently warming and, consequently, alpine flora, including rare cold-loving species, are moving upwards. Alpine vegetation displacement compresses the habitat for high-altitude plant species, in turn, affecting the organisms that depend on this vegetation for food and shelter (Cheddadi et al., 2017). This upward shift in alpine plant species is also observed in the Sierra Nevada mountain range. Some species that were normally limited to certain heights, or dependent on particular moisture regimes are now found at higher levels (Winkler et al., 2019). Endemic and specialised plant species suitable for cooler temperatures and certain moisture regimes are facing a reduction in habitat availability, which increases the likelihood of local extinction and biodiversity loss (Benito et al., 2011). Changing climatic conditions in the Peloponnese in Greece are affecting the distribution of forested areas. The mix of deciduous and evergreen species is being displaced as traditional forest boundaries move to higher elevations. Vegetation migration leads to a reshuffling of dominant tree species that changes the overall visual landscape and habitat suitability for associated fauna (Koulelis et al., 2023). Southern Spain experiences longer hotter days with lower precipitation. *Cistus* and lavender Mediterranean shrublands are now changing as a result of these changing conditions. These heat-tolerant shrub species are growing at the expense of drought-intolerant plants, altering the biodiversity and ecological dynamics of these landscapes. This kind of shift may further affect herbivores and pollinators, which depend on certain plant species (Gallego Fernández et al., 2004). In the Camargue wetlands in France, changes in rainfall patterns, which contribute to fluctuations in water levels, impact the composition and distribution of wetland plant species, including some critical species for waterfowl birds. It can alter the availability of good nesting and foraging grounds for birds (Nager et al., 2010).

Rising temperatures are also inducing shifts in distribution of animal species (Aurelle et al., 2022; Stefanescu et al., 2003). Birds, insects, and small mammals may migrate to higher temperatures (Maiorano et al., 2011). This may result in shifting predator-prey relations, resource competition, and modifications in species interactions in mountainous and hilly regions. Butterfly distribution in the Sierra Nevada mountain range has been affected by increasing temperatures. They are migrating to higher latitudes where climatic conditions better suit their life cycle requirements. The distribution of butterflies may also alter their interactions with plants, such as pollination dynamics. Moreover, it may adversely impact other butterfly-dependent species like insectivorous birds (Nice et al., 2014). Changing hotter temperatures in the Atlas Mountains are also changing the distribution of ant species. Ant colonies can migrate to higher elevations due to unfavourable temperatures, and the search for appropriate nesting grounds. This can have cascading effects on ecosystems, affecting seed dispersal, soil nutrient cycling etc. and other invertebrates (Ziyadi et al., 2019). There is also evidence of the migration of lizards and snakes in Crete, to areas with higher elevations. Changes in the distribution of reptiles can alter local ecosystems, including predators and prey (Karameta et al., 2023). In the Pyrenees mountain range, bird species, particularly those adapted to cooler conditions, are migrating to higher elevations where temperatures remain within their preferred range. These changes in the distribution of bird species can lead to altered predator-prey dynamics, competition for nesting sites, and shifts in the availability of food resources in mountainous regions (García-González et al., 2016).

Phenological changes and ecological asynchrony

The warming climate is disrupting the timing of key ecological events, known as phenology, affecting the synchrony between species interactions. Changes in the timing of phenological events, e.g. flowering and migration, can lead to mismatches between mutually dependent species, such as pollinators and flowering plants or predators and prey. This ecological asynchrony can have cascading effects on the entire ecosystem, from plants and pollinators to herbivores and predators. The spatial variability of flowering dates is also reduced during warm and dry years, especially for spring events (Gordo & Sanz, 2010). This reduction in spatial variability can also affect dependent species.

Ecological asynchrony due to changing climate patterns might occur when the timing of plant flowering shifts, affecting the availability of nectar and pollen for pollinators. If pollinators, such as bees, do not adjust their life cycles accordingly, a phenological mismatch can occur, potentially leading to reduced pollination success and seed production (Morton & Rafferty, 2017). Almond trees (*Prunus dulcis*) in Spain typically rely on honeybees for pollination. With warmer winters, almond trees are flowering earlier. However, honeybee activity might not adjust accordingly, leading to a potential phenological mismatch. If bees are not present when the almond trees are in full bloom, it can result in reduced pollination and almond yields (Henselek et al., 2018). On the other hand, climate change is influencing the timing of seasonal events, such as the arrival of migratory birds in the Iberian Peninsula (Gordo & Sanz, 2006). The altered timing of bird migration may no longer align with the peak availability of their insect prey. If migratory birds arrive before or after the peak abundance of their prey species, this can disrupt food availability, affecting the reproductive success of birds and potentially impacting insect populations (Acácio et al., 2022).

Genetic, epigenetic and metabolic impacts

Climate change is causing rapid genetic, epigenetic, and metabolomic changes in Mediterranean plant species. Field studies of altitudinal gradients in the Montseny Mountains (Jump et al., 2006a, 2006b) and field-warming and drought-manipulation experiments in typical Mediterranean shrubland (Jump et al., 2008) have demonstrated rapid responses for the acclimation and adaptation (evolution) of species to climate change by taking advantage of the existing genetic variability in natural populations (Peñuelas et al., 2018). Alterations in gene expression not attributable to variations in DNA sequences have also been detected in holm oak (*Quercus ilex*) subjected to experimentally induced drought (Rico et al., 2014). In response to drought stress, Mediterranean shrubs and trees often increase the production of secondary metabolites such as phenolic compounds and flavonoids. These compounds play a role in antioxidant defence and protection against oxidative stress induced by drought. These compounds can have various functions, including antioxidant activity and defence against herbivores and pathogens (Rivas-Ubach et al., 2012, 2014, 2016). Changes in plant genetics, epigenetics and metabolomics have resulted in changes in morphology, physiology, growth, reproduction, and mortality, with some species more affected than others. These changes could lead to a future dominance replacement of trees by tall shrubs (Peñuelas et al., 2018).

Expansion of arid and semi-arid zones

Warming temperatures, changes in precipitation patterns and increased evaporation contribute to the expansion of arid and semi-arid zones in the Mediterranean, leading to desertification and habitat loss. Mediterranean ecosystems, generally dominated by sclerophyllous woody plants with a herbaceous or shrubby understory, have an array of physiological and morphological adaptations to cope with drought and nutrient scarcity (Gulías et al., 2002; Padilla & Pugnaire, 2007; Vilagrosa et al., 2010). Nevertheless, in coming decades, the projected level of drought and aridity may have important effects on the functioning and structure of Mediterranean plants, forests and shrublands (Peñuelas et al., 2018). Species adapted to more arid environments, such as succulent plants, may thrive, while others dependent on historically more temperate conditions and moisture regimes may face challenges (Maestre et al., 2012; Vallejo et al., 2005), including local extinctions (Prigent et al., 2018). In Catalonia (northeastern Spain), rising temperatures, new patterns of precipitation and other climatic changes are affecting ecosystems (Peñuelas et al., 2018). In Almería (southeastern Spain), intensive agriculture, coupled with increasing temperatures and altered rainfall, has contributed to soil degradation and desertification, leading to a decline in natural vegetation.

Altered precipitation patterns, including increased drought frequency, pose significant challenges to water-dependent ecosystems. Wetlands, riparian zones, and freshwater habitats are particularly vulnerable, affecting species dependent on these unique environments. For example, Doñana National Park is a UNESCO World Heritage Site known for its wetlands and biodiversity. Altered precipitation patterns and increased drought frequency, together with high intensity levels of underground water extraction for irrigation, have led to reduced water availability in the park's wetlands, resulting in habitat loss and changes in the composition of aquatic plant species. Species like waterfowl birds, amphibians, and migratory birds that depend on these wetlands for breeding and feeding also face challenges due to reduced water resources (García de Jalón et al., 2014; Green et al., 2017).

Changes in nutrient cycling

Reduced soil moisture may impact the nutrient cycle due to its effects on microbial activity, mineralisation and other processes. Additionally, changes in temperature and precipitation patterns can influence the timing and nature of biotic interactions, such as plant-microbe relationships, impacting nutrient cycling processes. Take, for instance, mycorrhizal associations between plants and fungi. Fungi play a vital role in natural ecosystems and strongly influence the dynamics of forest ecosystems, including the ability of trees to access limited nutrients and store carbon. Fungal productivity has already decreased in certain areas due to climate change (Morera et al., 2022). Projections estimate that most significant changes in total productivity, including mycorrhizal fungi, will occur in subalpine and montane pine forests. In contrast, saprotrophic fungi could potentially benefit from more significant changes in climate and boost their productivity in supra– and meso– Mediterranean regions at mid–range elevations (Morera et al., 2022). These changes in nutrient cycling suggest potential net losses in the capacity of Mediterranean forests and shrublands to act as carbon sinks (Peñuelas et al., 2018) and to provide other ecosystem services, such as soil conservation, water storing capacity, biodiversity, timber, mushroom and food production, tourism, and recreation (*Table 2.5*; Peñuelas et al., 2017).

Elevated sea levels may influence nutrient dynamics in land and water systems at the coast. Saltwater intrusion can lead to changes in nutrient availability in coastal ecosystems which affect the quality of soils and waters. In return, it may influence plant and microbial communities (Bellafiore et al., 2021). Additionally, ocean acidification and changes in the marine ecosystem due to increased CO_2 levels in the atmosphere may have consequences for nutrient cycling processes in the Mediterranean Sea (Hassoun et al., 2022).

Impact of extreme events on ecosystems

Extreme events, such as heatwaves, wildfires, intense storms, and heavy rainfall, can have profound impacts on the structure and function of ecosystems in the Mediterranean Basin (Hochman et al., 2022). Wildfires are a significant threat that can lead to the destruction of vegetation, including forests, shrublands, and grasslands. Loss of vegetation alters the physical structure of ecosystems, leading to habitat fragmentation, soil erosion and changes in species composition. Post–fire, ecosystems often experience shifts in plant and animal populations (Caon et al., 2014; Duguy et al., 2013). Heatwaves can cause extreme temperatures beyond the norm, stressing plant and animal species and disrupting normal ecosystem functions. They can also lead to increased evaporation, affecting water–dependent ecosystems (El–Madany et al., 2020). On the other hand, extreme temperatures in the Mediterranean Sea can lead to marine heatwaves, causing coral bleaching, changes in fish distribution, and altered plankton dynamics. These events can disrupt marine food webs and alter the abundance and distribution of marine species. Some extreme situations of mass mortality in the Mediterranean Sea have been reported (Garrabou et al., 2022). Finally, intense rainfall events leading to flooding, particularly in coastal areas and riverine ecosystems, result in soil erosion, loss of vegetation, and habitat degradation. This may also lead to the displacement of species adapted to specific moisture conditions (Terrado et al., 2014).

Changes in aquatic ecosystems

The Mediterranean Sea represents the highest proportion of threatened marine habitats in Europe (32%), with 21% listed as vulnerable and 11% as endangered, and seagrass ecosystems experiencing the most rapid decline (UNEP/MAP & Plan Bleu, 2020). Marine ecosystems in the Mediterranean are sensitive to sea surface temperature increases. This has resulted in the occurrence of coral bleaching events, changes in the distribution of fish species, and altered abundance of marine organisms (Calvo et al., 2011). Elevated sea temperatures have the potential to perturb the distribution and behaviour of marine species, thereby causing alterations in migration patterns and posing a risk to those that are most susceptible (Hoegh–Guldberg et al., 2014; IPCC, 2022; Nurse et al., 2014; Pörtner et al., 2014; Wong et al., 2014). Changes in fish distribution can have implications for local fisheries, altering catch compositions and potentially leading to shifts in predator–prey dynamics within the marine food web (Giani et al., 2012). Besides corals, marine heatwaves will likely cause increasing mass mortality events of benthic species, mostly invertebrate organisms, such as sponges, bivalves, ascidians, and bryozoans, and increase the risks of abrupt collapse of endemic species (Garrabou et al., 2019, 2021; Kersting et al., 2013; Rivetti et al., 2014, 2017). Increased carbon dioxide absorption, which contributes to ocean acidification, can be detrimental to marine organisms possessing calcium–carbonate shells or skeletons, including corals and molluscs. Phytoplankton net primary productivity is set to drop on average by 10% at the end of the century and up to 50% in some regions, such as the Aegean Sea, as a result of both nutrient limitation and vertical stratification, with possible negative impacts on marine food webs and ecosystems. Benedetti et al. (2018) estimated that the diversity of copepods is expected to decline across most regions of the Mediterranean, influenced by various factors associated with environmental changes, such as variations in temperature, ocean currents, and nutrient availability. Changes in the abundance and composition of copepod communities may lead to shifts in fish distribution, growth rates, and overall ecosystem dynamics.

The loss of corals has a significant impact on the marine life that relies on them for shelter and food (Antoniadou et al., 2023) and also affects the coastline by reducing natural protection against waves and storm surges (Baker et al., 2008). Rising sea temperatures, increased nutrient runoff, and changes in storm patterns can all lead to the decline of Posidonia oceanica meadows, a keystone seagrass species. This decline can have a significant impact on coastal ecosystems, affecting fish nurseries, nutrient cycling, and sediment stability, with cascading effects on other marine organisms (Pergent-Martini et al., 2021). Fluctuations in precipitation and changes in hydrological regimes also influence aquatic ecosystems. The alteration of river flows can alter fish migration, spawning, and the availability of suitable habitats. Freshwater and estuarine species face the challenge of adapting to changing salinity levels, impacting the composition and distribution of these communities (Cid et al., 2017; Erol & Randhir, 2012). Altered precipitation patterns, coupled with increased drought frequency, have contributed to the reduction of water availability in the Camargue wetlands. Drought stress has led to the loss of wetland habitats, affecting water-dependent species such as amphibians, waterfowl, and various aquatic organisms. Amphibians, in particular, may face decline due to the reduced availability of suitable breeding habitats (Fraixedas et al., 2019). These examples underscore the complex and interconnected nature of aquatic ecosystems in the Mediterranean Basin, where changes in sea surface temperatures and levels of precipitation have far-reaching consequences on coral reefs, seagrass meadows, fish populations, and overall biodiversity.

Impacts in island ecosystems

Mediterranean islands are hotspots for global biodiversity and lie in one of the areas of the world that is the most susceptible to climate change. These include phenological changes and upward elevation shifts of species and plant communities; although evidence is frequently contrasting for different taxa (Vogiatzakis et al., 2016). Threats are also evident, mainly for endemic species from most taxonomic groups, while communities in mountain and coastal regions are likely to be affected most. Furthermore, the limited space on islands (especially habitat availability and climatic range limitations) places a barrier on species range expansion (Vogiatzakis et al., 2016).

2.5.1.2 Land Use and Land Cover Changes (LULCC)

Sustainable land management and conservation of terrestrial ecosystems are crucial for achieving the SDGs. LULCC may arise from a range of situations that are not always negative for ecosystems: the disturbance of a native or semi-natural ecosystem; altering the management or purpose of already humanised systems (e.g. agroecosystems, urban systems); rewilding of ecosystems or restoration in its various forms - ecological, mitigation, remediation, rehabilitation, revegetation, etc. (Gann et al., 2019). Demographic and lifestyle changes have increased the pressure on Mediterranean ecosystems. There is a pressure to expand agricultural and urban areas, together with all the infrastructure necessary for their functioning, at the cost of occupying former natural areas, thus fragmenting, and reducing the size of natural ecosystems as well as the services they provide (Haddad et al., 2015; Salvati et al., 2016). On the other hand, land abandonment of former agricultural areas, now subject to lack of management, favour colonisation by invasive species (IPBES, 2023) and create conditions for uncontrollable fires (e.g. Delgado-Artés et al., 2022; Mantero et al., 2020). The abandonment of traditional agriculture in the Mediterranean has also contributed to reducing the endemic biodiversity of the ecosystem and its functional resilience (IPBES, 2023). Traditional Mediterranean agriculture had the benefit of being diverse (in space and time - e.g. rotations, seasonal products) and practiced on small areas, facilitating interactions with nearby natural ecosystems. Large scale monocultures, without the implementation of natural corridors or "stepping-stones" (areas of heterogeneity) for natural biodiversity to be able to transit between more natural ecosystems and multiply their genetic pool, have a strong negative impact on ecosystems' health. Over the past few decades, the Mediterranean region has experienced a rise in agricultural intensification, an expansion of cultivated land and a shift towards high-yield crops to satisfy increasing demand for food globally. Within this particular context, extensive regions of forests, grasslands, and other natural ecosystems have undergone a transformation process, converting them into agricultural fields. The aforementioned practices were found to be associated with substantial LULCC patterns in the Mediterranean region, resulting in detrimental effects on the well-being of ecosystems. The Mediterranean Basin emerges as a significant non-point source of nitrogen, predominantly from agricultural intensification (UNEP/MAP & MED POL, 2011). While moderate amounts of nitrogen, particularly in the form of nitrate, prove beneficial for crops, especially in semi-arid soils, exceeding critical loads becomes a cause for concern (de Vries, 2021; Novara et al., 2020). This imbalance triggers shifts in competition among plant species, favouring fast-growing plants while stifling smaller plants due to limited access to light, ultimately leading to a decline in species richness (Calvete-Sogo et al., 2016). Moreover, the intolerance of most plants to synthetic fertilisers and high nitrogen levels allows nitrogen-tolerant species to thrive, outcompeting more sensitive wild plants and fungi, resulting in reduced wildlife diversity and impaired plant health (Midolo et al., 2019). In certain Mediterranean countries such as Portugal and Spain, intensive livestock production, coupled with the extensive use of manure and synthetic fertilisers, contributes to environmental issues like groundwater contamination with nitrates (Cameira et al., 2021) (see *Section 2.3.2.3*). Nitrogen influx to aquatic ecosystems contributes to algal blooms, diminishing oxygen availability, increasing eutrophication, and disrupting the delicate balance of aquatic life (Ochoa-Hueso et al., 2011; Padedda et al., 2019). Furthermore, contamination with pesticides, herbicides (such as glyphosate), and persistent organic pollutants are also found in high concentrations in soils across the Mediterranean region, affecting ecosystems (Kanakidou et al., 2022; Ochoa-Hueso et al., 2011). Finally, the creation of infrastructure on watercourses and its use for aquaculture or recreational activities has also impacted aquatic ecosystems, often with the introduction of exotic invasive species (IPBES, 2023; Zamora-Marín et al., 2023).

Urban areas compete for space with agroecosystems (housing and infrastructure vs. local food production) as well as with less humanised ecosystems (more pristine). In either case, they induce the fragmentation of habitats and increase pollution in its various forms (chemical, sound, light, etc.). The phenomenon of habitat loss and fragmentation can potentially cause the segregation of extant habitat patches, thereby causing a decline in inter-population connectivity (Pacifici et al., 2015). The transition to sustainable energy forms is not without impact on ecosystem health. Technologies have not yet achieved optimal performance, and often require conversion of land use, in vast areas, resulting in the loss and fragmentation of habitats (see *Section 2.4.2*).

2.5.1.3 Pollution

Pollution in the Mediterranean region yields both direct and intricate impacts on the quality of air, soil, and water, unfolding through diverse pathways that collectively undermine the overall health of ecosystems. Certain air pollutants, such as ozone (O_3) and particulate matter, damage plants. Elevated levels of these pollutants trigger a chain reaction leading to reduced growth rates, accumulation of harmful substances, and adverse effects on biodiversity and essential ecosystem services. Ozone levels surpassing safety thresholds infiltrate plant leaves, impeding photosynthesis and rendering plants more susceptible to pests and diseases (Calvete-Sogo et al., 2016; Monga et al., 2015). Air pollutants can also interfere with the behaviour of pollinators like bees and other insects. This interference may reduce pollination rates, a crucial step in the reproduction of many flowering plants. Additionally, prolonged exposure to high air pollution levels results in the decline of essential nutrients such as calcium, potassium, and magnesium in the soil, disrupting nutrient balance and triggering cascading effects within the intricate web of the ecosystem (de Vries, 2021; Ochoa-Hueso et al., 2011).

The anthropogenic noise generated by diverse activities (e.g. shipping traffic, construction and coastal development, fishing, renewable energy generation, etc.) has altered the quality of the marine environment with consequences on physiology, communication, behaviour, and energetics of different marine species (Abdulla & Linden, 2008; Chahouri et al., 2022; Rako-Gospić & Picciulin, 2019).

There are multiple consequences for soil contamination, impacting soil functions and disrupting crucial ecological functions through a reduction in the abundance of organisms for sensitive species, by reducing their fitness and reproductive ability and increasing their susceptibility to diseases. Additionally, sensitive species will be replaced by more tolerant ones, shifting species composition first (potentially favouring exotics) and decreasing species richness later on, again, with stronger impacts on local system functionality (Branquinho et al., 2019; Ferreira et al., 2022).

Escalation of pollution in the Mediterranean region directly puts its unique habitats and biodiversity at risk, precipitating shifts in the geographical ranges of species and reshaping the dynamics of their interactions (Martínez-Megías & Rico, 2023). These interconnected effects contribute significantly to the detriment of ecosystems, influencing the delicate balance of biodiversity, ecological equilibrium, and the invaluable services that ecosystems provide to communities (Kanakidou et al., 2022). Many species in this region exhibit specific environmental requirements for survival, and when pollution disrupts their habitats, the struggle for survival and reproductive challenges become pronounced (Albano et al., 2021). This disruption has the potential to lead to the loss of entire species or a decline in their populations, particularly impacting those that are uniquely adapted to the Mediterranean's distinct environmental conditions (Albano et al., 2021).

Furthermore, pollution in the Mediterranean alters environmental conditions, including temperature, water quality, and food availability (Papamichael et al., 2022). Sensitivity to these changes compels species to migrate or shift their distribution to more suitable locations. This ecological flux can trigger cascading effects, disrupting the intricate balance between different species and restructuring the communities that characterise the Mediterranean ecosystems. The influence of pollution extends to the behaviour, physiology, and reproductive capabilities of various species in the Mediterranean. These alterations reverberate through the intricate web of species interactions, potentially leading to changes in predator-prey dynamics, competition for resources, and overall shifts in ecosystem functioning (Ochoa-Hueso et al., 2017). Moreover, heightened pollution levels result in diminished productivity. In aquatic ecosystems, water pollution can hinder photosynthesis by marine plants due to reduced sunlight penetration or nutrient imbalances (López-Doval et al., 2013). Similarly, in terrestrial ecosystems, air and soil pollution can inhibit the growth and productivity of plants essential to the Mediterranean landscape (Ferreira et al., 2022). Additionally, pollution weakens the natural defences of organisms, rendering them more susceptible to stressors. Compromising immune systems in plants and animals makes them more vulnerable to diseases. Moreover, pollution can disrupt the abundance and distribution of certain species, paving the way for the proliferation of pests and invasive species and exacerbating the ecological challenges faced by the Mediterranean region. For instance, disease-driven mass mortality events, such as the one affecting the iconic *Pinna nobilis* pen shell in the Mediterranean Sea since 2016 caused by the parasite *Haplosporidium pinnae*, highlight the susceptibility of certain species to diseases (Katsanevakis et al., 2019). Similarly, the mass mortality event of the highly abundant non-indigenous mussel *Brachidontes pharaonis* along the Israeli rocky shore in 2016 underscores the potential impact of unknown causes linked to pollution (Rilov et al., 2020). The interconnected nature of these pollution-induced effects compounds into a cumulative threat to ecosystem health in the Mediterranean. This interconnected cascade has far-reaching consequences, impacting primary producers, herbivores, predators, and decomposers, ultimately leading to an overarching decline in the health of Mediterranean ecosystems.

2.5.2 Cascading impacts of climate-induced ecosystem changes on water, food, and energy

Climate change, through its effects on water availability (air, soil, groundwater, and streams), on temperature extremes (higher maximum and minimum temperatures) and on climatic extremes (heatwaves, flash floods, storms) has far-reaching effects on ecosystem health. These effects manifest in terms of decrease in productivity and decrease in diversity at all levels (intraspecific, species, interactions, and landscape). The noteworthy impact of climate change on the health of Mediterranean ecosystems is evidenced by its effects on their structure, composition, and functioning (see *Section 2.5.1.1*). The perturbations mentioned above have the potential to initiate a cascade of effects throughout the trophic levels, resulting in the destabilisation of ecological dynamics and the impairment of ecosystem functionality (Bagstad et al., 2017). These ecosystem functions change the delivery of several ecosystem services that in turn cascade to the other WEFE components, namely, water availability and quality, food availability and diversity and energy availability (*Figure 2.19*). The benefits that humans obtain from ecosystems, known as ecosystem services, are susceptible to significant effects from climate change. These effects cover the three ecosystem service types: (1) provisioning; (2) regulating; and (3) cultural (*Figure 2.19*).

The decrease in productivity due to climate change negatively impacts several provisioning ecosystem services, as it leads to a decline in the availability of food from wild plants and animals, the reduction of water supply for various human needs (due to less retention at vegetation level), and the reduction of biomass–based energy, resulting in the loss of food availability, water availability and energy availability, respectively.

Decreased vegetation productivity may lead to reduced water retention in the soil, affecting overall water availability in ecosystems (*Figure 2.19*). This reduction in water availability can directly impact water supply for various human needs, including agriculture, industrial processes, and domestic use (MedECC, 2020). Additionally, biomass–based energy resources, such as woody plants, agricultural residues, and organic waste, may experience decreased yields due to low vegetation productivity at ecosystem level (Peñuelas et al., 2017).

Decline in biological diversity, induced by climate change, leads to alterations in species composition, distribution, and abundance, which is critical for maintaining ecosystem functionality (Díaz et al., 2007). Biodiversity loss poses a serious threat to the overall resilience of ecosystems. Diverse ecosystems, with a variety of species, are better equipped to withstand environmental stressors, adapt to changes, and recover from disturbances. Networks of ecosystem functionality are supported by complex relationships existing between different species, contributing to the stability of ecosystems (Leslie & McCabe, 2013). Biodiversity loss also causes changes in trophic webs and interaction between organisms within the ecological system. For example, changes in predator–prey relations can destroy an ecological balance. A decline or disappearance of species is one of the initiators of a chain reaction resulting in increased abundance of others throughout the food web (Schmitz et al., 2004). Impacts are not limited to ecological structures, but further extend to other facets of biodiversity, such as functional diversity and phylogenetic diversity, impacting ecosystem functions and processes (Zhang et al., 2023). Biodiversity loss can substantially impact regulating ecosystem services and negatively affect five categories (*Figure 2.19*): (1) maintenance of soil structure and fertility; (2) decomposition, remineralisation, and recycling processes; (3) pollination; (4) seed dispersal; and (5) pest and disease control, which subsequently negatively impacts food availability (Hanisch et al., 2020). Reduced diversity can also limit the variety of foods available for consumption, affecting both human nutrition and cultural preferences. Changes in the distribution and abundance of plant and animal species decreases the availability of traditional food sources for local communities, such as wild thyme (*Thymus spp.*), wild asparagus, wild artichokes, various wild berries, wild mushrooms, wild game, and edible seaweeds.

Ecosystems are of paramount importance in the preservation of soil fertility and nutrient cycling, which are facilitated by diverse mechanisms, including decomposition. Accordingly, the reduction in biodiversity and degradation of ecosystems can lead to a decline in the supply of these services. Additionally, climate change has the capacity to alter vital ecological mechanisms, such as nutrient cycling, primary production, and decomposition rates, among others. These changes potentially result in a decrease in soil fertility and potential reductions in agricultural productivity, increasing dependence on synthetic fertilisers, thereby expanding associated GHG emissions and soil and water pollution.

Healthy ecosystems are also essential for maintaining soil structure, preventing soil erosion, and consequently reducing water pollution. Examples of species in the terrestrial realm that affect the maintenance of soil structure by anchoring the soil with their root systems, are *Cistus* and *Quercus ilex*. However, changes in precipitation patterns and increased temperatures may affect its distribution, abundance, and health, potentially resulting in

Climate change driver	Organismic responses	Ecosystemics responses	Effects on ecosystem services
Warming	- Fast genetic adaptation. - Metabolomic shift towards activated antistressmetabolic pathways. - Changes in elemental composition of plants. - Morphological and metabolomic acclimatation of plants under moderate warming. - Changes in phenology. - Increase terpene emissions. - The increase of VOCs (Volatile Organicic Coumpounds) will affect the signal effect of these coumpounds for pollinators, thereby influencing their competitive ability.	- Desertification - Asymmetrical adaptation capacity among plant community species drive to changes in species composition at medium and long–term. - Changes in the phenology of plant–pollinators relationships Increase of POPs (persistent organic pollutants) concentrations in environent and organisms. - Transformation of primary POPs to more toxic secondary POPs. - Exacerbation of phenological asynchronies between plants and their pollinators. These climate–induced phenological disruptions may also have unexpected eco–evolutionary consequences, biasing sex ratios in the populations of insect species where sex is determined by temperature. - Shifts of species distribution areas of plants and animais to higher latitudes and/or latitudes	- Decreased provision of several ecosystem services, such as water storing capacity, tituber, mushrooms, tourism, soil conservation. - Less water availability for human activities including food production and recreative services. - Increased land cover not situable for farmland and cropland activities.
Drought	- Fast genetic adaptation. - Metabolomic shifts towards activated anti–stress metaboloc pathways. - Changes in elemental composition of plants. - Morphological and metabolomic acclimation of plants under moderate drought. - Disappearance of less drought resistant species under prolonged drought events and/or chronic drought enhancement. - Changes in palatability in plant tissues. - Changed terpene emissions.	- Desertification asymmetrical adaptation capacity among plant community species drives to changes in species composition at medium and long–term favouring drought resistent species. - Decreases of total ecosystem nutrient content. - Changes of allocation to nutrients from leaves to roots, and from plants to soil. - Decrease in soil mineralization - Increases of more recalcitrant fractions of nutrients and decreases of more labile fractions in soils. - The increasing recurrent wildfires linked to drought have transformed several forested areas to shrublands in the last 20 years, e.g., in southern Portugal. - Reduction of ecosystem capacity to act as C–storage.	- Decreased provision of several ecosystem services, such as water storing capacity, tituber, mushrooms, tourism, soil conservation. - Less water availability for human activities including food production and recreative services. - Increase of land cover not situable for farmland and cropland activities. - Decrease of tourism and hiking. - Losses of biodiversity and ecosystem C–storing capacity. - Loss of soil protection capacity.

Table 2.5 | Main recent findings grouped by climate change driver: (1) responses from organisms; (2) responses from ecosystems; and (3) effects on ecosystem services.
Source: Peñuelas et al., (2017).

increased soil erosion (Raimundo et al., 2018; Sardans et al., 2020).

Changes in the distribution and behaviour of species due to climate change can impact crucial ecosystem services such as pollination and seed dispersal. *Apis mellifera* honeybees play a crucial role in pollinating various crops and wildflowers, contributing to the reproduction of plant species. However, changes in temperature and precipitation patterns can affect the abundance and distribution of floral resources which impact the foraging behaviour and overall health of honeybee colonies, potentially leading to decreased pollination services for crops and wild plants (Bartual et al., 2018). Many bird species in the Mediterranean (e.g. *Sylvia spp.*) are involved in seed dispersal, promoting the establishment of plant populations. In this way they play a role in the regeneration of forests and other habitats that serve as essential food and energy suppliers. Shifts in temperature, precipitation,

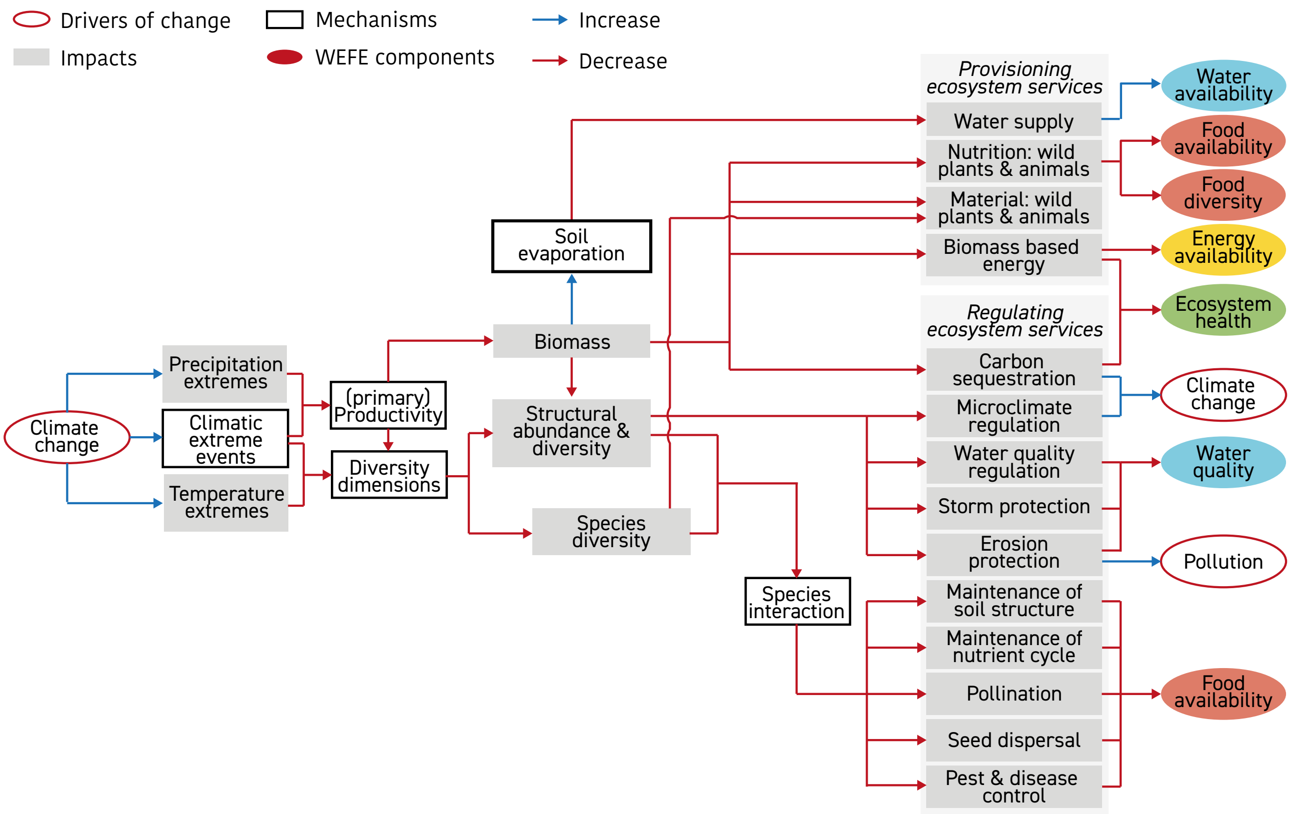

Figure 2.19 | Example of cascading impacts of climate-induced changes in ecosystems health on water, food, and energy, mediated through the impacts on ecosystem services.

and habitat availability can impact the distribution of these bird species which may affect the recruitment and diversity of plant species in the Mediterranean (Rey et al., 2021). European nightjar (*Caprimulgus europaeus*) is an insect-eating bird found in the Mediterranean and contributing to insect control, including nocturnal insects that may be pollinators or pests. Changes in temperature and insect abundance may influence the distribution and behaviour of nightjars, with indirect effects on pollination services through the impact on populations of nocturnal pollinators (Auger-Rozenberg et al., 2015).

Ecosystems in the Mediterranean region have the potential to significantly influence the availability of energy through the provision of renewable energy sources such as biomass, hydropower, and wind energy. As such, changes in ecosystems, including declines in forests or alterations in water availability, can impact the accessibility and durability of energy resources, thereby carrying potential implications for the production and provision of energy (Drobinski et al., 2020a; García-García, 2023).

The decrease in productivity due to climate change also carries some important implications for regulating ecosystem services, as it affects water quality regulation, storm protection and erosion protection. These services, in turn, play a crucial role in influencing and maintaining water quality standards. The protection of watersheds is a notable example that plays a crucial role in the conservation of robust ecosystems, such as forests and wetlands. These ecosystems act as significant controllers of water flow and quality. Wetlands serve as proficient natural filtration mechanisms, regulating the inflow of contaminants, sedimentation, and nutrient leaching into aquatic environments (Cao et al., 2022). Consequently, the degradation or depletion of ecosystems could potentially result in a reduction in water quality, a rise in sediment accumulation, and heightened concentrations of pollutants in aquatic environments. In addition, microclimate regulation and carbon sequestration are both negatively affected by the decrease in productivity, leading to an increase in climate change effects (*Figure 2.19*).

Finally, changes in ecosystem structure and function due to climate change will modify the way we appreciate ecosystems, thereby impacting the cultural ecosystem services that will ultimately affect human well-being (Castro et al., 2011) (*Figure 2.19*).

In general, understanding the interrelationships between ecosystem services and water, food, and energy systems in the Mediterranean region is crucial for the successful implementation of sustainable resource management strategies. The conservation and restoration of ecosystems have the potential to enhance the availability, quality, and resilience of these essential resources, thereby promoting sustainable development and safe guarding human well-being.

2.5.3 Cascading impacts of LULCC-induced ecosystem changes on water, food and energy

From an anthropocentric view, ecosystems provide us with services that are often only noticed when not available anymore. Ecosystem change (mediated by LULCC) will impact on services that cascade into water, food and energy systems. Some examples are described (*Figure 2.20*).

LULCC, resulting from the abandonment of formerly agricultural areas (either caused by land degradation or rural exodus) may take contrasting pathways in terms of ecosystem health. If the rewilding pathway is selected, the loss of direct human food production may be counterbalanced by the increase in regulation services (e.g. pollination), which indirectly benefit other agricultural areas nearby (food availability) and the diversity of wild food sources, including game animals. As the ecological succession proceeds, biomass is produced that (1) covers the soil, reducing surface erosion while biocrusts and the new plants' roots help fixate the soil; (2) biomass above and below ground from plants filters the water and captures micronutrients or even pollutants, improving its quality; (3) more biodiverse plants increase biomass CO_2 fixation, and promote soil organic matter production (and biodiversity), reducing the need for external fertiliser inputs (Oldfield et al., 2019); (4) more organic matter in the soil and more biomass covering the soil, as well as the existence of several strata of vegetation, induces a microclimate that is prone to water retention and protects from aridity, reducing energy (and water) demand; and (5) managed biomass may be used for energy production, although uncontrolled growth can lead to an increase in rural/forest fires. If the abandoned land already has very degraded soil, then there is a less clearly positive trend for the ecosystem. Either the plant cover has difficulties getting established (exacerbating erosion problems) or the species that colonise are inappropriate, in the sense that exotic invasive species may take over more easily due to lack of competition from native species. This may compromise a series of regulatory services based on ecological networks (e.g. food chains).

Industrial agriculture is focused on expanding the areas of monocultures (low biodiversity) which can be easily managed with machinery and with low levels of human labour. Industrial agriculture has to recurrently use agrochemicals (fertilisers, pesticides and herbicides), since natural nutrient cycles are too slow for the high demand and are broken by the overexploitation of natural resources. Excessive use of synthetic fertilisers exacerbates the problem by acidifying soils and disrupting soil health. In addition, the fact that ecological balances between species are missing, facilitates the development of pests and diseases.

Another example (*Figure 2.20*) is the LULCC intensification of agriculture, changing from traditional agricultural forms or semi-natural woodlands, to intensive and industrial, generally monoculture areas. By favouring an immediate increase in food production, ecosystem health is neglected, as well as the long-term productivity and sustainability of the system. Although food availability of one crop is increased (provision services), food diversity and nutritional quality is reduced (Hasanaliyeva et al., 2023) in the cultivated crops, and other sources of biodiverse food (e.g. wild crops and game) are reduced. Intensive agriculture requires the use of irrigation in naturally dry seasons (like the Mediterranean climate has), altering the seasonal patterns of water distribution, and the microclimate for soil microorganisms and decomposition processes (regulation services). Soils forming less organic matter also retain less humidity and need more frequent irrigation, decreasing water availability. Changing to intensive agriculture decreases the soil

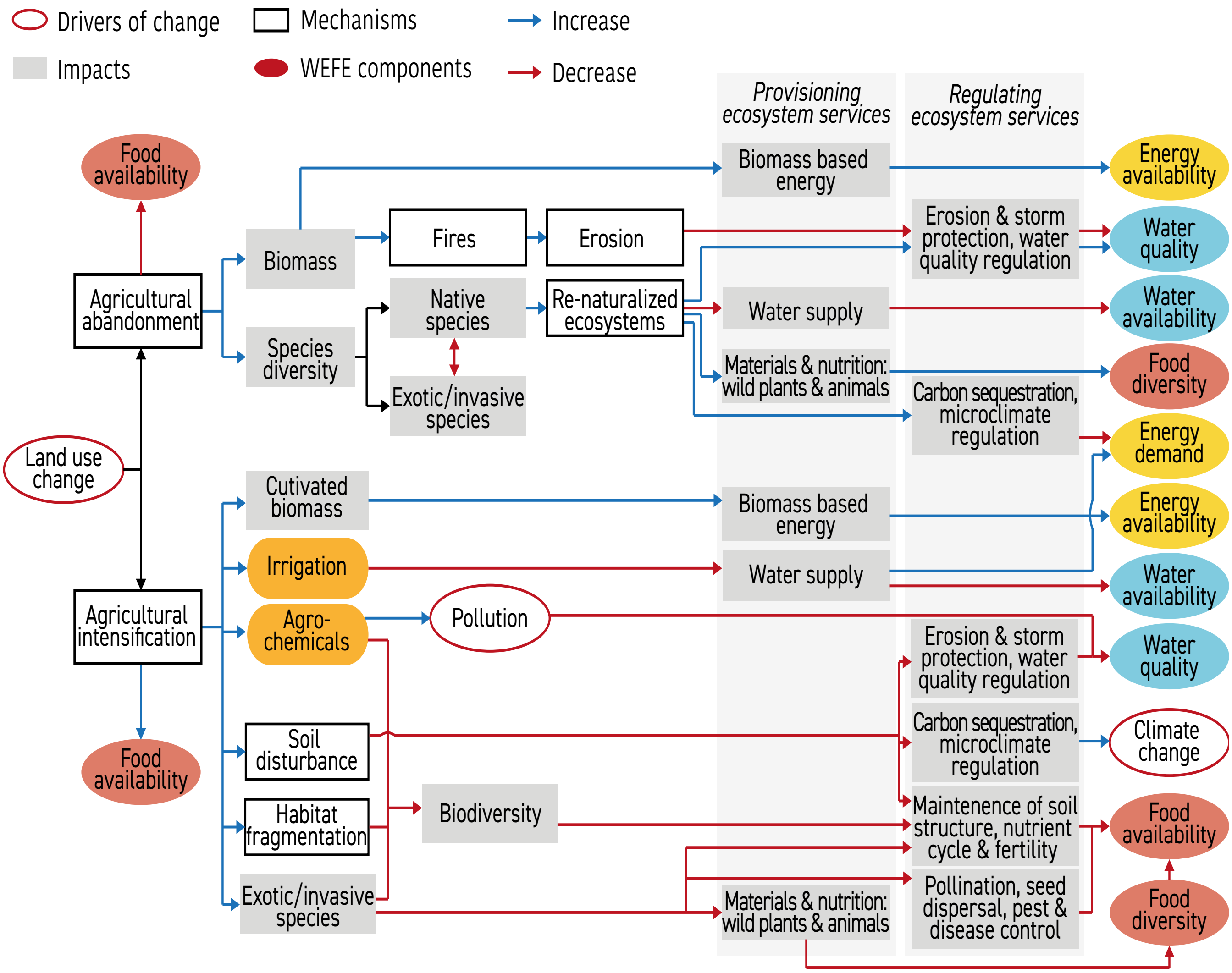

Figure 2.20 | Example of cascading impacts of land use-induced changes in ecosystems health on water, food, and energy, mediated through the impacts on ecosystem services.

biodiversity that maintains soil fertility, from micro– and macrofauna soil engineers (that participate in soil structuring) to microflora decomposers (that maintain nutrient cycles). It also decreases biodiversity above ground, from seed disperser and pollinator species to predators that control the numbers of potentially harmful pests. When the biodiversity of the ecosystem is decreased, it is easier for pests and diseases to get established in the unbalanced network, requiring a higher input of agrochemicals, with impact on water use and quality, energy use and associated pollution.

Changing to an intensive agriculture regime reduces carbon sequestration by reducing soil organic matter. When crops and their residues are removed from cultivation areas, the recycling of nutrients on site is reduced, there is no accumulation of organic matter, carbon sequestration is reduced in the soil, and humidity is not retained, all contributing to climate change.

References

Abd-Elmabod, S. K., Muñoz-Rojas, M., Jordán, A., Anaya-Romero, M., Phillips, J. D., Laurence, J., Zhang, Z., Pereira, P., Fleskens, L., van der Ploeg, M., & de la Rosa, D. (2020). Climate change impacts on agricultural suitability and yield reduction in a Mediterranean region. *Geoderma, 374*, 114453. doi: 10.1016/J.GEODERMA.2020.114453

Abdulla, A., & Linden, O. (2008). *Maritime Traffic Effects on Biodiversity in the Mediterranean Sea: Review of impacts, priority areas and mitigation measures.* Malaga, Spain: IUCN Centre for Mediterranean Cooperation. 184 pp.

Abouaiana, A., & Battisti, A. (2022). Multifunction Land Use to Promote Energy Communities in Mediterranean Region: Cases of Egypt and Italy. *Land, 11(5),* 673. doi: 10.3390/land11050673

Acácio, M., Catry, I., Soriano-Redondo Andrea and Silva, J. P., Atkinson, P. W., & Franco, A. M. A. (2022). Timing is critical: consequences of asynchronous migration for the performance and destination of a long-distance migrant. *Movement Ecology, 10, 28.* doi: 10.1186/s40462-022-00328-3

Achite, M., Caloiero, T., Wał ega, A., Krakauer, N., & Hartani, T. (2021). Analysis of the spatiotemporal annual rainfall variability in the Wadi Cheliff basin (Algeria) over the period 1970 to 2018. *Water, 13(11)*, 1477. doi: 10.3390/w13111477

Adamovic, M., Bisselink, B., de Felice, M., de Roo, A., Dorati, C., Ganora, D., Medarac, H., Pistocchi, A., van de Bund, W., & Vanham, D. (2019). Water-Energy Nexus in Europe. In D. Magagna, G. Bidoglio, I. Hidalgo Gonzalez, & E. Peteves (Eds.), *Publications Office of the European Union.* EUR 29743 EN, Publications Office of the European Union, Luxembourg. doi: 10.2760/968197

Agoubi, B. (2021). A review: saltwater intrusion in North Africa's coastal areas—current state and future challenges. *Environmental Science and Pollution Research, 28(14)*, 17029–17043. doi: 10.1007/s11356-021-12741-z

Aguilera, E., Díaz-Gaona, C., García-Laureano, R., Reyes-Palomo, C., Guzmán, G. I., Ortolani, L., Sánchez-Rodríguez, M., & Rodríguez-Estévez, V. (2020). Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. *Agricultural Systems, 181*, 102809. doi: 10.1016/J.AGSY.2020.102809

Aguilera, E., Guzmán, G. I., Álvaro-Fuentes, J., Infante-Amate, J., García-Ruiz, R., Carranza-Gallego, G., Soto, D., & González de Molina, M. (2018). A historical perspective on soil organic carbon in Mediterranean cropland (Spain, 1900–2008). *Science of The Total Environment, 621,* 634–648. doi: 10.1016/J.SCITOTENV.2017.11.243

Aguilera, E., & Rivera Ferre, M. G. (2022). La urgencia de una transición agroecológica en España. *Amigos de la Tierra, 52.*

Aguilera, E., Sanz-Cobena, A., Infante-Amate, J., García-Ruiz, R., Vila-Traver, J., Guzmán, G. I., Molina, M., Rodríguez, A., Piñer, P., & Lassaletta, L. (2021). Long-term trajectories of the C footprint of N fertilization in Mediterranean agriculture (Spain, 1860–2018). *Environmental Research Letters, 16(8)*, 85010. doi: 10.1088/1748-9326/ac17b7

Ahmed, S. A., Saad-Hussein, A., El Feel, A., & Hamed, M. A. (2014). Time series trend of Bilharzial bladder cancer in Egypt and its relation to climate change: a study from 1995–2005. *International Journal of Pharmaceutical and Clinical Research, 6(1)*, 46–53.

Al Atawneh, D., Cartwright, N., & Bertone, E. (2021). Climate change and its impact on the projected values of groundwater recharge: A review. *Journal of Hydrology, 601*, 126602. doi: 10.1016/j.jhydrol.2021.126602

Albano, P. G., Steger, J., Bošnjak, M., Dunne, B., Guifarro, Z., Turapova, E., Hua, Q., Kaufman, D. S., Rilov, G., & Zuschin, M. (2021). Native biodiversity collapse in the eastern Mediterranean. *Proceedings of the Royal Society B, 288(1942)*, 20202469.

Albek, M., Ö□□tveren, Ü. B., & Albek, E. (2004). Hydrological modeling of Seydi Suyu watershed (Turkey) with HSPF. *Journal of Hydrology, 285(1–4)*, 260–271. doi: 10.1016/j.jhydrol.2003.09.002

Al-Muqdadi, S. W. H. (2022). The Spiral of Escalating Water Conflict: The Theory of Hydro-Politics. *Water, 14(21)*, 3466. doi: 10.3390/w14213466

Al-Saidi, M. (2023). Caught off guard and beaten: The Ukraine war and food security in the Middle East. *Frontiers in Nutrition, 10*, 983346. doi: 10.3389/fnut.2023.983346

Anastasopoulou, A., & Fortibuoni, T. (2019). Impact of Plastic Pollution on Marine Life in the Mediterranean Sea. In F. Stock, G. Reifferscheid, N. Brennholt, & E. Kostianaia (Eds.), *Plastics in the Aquatic Environment - Part I. The Handbook of Environmental Chemistry* (Vol. 111). Springer, Cham. doi: 10.1007/698_2019_421

Anav, A., Friedlingstein, P., Beer Christian and Ciais, P., Harper, A., Jones, C., Murray-Tortarolo, G., Papale, D., Parazoo, N. C., Peylin, P., Piao, S., Sitch, S., Viovy, N., Wiltshire, A., & Zhao, M. (2015). Spatiotemporal patterns of terrestrial gross primary production: A review. *Reviews of Geophysics, 53(3)*, 785–818. doi: 10.1002/2015RG000483

Andréassian, V. (2004). Waters and forests: from historical controversy to scientific debate. *Journal of Hydrology, 291(1–2)*, 1–27. doi: 10.1016/j.jhydrol.2003.12.015

Antoniadou, C., Pantelidou, M., Skoularikou, M., & Chintiroglou, C. C. (2023). Mass Mortality of Shallow-Water Temperate Corals in Marine Protected Areas of the North Aegean Sea (Eastern Mediterranean). *Hydrobiology, 2(2),* 311–325. doi: 10.3390/hydrobiology2020020

Appiagyei, B. D., Belhoucine-Guezouli, L., Bessah, E., & Morsli, B. (2023). The changing land use and land cover in the Mediterranean Basin: implications on forest ecosystem services. *Folia Oecologica, 50(1),* 60–71. doi: 10.2478/foecol-2023-0005

Auger-Rozenberg, M.-A., Barbaro, L., Battisti, A., Blache, S., Charbonnier, Y., Denux, O., Garcia, J., Goussard, F., Imbert, C.-E., Kerdelhué, C., Roques, A., Torres-Leguizamon, M., & Vetillard, F. (2015). Ecological Responses of Parasitoids, Predators and Associated Insect Communities to the Climate-Driven Expansion of the Pine Processionary Moth. In A. Roques (Ed.), *Processionary Moths and Climate Change: An Update* (pp. 311–357). Springer Netherlands, Dordrecht. doi: 10.1007/978-94-017-9340-7_7

Aurelle, D., Thomas, S., Albert, C., Bally, M., Bondeau, A., Boudouresque, C. F., Cahill, A. E., Carlotti, F., Chenuil, A., Cramer, W., Davi, H., De Jode, A., Ereskovsky, A., Farnet, A. M., Fernandez, C., Gauquelin, T., Mirleau, P., Monnet, A. C., Prévosto, B., ... Fady, B. (2022). Biodiversity, climate change, and adaptation in the Mediterranean. *Ecosphere, 13(4)*, e3915. doi: 10.1002/ECS2.3915

Aw-Hassan, A., Rida, F., Telleria, R., & Bruggeman, A. (2014). The impact of food and agricultural policies on groundwater use in Syria. *Journal of Hydrology, 513*, 204–215. doi: 10.1016/j.jhydrol.2014.03.043

Axaopoulos, P., & Sofianos, S. (2010). Long Term Variability of Sea Surface Temperature in Mediterranean Sea. *7th International Conference of the Balkan Physical Union, Organized by the Hellenic Physical Society with the Cooperation of the Physics Departments of Greek Universities: AIP Conference Proceedings, 1203(1)*, 899–904. doi: 10.1063/1.3322579

Baer-Nawrocka, A., & Sadowski, A. (2019). Food security and food self-sufficiency around the world: A typology of countries. *PLoS One, 14(3*), e0213448. doi: 10.1371/JOURNAL.PONE.0213448

Bagstad, K. J., Semmens, D. J., Ancona, Z. H., & Sherrouse, B. C. (2017). Evaluating alternative methods for biophysical and cultural ecosystem services hotspot mapping in natural resource planning. *Landscape Ecology, 32(1)*, 77–97. doi: 10.1007/s10980-016-0430-6

Baker, A. C., Glynn, P. W., & Riegl, B. (2008). Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuarine, *Coastal and Shelf Science, 80(4),* 435–471. doi: 10.1016/j.ecss.2008.09.003

Baldi, M., Dalu, G., Maracchi, G., Pasqui, M., & Cesarone, F. (2006). Heat waves in the Mediterranean: a local feature or a larger-scale effect? International Journal of Climatology: *A Journal of the Royal Meteorological Society, 26(11)*, 1477–1487. doi: 10.1002/joc.1389

Ballabio, C., Panagos, P., Lugato, E., Huang, J.-H., Orgiazzi, A., Jones, A., Fernández-Ugalde, O., Borrelli, P., & Montanarella, L. (2018). Copper distribution in European topsoils: An assessment based on LUCAS soil survey. *Science of The Total Environment, 636,* 282–298. doi: 10.1016/j.scitotenv.2018.04.268

Bangash, R. F., Passuello, A., Sanchez-Canales, M., Terrado, M., López, A., Elorza, F. J., Ziv, G., Acuña, V., & Schuhmacher, M. (2013). Ecosystem services in Mediterranean river basin: climate change impact on water provisioning and erosion control. *Science of The Total Environment, 458–460,* 246–255. doi: 10.1016/j.scitotenv.2013.04.025

Barata, C., Lekumberri, I., Vila-Escalé, M., Prat, N., & Porte, C. (2005). Trace metal concentration, antioxidant enzyme activities and susceptibility to oxidative stress in the tricoptera larvae Hydropsyche exocellata from the Llobregat river basin (NE Spain). *Aquatic Toxicology, 74(1)*, 3–19. doi: 10.1016/j.aquatox.2005.04.002

Barbieri, M., Barberio, M. D., Banzato, F., Billi, A., Boschetti, T., Franchini, S., Gori, F., & Petitta, M. (2023). Climate change and its effect on groundwater quality. *Environmental Geochemistry and Health, 45(4)*, 1133–1144. doi: 10.1007/s10653-021-01140-5

Barrow, C. J., & Hicham, H. (2000). Two complimentary and integrated land uses of the western High Atlas Mountains, Morocco: The potential for sustainable rural livelihoods. Applied Geography, 20(4), 369–394. doi: 10.1016/S0143-6228(00)00010-2

Bartual, M., Bocci, G., Marini, S., & Moonen, A. C. (2018). Local and landscape factors affect sunflower pollination in a Mediterranean agroecosystem. *PLoS One, 13(9)*, e0203990. doi: 10.1371/journal.pone.0203990

Bassu, S., Asseng, S., Motzo, R., & Giunta, F. (2009). Optimising sowing date of durum wheat in a variable Mediterranean environment. *Field Crops Research, 111(1–2)*, 109–118. doi: 10.1016/j.fcr.2008.11.002

Battarra, R., & Mazzeo, G. (2022). Challenges of Mediterranean metropolitan systems: smart planning and mobility. T*ransportation Research Procedia, 60,* 92–99. doi: 10.1016/j.trpro.2021.12.013

Battilani, P., Toscano, P., Van Der Fels-Klerx, H. J., Moretti, A., Camardo Leggieri, M., Brera, C., Rortais, A., Goumperis, T., & Robinson, & T. (2016). Aflatoxin B 1 contamination in maize in Europe increases due to climate change. *Scientific Reports, 6(1)*, 24328. doi: 10.1038/srep24328

Beguería, S., López-Moreno, J. I., Lorente, A., Seeger, M., & Garcia-Ruiz, J. M. (2003). Assessing the effect of climate oscillations and land-use changes on streamflow in the central Spanish Pyrenees. *AMBIO: A Journal of the Human Environment, 32(4),* 283–286. doi: 10.1579/0044-7447-32.4.283

Bekkar, Y., Kuper, M., Hammani, A., Dionnet, M., & Eliamani, A. (2007). Reconversion vers des systèmes d'irrigation localisée au Maroc : quels enseignements pour l'agriculture familiale ? *Hommes la Terre, l'Eau, 137*, 7–20.

Belaid, M. A. (2003). Urban-rural use detection and analysis using GIS & RS technologies. *2nd FIG Regional Conference Marrakech, Morocco, December 2-5*, 2003.

Bellafiore, D., Ferrarin, C., Maicu Francesco and Manfè, G., Lorenzetti, G., Umgiesser, G., Zaggia, L., & Levinson, A. V. (2021). Saltwater intrusion in a Mediterranean delta under a changing climate. *Journal of Geophysical Research: Oceans, 126(2),* e2020JC016437. doi: 10.1029/2020jc016437

Bellot, J., Bonet, A., Peña, J., & Sánchez, J. R. (2007). Human impacts on land cover and water balances in a coastal Mediterranean county. *Environmental Management, 39,* 412–422. doi: 10.1007/s00267-005-0317-9

Bellout, A., Bousbaine, A., Akkari, C., & Bryant, C. (2020). Action research: An essential approach to the development of the agricultural field of the Mitidja Plain, North of Algeria, and comparisons with other territories in developed countries. In E. Vaz (Ed.), *Regional Intelligence (pp. 191–204)*. Springer, Cham. doi: 10.1007/978-3-030-36479-3_10

Ben Hassen, T., & El Bilali, H. (2022). Impacts of the Russia-Ukraine War on Global Food Security: Towards More Sustainable and Resilient Food Systems? *Foods, 11(15).* doi: 10.3390/foods11152301

Ben Rais Lasram, F., Guilhaumon, F., Albouy, C., Somot, S., Thuiller, W., & Mouillot, D. (2010). The Mediterranean Sea as a 'cul-de-sac' for endemic fishes facing climate change. *Global Change Biology, 16(12)*, 3233–3245. doi: 10.1111/j.1365-2486.2010.02224.x

Bencheikh, Z., Refes, W., Brito, P. M., Prodocimo, M. M., Gusso-Choueri, P. K., Choueri, R. B., & de Oliveira Ribeiro, C. A. (2022). Chemical pollution impairs the health of fish species and fishery activities along the Algeria coastline, Mediterranean Sea. *Environmental Monitoring and Assessment, 194(7),* 497. doi: 10.1007/s10661-022-10059-y

Benedetti, F., Vogt, M., Righetti, D., Guilhaumon, F., & Ayata, S. D. (2018). Do functional groups of planktonic copepods differ in their ecological niches? *Journal of Biogeography, 45(3)*, 604–616. doi: 10.1111/jbi.13166

Benito, B., Lorite, J., & Peñas, J. (2011). Simulating potential effects of climatic warming on altitudinal patterns of key species in Mediterranean-alpine ecosystems. *Climatic Change, 108(3),* 471–483. doi: 10.1007/s10584-010-0015-3

Bernabucci, U., Biffani, S., Buggiotti, L., Vitali, A., Lacetera, N., & Nardone, A. (2014). The effects of heat stress in Italian Holstein dairy cattle. *Journal of Dairy Science, 97(1),* 471–486. doi: 10.3168/jds.2013-6611

Bezner Kerr, R., Hasegawa, T., Lasco, R., Bhatt, I., Deryng, D., Farrell, A., Gurney-Smith, H., Ju, H., Lluch-Cota, S., Meza, F., Nelson, G., Neufeldt, H., & Thornton, P. (2022). Food, Fibre, and Other Ecosystem Products. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 713-906).* Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009325844.007

Billen, G., Lasseletta, L., & Garnier, J. (2014). A biogeochemical view of the global agro-food system: Nitrogen flows associated with protein production, consumption and trade. *Global Food Security, 3(3-4),* 209–219. doi: 10.1016/j.gfs.2014.08.003

Billen, G., Le Noë, J., & Garnier, J. (2018). Two contrasted future scenarios for the French agro-food system. *Science of The Total Environment, 637-638,* 695–705. doi: 10.1016/J.SCITOTENV.2018.05.043

Bioversity International. (2022). Agrobiodiversity Index Report 2021: Assessing Mediterranean food systems. *Bioversity International, Rome (Italy), 184 pp.* https://hdl.handle.net/10568/118471

Blanco-Ward, D., Ribeiro, A., Paoletti, E., & Miranda, A. I. (2021). Assessment of tropospheric ozone phytotoxic effects on the grapevine (Vitis vinifera L.): A review. *Atmospheric Environment, 244,* 117924.

Blas, A., Garrido, A., Unver, O., & Willaarts, B. (2019). A comparison of the Mediterranean diet and current food consumption patterns in Spain from a nutritional and water perspective. *Science of The Total Environment, 664,* 1020–1029. doi: 10.1016/j.scitotenv.2019.02.111

Borelli, T., Güzelsoy, N. A., Hunter, D., Tan, A., Karabak, S., Uçurum, H. Ö., Çavuş, F., Ay, S. T., Adanacıoğlu, N., Özbek, K., Özen, B., Tokat, E., & Taşçı, R. (2022). Assessment of the Nutritional Value of Selected Wild Food Plants in Türkiye and Their Promotion for Improved Nutrition. *Sustainability, 14(17),* 11015. doi: 10.3390/su141711015

Bosch, J. M., & Hewlett, J. D. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology, 55(1-4),* 3–23. doi: 10.1016/0022-1694(82)90117-2

Bouchelkha, M. (2016). Agricultural modernization, internal migration and the formation of a wage labour market in the Souss region, Morocco. In A. Corrado, C. de Castro, & D. Perrotta (Eds.), *Migration and Agriculture. Mobility and change in the Mediterranean area (pp. 246–258)*. Routledge.

Boudalia, S., Gueroui, Y., Zebsa, R., Arbia, T., Chiheb, A. E., Benada, M., Hadri, Z., Youcefi, A., & Bousbia, A. (2023). Camel livestock in the Algerian Sahara under the context of climate change: Milk properties and livestock production practices. Journal of *Agriculture and Food Research, 11*, 100528. doi: 10.1016/J.JAFR.2023.100528

Boudebbouz, A., Boudalia, S., Bousbia, A., Gueroui, Y., Boussadia, M. I., Chelaghmia, M. L., Zebsa, R., Affoune, A. M., & Symeon, G. K. (2023). Determination of Heavy Metal Levels and Health Risk Assessment of Raw Cow Milk in Guelma Region, Algeria. *Biological Trace Element Research, 201(4)*, 1704–1716. doi: 10.1007/S12011-022-03308-1

Bouramdane, A., Tantet, A., & Drobinski, P. (2020). Adequacy of Renewable Energy Mixes with Concentrated Solar Power and Photovoltaics in Morocco: Impact of Thermal Storage and Cost. *Energies, 13(19)*, 5087. doi: 10.3390/en13195087

Bouramdane, A., Tantet, A., & Drobinski, P. (2021). Utility-Scale PV-Battery versus CSP-Thermal Storage in Morocco: Storage and Cost Effect under Penetration Scenarios. *Energies, 14(15)*, 4675. doi: 10.3390/en14154675

Bousbih, S., Zribi, M., El Hajj, M., Baghdadi, N., Lili-Chabaane, Z., Gao, Q., & Fanise, P. (2018). Soil Moisture and Irrigation Mapping in A Semi-Arid Region, Based on the Synergetic Use of Sentinel-1 and Sentinel-2 Data. *Remote Sensing, 10(12)*, 1953. doi: 10.3390/rs10121953

Brankov, T., Matkovski, B., Jeremić, M., & Đurić, I. (2021). Food Self-Sufficiency of the SEE Countries; Is the Region Prepared for a Future Crisis? *Sustainability, 13(16)*, 8747. doi: 10.3390/SU13168747

Branquinho, C., Serrano, H. C., Nunes, A., Pinho, P., & Matos, P. (2019). Essential biodiversity change indicators for evaluating the effects of Anthropocene in ecosystems at a global scale. In E. Casetta & J. V. D. Marques da Silva (Eds.), From Assessing to Conserving Biodiversity. *History, Philosophy and Theory of the Life Sciences (Vol. 24, pp. 137–163)*. Springer, Cham. doi: 10.1007/978-3-030-10991-2_7

Bregaglio, S., Hossard, L., Cappelli, G., Resmond, R., Bocchi, S., Barbier, J.-M., Ruget, F., & Delmotte, S. (2017). Identifying trends and associated uncertainties in potential rice production under climate change in Mediterranean areas. *Agricultural and Forest Meteorology, 237-238, 219–232*. doi: 10.1016/j.agrformet.2017.02.015

Breisinger, C., Zhu, T., Al Riffai, P., Nelson, G., Robertson, R., Funes, J., & Verner, D. (2011). Global and Local Economic Impacts of Climate Change in Syria and Options for Adaptation. International Food Policy Research Institute (IFPRI) *Discussion Paper 01091, 64 pp.*

Bremberg, N., Cramer, W., Dessì, A., Philippe, D., Fusco, F., Guiot, J., Pariente-David, S., & Raineri, L. (2022). Climate Change and Security in the Mediterranean: Exploring the Nexus, Unpacking International Policy Responses (A. Dessì & F. Fusco, Eds.). *Nuova Cultura, 146 pp.*

Brown, S., Hanson, S., & Nicholls, R. J. (2014). Implications of sea-level rise and extreme events around Europe: a review of coastal energy infrastructure. *Climatic Change, 122,* 81–95. doi: 10.1007/s10584-013-0996-9

Brück, T., d'Errico, M., & Pietrelli, R. (2019). The effects of violent conflict on household resilience and food security: Evidence from the 2014 Gaza conflict. *World Development, 119(C)*, 203–223. doi: 10.1016/J.WORLDDEV.2018.05.008

Butler, C. D. (2018). Climate change, health and existential risks to civilization: a comprehensive review (1989–2013). *International Journal of Environmental Research and Public Health, 15(10)*, 2266. doi: 10.3390/ijerph15102266

Caloiero, T., Caloiero, P., & Frustaci, F. (2018a). Long-term precipitation trend analysis in Europe and in the Mediterranean basin. *Water and Environment Journal, 32(3)*, 433–445. doi: 10.1111/wej.12346

Caloiero, T., Veltri, S., Caloiero, P., & Frustaci, F. (2018b). Drought Analysis in Europe and in the Mediterranean Basin using the standardized precipitation index. *Water, 10(8)*, 1043. doi: 10.3390/w10081043

Calvete-Sogo, H., González-Fernández, I., Sanz, J., Elvira, S., Alonso, R., Garcia-Gómez, H., Ibáñez-Ruiz, M. A., & Bermejo-Bermejo, V. (2016). Heterogeneous responses to ozone and nitrogen alter the species composition of Mediterranean annual pastures. *Oecologia, 181,* 1055–1067. doi: 10.1007/s00442-016-3628-z

Calvo, E., Simó, R., Coma, R., Ribes, M., Pascual J and Sabatés, A., Gili, J. M., & Pelejero, C. (2011). Effects of climate change on Mediterranean marine ecosystems: the case of the Catalan Sea. *Climate Research, 50(1)*, 1–29. doi: 10.3354/cr01040

Camarasa-Belmonte, A. M. (2016). Flash floods in Mediterranean ephemeral streams in Valencia Region (Spain). *Journal of Hydrology, 541*, 99–115. doi: 10.1016/j.jhydrol.2016.03.019

Cameira, M. do R., Rolim, J., Valente, F., Mesquita, M., Dragosits, U., & Cordovil, C. M. d. S. (2021). Translating the agricultural N surplus hazard into groundwater pollution risk: Implications for effectiveness of mitigation measures in nitrate vulnerable zones. Agriculture, *Ecosystems & Environment, 306,* 107204. doi: 10.1016/j.agee.2020.107204

Cammarano, D., Ceccarelli, S., Grando Stefania and Romagosa, I., Benbelkacem, A., Akar Tanek and Al-Yassin, A., Pecchioni, N., & Francia Enrico and Ronga, D. (2019). The impact of climate change on barley yield in the Mediterranean basin. *European Journal of Agronomy, 106,* 1–11. doi: 10.1016/j.eja.2019.03.002

Cao, Y., Ma, Y., Liu, T., Li, J., Zhong, R., Wang, Z., & Zan, C. (2022). Analysis of Spatial-Temporal Variations and Driving Factors of Typical Tail-Reach Wetlands in the Ili-Balkhash Basin, Central Asia. *Remote Sensing, 14(16),* 3986. doi: 10.3390/rs14163986

Caon, L., Vallejo, V. R., Ritsema, C. J., & Geissen, V. (2014). Effects of wildfire on soil nutrients in Mediterranean ecosystems. *Earth-Science Reviews, 139,* 47–58. doi: 10.1016/j.earscirev.2014.09.001

Capodiferro, M., Marco, E., & Grimalt, J. O. (2022). Wild fish and seafood species in the western Mediterranean Sea with low safe mercury concentrations. *Environmental Pollution, 314,* 120274. doi: 10.1016/j.envpol.2022.120274

Capone, R., Bilali, H. El, Debs, P., Cardone, G., & Driouech, N. (2014). Mediterranean Food Consumption Patterns Sustainability: Setting Up a Common Ground for Future Research and Action. *American Journal of Nutrition and Food Science, 1(2),* 37. doi: 10.12966/ajnfs.04.04.2014

Cardell, M. F., Amengual, A., & Romero, R. (2019). Future effects of climate change on the suitability of wine grape production across Europe. *Regional Environmental Change, 19,* 2299–2310. doi: 10.1007/s10113-019-01502-x

Caretta, M. A., Mukherji, A., Arfanuzzaman, M., Betts, R. A., Gelfan, A., Hirabayashi, Y., Lissner, T. K., Liu, J., Lopez Gunn, E., Morgan, R., Mwanga, S., & Suprati, S. (2022). Water. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 551–712).* Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009325844.006

Carosi, A. (2022). Effects of Climate Change on Freshwater Biodiversity. *Water, 14(23),* 3953. doi: 10.3390/w14233953

Cascarano, M. C., Stavrakidis-Zachou, O., Mladineo, I., Thompson, K. D., Papandroulakis, N., & Katharios, P. (2021). Mediterranean Aquaculture in a Changing Climate: Temperature Effects on Pathogens and Diseases of Three Farmed Fish Species. *Pathogens, 10(9),* 1205. doi: 10.3390/PATHOGENS10091205

Castro, A. J., Martin-López, B., Garcia-Llorente, M., Aguilera, P. A., López, E., & Cabello, J. (2011). Social preferences regarding the delivery of ecosystem services in a semiarid Mediterranean region. *Journal of Arid Environments, 75(11),* 1201–1208. doi: 10.1016/j.jaridenv.2011.05.013

Chahouri, A., Elouahmani, N., & Ouchene, H. (2022). Recent progress in marine noise pollution: *A thorough review. Chemosphere, 291(Part 2),* 132983. doi: 10.1016/j.chemosphere.2021.132983

Chebli, Y., Chentouf, M., Ozer, P., Hornick, J. L., & Cabaraux, J. F. (2018). Forest and silvopastoral cover changes and its drivers in northern Morocco. *Applied Geography, 101,* 23–35. doi: 10.1016/j.apgeog.2018.10.006

Cheddadi, R., Henrot, A., François, L., Boyer, F., Bush, M., Carré, M., Coissac, E., Oliveira, P. E., Ficetola, F., Hambuckers, A., Huang, K., Lézine, A., Nourelbait, M., Rhoujjati, A., Taberlet, P., & Sarmiento F and Zheng, Z. (2017). Microrefugia, Climate Change, and Conservation of Cedrus atlantica in the Rif Mountains, Morocco. *Frontiers in Ecology and Evolution, 5,* 114. doi: 10.3389/fevo.2017.00114

Chen, D., Elhadj, A., Xu, H., & Xu Xinliang and Qiao, Z. (2020). A Study on the Relationship between Land Use Change and Water Quality of the Mitidja Watershed in Algeria Based on GIS and RS. *Sustainability, 12(9),* 3510. doi: 10.3390/su12093510

Chen, F., & Chen, Z. (2021). Cost of economic growth: Air pollution and health expenditure. *Science of The Total Environment, 755,* 142543. doi: 10.1016/j.scitotenv.2020.142543

Cherif, S., Doblas-Miranda, E., Lionello, P., Borrego, C., Giorgi, F., Iglesias, A., Jebari, S., Mahmoudi, E., Moriondo, M., Pringault, O., Rilov, G., Somot, S., Tsikliras, A., Vila, M., & Zittis, G. (2020). Drivers of change. In W. Cramer, J. Guiot, & K. Marini (Eds.), Climate and Environmental Change in the Mediterranean Basin-Current Situation and Risks for the Future. *First Mediterranean Assessment Report. (pp. 59–180).* Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France. doi: 10.5281/zenodo.7100601

Choukr-Allah, R., Nghira, A., Hirich, A., & Bouchaou, L. (2016). Water Resources Master Plan for Sustainable Development of the Souss-Massa River Basin. In R. Choukr-Allah, R. Ragab, & L. B. D. Bouchaou (Eds.), The Souss-Massa River Basin, Morocco. *The Handbook of Environmental Chemistry (Vol. 53, pp. 1–26).* Springer, Cham. doi: 10.1007/698_2016_67

Cid, N., Bonada, N., Carlson, S. M., Grantham, T. E., Gasith, A., & Resh, V. H. (2017). High variability is a defining component of Mediterranean-climate rivers and their biota. *Water, 9(1),* 52. doi: 10.3390/w9010052

Cook, B. I., Anchukaitis, K. J., Touchan, R., Meko, D. M., & Cook, E. R. (2016). Spatiotemporal drought variability in the Mediterranean over the last 900 years. *Journal of Geophysical Research: Atmospheres, 121(5),* 2060–2074. doi: 10.1002/2015JD023929

Cooper, S. D., Lake, P. S., Sabater, S., Melack, J. M., & Sabo, J. L. (2013). The effects of land use changes on streams and rivers in mediterranean climates. *Hydrobiologia, 719,* 383–425. doi: 10.1007/s10750-012-1333-4

Copetti, D., Carniato, L., Crise, A., Guyennon, N., Palmeri, L., Pisacane, G., Struglia, M. V, & Tartari, G. (2013). Impacts of Climate Change on Water Quality. In A. Navarra & L. Tubiana (Eds.), *Regional Assessment on Climate Change in the Mediterranean (Part 2: Water)* (pp. 307–332). doi: 10.1007/978-94-007-5781-3_10

Corrado, A., de Castro, C., & Perrotta, D. (2017). Migration and Agriculture. Mobility and change in the Mediterranean Area. *Routledge, 370 pp.* doi: 10.4000/etudesrurales.13104

Cosandey, C., Andréassian, V., Martin, C., Didon-Lescot, J. F., Lavabre, J., Folton, N., Mathys, N., & Richard, D. (2005). The hydrological impact of the mediterranean forest: A review of French research. *Journal of Hydrology, 301(1–4),* 235–249. doi: 10.1016/j.jhydrol.2004.06.040

Cotrozzi, L., Townsend, P. A., Pellegrini Elisa and Nali, C., & Couture, J. J. (2018). Reflectance spectroscopy: a novel approach to better understand and monitor the impact of air pollution on Mediterranean plants. *Environmental Science and Pollution Research, 25,* 8249–8267. doi: /10.1007/s11356-017-9568-2

Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J.-P., Iglesias, A., Lange, M. A., Lionello, P., Llasat, M. C., Paz, S., Peñuelas, J., Snoussi, M., Toreti, A., Tsimplis, M. N., & Xoplaki, E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change, 8(11),* 972–980. doi: 10.1038/s41558-018-0299-2

Daccache, A., Ciurana, J. S., Rodriguez Diaz, J. A., & Knox, J. W. (2014). Water and energy footprint of irrigated agriculture in the Mediterranean region. *Environmental Research Letters, 9(12),* 124014. doi: 10.1088/1748-9326/9/12/124014

Dafka, S., Toreti, A., Luterbacher, J., Zanis, P., Tyrlis, E., & Xoplaki, E. (2018). Simulating Extreme Etesians over the Aegean and Implications for Wind Energy Production in Southeastern Europe. *Journal of Applied Meteorology and Climatology, 57(5),* 1123–1134. doi: 10.1175/JAMC-D-17-0172.1

Dafka, S., Toreti, A., Zanis, P., Xoplaki, E., & Luterbacher, J. (2019). Twenty-First-Century Changes in the Eastern Mediterranean Etesians and Associated Midlatitude Atmospheric Circulation. *Journal of Geophysical Research: Atmospheres, 124(23),* 12741–12754. doi: 10.1029/2019JD031203

Daher, B., Bachour, R., Yanni, S. F., Koo-Oshima, S., & Mohtar, R. H. (2022). Food security under compound shocks: Can Lebanon produce its own Mediterranean food basket? *Frontiers in Sustainable Food Systems, 6,* 969248. doi: 10.3389/fsufs.2022.969248

Dai, A., Qian, T., Trenberth, K. E., & Milliman, J. D. (2009). Changes in continental freshwater discharge from 1948 to 2004. *Journal of Climate, 22(10),* 2773–2792. doi: 10.1175/2008JCLI2592.1

Dalin, C., Taniguchi, M., & Green, T. R. (2019). Unsustainable groundwater use for global food production and related international trade. *Global Sustainability, 2*, e12. doi: 10.1017/sus.2019.7

Dalin, C., Wada, Y., Kastner, T., & Puma, M. J. (2017). Groundwater depletion embedded in international food trade. *Nature, 543,* 700–704. doi: 10.1038/nature21403

Danovaro, R. (2003). Pollution threats in the Mediterranean Sea: An overview. Chemistry and *Ecology, 19(1),* 15–32. doi: 10.1080/0275754031000081467

Darwish, T., Atallah, T., Francis, R., Saab, C., Jomaa I and Shaaban, A., Sakka, H., & Zdruli, P. (2011). Observations on soil and groundwater contamination with nitrate: A case study from Lebanon-East Mediterranean. *Agricultural Water Management, 99(1),* 74–84. doi: 10.1016/j.agwat.2011.07.016

de Filippis, G., Foglia, L., Giudici, M., Mehl, S., Margiotta, S., & Negri, S. L. (2016). Seawater intrusion in karstic, coastal aquifers: Current challenges and future scenarios in the Taranto area (southern Italy). *Science of The Total Environment, 573,* 1340–1351. doi: 10.1016/j.scitotenv.2016.07.005

de Lima, C. Z., Buzan, J. R., Moore, F. C., Baldos, U. L. C., Huber, M., & Hertel, T. W. (2021). Heat stress on agricultural workers exacerbates crop impacts of climate change. *Environmental Research Letters, 16(4),* 044020. doi: 10.1088/1748-9326/abeb9f

de Vries, W. (2021). Impacts of nitrogen emissions on ecosystems and human health: A mini review. *Current Opinion in Environmental Science & Health, 21,* 100249. doi: 10.1016/j.coesh.2021.100249

de Vries, W., Römkens, P. F. A. M., Kros, J., Voogd, J. C., & Schulte-Uebbing, L. F. (2022). Impacts of nutrients and heavy metals in European agriculture. *Current and critical inputs in relation to air, soil and water quality. European Topic Centre on Data integration and digitalisation (ETC-DI),* 72 pp.

Debolini, M., Marraccini, E., Dubeuf, J. P., Geijzendorffer, I. R., Guerra, C., Simon, M., Targetti, S., & Napoléone, C. (2018). Land and farming system dynamics and their drivers in the Mediterranean Basin. *Land Use Policy, 75,* 702–710. doi: 10.1016/J.LANDUSEPOL.2017.07.010

Debussche, M., Lepart, J., & Dervieux, A. (1999). Mediterranean landscape changes: evidence from old postcards. *Global Ecology and Biogeography, 8(1),* 3–15. doi: 10.1046/j.1365-2699.1999.00316.x

Deitch, M. J., Sapundjieff, M. J., & Feirer, S. T. (2017). Characterizing Precipitation Variability and Trends in the World's Mediterranean-Climate Areas. *Water, 9(4),* 259. doi: 10.3390/w9040259

del Barrio, G., Sanjuan, M., Hirche, A., Yassin, M., Ruiz, A., Ouessar, M., Martinez Valderrama, J., Essifi, B., & Puigdefabregas, J. (2016). Land Degradation States and Trends in the Northwestern Maghreb Drylands, 1998–2008. *Remote Sensing, 8(7),* 603. doi: 10.3390/rs8070603

Delgado-Artés, R., Garófano-Gómez Virginia and Oliver-Villanueva, J.-V., & Rojas-Briales, E. (2022). Land use/cover change analysis in the Mediterranean region: a regional case study of forest evolution in Castelló (Spain) over 50 years. *Land Use Policy, 114,* 105967. doi: 10.1016/j.landusepol.2021.105967

Delrieu, G., Nicol, J., Yates, E., Kirstetter, P.-E., Creutin, J.-D., Anquetin, S., Obled, C., Saulnier, G.-M., Ducrocq, V., Gaume, E., Payrastre, O., Andrieu, H., Ayral, P.-A., Bouvier, C., Neppel, L., Livet, M., Lang M and du-Châtelet, J. P., Walpersdorf, A., Wobrock, W., … Wobrock, W. (2005). The Catastrophic Flash-Flood Event of 8–9 September 2002 in the Gard Region, France: A First Case Study for the Cévennes-Vivarais Mediterranean Hydrometeorological Observatory. *Journal of Hydrometeorology, 6(1),* 34–52. doi: 10.1175/JHM-400.1

Deroubaix, A., Labuhn, I., Camredon, M., Gaubert, B., Monerie, P. A., Popp, M., Ramarohetra, J., Ruprich-Robert Y and Silvers, L. G., & Siour, G. (2021). Large uncertainties in trends of energy demand for heating and cooling under climate change. *Nature Communications, 12,* 5197. doi: 10.1038/s41467-021-25504-8

Deyà Tortella, B., & Tirado, D. (2011). Hotel water consumption at a seasonal mass tourist destination. The case of the island of Mallorca. *Journal of Environmental Management, 92(10),* 2568–2579. doi: 10.1016/j.jenvman.2011.05.024

Díaz, S., Lavorel, S., de Bello, F., Quétier, F., Grigulis, K., & Robson, T. M. (2007). Incorporating plant functional diversity effects in ecosystem service assessments. *Proceedings of the National Academy of Sciences of the United States of America, 104(52)*, 20684–20689. doi: 10.1073/pnas.0704716104

Diffenbaugh, N. S., Pal, J. S., Giorgi, F., & Gao, X. (2007). Heat stress intensification in the Mediterranean climate change hotspot. *Geophysical Research Letters, 34(11).* doi: 10.1029/2007GL030000

Directorate-General for Energy. (2022). EU Egypt Israel Memorandum of Understanding. https://energy.ec.europa.eu/publications/eu-egypt-israel-memorandum-understanding_en

Doblas-Reyes, F. J., Sörensson, A. A., Almazroui, M., Dosio, A., Gutowski, W. J., Haarsma, R., Hamdi, R., Hewitson, B., Kwon, W.-T., Lamptey, B. L., Maraun, D., Stephenson, T. S., Takayabu, I., Terray, L., Turner, A., & Zuo, Z. (2021). Linking Global to Regional Climate Change. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), Climate Change 2021: The Physical Science Basis. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1363–1512).* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi: 10.1017/9781009157896.012

Donmez, C., Berberoglu, S., & Curran, P. J. (2011). Modelling the current and future spatial distribution of NPP in a Mediterranean watershed. *International Journal of Applied Earth Observation and Geoinformation, 13(3),* 336–345. doi: 10.1016/j.jag.2010.12.005

Drobinski, P., Azzopardi, B., Ben Janet Allal, H., Bouchet, V., Civel, E., Creti, A., Duic, N., Fylaktos N., Mutale, J., Pariente-David, S., Ravetz, J., Taliotis, C., & Vautard, R. (2020a). Energy transition in the Mediterranean. In W. Cramer, J. Guiot, & K. Marini (Eds.), Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. *First Mediterranean Assessment Report (pp. 265–322).* Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France. doi: 10.5281/zenodo.7101088

Drobinski, P., Silva, N. Da, Panthou, G., Bastin, S., Muller, C., Ahrens, B., Borga, M., Conte, D., Fosser, G., Giorgi, F., Güttler, I., Kotroni, V., Li, L., Morin, E., Önol, B. s, Quintana-Segui, P., Romera, R., & Torma, C. Z. (2018). Scaling precipitation extremes with temperature in the Mediterranean: past climate assessment and projection in anthropogenic scenarios. *Climate Dynamics, 51,* 1237–1257. doi: 10.1007/s00382-016-3083-x

Drobinski, P., Silva, N., Bastin, S., Mailler, S., Muller, C., Ahrens, B., Christensen, O. B., & Lionello, P. (2020b). How warmer and drier will the Mediterranean region be at the end of the twenty-first century? *Regional Environmental Change, 20(78),* 1–20. doi: 10.1007/s10113-020-01659-w

Drobinski, P., & Tantet, A. (2022). Integration of Climate Variability and Climate Change in Renewable Energy Planning. *Physics-Uspekhi, 65(11),* 1119–1128. doi: 10.3367/UFNe.2021.07.039080

Droogers, P., Immerzeel, W. W., Terink, W., Hoogeveen, J., Bierkens, M. F. P., Beek, L. P. H., & Debele, B. (2012). Water resources trends in Middle East and North Africa towards 2050. *Hydrology and Earth System Sciences, 16(9),* 3101–3114. doi: 10.5194/hess-16-3101-2012

Duarte, R., Pinilla, V., & Serrano, A. (2021). The globalization of Mediterranean agriculture: A long-term view of the impact on water consumption. *Ecological Economics, 183,* 106964. doi: 10.1016/J.ECOLECON.2021.106964

Duguy, B., Paula, S., Pausas, J. G., Alloza, J. A., Gimeno, T., & Vallejo, R. V. (2013). Effects of climate and extreme events on wildfire regime and their ecological impacts. In A. Navarra & L. Tubiana (Eds.), Regional Assessment of Climate Change in the Mediterranean. *Advances in Global Change Research (Vol. 51, pp. 101–134).* Springer, Dordrecht. doi: 10.1007/978-94-007-5772-1_6

EEA. (2014). Well-being and the environment. Building a resource-efficient and circular economy in Europe. In EEA Signals. EEA Signals 2014, *European Environment Agency, 52 pp.* doi: 10.2800/13662

EEA, Roddier-Quefelec, C., Spiteri, C., & Veiga, J. (2020). *Towards a cleaner Mediterranean – A decade of progress – Monitoring Horizon 2020 regional initiative* (Joint EEA-UNEP/MAP Report, Ed.). Publications Office of the European Union. doi: 10.2800/623712

EEA, & UNEP/MAP. (2014). *Horizon 2020 Mediterranean report Toward shared environmental information systems.* EEA Technical report no.6/2014, Publications Office of the European Union, Luxembourg.

EEAA. (2016). Egypt Third National Communication Under the United Nations Framework Convention on Climate Change. *Egyptian Environmental Affairs Agency (EEAA), 245 pp.*

EFSA. (2008). Annual Report 2007. Committed to ensuring that Europe's food is safe. *European Food Safety Authority, 76 pp.*

El Hafyani, M., Essahlaoui, A., Van Rompaey Anton and Mohajane, M., El Hmaidi, A., El Ouali, A., Moudden, F., & Serrhini, N.-E. (2020). Assessing Regional Scale Water Balances through Remote Sensing Techniques: A Case Study of Boufakrane River Watershed, Meknes Region, Morocco. *Water, 12(2),* 320. doi: 10.3390/w12020320

El Kenawy, A., López-Moreno, J. I., Brunsell, N. A., & Vicente-Serrano, S. M. (2013). Anomalously severe cold nights and warm days in northeastern Spain: their spatial variability, driving forces and future projections. *Global and Planetary Change, 101,* 12–32. doi: 10.1016/j.gloplacha.2012.11.011

El Kenawy, A., López-Moreno, J. I., & Vicente-Serrano, S. M. (2012). Trend and variability of surface air temperature in northeastern Spain (1920–2006): linkage to atmospheric circulation. *Atmospheric Research, 106,* 159–180. doi: 10.1016/j.atmosres.2011.12.006

El Kenawy, A. M., Lopez-Moreno, J. I., McCabe Matthew F and Robaa, S. M., Dominguez-Castro, F., Peña-Gallardo, M., Trigo, R. M., Hereher, M. E., Al-Awadhi, T., & Vicente-Serrano, S. M. (2019). Daily temperature extremes over Egypt: Spatial patterns, temporal trends, and driving forces. *Atmospheric Research, 226,* 219–239. doi: 10.1016/j.atmosres.2019.04.030

El-Madany, T. S., Carrara, A., Martin, M. P., Moreno G and Kolle, O., Pacheco-Labrador, J., Weber, U., Wutzler T and Reichstein, M., & Migliavacca, M. (2020). Drought and heatwave impacts on semi-arid ecosystems' carbon fluxes along a precipitation gradient. *Philosophical Transactions of the Royal Society B, 375(1810),* 20190519. doi: 10.1098/rstb.2019.0519

Ercilla-Montserrat, M., Muñoz, P., Montero, J. I., Gabarrell, X., & Rieradevall, J. (2018). A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). *Journal of Cleaner Production, 195,* 385–395. doi: 10.1016/j.jclepro.2018.05.183

Erol, A., & Randhir, T. O. (2012). Climatic change impacts on the ecohydrology of Mediterranean watersheds. *Clim. Change, 114(2),* 319–341. doi: 10.1007/s10584-012-0406-8

Fader, M., Giupponi, C., Burak, S., Dakhlaoui, H., Koutroulis, A., Lange, M. A., Llasat, M. C., Pulido-Velazquez, D., & Sanz-Cobeña, A. (2020). Water. In W. Cramer, J. Guiot, & K. Marini (Eds.), Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. *First Mediterranean Assessment Report (pp. 181–236).* Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France. doi: 10.5281/zenodo.7101074

Fagnano, M., Maggio, A., & Fumagalli, I. (2009). Crops' responses to ozone in Mediterranean environments. *Environmental Pollution, 157(5),* 1438–1444. doi: 10.1016/j.envpol.2008.09.001

Fahim, M. A., Hassanein, M. K., Khalil, A. A., & Abou Hadid, A. F. (2013). Climate change adaptation needs for food security in Egypt. *Nature and Science, 11(12),* 68–74.

FAO. (1994). *Forest Assessment 1990 non tropical countries Mediterranean Region.* Food and Agriculture Organization of the United Nations, Rome.

FAO. (2023). *AQUASTAT, FAO's Information System on Water and Agriculture.* https://www.fao.org/aquastat/en/databases/

FAO, & Plan Bleu. (2018). State of Mediterranean Forests 2018. Food and Agriculture Organization of the United Nations, Rome and Plan Bleu, Marseille.

Fernandes, D., Potrykus, J., Morsiani, C., Raldua, D., Lavado, R., & Porte, C. (2002). The Combined Use of Chemical and Biochemical Markers to Assess Water Quality in Two Low-Stream Rivers (NE Spain). *Environmental Research, 90(2),* 169–178. doi: 10.1006/enrs.2002.4390

Ferreira, C. S. S., Seifollahi-Aghmiuni, S., Destouni, G., Ghajarnia, N., & Kalantari, Z. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. *Science of The Total Environment, 805,* 150106. doi: 10.1016/j.scitotenv.2021.150106

Ferrise, R., Trombi, G., Moriondo, M., & Bindi, M. (2016). Climate Change and Grapevines: A Simulation Study for the Mediterranean Basin. *Journal of Wine Economics, 11(1),* 88–104. doi: 10.1017/jwe.2014.30

Filipe, A. F., Lawrence, J. E., & Bonada, N. (2013). Vulnerability of stream biota to climate change in mediterranean climate regions: a synthesis of ecological responses and conservation challenges. *Hydrobiologia, 719,* 331–351. doi: 10.1007/s10750-012-1244-4

Finger, D., Heinrich, G., Gobiet, A., & Bauder, A. (2012). Projections of future water resources and their uncertainty in a glacierized catchment in the Swiss Alps and the subsequent effects on hydropower production during the 21st century. *Water Resources Research, 48(2).* doi: 10.1029/2011WR010733

Fiott, D. (2022). The Fog of War: Russia's War on Ukraine, European Defence Spending and Military Capabilities. *Intereconomics, 57(3),* 152–156. doi: 10.1007/s10272-022-1051-8

Flecha, S., Pérez, F. F., García-Lafuente, J., Sammartino, S., Ríos, A. F., & Huertas, I. E. (2015). Trends of pH decrease in the Mediterranean Sea through high frequency observational data: indication of ocean acidification in the basin. *Scientific Reports, 5(1),* 16770. doi: 10.1038/srep16770

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder, P. K. (2005). Global consequences of land use. *Science, 309 (5734),* 570–574. doi: 10.1126/science.1111772

Fordham, D. A., Akçakaya, H. R., Brook, B. W., Rodriguez, A., Alves, P. C., Civantos, E., Triviño, M., Watts, M. J., & Araújo, M. B. (2013). Adapted conservation measures are required to save the Iberian lynx in a changing climate. *Nature Climate Change, 3(10),* 899–903. doi: 10.1038/nclimate1954

Fortes, P., Simoes, S. G., Brás, T. A., & Amorim, F. (2022). Competing water uses between agriculture and energy: Quantifying future climate change impacts for the Portuguese power sector. *Journal of Cleaner Production, 371,* 133629. doi: 10.1016/j.jclepro.2022.133629

Fortibuoni, T., Aldighieri, F., Giovanardi, O., Pranovi, F., & Zucchetta, M. (2015). Climate impact on Italian fisheries (Mediterranean Sea). *Regional Environmental Change, 15,* 931–937. doi: 10.1007/s10113-015-0781-6

Forzieri, G., Feyen, L., Rojas, R., Flörke, M., Wimmer, F., & Bianchi, A. (2014). Ensemble projections of future streamflow droughts in Europe. *Hydrology and Earth System Sciences, 18,* 85–108. doi : 10.5194/hess-18-85-2014

Fraga, H., García de Cortázar Atauri, I., Malheiro, A. C., & Santos, J. A. (2016). Modelling climate change impacts on viticultural yield, phenology and stress conditions in Europe. *Global Change Biology, 22(11),* 3774–3788. doi: 10.1111/GCB.13382

Fraga, H., Molitor, D., Leolini, L., & Santos, J. A. (2020a). What Is the Impact of Heatwaves on European Viticulture? A Modelling Assessment. *Applied Sciences, 10(9),* 3030. doi: 10.3390/app10093030

Fraga, H., Pinto, J. G., Viola, F., & Santos, J. A. (2020b). Climate change projections for olive yields in the Mediterranean Basin. *International Journal of Climatology, 40(2),* 769–781. doi: 10.1002/joc.6237

Fraixedas, S., Galewski, T., Ribeiro-Lopes, S., Loh, J., Blondel, J., Fontès, H., Grillas, P., Lambret, P., Nicolas, D., Olivier, A., & Geijzendorffer, I. R. (2019). Estimating biodiversity changes in the Camargue wetlands: An expert knowledge approach. *PLoS One, 14(10),* e0224235. doi: 10.1371/journal.pone.0224235

Fumagalli, I., Gimeno, B. S., Velissariou, D., De Temmerman, L., & Mills, G. (2001). Evidence of ozone-induced adverse effects on crops in the Mediterranean region. *Atmospheric Environment, 35(14),* 2583–2587. doi: 10.1016/S1352-2310(00)00468-4

Funes, I., Savé, R., de Herralde, F., Biel, C., Pla, E., Pascual, D., Zabalza, J., Cantos, G., Borràs, G., Vayreda, J., & Aranda, X. (2021). Modeling impacts of climate change on the water needs and growing cycle of crops in three Mediterranean basins. *Agricultural Water Management, 249,* 106797. doi: 10.1016/J.AGWAT.2021.106797

Gallart, F., Llorens, P., Latron, J., & Regüés, D. (2002). Hydrological processes and their seasonal controls in a small Mediterranean mountain catchment in the Pyrenees. *Hydrology and Earth System Sciences, 6,* 527–537. doi: 10.5194/hess-6-527-2002

Gallego Fernández, J. B., Rosario García Mora, M., & García Novo, F. (2004). Vegetation dynamics of Mediterranean shrublands in former cultural landscape at Grazalema Mountains, South Spain. *Plant Ecology, 172,* 83–94. doi: 10.1023/B:VEGE.0000026039.00969.7a

Galli, A., Iha, K., Halle, M., El Bilali, H., Grunewald, N., Eaton, D., Capone, R., Debs, P., & Bottalico, F. (2017). Mediterranean countries' food consumption and sourcing patterns: An Ecological Footprint viewpoint. *Science of The Total Environment, 578,* 383–391. doi: 10.1016/J.SCITOTENV.2016.10.191

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverria, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology, 27(S1),* S1–S46. doi: 10.1111/rec.13035

García, C., Deyá-Tortella, B., Lorenzo-Lacruz, J., Morán-Tejda, E., Rodríguez-Lozano, P., & Tirado, D. (2022). Zero tourism due to COVID-19: an opportunity to assess water consumption associated to tourism. *Journal of Sustainable Tourism, 31(8),* 1869–1884. doi: 10.1080/09669582.2022.2079652

García de Jalón, S., Iglesias, A., Cunningham, R., & Pérez Díaz, J. I. (2014). Building resilience to water scarcity in Southern Spain: A case study of rice farming in Doñana protected wetlands. *Regional Environmental Change, 14,* 1229–1242. doi: 10.1007/s10113-013-0569-5

García-García, P. (2023). Assessing the security status and future scenarios of the Mediterranean region through the water-energy-food nexus: A cluster analysis approach. *Cuadernos de Investigación Geográfica.* doi: 10.18172/cig.5724

García-González, R., Aldezabal, A., Laskurain N A and Margalida, A., & Novoa, C. (2016). Influence of snowmelt timing on the diet quality of Pyrenean rock ptarmigan (Lagopus muta pyrenaica): implications for reproductive success. *PLoS One, 11(2),* e0148632. doi: 10.1371/journal.pone.0148632

García-Nieto, A. P., Geijzendorffer, I. R., Baró F and Roche, P. K., Bondeau, A., & Cramer, W. (2018). Impacts of urbanisation around Mediterranean cities: Changes in ecosystem service supply. *Ecological Indicators, 91,* 589–606. doi: 10.1016/j.ecolind.2018.03.082

García-Ruiz, J. M., & Lana-Renault, N. (2011). Hydrological and erosive consequences of farmland abandonment in Europe, with special reference to the Mediterranean region – *A review. Agriculture, Ecosystems & Environment, 140(3-4),* 317–338. doi: 10.1016/j.agee.2011.01.003

García-Ruiz, J. M., López-Moreno, J. I., Vicente-Serrano, S. M., Lasanta-Martínez, T., & Beguería, S. (2011). Mediterranean water resources in a global change scenario. *Earth-Science Reviews, 105(3-4),* 121–139. doi: 10.1016/j.earscirev.2011.01.006

Garrabou, J., Gómez-Gras, D., Ledoux, J.-B., Linares, C., Bensoussan, N., López-Sendino, P., Bazairi, H., Espinosa Free and Ramdani, M., Grimes, S., Benabdi, M., Souissi, J. Ben, Soufi, E., Khamassi, F., Ghanem, R., Ocaña, O., Ramos-Esplà Alfonso and Izquierdo, A., Anton, I., Rubio-Portillo Esther and Barbera, C., Cebrian, E., … Harmelin, J. G. (2019). Collaborative Database to Track Mass Mortality Events in the Mediterranean Sea. *Frontiers in Marine Science, 6,* 707. doi: 10.3389/fmars.2019.00707

Garrabou, J., Gómez-Gras, D., Medrano, A., Cerrano, C., Ponti, M., Schlegel, R., Bensoussan, N., Turicchia, E., Sini, M., Gerovasileiou, V., Teixido, N., Mirasole, A., Tamburello, L., Cebrian, E., Rilov, G., Ledoux, J.-B., Souissi, J. Ben, Khamassi, F., Ghanem, R., … Harmelin, J.-G. (2022). Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea. *Global Change Biology, 28(19),* 5708–5725. doi: 10.1111/gcb.16301

Garrabou, J., Ledoux, J. B., Bensoussan, N., Gómez-Gras, D., & Linares, C. (2021). Sliding Toward the Collapse of Mediterranean Coastal Marine Rocky Ecosystems. In J. G. Canadell & R. B. Jackson (Eds.), Ecosystem Collapse and Climate Change. *Ecological Studies (Vol. 241, pp. 291–324).* Springer, Cham.

Garrett, R., & Rueda, X. (2019). Telecoupling and Consumption in Agri-Food Systems. *Telecoupling, 115–137.* doi: 10.1007/978-3-030-11105-2_6

Gedik, K., & Eryaşar, A. R. (2020). Microplastic pollution profile of Mediterranean mussels (Mytilus galloprovincialis) collected along the Turkish coasts. *Chemosphere, 260,* 127570. doi: 10.1016/j.chemosphere.2020.127570

Giani, M., Djakovac, T., Degobbis, D., Cozzi, S., Solidoro, C., & Umani, S. F. (2012). Recent changes in the marine ecosystems of the northern Adriatic Sea. *Estuarine, Coastal and Shelf Science, 115,* 1–13. doi: 10.1016/j.ecss.2012.08.023

Gilmore, E. A., Herzer Risi, L., Tennant, E., & Buhaug, H. (2018). Bridging research and policy on climate change and conflict. *Current Climate Change Reports, 4,* 313–319. doi: 10.1007/s40641-018-0119-9

Giorgi, F., & Lionello, P. (2008). Climate change projections for the Mediterranean region. *Global and Planetary Change, 63(2-3),* 90–104. doi: 10.1016/j.gloplacha.2007.09.005

Goma, A. A., & Phillips, C. J. C. (2021). The Impact of Anthropogenic Climate Change on Egyptian Livestock Production. *Animal, 11(11),* 3127. doi: 10.3390/ani11113127

Goma, A. A., & Phillips, C. J. C. (2022). 'Can They Take the Heat?'—The Egyptian Climate and Its Effects on Livestock. *Animals, 12(15),* 1937. doi: 10.3390/ani12151937

Gómez Murciano, M., Liu, Y., Ünal, V., & Sánchez LIzaso, J. L. (2021). Comparative analysis of the social vulnerability assessment to climate change applied to fisheries from Spain and Turkey. *Scientific Reports, 11(1),* 13949. doi: 10.1038/s41598-021-93165-0

Gönül, Ö., Can Duman, A., Deveci, K., & Güler, Ö. (2021). An assessment of wind energy status, incentive mechanisms and market in Turkey. Engineering *Science and Technology, an International Journal, 24(6),* 1383–1395. doi: 10.1016/j.jestch.2021.03.016

González de Molina, M., Soto Fernández, D., Guzmán Casado, G., Infante-Amate, J., Aguilera Fernández, E., Vila Traver, J., & García Ruiz, R. (2020). The Social Metabolism of Spanish Agriculture, 1900-2008. The Mediterranean Way Towards Industrialization. *Environmental History, Springer Nature, 281 pp.* doi: 10.1007/978-3-030-20900-1

González-Fernández, I., Calvo, E., Gerosa, G., Bermejo, V., Marzuoli, R., Calatayud, V., & Alonso, R. (2014). Setting ozone critical levels for protecting horticultural Mediterranean crops: Case study of tomato. *Environmental Pollution, 185,* 178-187. doi: 10.1016/j.envpol.2013.10.033

González-Fernández, I., Elvira, S., Calatayud, V., Calvo, E., Aparicio, P., Sánchez, M., Alonso, R., & Bermejo Bermejo, V. (2016). Ozone effects on the physiology and marketable biomass of leafy vegetables under Mediterranean conditions: Spinach. *Agriculture, Ecosystems and Environment, 235,* 215-228. doi: 10.1016/j.agee.2016.10.023

Gordo, O., & Sanz, J. J. (2006). Climate change and bird phenology: A long-term study in the Iberian Peninsula. *Global Change Biology, 12(10),* 1993-2004. doi: 10.1111/j.1365-2486.2006.01178.x

Gordo, O., & Sanz, J. J. (2010). Impact of climate change on plant phenology in Mediterranean ecosystems. *Global Change Biology, 16(3),* 1082-1106. doi: 10.1111/J.1365-2486.2009.02084.X

Gouveia, C. M., Trigo, R. M., Beguería, S., & Vicente-Serrano, S. M. (2017). Drought impacts on vegetation activity in the Mediterranean region: An assessment using remote sensing data and multi-scale drought indicators. *Global and Planetary Change, 151,* 15-27. doi: 10.1016/j.gloplacha.2016.06.011

Green, A. J., Alcorlo, P., Peeters, E. T., Morris, E. P., Espinar, J. L., Bravo-Utrera, M. A., Bustamante, J., Diaz-Delgado, R., Koelmans, A. A., Mateo, R., Mooij, W. M., Rodriguez-Rodriguez, M., van Nes, E. H., & Scheffer, M. (2017). Creating a safe operating space for wetlands in a changing climate. *Frontiers in Ecology and the Environment, 15(2),* 99-107. doi: 10.1002/fee.1459

Green, T. R., Taniguchi, M., Kooi, H., Gurdak, J. J., Allen, D. M., Hiscock, K. M., Treidel, H., & Aureli, A. (2011). Beneath the surface of global change: Impacts of climate change on groundwater. *Journal of Hydrology, 405(3-4),* 532-560. doi: 10.1016/j.jhydrol.2011.05.002

Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner D and Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M. E., Meng, J., Mulligan, M., Nilsson, C., ... Zarfl, C. (2019). Mapping the world's free-flowing rivers. *Nature, 569,* 215-221. doi: 10.1038/s41586-019-1111-9

Grosso, G., Marventano, S., Giorgianni, G., Raciti, T., Galvano, F., & Mistretta, A. (2014). Mediterranean diet adherence rates in Sicily, southern Italy. *Public Health Nutrition, 17(9),* 2001-2009. doi: 10.1017/S1368980013002188

Gulías, J., Flexas, J., Abadía, A., & Medrano, H. (2002). Photosynthetic responses to water deficit in six Mediterranean sclerophyll species: Possible factors explaining the declining distribution of Rhamnus ludovici-salvatoris, an endemic Balearic species. *Tree Physiology, 22(10),* 687-697. doi: 10.1093/TREEPHYS/22.10.687

Güven, O., Gökdağ, K., Jovanović, B., & Kdeyş, A. E. (2017). Microplastic litter composition of the Turkish territorial waters of the Mediterranean Sea, and its occurrence in the gastrointestinal tract of fish. *Environmental Pollution, 223,* 286-294. doi: 10.1016/j.envpol.2017.01.025

Guyennon, N., Salerno, F., Portoghese, I., & Romano, E. (2017). Climate Change Adaptation in a Mediterranean Semi-Arid Catchment: Testing Managed Aquifer Recharge and Increased Surface Reservoir Capacity. *Water, 9(9),* 689. doi: 10.3390/w9090689

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., & Collins, C. D. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances, 1(2),* e1500052. doi: 10.1126/sciadv.1500052

Haj-Amor, Z., Acharjee, T. K., Dhaouadi, L., & Bouri, S. (2020). Impacts of climate change on irrigation water requirement of date palms under future salinity trend in coastal aquifer of Tunisian oasis. *Agricultural Water Management, 228,* 105843. doi: 10.1016/j.agwat.2019.105843

Hanisch, M., Schweiger, O., Cord, A. F., Volk, M., & Knapp, S. (2020). Plant functional traits shape multiple ecosystem services, their trade-offs and synergies in grasslands. *Journal of Applied Ecology, 57(8),* 1535-1550. doi: 10.1111/1365-2664.13644

Harchaoui, S., & Chatzimpiros, P. (2019). Energy, Nitrogen, and Farm Surplus Transitions in Agriculture from Historical Data Modeling. France, 1882-2013. *Journal of Industrial Ecology, 23(2),* 412-425. doi: 10.1111/JIEC.12760

Harmelin-Vivien, M., Bodiguel, X., Charmasson, S., Loizeau, V., Mellon-Duval, C., Tronczyński, J., & Cossa, D. (2012). Differential biomagnification of PCB, PBDE, Hg and Radiocesium in the food web of the European hake from the NW Mediterranean. *Marine Pollution Bulletin, 64(5),* 974-983. doi: 10.1016/j.marpolbul.2012.02.014

Hasanaliyeva, G., Sufar, E. K., Wang, J., Rempelos, L., Volakakis, N., Iversen, P. O., & Leifert, C. (2023). Effects of agricultural intensification on Mediterranean diets: A narrative review. *Foods, 12(20),* 3779. doi: 10.3390/foods12203779

Hassoun, A. E. R., Bantelman, A., Canu Donata and Comeau, S., Galdies, C., Gattuso Jean-Pierre and Giani, M., Grelaud, M., Hendriks, I. E., Ibello, V., Idrissi, M., Krasakopoulou, E., Shaltout, N., Solidoro, C., Swarzenski, P. W., & Ziveri, P. (2022). Ocean acidification research in the Mediterranean Sea: Status, trends and next steps. *Frontiers in Marine Science, 9*, 892670. doi: 10.3389/fmars.2022.892670

Hassoun, A. E. R., Gemayel, E., Krasakopoulou, E., Goyet, C., Abboud-Abi Saab, M., Guglielmi, V., Touratier, F., & Falco, C. (2015). Acidification of the Mediterranean Sea from anthropogenic carbon penetration. *Deep Sea Research Part I: Oceanographic Research Papers, 102,* 1–15. doi: 10.1016/j.dsr.2015.04.005

Henselek, Y., Eilers, E. J., Kremen, C., Hendrix, S. D., & Klein, A. M. (2018). Pollination requirements of almond (Prunus dulcis): combining laboratory and field experiments. *Journal of Economic Entomology, 111(3),* 1006–1013. doi: 10.1093/jee/toy053

Hepcan, S., Coskun Hepcan, C., Kilicaslan, C., & Ozkan M B and Kocan, N. (2012). Analyzing Landscape Change and Urban Sprawl in a Mediterranean Coastal Landscape: A Case Study from Izmir, Turkey. *Journal of Coastal Research, 29(2),* 301–310. doi: 10.2112/JCOASTRES-D-11-00064.1

Hochman, A., Marra, F., Messori, G., Pinto, J. G., Raveh-Rubin, S., Yosef, Y., & Zittis, G. (2022). Extreme weather and societal impacts in the eastern Mediterranean. *Earth System Dynamics, 13(2),* 749–777. doi: 10.5194/esd-13-749-2022

Hódar, J. A., Castro, J., & Zamora, R. (2003). Pine processionary caterpillar Thaumetopoea pityocampa as a new threat for relict Mediterranean Scots pine forests under climatic warming. *Biological Conservation, 110(1),* 123–129. doi: 10.1016/S0006-3207(02)00183-0

Hoegh-Guldberg, O., Cai, R., Poloczanska, E. S., Brewer, P. G., Sundby, S., Hilmi, K., Fabry, V. J., & Jung, S. (2014). The Ocean. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1655–1731).* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Hoerling, M., Eischeid, J., Perlwitz, J., Quan, X., Zhang, T., & Pegion, P. (2012). On the Increased Frequency of Mediterranean Drought. *Journal of Climate, 25(6),* 2146–2161. doi: 10.1175/JCLI-D-11-00296.1

Hof, A., Morán-Tejeda, E., Lorenzo-Lacruz, J., & Blázquez-Salom, M. (2018). Swimming Pool Evaporative Water Loss and Water Use in the Balearic Islands (Spain). *Water, 10(12),* 1883. doi: 10.3390/w10121883

Hof, A., & Schmitt, T. (2011). Urban and tourist land use patterns and water consumption: Evidence from Mallorca, Balearic Islands. *Land Use Policy, 28(4),* 792–804. doi: 10.1016/j.landusepol.2011.01.007

Hssaisoune, M., Bouchaou, L., Sifeddine, A., Bouimetarhan, I., & Chehbouni, A. (2020). Moroccan groundwater resources and evolution with global climate changes. *Geosciences, 10(2), 81.* doi: 10.3390/geosciences10020081

IAEA. (2022). Climate Change and Nuclear Power 2022. Securing Clean Energy for Climate Resilience. International Atomic Energy Agency (IAEA), 115 pp.

Ibrahim, O., Mohamed, B., & Nagy, H. (2021). Spatial Variability and Trends of Marine Heat Waves in the Eastern Mediterranean Sea over 39 Years. *Journal of Marine Science and Engineering, 9(6),* 643. doi: 10.3390/jmse9060643

Ide, T. (2018). Climate War in the Middle East? Drought, the Syrian Civil War and the State of Climate-Conflict Research. *Current Climate Change Reports, 4(4),* 347–354. doi: 10.1007/S40641-018-0115-0

IEA. (2020). Monthly Energy Review. *U.S. Energy Information Administration.*

IEA. (2021). Net Zero by 2050. A Roadmap for the Global Energy Sector. *International Energy Agency, 224 pp.*

IEA. (2022). World Energy Outlook. *International Energy Agency (IEA), 524 pp.*

Iglesias, A., Garrote, L., Flores, F., & Moneo, M. (2007). Challenges to manage the risk of water scarcity and climate change in the Mediterranean. *Water Resources Management, 21,* 775–788. doi: 10.1007/s11269-006-9111-6

Iglesias, A., Quiroga, S., Moneo, M., & Garrote, L. (2012). From climate change impacts to the development of adaptation strategies: challenges for agriculture in Europe. *Climatic Change, 112, 143–168.* doi: 10.1007/s10584-011-0344-x

IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (E. S. Brondizio, J. Settele, S. Díaz, & H. T. Ngo, Eds.). IPBES secretariat, Bonn, Germany. 1148 pp. doi: 10.5281/zenodo.3831673

IPBES. (2023). *Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (H. E. Roy, A. Pauchard, P. Stoett, & T. Renard Truong, Eds.). IPBES secretariat, Bonn, Germany, 952 pp. doi: 10.5281/zenodo.7430682

IPCC. (2021). *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou, Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi: 10.1017/9781009157896

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama, Eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp. doi: 10.1017/9781009325844

Jacob, D., Petersen, J., Eggert, B., Alias, A., Christensen, O. B., Bouwer, L. M., Braun, A., Colette, A., Déqué, M., Georgievski, G., Georgopoulou, E., Gobiet, A., Menut, L., Nikulin, G., Haensler, A., Hempelmann, N., Jones, C., Keuler, K., Kovats, S., … Yiou, P. (2014). EURO-CORDEX: new high-resolution climate change projections for European impact research. *Regional Environmental Change, 14,* 563–578. doi: 10.1007/s10113-013-0499-2

Johnson, D. L. (1996). Development trends and environmental deterioration in the agropastoral systems of the Central Middle Atlas. In W. D. Swearingen & A. Bencherifa (Eds.), *The North African Environment at Risk* (pp. 35-54). Routledge, 304 pp.

Jomaa, I., Auda, Y., Abi Saleh, B., Hamzé, M., & Safi, S. (2008). Landscape spatial dynamics over 38 years under natural and anthropogenic pressures in Mount Lebanon. *Landscape and Urban Planning, 87(1),* 67–75. doi: 10.1016/j.landurbplan.2008.04.007

Jump, A. S., Hunt, J. M., Martínez-Izquierdo, J. A., & Peñuelas, J. (2006a). Natural selection and climate change: Temperature-linked spatial and temporal trends in gene frequency in Fagus sylvatica. *Molecular Ecology, 15(11),* 3469–3480. doi: 10.1111/J.1365-294X.2006.03027.X

Jump, A. S., Hunt, J. M., & Pen⎕uelas, J. (2006b). Rapid climate change-related growth decline at the southern range edge of Fagus sylvatica. *Global Change Biology, 12(11),* 2163–2174. doi: 10.1111/J.1365-2486.2006.01250.X

Jump, A. S., Peñuelas, J., Rico, L., Ramallo, E., Estiarte, M., Martínez-Izquierdo, J. A., & Lloret, F. (2008). Simulated climate change provokes rapid genetic change in the Mediterranean shrub Fumana thymifolia. *Global Change Biology, 14(3),* 637–643. doi: 10.1111/j.1365-2486.2007.01521.x

Kalabokas, P., Zanis, P., Akritidis, D., Georgoulias A K, Kapsomenakis, J., Zerefos, C. S., Dufour, G., Gaudel Audrey, Sellitto, P., Armengaud, A., Ancellet, G., Gheusi, F., & Dulac, F. (2023). Ozone in the Mediterranean Atmosphere. In F. Dulac, S. Sauvage, & E. Hamonou (Eds.), *Atmospheric Chemistry in the Mediterranean Region. Volume 1 - Background Information and Pollutant Distribution* (pp. 413–470). Springer Cham. doi: 10.1007/978-3-031-12741-0_13

Kalogeri, C., Galanis, G., Spyrou, C., Diamantis, D., Baladima, F., Koukoula, M., & Kallos, G. (2017). Assessing the European offshore wind and wave energy resource for combined exploitation. *Renewable Energy, 101,* 244–264. doi: 10.1016/j.renene.2016.08.010

Kanakidou, M., Sfakianaki, M., & Probst, A. (2022). Impact of Air Pollution on Terrestrial Ecosystems. In F. Dulac, S. Sauvage, & E. Hamonou (Eds.), *Atmospheric Chemistry in the Mediterranean Region* (pp. 511–542). Springer, Cham. doi: 10.1007/978-3-030-82385-6_24

Kapsenberg, L., Alliouane, S., Gazeau, F., Mousseau, L., & Gattuso, J.-P. (2017). Coastal ocean acidification and increasing total alkalinity in the northwestern Mediterranean Sea. *Ocean Science, 13(3),* 411–426. doi: 10.5194/os-13-411-2017

Karameta, E., Gavriilidi, I., Sfenthourakis, S., & Pafilis, P. (2023). Seasonal Variation in the Thermoregulation Pattern of an Insular Agamid Lizard. *Animals, 13(20),* 3195. doi: 10.3390/ani13203195

Kath, J., Powell, S., Reardon-Smith, K., El Sawah, S., Jakeman, A. J., Croke, B. F., & Dyer, F. J. (2015). Groundwater salinization intensifies drought impacts in forests and reduces refuge capacity. *Journal of Applied Ecology, 52(5),* 1116–1125. doi: 10.1111/1365-2664.12495

Katsanevakis, S., Tsirintanis, K., Tsaparis, D., Doukas, D., Sini, M., Athanassopoulou, F., Kolygas, M. N., Tontis, D., Koutsoubas, D., & Bakopoulos, V. (2019). The cryptogenic parasite Haplosporidium pinnae invades the Aegean Sea and causes the collapse of Pinna nobilis populations. *Aquatic Invasions, 14(2),* 150–164. doi: 10.3391/ai.2019.14.2.01

Kebede, A. S., Nicholls, R. J., Clarke, D., Savin, C., & Harrison, P. A. (2021). Integrated assessment of the food-water-land-ecosystems nexus in Europe: Implications for sustainability. *Science of The Total Environment, 768,* 144461. doi: 10.1016/j.scitotenv.2020.144461

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R., & Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. *Proceedings of the National Academy of Sciences, 112(11),* 3241–3246. doi: 10.1073/pnas.1421533112

Kersting, D. K., Casado, C., López-Legentil, S., & Linares, C. (2013). Unexpected patterns in the sexual reproduction of the Mediterranean scleractinian coral Cladocora caespitosa. *Marine Ecology Progress Series, 486,* 165–171. doi: 10.3354/meps10356

Keshta, A. E., Shaltout, K. H., Baldwin, A. H., & Sharaf El-Din, A. A. (2020). Sediment clays are trapping heavy metals in urban lakes: An indicator for severe industrial and agricultural influence on coastal wetlands at the Mediterranean coast of Egypt. *Marine Pollution Bulletin, 151,* 110816. doi: 10.1016/j.marpolbul.2019.110816

Kjellstrom, T., Kovats, R. S., Lloyd, S. J., Holt, T., & Tol, R. S. J. (2009). The Direct Impact of Climate Change on Regional Labor Productivity. *Archives of Environmental & Occupational Health, 64(4),* 217–227. doi: 10.1080/19338240903352776

Koulelis, P. P., Proutsos, N., Solomou, A. D., Avramidou E V and Malliarou, E., Athanasiou, M., Xanthopoulos, G., & Petrakis, P. V. (2023). Effects of Climate Change on Greek Forests: A Review. *Atmosphere, 14(7),* 1155. doi: 10.3390/atmos14071155

Kuglitsch, F. G., Toreti, A., Xoplaki, E., Della-Marta P M and Zerefos, C. S., Türkeş, M., & Luterbacher, J. (2010). Heat wave changes in the eastern Mediterranean since 1960. *Geophysical Research Letters, 37(4).* doi: 10.1029/2009GL041841

Kuper, M., Amichi, H., & Mayaux, P.-L. (2017). Groundwater use in North Africa as a cautionary tale for climate change adaptation. *Water International, 42(6),* 725–740. doi: 10.1080/02508060.2017.1351058

Kuriqi, A., Pinheiro, A. N., Sordo-Ward, A., Bejarano, M. D., & Garrote, L. (2021). Ecological impacts of run-of-river hydropower plants—Current status and future prospects on the brink of energy transition. *Renewable and Sustainable Energy Reviews, 142,* 110833. doi: 10.1016/j.rser.2021.110833

Kurylyk, B. L., MacQuarrie, K. T. B., & Voss, C. I. (2014). Climate change impacts on the temperature and magnitude of groundwater discharge from shallow, unconfined aquifers. *Water Resources Research, 50(4),* 3253–3274. doi: 10.1002/2013WR014588

Kyriacou, A., Evans, J. M. M., Economides, N., & Kyriacou, A. (2015). Adherence to the Mediterranean diet by the Greek and Cypriot population: a systematic review. *European Journal of Public Health, 25(6),* 1012–1018. doi: 10.1093/EURPUB/CKV124

Labrousse, C., Ludwig, W., Pinel, S., Sadaoui, M., Toreti, A., & Lacquement, G. (2022). Declining water resources in response to global warming and changes in atmospheric circulation patterns over southern Mediterranean France. *Hydrology and Earth System Sciences, 26(23),* 6055–6071. doi: 10.5194/hess-26-6055-2022

Lacirignola, C., Capone, R., Debs, P., El Bilali, H., & Bottalico, F. (2014). Natural resources – food nexus: food-related environmental footprints in the mediterranean countries. *Frontiers in Nutrition, 1, 23.* doi: 10.3389/fnut.2014.00023

Lana-Renault, N., Morán-Tejeda, E., Heras, M., Lorenzo-Lacruz, J., & López-Moreno, J. I. (2020). Land use change and impacts. In M. Zribi, L. Brocca, Y. Tramblay, & F. Molle (Eds.), *Water Resources in the Mediterranean Region* (pp. 257–296). Elsevier. doi: 10.1016/B978-0-12-818086-0.00010-8

Lana-Renault, N., Nadal-Romero, E., Serrano-Muela, M. P., Alvera, B., Sánchez-Navarrete, P., Sanjuan, Y., & García-Ruiz, J. M. (2014). Comparative analysis of the response of various land covers to an exceptional rainfall event in the central Spanish Pyrenees. *Earth Surface Processes and Landforms, 39(5),* 581–592. doi: 10.1002/esp.3465

Lange, M. A. (2020). Climate change in the Mediterranean: environmental impacts and extreme events. *In IEMed Mediterranean Yearbook 2020* (pp. 30–45). European Institute of the Mediterranean (IEMed), Barcelona.

Lazoglou, G., Anagnostopoulou, C., & Koundouras, S. (2018). Climate change projections for Greek viticulture as simulated by a regional climate model. *Theoretical and Applied Climatology, 133(1-2)*, 551–567. doi: 10.1007/S00704-017-2198-2

Leduc, C., Ben Ammar, S., Favreau, G., Beji, R., Virrion, R., Lacombe, G., Tarhouni, J., Aouadi, C., Zenati Chelli, B., Jebnoun, N., Oi, M., Michelot, J. L., & Zouari, K. (2007). Impacts of hydrological changes in the Mediterranean zone: Environmental modifications and rural development in the Merguellil catchment, central Tunisia. *Hydrological Sciences Journal, 52(6),* 1162–1178. doi: 10.1623/hysj.52.6.1162

Leduc, C., Pulido-Bosch, A., & Remini, B. (2017). Anthropization of groundwater resources in the Mediterranean region: processes and challenges. *Hydrogeology Journal, 25(6),* 1529–1547. doi: 10.1007/s10040-017-1572-6

Lefebvre, G., Redmond, L., Germain Christophe, Palazzi, E., Terzago, S., Willm, L., & Poulin, B. (2019). Predicting the vulnerability of seasonally-flooded wetlands to climate change across the Mediterranean Basin. *Science of The Total Environment, 692,* 546–555. doi: 10.1016/j.scitotenv.2019.07.263

Leslie, P., & McCabe, J. T. (2013). Response diversity and resilience in social-ecological systems. *Current Anthropology, 54(2),* 114–144. doi: 10.1086/669563

Liadze, I., Macchiarelli, C., Mortimer-Lee, P., & Sanchez Juanino, P. (2023). Economic costs of the Russia-Ukraine war. *The World Economy, 46(4),* 874–886. doi: 10.1111/twec.13336

Lin, T. K., Kafri, R., Hammoudeh, W., Mitwalli, S., Jamaluddine, Z., Ghattas, H., Giacaman, R., & Leone, T. (2022). Pathways to food insecurity in the context of conflict: the case of the occupied Palestinian territory. *Conflict and Health, 16, 38.* doi: 10.1186/s13031-022-00470-0

Link, P. M., Kominek, J., & Scheffran, J. (2013). Impacts of accelerated sea level rise on the coastal zones of Egypt. *Mainzer Geographische Studien, 55,* 79–94.

Lionello, P., & Giorgi, F. (2007). Winter precipitation and cyclones in the Mediterranean region: future climate scenarios in a regional simulation. *Advances in Geosciences, 12,* 153–158. doi: 10.5194/adgeo-12-153-2007

Lionello, P., & Scarascia, L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change, 18,* 1481–1493. doi: 10.1007/s10113-018-1290-1

Llamas-Dios, M. I., Vadillo, I., Jiménez-Gavilán, P., Candela, L., & Corada-Fernández, C. (2021). Assessment of a wide array of contaminants of emerging concern in a Mediterranean water basin (Guadalhorce river, Spain): Motivations for an improvement of water management and pollutants surveillance. *Science of The Total Environment, 788,* 147822. doi: 10.1016/j.scitotenv.2021.147822

Llasat, M. C., Llasat-Botija, M., Petrucci, O., Pasqua, A. A., Rosselló, J., Vinet, F., & Boissier, L. (2013). Towards a database on societal impact of Mediterranean floods within the framework of the HYMEX project. *Natural Hazards and Earth System Sciences, 13(5),* 1337–1350. doi: 10.5194/nhess-13-1337-2013

Llorens, P., & Domingo, F. (2007). Rainfall partitioning by vegetation under Mediterranean conditions. A review of studies in Europe. *Journal of Hydrology, 335(1-2),* 37–54. doi: 10.1016/j.jhydrol.2006.10.032

López-Doval, J. C., Ginebreda, A., & Caquet, T. (2013). Pollution in mediterranean-climate rivers. *Hydrobiologia, 719,* 427–450. doi: 10.1007/s10750-012-1369-5

López-Moreno, J. I., & Latron, J. (2008). Influence of canopy density on snow distribution in a temperate mountain range. *Hydrological Processes, 22(1),* 117–126. doi: 10.1002/hyp.6572

López-Moreno, J. I., Vicente-Serrano, S. M., Moran-Tejeda, E., Zabalza, J., Lorenzo-Lacruz, J., & Garcia-Ruiz, J. M. (2011). Impact of climate evolution and land use changes on water yield in the ebro basin. *Hydrology and Earth System Sciences, 15(1),* 311–322. doi: 10.5194/hess-15-311-2011

Lorenzo-Lacruz, J., Amengual, A., Garcia, C., Morán-Tejeda, E., Homar, V., Maimó-Far, A., Hermoso, A., Ramis, C., & Romero, R. (2019). Hydro-meteorological reconstruction and geomorphological impact assessment of the October 2018 catastrophic flash flood at Sant Llorenç, Mallorca (Spain). Natural Hazards and *Earth System Sciences, 19(11),* 2597–2617. doi: 10.5194/nhess-19-2597-2019

Louhaichi, M., Ouled Belgacem, A., Petersen, S. L., & Hassan, S. (2019). Effects of climate change and grazing practices on shrub communities of West Asian rangelands. *International Journal of Climate Change Strategies and Management, 11(15),* 660–671. doi: 10.1108/IJCCSM-02-2018-0017

Ludwig, W., Bouwman, A. F., Dumont, E., & Lespinas, F. (2010). Water and nutrient fluxes from major Mediterranean and Black Sea rivers: Past and future trends and their implications for the basin-scale budgets. *Global Biogeochemical Cycles, 24(4).* doi: 10.1029/2009GB003594

Lundquist, J. D., Dickerson-Lange, S. E., Lutz, J. A., & Cristea, N. C. (2013). Lower forest density enhances snow retention in regions with warmer winters: A global framework developed from plot-scale observations and modeling. *Water Resources Research, 49(10),* 6356–6370. doi: 10.1002/wrcr.20504

Lutz, S. R., Mallucci, S., Diamantini, E., Majone, B., Bellin, A., & Merz, R. (2016). Hydroclimatic and water quality trends across three Mediterranean river basins. *Science of The Total Environment, 571,* 1392–1406. doi: 10.1016/j.scitotenv.2016.07.102

Maestre, F. T., Salguero-Gómez, R., & Quero, J. L. (2012). It is getting hotter in here: determining and projecting the impacts of global environmental change on drylands. *Philosophical Transactions of the Royal Society B: Biological Sciences, 367(1606),* 3062–3075. doi: 10.1098/rstb.2011.0323

Maiorano, L., Falcucci, A., Zimmermann, N. E., Psomas, A., Pottier, J., Baisero Daniele, Rondinini, C., Guisan, A., & Boitani, L. (2011). The future of terrestrial mammals in the Mediterranean basin under climate change. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1578),* 2681–2692.

Mairech, H., López-Bernal, Á., Moriondo, M., Dibari, C., Regni, L., Proietti, P., Villalobos, F. J., & Testi, L. (2021). Sustainability of olive growing in the Mediterranean area under future climate scenarios: Exploring the effects of intensification and deficit irrigation. *European Journal of Agronomy, 129,* 126319. doi: 10.1016/j.eja.2021.126319

Malek, Ž., Verburg, P. H., R Geijzendorffer, I., Bondeau, A., & Cramer, W. (2018). Global change effects on land management in the Mediterranean region. *Global Environmental Change, 50,* 238–254. doi: 10.1016/J.GLOENVCHA.2018.04.007

Mancuso, G., Lavrnić, S., & Toscano, A. (2020). Reclaimed water to face agricultural water scarcity in the Mediterranean area: An overview using Sustainable Development Goals preliminary data. In P. Verlicchi (Ed.), *Advances in Chemical Pollution, Environmental Management and Protection (Vol. 5, pp.* 113–143). Elsevier. doi: 10.1016/bs.apmp.2020.07.007

Månsson, A. (2014). Energy, conflict and war: Towards a conceptual framework. *Energy Research & Social Science, 4(C),* 106–116. doi: 10.1016/J.ERSS.2014.10.004

Mantero, G., Morresi, D., & Marzano, R. (2020). The influence of land abandonment on forest disturbance regimes: a global review. *Landscape Ecology, 35(12),* 2723–2744. doi: 10.1007/s10980-020-01147-w

Marcé, R., & Armengol, J. (2010). Water Quality in Reservoirs Under a Changing Climate. In S. Sabater & D. Barceló (Eds.), *Water Scarcity in the Mediterranean: Perspectives Under Global Change (pp. 73–94).* Springer Berlin Heidelberg.

March, H., & Saurí, D. (2010). The suburbanisation of water scarcity in the Barcelona metropolitan region: Sociodemographic and urban changes influencing domestic water consumption. *The Professional Geographer, 62(1)*, 32–45. doi: 10.1080/00330120903375860

Mariotti, A., Pan, Y., Zeng, N., & Alessandri, A. (2015). Long-term climate change in the Mediterranean region in the midst of decadal variability. *Climate Dynamics, 44,* 1437–1456. doi: 10.1007/s00382-015-2487-3

Martínez-Granados, D., Maestre-Valero, J. F., Calatrava, J., & Martínez-Alvarez, V. (2011). The economic impact of water evaporation losses from water reservoirs in the Segura basin, SE Spain. *Water Resources Management, 25,* 3153–3175. doi: 10.1007/s11269-011-9850-x

Martínez-Megías, C., & Rico, A. (2023). Biodiversity impacts by multiple anthropogenic stressors in Mediterranean coastal wetlands. *Science of The Total Environment, 818,* 151712. doi: 10.1016/j.scitotenv.2021.151712

Martínez-Valderrama, J., Sanjuán, M. E., del Barrio, G., Guirado, E., Ruiz, A., & Maestre, F. T. (2021). *Mediterranean Landscape Re-Greening at the Expense of South American Agricultural Expansion. Land, 10(2),* 204. doi: 10.3390/land10020204

Martín-Queller, E., Moreno-Mateos, D., Pedrocchi, C., Cervantes, J., & Martínez, G. (2010). Impacts of intensive agricultural irrigation and livestock farming on a semi-arid Mediterranean catchment. *Environmental Monitoring and Assessment, 167,* 423–435. doi: 10.1007/s10661-009-1061-z

Marventano, S., Godos, J., Platania, A., Galvano, F., Mistretta, A., & Grosso, G. (2018). Mediterranean diet adherence in the Mediterranean healthy eating, aging and lifestyle (MEAL) study cohort. *International Journal of Food Sciences and Nutrition, 69, 1,* 100–107. doi: 10.1080/09637486.2017.1332170

Mas-Pla, J., & Menció, A. (2019). Groundwater nitrate pollution and climate change: learnings from a water balance-based analysis of several aquifers in a western Mediterranean region (Catalonia). *Environmental Science and Pollution Research, 26(3),* 2184–2202. doi: 10.1007/s11356-018-1859-8

Mastrocicco, M., & Colombani, N. (2021). The issue of groundwater salinization in coastal areas of the mediterranean region: A review. *Water, 13(1),* 90. doi: 10.3390/w13010090

Mastrocicco, M., Gervasio, M. P., Busico, G., & Colombani, N. (2021). Natural and anthropogenic factors driving groundwater resources salinization for agriculture use in the Campania plains (Southern Italy). *Science of The Total Environment, 758,* 144033. doi: 10.1016/j.scitotenv.2020.144033

Mateos, R. M., Sarro, R., Díez-Herrero, A., Reyes-Carmona, C., López-Vinielles, J., Ezquerro, P., Martínez-Corbella, M., Bru, G., Luque, J. A., Barra A, Martín, P., Millares, A., Ortega, M., López A, Galve, J. P., Azañón, J. M., Pereira, S., Santos, P. P., Zêzere, J. L., … Monserrat, O. (2023). Assessment of the Socio-Economic Impacts of Extreme Weather Events on the Coast of Southwest Europe during the Period 2009-2020. *Applied Sciences, 13(4),* 2640. doi: 10.3390/app13042640

Matono, P., Batista, T., Sampaio, E., & Ilhéu, M. (2019). Effects of agricultural land use on the ecohydrology of small-medium Mediterranean river basins: Insights from a case study in the south of Portugal. In L. C. Loures (Ed.), *Land Use - Assessing the Past, Envisioning the Future (pp. 30-51).* IntechOpen. doi: 10.5772/intechopen.79756

Mazi, K., Koussis, A. D., & Destouni, G. (2014). Intensively exploited Mediterranean aquifers: resilience to seawater intrusion and proximity to critical thresholds. *Hydrology and Earth System Sciences, 18(5),* 1663–1677. doi: 10.5194/hess-18-1663-2014

Mbow, C., Rosenzweig, C., Barioni, L. G., Benton, T. G., Herrero, M., Krishnapillai, M., Liwenga, E., Pradhan, P., Rivera-Ferre, M. G., Sapkota, T., Tubiello, F. N., & Xu, Y. (2019). Food Security. In P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, … J. Malley (Eds.), *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. In press.

Médail, F. (2017). The specific vulnerability of plant biodiversity and vegetation on Mediterranean islands in the face of global change. *Regional Environmental Change, 17(6),* 1775-1790. doi: 10.1007/s10113-017-1123-7

MedECC. (2020). Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report (W. Cramer, J. Guiot, & K. Marini, Eds.). *Union for the Mediterranean,* Plan Bleu, UNEP/MAP, Marseille, France. doi: 10.5281/zenodo.4768833

Medina, A., Akbar, A., Baazeem, A., Rodriguez, A., & Magan, N. (2017). Climate change, food security and mycotoxins: Do we know enough? *Fungal Biology Reviews, 31(3),* 143–154. doi: 10.1016/J.FBR.2017.04.002

Medland, L. (2021). 'There is no time': Agri-food internal migrant workers in Morocco's tomato industry. *Journal of Rural Studies, 88,* 482–490. doi: 10.1016/J.JRURSTUD.2021.04.015

Menichetti, E. (2021). *The evolution of greenhouse gas emission and mitigation policies.* Factsheet 13 of the Plan Bleu MED2050 Foresight programme.

Meyssignac, B., Calafat, F. M., Somot, S., Rupolo, V., Stocchi, P., Llovel, W., & Cazenave, A. (2011). Two-dimensional reconstruction of the Mediterranean sea level over 1970–2006 from tide gage data and regional ocean circulation model outputs. *Global and Planetary Change, 77(1-2),* 49–61. doi: 10.1016/j.gloplacha.2011.03.002

Midolo, G., Alkemade, R., Schipper, A. M., Benitez-López, A., Perring, M. P., & de Vries, W. (2019). Impacts of nitrogen addition on plant species richness and abundance: A global meta-analysis. *Global Ecology and Biogeography, 28(3),* 398–413. doi: 10.1111/geb.12856

Miftah, A. (2018). Les migrations internationales et leurs effets. *Hommes & Migrations, 1320,* 114–120. doi: 10.4000/hommesmigrations.4067

Millward-Hopkins, J. (2022). Inequality can double the energy required to secure universal decent living. *Nature Communications, 13(1),* 1–9. doi: 10.1038/s41467-022-32729-8

Moatti, J. P., & Thiébault, S. (2018). *The mediterranean region under climate change: a scientific update.* IRD Éditions, 736 pp. doi: 10.4000/books.irdeditions.22908

Molina-Navarro, E., Trolle, D., Martínez-Pérez, S., Sastre-Merlín, A., & Jeppesen, E. (2014). Hydrological and water quality impact assessment of a Mediterranean limno-reservoir under climate change and land use management scenarios. *Journal of Hydrology, 509,* 354–366. doi: 10.1016/j.jhydrol.2013.11.053

Molle, F., & Tanouti, O. (2017). Squaring the circle: Agricultural intensification vs. water conservation in Morocco. *Agricultural Water Management, 192,* 170–179. doi: 10.1016/j.agwat.2017.07.009

Monga, R., Marzuoli, R., Alonso, R., Bermejo, V., González-Fernández, I., Faoro, F., & Gerosa, G. (2015). Varietal screening of ozone sensitivity in Mediterranean durum wheat (Triticum durum, Desf.). *Atmospheric Environment, 110,* 18–26. doi: 10.1016/j.atmosenv.2015.03.040

Morán-Tejeda, E., Ceballos-Barbancho, A., Llorente-Pinto, J. M., & López-Moreno, J. I. (2012). Land-cover changes and recent hydrological evolution in the Duero Basin (Spain). *Regional Environmental Change, 12(1),* 17–33. doi: 10.1007/s10113-011-0236-7

Moreno-de-las-Heras, M., Lindenberger, F., Latron, J., Lana-Renault, N., Llorens, P., Arnáez, J., Romero-Díaz, A., & Gallart, F. (2019). Hydro-geomorphological consequences of the abandonment of agricultural terraces in the Mediterranean region: Key controlling factors and landscape stability patterns. *Geomorphology, 333,* 73–91. doi: 10.1016/j.geomorph.2019.02.014

Morera, A., Martínez de Aragón, J., De Cáceres, M., Bonet, J. A., & de-Miguel, S. (2022). Historical and future spatially-explicit climate change impacts on mycorrhizal and saprotrophic macrofungal productivity in Mediterranean pine forests. *Agricultural and Forest Meteorology, 319,* 108918. doi: 10.1016/J.AGRFORMET.2022.108918

Moretti, A., Pascale, M., & Logrieco, A. F. (2019). Mycotoxin risks under a climate change scenario in Europe. *Trends in Food Science & Technology, 84,* 38–40. doi: 10.1016/J.TIFS.2018.03.008

Morton, E. M., & Rafferty, N. E. (2017). Plant-pollinator interactions under climate change: The use of spatial and temporal transplants. *Applications in Plant Sciences, 5(6),* 1600133. doi: 10.3732/apps.1600133

Mrabet, R., Savé, R., Toreti, A., Caiola, N., Chentouf, M., Llasat, M. C., Mohamed, A. A. A., Santeramo, F. G., Sanz-Cobena, A., & Tsikliras, A. (2020). Food. In W. Cramer, J. Guiot, & K. Marini (Eds.), Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report (pp. 237–264). *Union for the Mediterranean,* Plan Bleu, UNEP/MAP, Marseille, France. doi: 10.5281/zenodo.7101080

Muhammadsidiqov, M. (2015). Stability of North African Region. *International Journal of Multidisciplinary and Current Research, 3,* 3.

Müller-Funk, L. (2023). Violence, life aspirations and displacement trajectories in civil war. *International Migration, 61(6),* 209–227. doi: 10.1111/imig.13161

Mycoo, M., Wairiu, M., Campbell, D., Duvat, V., Golbuu, Y., Maharaj, S., Nalau, J., Nunn, P., Pinnegar, J., & Warrick, O. (2022). Small Islands. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 2043–2121). Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009325844.017

Nager, R. G., Hafner, H., Johnson, A. R., & Cézilly, F. (2010). Environmental impacts on wetland birds: long-term monitoring programmes in the Camargue, France. *Ardea, 98(3),* 309–318. doi: 10.5253/078.098.0305

Naja, F., Hwalla, N., Hachem, F., Abbas, N., Chokor, F. A. Z., Kharroubi, S., Chamieh, M.-C., Jomaa, L., & Nasreddine, L. (2020). Erosion of the Mediterranean diet among adolescents: evidence from an Eastern Mediterranean Country. *British Journal of Nutrition, 125(3),* 346–356. doi: 10.1017/s0007114520002731

Naja, F., Itani, L., Hamade, R., Chamieh, M. C., & Hwalla, N. (2019). Mediterranean Diet and Its Environmental Footprints Amid Nutrition Transition: The Case of Lebanon. *Sustainability, 11(23)*, 6690. doi: 10.3390/SU11236690

Nashwan, M. S., Shahid, S., & Chung, E.-S. (2020). High-Resolution Climate Projections for a Densely Populated Mediterranean Region. *Sustainability, 12(9),* 3684. doi: 10.3390/su12093684

Naulleau, A., Gary, C., Prévot, L., Berteloot, V., Fabre, J.-C., Crevoisier, D., Gaudin, R., & Hossard, L. (2022). Participatory modeling to assess the impacts of climate change in a Mediterranean vineyard watershed. *Environmental Modelling & Software, 150,* 105342. doi: 10.1016/j.envsoft.2022.105342

Nice, C. C., Forister, M. L., Gompert, Z., Fordyce, J. A., & Shapiro, A. M. (2014). A hierarchical perspective on the diversity of butterfly species' responses to weather in the Sierra Nevada Mountains. *Ecology, 95(8),* 2155–2168. doi: 10.1890/13-1227.1

Nijhawan, A., & Howard, G. (2022). Associations between climate variables and water quality in low- and middle-income countries: A scoping review. *Water Research, 210,* 117996. doi: 10.1016/j.watres.2021.117996

Noguera, I., Domínguez-Castro, F., & Vicente-Serrano, S. M. (2021). Flash drought response to precipitation and atmospheric evaporative demand in Spain. *Atmosphere, 12(2),* 165. doi: 10.3390/atmos12020165

Nøland, J. K., Auxepaules, J., Rousset, A., Perney, B., & Falletti, G. (2022). Spatial energy density of large-scale electricity generation from power sources worldwide. *Scientific Reports, 12(1),* 21280. doi: 10.1038/s41598-022-25341-9

Noto, L. V, Cipolla, G., Francipane, A., & Pumo, D. (2022). Climate change in the Mediterranean Basin (Part I): induced alterations on climate forcings and hydrological processes. *Water Resources Management, 37,* 2287–2305. doi: 10.1007/s11269-022-03400-0

Noto, L. V, Cipolla, G., Pumo, D., & Francipane, A. (2023). Climate change in the Mediterranean Basin (Part II): a review of challenges and uncertainties in climate change modeling and impact analyses. *Water Resources Management, 37(6),* 2307–2323. doi: 10.1007/s11269-023-03444-w

Novara, A., Catania, V., Tolone, M., Gristina, L., Laudicina, V. A., & Quatrini, P. (2020). Cover Crop Impact on Soil Organic Carbon, Nitrogen Dynamics and Microbial Diversity in a Mediterranean Semiarid Vineyard. *Sustainability, 12(8),* 3256. doi: 10.3390/su12083256

Nsibi, R., Souayah, N., Khouja, K., & S, B. (2006). Biotics and abiotics factors responsible of the Tunisian Cork oak forest deterioration. *Geo-Eco-Trop, 30(1),* 25–34.

Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., Tompkins, E., & Webb, A. (2014). Small islands. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1613–1654). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ochoa-Hueso, R., Allen, E. B., Branquinho, C., Cruz, C., Dias, T., Fenn, M. E., Esteban Manrique, M. E. P.-C., Sheppard, L. J., & Stock, W. D. (2011). Nitrogen deposition effects on Mediterranean-type ecosystems: An ecological assessment. *Environmental Pollution, 159(10),* 2265–2279. doi: 10.1016/j.envpol.2010.12.019

Ochoa-Hueso, R., Munzi, S., Alonso, R., Arróniz-Crespo, M., Avila, A., Bermejo, V., Bobbink, R., Branquinho, C., Concostrina-Zubiri, L., Cruz, C., Cruz de Carvalho, R., De Marco, A., Dias, T., Elustondo, D., Elvira, S., Estébanez, B., Fusaro, L., Gerosa, G., Izquieta-Rojano, S., ... Theobald, M. R. (2017). Ecological impacts of atmospheric pollution and interactions with climate change in terrestrial ecosystems of the Mediterranean Basin: Current research and future directions. *Environmental Pollution, 227,* 194–206. doi: 10.1016/j.envpol.2017.04.062

Odada, E. O., Ochola, W. O., & Olago, D. O. (2009). Drivers of ecosystem change and their impacts on human well-being in Lake Victoria basin. *African Journal of Ecology, 47,* 46–54. doi: 10.1111/j.1365-2028.2008.01049.x

Oldfield, E. E., Bradford, M. A., & Wood, S. A. (2019). Global meta-analysis of the relationship between soil organic matter and crop yields. *Soil, 5(1),* 15–32. doi: 10.5194/soil-5-15-2019

OME. (2022). *Mediterranean Energy Perspectives 2022.* Organisation Méditerranéenne de l'Energie et du Climat, Paris.

OME. (2023). *Mediterranean Energy Perspectives 2023.* Organisation Méditerranéenne de l'Energie et du Climat, Paris.

Ortega, J. A., & Garzón-Heydt, G. G. (2009). Geomorphological and sedimentological analysis of flash-flood deposits: The case of the 1997 Rivillas flood (Spain). *Geomorphology, 112(1-2),* 1–14. doi: 10.1016/j.geomorph.2009.05.004

Ortigosa, L. M., Garcia-Ruiz, J. M., & Gil-Pelegrin, E. (1990). Land reclamation by reforestation in the Central Pyrenees. *Mountain Research and Development, 10(3),* 281–288. doi: 10.2307/3673607

Ouda, S., & Zohry, A. E.-H. (2020). Climate Change Assessment in Egypt: A Review. In S. Ouda, A. E. H. Zohry, & T. Noreldin (Eds.), *Deficit Irrigation: A Remedy for Water Scarcity* (pp. 139–159). Springer, Cham. doi: 10.1007/978-3-030-35586-9_7

Özdoğan, M. (2011). Modeling the impacts of climate change on wheat yields in Northwestern Turkey. Agriculture, *Ecosystems & Environment, 141(1–2),* 1–12. doi: 10.1016/j.agee.2011.02.001

Ozgenc Aksoy, A. (2017). Investigation of sea level trends and the effect of the north atlantic oscillation (NAO) on the black sea and the eastern mediterranean sea. *Theoretical and Applied Climatology, 129,* 129–137. doi: 10.1007/s00704-016-1759-0

Pacifici, M., Foden, W. B., Visconti, P., Watson, J. E. M., Butchart, S. H. M., Kovacs, K. M., Scheffers, B. R., Hole, D. G., Martin, T. G., Akçakaya, H. R., Corlett, R. T., Huntley, B., Bickford, D., Carr, J. A., Hoffmann, A. A., Midgley, G. F., Pearce-Kelly, P., Pearson, R. G., Williams, S. E., … Rondinini, C. (2015). Assessing species vulnerability to climate change. *Nature Climate Change, 5(3),* 215–224. doi: 10.1038/nclimate2448

Padedda, B., Pulina, S., Satta, C., Lugliè, A., & Magni, P. (2019). Eutrophication and Nutrient Fluxes in Mediterranean Coastal Lagoons. In P. A. Maurice (Ed.), *Encyclopedia of Water (pp. 1–16).* John Wiley & Sons. doi: 10.1002/9781119300762.wsts0161

Padilla, F. M., & Pugnaire, F. I. (2007). Rooting depth and soil moisture control Mediterranean woody seedling survival during drought. *Functional Ecology, 21(3),* 489–495. doi: 10.1111/J.1365-2435.2007.01267.X

Panagos, P., Van Liedekerke, M., Yigini, Y., & Montanarella, L. (2013). Contaminated Sites in Europe: Review of the Current Situation Based on Data Collected through a European Network. *Journal of Environmental and Public Health, 2013,* 1–11. doi: 10.1155/2013/158764

Papamichael, I., Voukkali, I., & Zorpas, A. A. (2022). Mediterranean: main environmental issues and concerns. *Euro-Mediterranean Journal for Environmental Integration, 7(4),* 477–481. doi: 10.1007/s41207-022-00336-0

Papastergiadou, E., Kagalou, I., Stefanidis, K., & Retalis A and Leonardos, I. (2010). Effects of Anthropogenic Influences on the Trophic State, Land Uses and Aquatic Vegetation in a Shallow Mediterranean Lake: Implications for Restoration. *Water Resources Management, 24,* 415–435. doi: 10.1007/s11269-009-9453-y

Paschalidou, A., Tsatiris, M., & Kitikidou, K. (2016). Energy crops for biofuel production or for food? – SWOT analysis (case study: Greece). *Renewable Energy, 93,* 636–647. doi: 10.1016/J.RENENE.2016.03.040

Pastor, F., Valiente, J., & Palau, J. L. (2018). Sea surface temperature in the Mediterranean climatology, trends and spatial patterns (1982–2016). *Pure and Applied Geophysics, 175,* 4017–4029. doi: 10.1007/s00024-017-1739-z

Patt, A., Pfenninger, S., & Lilliestam, J. (2013). Vulnerability of solar energy infrastructure and output to climate change. *Climatic Change, 121,* 93–102. doi: 10.1007/s10584-013-0887-0

Pausas, J. G., & Fernández-Muñoz, S. (2012). Fire regime changes in the Western Mediterranean Basin: From fuel-limited to drought-driven fire regime. *Climatic Change, 110,* 215–226. doi: 10.1007/s10584-011-0060-6

Pausas, J. G., & Millán, M. M. (2019). Greening and Browning in a Climate Change Hotspot: The Mediterranean Basin. *Bioscience, 69(2),* 143–151. doi: 10.1093/biosci/biy157

Peña-Angulo, D., Vicente-Serrano, S. M., Domínguez-Castro, F., Noguera, I., Tomas-Burguera, M., López-Moreno, J. I., Lorenzo-Lacruz, J., & El Kenawy, A. (2021). Unravelling the role of vegetation on the different trends between climatic and hydrologic drought in headwater catchments of Spain. *Anthropocene, 36,* 100309. doi: 10.1016/j.ancene.2021.100309

Peñuelas, J., Sardans, J., Filella, I., Estiarte, M., Llusià, J., Ogaya, R., Carnicer, J., Bartrons, M., Rivas-Ubach, A., Grau, O., Peguero, G., Margalef, O., Pla-Rabés, S., Stefanescu, C., Asensio, D., Preece, C., Liu, L., Verger, A., Barbeta, A., … Terradas, J. (2017). Impacts of Global Change on Mediterranean Forests and Their Services. *Forests, 8(12),* 463. doi: 10.3390/F8120463

Peñuelas, J., Sardans, J., Filella, I., Estiarte, M., Llusià, J., Ogaya, R., Carnicer, J., Bartrons, M., Rivas-Ubach, A., Grau, O., Peguero, G., Margalef, O., Pla-Rabés, S., Stefanescu, C., Asensio, D., Preece, C., Liu, L., Verger, A., Rico, L., … Terradas, J. (2018). Assessment of the impacts of climate change on Mediterranean terrestrial ecosystems based on data from field experiments and long-term monitored field gradients in Catalonia. *Environmental and Experimental Botany, 152,* 49–59. doi: 10.1016/J.ENVEXPBOT.2017.05.012

Pergent-Martini, C., Pergent, G., Monnier, B., Boudouresque, C. F., Mori, C., & Valette-Sansevin, A. (2021). Contribution of Posidonia oceanica meadows in the context of climate change mitigation in the Mediterranean Sea. *Marine Environmental Research, 165,* 105236. doi: 10.1016/j.marenvres.2020.105236

Perrin, J. L., Raïs, N., Chahinian, N., Moulin, P., & Ijjaali, M. (2014). Water quality assessment of highly polluted rivers in a semi-arid Mediterranean zone Oued Fez and Sebou River (Morocco). *Journal of Hydrology, 510,* 26–34. doi: 10.1016/j.jhydrol.2013.12.002

Petrović, E., Ćosić, J., & Vrandečić K and Godena, S. (2023). Occurrence of mycotoxins in food and beverages. *Journal of Central European Agriculture, 24(1),* 137–150. doi: 10.5513/JCEA01/24.1.3704

Pfahl, S. (2014). Characterising the relationship between weather extremes in Europe and synoptic circulation features. *Natural Hazards and Earth System Sciences, 14(6),* 1461–1475. doi: 10.5194/nhess-14-1461-2014

Pisinaras, V., Paraskevas, C., & Panagopoulos, A. (2021). Investigating the effects of agricultural water management in a Mediterranean coastal aquifer under current and projected climate conditions. *Water, 13(1),* 108. doi: 10.3390/w13010108

Plan Bleu. (2012). T*owards a Euro-Mediterranean sustainable urban strategy (EMSUS) within the framework of the Union for the Mediterranean.* 13 pp.

Planton, S., Lionello, P., Artale, V., Aznar, R., Carrillo, A., Colin, J., Congedi, L., Dubois, C., Elizalde, A., & Gualdi, S. (2012). 8 – The Climate of the Mediterranean Region in Future Climate Projections. In P. Lionello (Ed.), *The Climate of the Mediterranean Region* (pp. 449–502). Elsevier.

Ponti, L., Gutierrez, A. P., Ruti, P. M., & Dell'Aquila, A. (2014). Fine-scale ecological and economic assessment of climate change on olive in the Mediterranean Basin reveals winners and losers. *Proceedings of the National Academy of Sciences of the United States of America, 111(15),* 5598–5603. doi: 10.1073/pnas.1314437111

Pörtner, H. O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Barnes, D., Burrows, M., Chan, L., Cheung, W. L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C. , Hickler, T. , … Ngo, H. T. (2021). *Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change.* IPBES secretariat, Bonn, Germany, doi: 10.5281/zenodo.4659158

Pörtner, H.-O., Karl, D. M., Boyd, P. W., Cheung, W. W. L., Lluch-Cota, S. E., Nojiri, Y., Schmidt, D. N., & Zavialov, P. O. (2014). Ocean systems. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 411–484). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

PRB. (2019). *World Population Data Sheet – Population Reference Bureau.* https://www.prb.org/worldpopdata/

Prigent, O., Wynn Owen, P., Homrich Hickmann, M., Bryan K and Caruda Ruiz, A., & Huth, J. (2018). Combating desertification in the EU: a growing threat in need of more action. *European Court of Auditors.*

Principe, A., Matos, P., Sarris, D., Gaiola, G., Rosário, L., Correia, O., & Branquinho, C. (2019). In Mediterranean drylands microclimate affects more tree seedlings than adult trees. *Ecological Indicators, 106,* 105476.

Puig-Gironès, R., Muriana, M., Real, J., & Sabaté, S. (2023). Unravelling the influence of annual weather conditions and Mediterranean habitat types on acorn production, availability and predation. *Forest Ecology and Management, 543,* 121149.

Pulido-Velazquez, D., Collados-Lara, A. J., & Alcalá, F. J. (2018). *Assessing impacts of future potential climate change scenarios on aquifer recharge in continental Spain. J. Hydrol., 567,* 803–819.

Pulido-Velazquez, D., García-Aróstegui, J. L., Molina, J. L., & Pulido-Velazquez, M. (2015). Assessment of future groundwater recharge in semi-arid regions under climate change scenarios (Serral-Salinas aquifer, SE Spain). Could increased rainfall variability increase the recharge rate? *Hydrological Processes, 29(6),* 828–844.

Pulighe, G., Bonati, G., Colangeli, M., Morese, M. M., Traverso, L., Lupia, F., Khawaja, C., Janssen, R., & Fava, F. (2019). Ongoing and emerging issues for sustainable bioenergy production on marginal lands in the Mediterranean regions. Renewable and *Sustainable Energy Reviews, 103,* 58–70. doi: 10.1016/j.rser.2018.12.043

Quagliarotti, D. (2023). The Water-Energy-Food Nexus in the Mediterranean Region in a scenario of polycrisis. TeMA – *Journal of Land Use, Mobility and Environment, 2,* 109–122.

Raimundo, J. R., Frazão, D. F., Domingues, J. L., Quintela-Sabarís, C., Dentinho, T. P., Anjos, O., Alves, M., & Delgado, F. (2018). Neglected Mediterranean plant species are valuable resources: the example of Cistus ladanifer. *Planta, 248(6),* 1351–1364. doi: 10.1007/s00425-018-2997-4

Rako-Gospić, N., & Picciulin, M. (2019). Chapter 20 – Underwater Noise: Sources and Effects on Marine Life. In C. Sheppard (Ed.), *World Seas: An Environmental Evaluation (Second Edition)* (pp. 367–389). Academic Press. doi: 10.1016/B978-0-12-805052-1.00023-1

Ranasinghe, R., Ruane, A. C., Vautard, R., Arnell, N., Coppola, E., Cruz, F. A., Dessai, S., Islam, A. S., Rahimi, M., Ruiz Carrascal, D., Sillmann, J., Sylla, M. B., Tebaldi, C., Wang, W., & Zaaboul, R. (2021). Climate Change Information for Regional Impact and for Risk Assessment. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1767–1926). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi: 10.1017/9781009157896.014

Rauschendorfer, J., & Krivonos, E. (2022). Implications of the war in Ukraine for agrifood trade and food security in the Southern and Eastern Mediterranean: Egypt, Jordan, Lebanon, Morocco and Tunisia. *Food and Agriculture Organization of the United Nations (FAO),* Rome, 84 pp. doi: 10.4060/cc0955en

Raymond, F., Ullmann, A., Camberlin, P., Oueslati, B., & Drobinski, P. (2018). Atmospheric conditions and weather regimes associated with extreme winter dry spells over the Mediterranean basin. *Climate Dynamics, 50,* 4437–4453. doi: 10.1007/s00382-017-3884-6

Raymond, F., Ullmann, A., Tramblay, Y., Drobinski, P., & Camberlin, P. (2019). Evolution of Mediterranean extreme dry spells during the wet season under climate change. *Regional Environmental Change, 19,* 2339–2351. doi: 10.1007/s10113-019-01526-3

Re, V., Sacchi, E., Mas-Pla, J., Menció, A., & El Amrani, N. (2014). Identifying the effects of human pressure on groundwater quality to support water management strategies in coastal regions: A multi-tracer and statistical approach (Bou-Areg region, Morocco). *Science of The Total Environment, 500-501,* 211–223. doi: 10.1016/j.scitotenv.2014.08.115

Reale, M., Cossarini, G., Lazzari, P., Lovato, T., Bolzon, G., Masina, S., Solidoro, C., & Salon, S. (2022a). Acidification, deoxygenation, nutrient and biomasses decline in a warming Mediterranean Sea. *Biogeosciences, 19,* 4035–4065. doi: 10.5194/bg-19-4035-2022

Reale, M., Narvaez, W. D. C., Cavicchia, L., Conte, D., Coppola, E., Flaounas, E., Giorgi, F., Gualdi, S., Hochman, A., Li, L., Lionello, P., Podrascanin, Z., Salon, S., Sanchez-Gomez, E., Scoccimarro, E., Sein, D. V, & Somot, S. (2022b). Future projections of Mediterranean cyclone characteristics using the Med-CORDEX ensemble of coupled regional climate system models. *Climate Dynamics, 58(9-10),* 2501–2524. doi: 10.1007/s00382-021-06018-x

Renna, M., Montesano, F. F., Serio, F., & Gonnella, M. (2021). The Mediterranean diet between traditional foods and human health through culinary examples. In C. M. Galanakis (Ed.), *Gastronomy and Food Science* (pp. 75–99). Elsevier. doi: 10.1016/B978-0-12-820057-5.00005-4

Resch, G., Welisch, M., Ortner, A., Totschnig, G., Türk, A., & Steiner, D. (2015). *Integrative Assessment of RES cooperation with Third countries* (D6.4). Bringing Europe and Third countries closer together through renewable Energies (BETTER), Intelligent Energy – Europe (IEE), Contract N°: IEE/11/845/SI2.616378, 148 pp.

Resco de Dios, V., Fischer, C., & Colinas, C. (2007). Climate Change Effects on Mediterranean Forests and Preventive Measures. *New Forests, 33(1),* 29–40. doi: 10.1007/s11056-006-9011-x

Resco, P., Iglesias, A., Bardají, I., & Sotés, V. (2016). Exploring adaptation choices for grapevine regions in Spain. *Regional Environmental Change, 16(4),* 979–993. doi: 10.1007/s10113-015-0811-4

Revuelto, J., López-Moreno, J.-I., Azorin-Molina, C., Alonso-González, E., & Sanmiguel-Vallelado, A. (2016). Small-Scale Effect of Pine Stand Pruning on Snowpack Distribution in the Pyrenees Observed with a Terrestrial Laser Scanner. *Forests, 7(8),* 166. doi: 10.3390/f7080166

Rey, P. J., Camacho, F. M., Tarifa, R., Martínez-Núñez, C., Salido, T., Pérez, A. J., & García, D. (2021). Persistence of Seed Dispersal in Agroecosystems: Effects of Landscape Modification and Intensive Soil Management Practices in Avian Frugivores, Frugivory and Seed Deposition in Olive Croplands. *Frontiers in Ecology and Evolution, 9,* 782462. doi: 10.3389/fevo.2021.782462

Richon, C., Dutay, J.-C., Bopp, L., Le Vu, B., Orr, J. C., Somot, S., & Dulac, F. (2019). Biogeochemical response of the Mediterranean Sea to the transient SRES-A2 climate change scenario. *Biogeosciences, 16(1),* 135–165. doi: 10.5194/bg-16-135-2019

Rico, L., Ogaya, R., Barbeta, A., & Peñuelas, J. (2014). Changes in DNA methylation fingerprint of Quercus ilex trees in response to experimental field drought simulating projected climate change. *Plant Biology, 16(2),* 419–427. doi: 10.1111/plb.12049

Rico-Amoros, A. M., Olcina-Cantos, J., & Sauri, D. (2009). Tourist land use patterns and water demand: Evidence from the Western Mediterranean. *Land Use Policy, 26(2),* 493–501. doi: 10.1016/j.landusepol.2008.07.002

Rilov, G., Peleg, O., Guy-Haim, T., & Yeruham, E. (2020). Community dynamics and ecological shifts on Mediterranean vermetid reefs. Marine *Environmental Research, 160,* 105045. doi: 10.1016/j.marenvres.2020.105045

Rivas-Ubach, A., Barbeta, A., Sardans, J., Guenther, A., Ogaya, R., Oravec, M., Urban, O., & Peñuelas, J. (2016). Topsoil depth substantially influences the responses to drought of the foliar metabolomes of Mediterranean forests. *Perspectives in Plant Ecology, Evolution and Systematics, 21,* 41–54. doi: 10.1016/j.ppees.2016.06.001

Rivas-Ubach, A., Gargallo-Garriga, A., Sardans, J., Oravec, M., Mateu-Castell, L., Pérez-Trujillo, M., Parella, T., Ogaya, R., Urban, O., & Peñuelas, J. (2014). Drought enhances folivory by shifting foliar metabolomes in Quercus ilex trees. *New Phytologist, 202(3),* 874–885. hdoi: 10.1111/nph.12687

Rivas-Ubach, A., Sardans, J., Pérez-Trujillo, M., Estiarte, M., & Peñuelas, J. (2012). Strong relationship between elemental stoichiometry and metabolome in plants. *Proceedings of the National Academy of Sciences, 109(11),* 4181–4186. doi: 10.1073/pnas.1116092109

Rivera-Ferre, M. G., López-i-Gelats, F., Howden, M., Smith, P., Morton, J. F., & Herrero, M. (2016). Re-framing the climate change debate in the livestock sector: mitigation and adaptation options. *WIREs Climate Change, 7(6),* 869–892. doi: 10.1002/wcc.421

Rivetti, I., Boero, F., Fraschetti, S., Zambianchi, E., & Lionello, P. (2017). Anomalies of the upper water column in the Mediterranean Sea. *Global and Planetary Change, 151,* 68–79. doi: 10.1016/j.gloplacha.2016.03.001

Rivetti, I., Fraschetti, S., Lionello, P., Zambianchi, E., & Boero, F. (2014). Global Warming and Mass Mortalities of Benthic Invertebrates in the Mediterranean Sea. *PLoS ONE, 9(12),* e115655. doi: 10.1371/journal.pone.0115655

Rocha, J., Carvalho-Santos, C., Diogo, P., Beça, P., Keizer, J. J., & Nunes, J. P. (2020). Impacts of climate change on reservoir water availability, quality and irrigation needs in a water scarce Mediterranean region (southern Portugal). *Science of The Total Environment, 736,* 139477. doi: 10.1016/j.scitotenv.2020.139477

Rodríguez Eugenio, N., McLaughlin, M., & Pennock, D. (2018). Soil pollution: a hidden reality. *Food and Agriculture Organization of the United Nations, Rome,* 142 pp.

Rodríguez-Díaz, J. A., Pérez-Urrestarazu, L., Camacho-Poyato, E., & Montesinos, P. (2011). The paradox of irrigation scheme modernization: more efficient water use linked to higher energy demand. *Spanish Journal of Agricultural Research, 9(4),* 1000–1008. doi: 10.5424/sjar/20110904-492-10

Rosa, R., Marques, A., & Nunes, M. L. (2012). Impact of climate change in Mediterranean aquaculture. *Reviews in Aquaculture, 4(3),* 163–177. doi: 10.1111/j.1753-5131.2012.01071.x

Ruhí, A., Acuña, V., Barceló, D., Huerta, B., Mor, J.-R., Rodríguez-Mozaz, S., & Sabater, S. (2016). Bioaccumulation and trophic magnification of pharmaceuticals and endocrine disruptors in a Mediterranean river food web. *Science of The Total Environment, 540,* 250–259. doi: 10.1016/j.scitotenv.2015.06.009

Saad, A., & Hassanien, M. A. (2001). Assessment of arsenic level in the hair of the nonoccupational Egyptian population: Pilot study. *Environment International, 27(6),* 471–478. doi: 10.1016/S0160-4120(01)00102-7

Saadi, S., Todorovic, M., Tanasijevic, L., Pereira, L. S., Pizzigalli, C., & Lionello, P. (2015). Climate change and Mediterranean agriculture: Impacts on winter wheat and tomato crop evapotranspiration, irrigation requirements and yield. *Agricultural Water Management, 147,* 103–115. doi: 10.1016/j.agwat.2014.05.008

Sala, B., Giménez, J., Fernández-Arribas, J., Bravo, C., Lloret-Lloret, E., Esteban, A., Bellido, J. M., Coll, M., & Eljarrat, E. (2022). Organophosphate ester plasticizers in edible fish from the Mediterranean Sea: Marine pollution and human exposure. *Environmental Pollution, 292,* 118377. doi: 10.1016/j.envpol.2021.118377

Salhi, A., Benabdelouahab, S., Bouayad, E. O., Benabdelouahab, T., Larifi, I., El Mousaoui, M., Acharrat, N., Himi, M., & Casas Ponsati, A. (2021). Impacts and social implications of landuse-environment conflicts in a typical Mediterranean watershed. *Science of The Total Environment, 764,* 142853. doi: 10.1016/j.scitotenv.2020.142853

Salvati, L., Quatrini, V., Barbati, A., Tomao, A., Mavrakis, A., Serra, P., Sabbi, A., Merlini, P., & Corona, P. (2016). Soil occupation efficiency and landscape conservation in four Mediterranean urban regions. *Urban Forestry & Urban Greening, 20,* 419–427. doi: 10.1016/j.ufug.2016.10.006

Samaniego, L., Thober, S., Kumar, R., Wanders, N., Rakovec, O., Pan, M., Zink, M., Sheffield, J., Wood, E. F., & Marx, A. (2018). Anthropogenic warming exacerbates European soil moisture droughts. *Nature Climate Change, 8(5),* 421–426. doi: 10.1038/s41558-018-0138-5

Sánchez-Arcilla, A., Mösso, C., Sierra, J. P., Mestres, M., Harzallah, A., Senouci, M., & Raey, M. El. (2011). Climatic drivers of potential hazards in Mediterranean coasts. *Regional Environmental Change, 11(3),* 617–636. doi: 10.1007/s10113-010-0193-6

Santonja, M., Fernandez, C., Proffit, M., Gers, C., Gauquelin, T., Reiter, I. M., Cramer, W., & Baldy, V. (2017). Plant litter mixture partly mitigates the negative effects of extended drought on soil biota and litter decomposition in a Mediterranean oak forest. *Journal of Ecology, 105(3),* 801–815. doi: 10.1111/1365-2745.12711

Sanz-Cobena, A., Lassaletta, L., Rodríguez, A., Aguilera, E., Piñero, P., Moro, M., Garnier, J., Billen, G., Einarsson, R., Bai, Z., Ma, L., Puigdueta, I., Ruíz-Ramos, M., Vallejo, A., Zaman, M., Infante-Amate, J., & Gimeno, B. S. (2023). Fertilization strategies for abating N pollution at the scale of a highly vulnerable and diverse semi-arid agricultural region (Murcia, Spain). *Environmental Research Letters, 18(6),* 064030. doi: 10.1088/1748-9326/acd709

Sardans, J., Urbina, I., Grau, O., Asensio, D., Ogaya, R., & Peñuelas, J. (2020). Long-term drought decreases ecosystem C and nutrient storage in a Mediterranean holm oak forest. *Environmental and Experimental Botany, 177,* 104135. doi: 10.1016/j.envexpbot.2020.104135

Sargentis, G.-F., Siamparina, P., Sakki, G.-K., Efstratiadis, A., Chiotinis, M., & Koutsoyiannis, D. (2021). Agricultural Land or Photovoltaic Parks? The Water-Energy-Food Nexus and Land Development Perspectives in the Thessaly Plain, Greece. *Sustainability, 13(16),* 8935. doi: 10.3390/su13168935

Scardino, G., Anzidei, M., Petio, P., Serpelloni, E., De Santis, V., Rizzo, A., Liso, S. I., Zingaro, M., Capolongo, D., Vecchio, A., Refice, A., & Scicchitano, G. (2022). The Impact of Future Sea-Level Rise on Low-Lying Subsiding Coasts: A Case Study of Tavoliere Delle Puglie (Southern Italy). *Remote Sensing, 14(19),* 4936. doi: 10.3390/rs14194936

Scheffran, J. (2020). Climate extremes and conflict dynamics. In J. Sillmann, S. Sippel, & S. Russo (Eds.), *Climate Extremes and Their Implications for Impact and Risk Assessment* (pp. 293–315). Elsevier. doi: 10.1016/B978-0-12-814895-2.00016-1

Scheffran, J., & Brauch, H. G. (2014). Conflicts and Security Risks of Climate Change in the Mediterranean Region. In S. Goffredo & Z. Dubinsky (Eds.), *The Mediterranean Sea. Its history and present challenges* (pp. 625–640). Springer Netherlands. doi: 10.1007/978-94-007-6704-1_39

Schilling, J., Freier, K. P., Hertig, E., & Scheffran, J. (2012). Climate change, vulnerability and adaptation in North Africa with focus on Morocco. Agriculture, *Ecosystems & Environment, 156,* 12–26. doi: 10.1016/j.agee.2012.04.021

Schilling, J., Hertig, E., Tramblay, Y., & Scheffran, J. (2020). Climate change vulnerability, water resources and social implications in North Africa. *Regional Environmental Change, 20(1),* 15. doi: 10.1007/s10113-020-01597-7

Schleussner, C.-F., Lissner, T. K., Fischer, E. M., Wohland, J., Perrette, M., Golly, A., Rogelj, J., Childers, K., Schewe, J., Frieler, K., Mengel, M., Hare, W., & Schaeffer, M. (2016). Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 °C and 2 °C. *Earth System Dynamics, 7(2),* 327–351. doi: 10.5194/esd-7-327-2016

Schmitz, O. J., Krivan, V., & Ovadia, O. (2004). Trophic cascades: the primacy of trait-mediated indirect interactions. *Ecology Letters, 7(2),* 153–163. doi: 10.1111/j.1461-0248.2003.00560.x

Schwan, S., & Yu, X. (2018). Social protection as a strategy to address climate-induced migration. *International Journal of Climate Change Strategies and Management, 10(1),* 43–64. doi: 10.1108/IJCCSM-01-2017-0019

Sefelnasr, A., & Sherif, M. (2014). Impacts of Seawater Rise on Seawater Intrusion in the Nile Delta Aquifer, Egypt. *Groundwater, 52(2),* 264–276. doi: 10.1111/gwat.12058

Selby, J., Dahi, O. S., Fröhlich, C., & Hulme, M. (2017). Climate change and the Syrian civil war revisited. *Political Geography, 60,* 232–244. doi: 10.1016/j.polgeo.2017.05.007

Seneviratne, S. I. , Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S. M., Wehner, M., & Zhou, B. (2021). Weather and Climate Extreme Events in a Changing Climate. In Masson-Delmotte V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1513–1766). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi: 10.1017/9781009157896.013

Serpa, D., Nunes, J. P., Keizer, J. J., & Abrantes, N. (2017). Impacts of climate and land use changes on the water quality of a small Mediterranean catchment with intensive viticulture. *Environmental Pollution, 224,* 454–465. doi: 10.1016/j.envpol.2017.02.026

Serra, P., Pons, X., & Saurí, D. (2008). Land-cover and land-use change in a Mediterranean landscape: A spatial analysis of driving forces integrating biophysical and human factors. *Applied Geography, 28(3),* 189–209. doi: 10.1016/j.apgeog.2008.02.001

Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. *Applied Geography, 27(1),* 28–41. doi: 10.1016/j.apgeog.2006.09.004

Shaltout, M., & Omstedt, A. (2014). Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *OCEANOLOGIA, 56.* doi: 10.5697/oc.56-3.000

Sharif, A., Mishra, S., Sinha, A., Jiao, Z., Shahbaz, M., & Afshan, S. (2020). The renewable energy consumption-environmental degradation nexus in Top-10 polluted countries: Fresh insights from quantile-on-quantile regression approach. *Renewable Energy, 150,* 670–690. doi: 10.1016/j.renene.2019.12.149

Sicard, P., Agathokleous, E., Anenberg, S. C., De Marco, A., Paoletti, E., & Calatayud, V. (2023). Trends in urban air pollution over the last two decades: A global perspective. *Science of The Total Environment, 858,* 160064. doi: 10.1016/j.scitotenv.2022.160064

Signa, G., Mazzola, A., Tramati, C. D., & Vizzini, S. (2017). Diet and habitat use influence Hg and Cd transfer to fish and consequent biomagnification in a highly contaminated area: Augusta Bay (Mediterranean Sea). *Environmental Pollution, 230,* 394–404. doi: 10.1016/j.envpol.2017.06.027

Silanikove, N., & Koluman (Darcan), N. (2015). Impact of climate change on the dairy industry in temperate zones: Predications on the overall negative impact and on the positive role of dairy goats in adaptation to earth warming. *Small Ruminant Research, 123(1),* 27–34. doi: 10.1016/j.smallrumres.2014.11.005

Solaun, K., & Cerdá, E. (2019). Climate change impacts on renewable energy generation. A review of quantitative projections. *Renewable and Sustainable Energy Reviews, 116,* 109415. doi: 10.1016/j.rser.2019.109415

Solé, M., López de Alda, M. J., Castillo, M., Porte, C., Ladegaard-Pedersen, K., & Barceló, D. (2000). Estrogenicity Determination in Sewage Treatment Plants and Surface Waters from the Catalonian Area (NE Spain). *Environmental Science & Technology, 34(24),* 5076–5083. doi: 10.1021/es991335n

Solidoro, C., Cossarini, G., Lazzari, P., Galli, G., Bolzon, G., Somot, S., & Salon, S. (2022). Modeling Carbon Budgets and Acidification in the Mediterranean Sea Ecosystem Under Contemporary and Future Climate. *Frontiers in Marine Science, 8.* doi: 10.3389/fmars.2021.781522

Solinas, S., Fazio, S., Seddaiu, G., Roggero, P. P., Deligios, P. A., Doro, L., & Ledda, L. (2015). Environmental consequences of the conversion from traditional to energy cropping systems in a Mediterranean area. *European Journal of Agronomy, 70,* 124–135. doi: 10.1016/j.eja.2015.07.008

Sonmez, N. K., & Sari, M. (2007). Monitoring land use change in the West Mediterranean region of Turkey: A case study on Antalya-Turkey coast. *Fresenius Environmental Bulletin, 16,* 1325–1330.

Souissi, I., Boisson, J. M., Mekki, I., Therond, O., Flichman, G., Wery, J., & Belhouchette, H. (2018). Impact assessment of climate change on farming systems in the South Mediterranean area: a Tunisian case study. *Regional Environmental Change, 18(3),* 637–650. doi: 10.1007/s10113-017-1130-8

Sousa, P. M., Trigo, R. M., Aizpurua, P., Nieto, R., Gimeno, L., & Garcia-Herrera, R. (2011). Trends and extremes of drought indices throughout the 20th century in the Mediterranean. *Natural Hazards and Earth System Sciences, 11(1),* 33–51. doi: 10.5194/nhess-11-33-2011

Stefanescu, C., Peñuelas, J., & Filella, I. (2003). Effects of climatic change on the phenology of butterflies in the northwest Mediterranean Basin. *Global Change Biology, 9(10),* 1494–1506. doi: 10.1046/j.1365-2486.2003.00682.x

Stefanidis, K., Kostara, A., & Papastergiadou, E. (2016). Implications of Human Activities, Land Use Changes and Climate Variability in Mediterranean Lakes of Greece. *Water, 8(11),* 483. doi: 10.3390/w8110483

Sterman, J. D., Siegel, L., & Rooney-Varga, J. N. (2018). Does replacing coal with wood lower CO_2 emissions? Dynamic lifecycle analysis of wood bioenergy. *Environmental Research Letters, 13(1),* 015007. doi: 10.1088/1748-9326/aaa512

Stigter, T. Y., Nunes, J. P., Pisani, B., Fakir, Y., Hugman, R., Li, Y., Tomé, S., Ribeiro, L., Samper, J., Oliveira, R., Monteiro, J. P., Silva, A., Tavares, P. C. F., Shapouri, M., Cancela da Fonseca, L., & El Himer, H. (2014). Comparative assessment of climate change and its impacts on three coastal aquifers in the Mediterranean. *Regional Environmental Change, 14(S1),* 41–56. doi: 10.1007/s10113-012-0377-3

Storelli, M. M., Giacominelli-Stuffler, R., Storelli, A., & Marcotrigiano, G. O. (2005). Accumulation of mercury, cadmium, lead and arsenic in swordfish and bluefin tuna from the Mediterranean Sea: A comparative study. *Marine Pollution Bulletin, 50(9),* 1004–1007. doi: 10.1016/j.marpolbul.2005.06.041

Sun, F., Dai, Y., & Yu, X. (2017). Air pollution, food production and food security: A review from the perspective of food system. *Journal of Integrative Agriculture, 16(12),* 2945–2962. doi: 10.1016/S2095-3119(17)61814-8

Szewczyk, W., Mongelli, I., & Ciscar, J.-C. (2021). Heat stress, labour productivity and adaptation in Europe—a regional and occupational analysis. *Environmental Research Letters, 16(10),* 105002. doi: 10.1088/1748-9326/ac24cf

Taghizadeh Moghaddam, H., Sayedi, S. J., Emami Moghadam, Z., Bahreini, A., Ajilian Abbasi, M., & Saeidi, M. (2017). Refugees in the Eastern Mediterranean Region: Needs, Problems and Challenges. *International Journal of Pediatrics, 5(3),* 4625–4639. doi: 10.22038/ijp.2017.8452

Taïbi, S., Meddi, M., & Mahé, G. (2019). Seasonal rainfall variability in the southern Mediterranean border: Observations, regional model simulations and future climate projections. *Atmósfera, 32(1),* 39–54. doi: 10.20937/ATM.2019.32.01.04

Tanrivermis, H. (2003). Agricultural land use change and sustainable use of land resources in the mediterranean region of Turkey. *Journal of Arid Environments, 54(3),* 553–564. doi: 10.1006/jare.2002.1078

Tarifa, R., Martínez-Núñez, C., Valera, F., González-Varo, J. P., Salido, T., & Rey, P. J. (2021). Agricultural intensification erodes taxonomic and functional diversity in Mediterranean olive groves by filtering out rare species. *Journal of Applied Ecology, 58(10),* 2266–2276. doi: 10.1111/1365-2664.13970

Teixidó, E., Olivella, L., Figueras, M., Ginebreda, A., & Tauler, R. (2001). Multivariate Exploratory Data Analysis of the Organic Micropollutants Found in the Llobregat River (Catalonia, Spain). *International Journal of Environmental Analytical Chemistry, 81(4),* 295–313. doi: 10.1080/03067310108044250

Terrado, M., Acuña, V., Ennaanay, D., Tallis, H., & Sabater, S. (2014). Impact of climate extremes on hydrological ecosystem services in a heavily humanized Mediterranean basin. *Ecological Indicators, 37*, 199–209. doi: 10.1016/j.ecolind.2013.01.016

Touhami, I., Chirino, E., Andreu, J. M., Sánchez, J. R., Moutahir, H., & Bellot, J. (2015). Assessment of climate change impacts on soil water balance and aquifer recharge in a semiarid region in south east Spain. *Journal of Hydrology, 527,* 619–629. doi: 10.1016/j.jhydrol.2015.05.012

Touhami, I., Rzigui, T., Zribi, L., Ennajah, A., Dhahri, S., Aouinti, H., Elaieb, M. T., Fkiri, S., Ghazghazi, H., Khorchani, A., Candelier, K., Khaldi, A., & Khouja, M. L. (2023). Climate change-induced ecosystem disturbance: a review on sclerophyllous and semi-deciduous forests in Tunisia. *Plant Biology, 25(4),* 481–497. doi: 10.1111/plb.13524

Tourret, J.-C. (2006). The Great Challenges of Mediterranean Cities. In *IEMed Mediterranean Yearbook 2006.* European Institute of the Mediterranean (IEMed), Barcelona.

Tramblay, Y., Jarlan, L., Hanich, L., & Somot, S. (2018). Future Scenarios of Surface Water Resources Availability in North African Dams. *Water Resources Management, 32(4),* 1291–1306. doi: 10.1007/s11269-017-1870-8

Tramblay, Y., Koutroulis, A., Samaniego, L., Vicente-Serrano, S. M., Volaire, F., Boone, A., Le Page, M., Llasat, M. C., Albergel, C., Burak, S., Cailleret, M., Kalin, K. C., Davi, H., Dupuy, J.-L., Greve, P., Grillakis, M., Hanich, L., Jarlan, L., Martin-StPaul, N., … Polcher, J. (2020a). Challenges for drought assessment in the Mediterranean region under future climate scenarios. *Earth-Science Reviews, 210,* 103348. doi: 10.1016/j.earscirev.2020.103348

Tramblay, Y., Llasat, M. C., Randin, C., & Coppola, E. (2020b). Climate change impacts on water resources in the Mediterranean. *Regional Environmental Change, 20(3),* 83. doi: 10.1007/s10113-020-01665-y

Tramblay, Y., & Somot, S. (2018). Future evolution of extreme precipitation in the Mediterranean. *Climatic Change, 151(2),* 289–302. doi: 10.1007/s10584-018-2300-5

Tsanis, I. K., Koutroulis, A. G., Daliakopoulos, I. N., & Jacob, D. (2011). Severe climate-induced water shortage and extremes in Crete. *Climatic Change, 106(4),* 667–677. doi: 10.1007/s10584-011-0048-2

Tsimplis, M. N., Calafat, F. M., Marcos, M., Jordà, G., Gomis, D., Fenoglio-Marc, L., Struglia, M. V., Josey, S. A., & Chambers, D. P. (2013). The effect of the NAO on sea level and on mass changes in the Mediterranean Sea. *Journal of Geophysical Research: Oceans, 118(2),* 944–952. doi: 10.1002/jgrc.20078

Turner, S. W. D., Ng, J. Y., & Galelli, S. (2017). Examining global electricity supply vulnerability to climate change using a high-fidelity hydropower dam model. *Science of The Total Environment, 590–591,* 663–675. doi: 10.1016/j.scitotenv.2017.03.022

Tzanatos, E., Raitsos, D. E., Triantafyllou, G., Somarakis, S., & Tsonis, A. A. (2014). Indications of a climate effect on Mediterranean fisheries. *Climatic Change, 122(1–2),* 41–54. doi: 10.1007/s10584-013-0972-4

Ulbrich, U., Lionello, P., Belušić, D., Jacobeit, J., Knippertz, P., Kuglitsch, F. G., Leckebusch, G. C., Luterbacher, J., Maugeri, M., Maheras, P., Nissen, K. M., Pavan, V., Pinto, J. G., Saaroni, H., Seubert, S., Toreti, A., Xoplaki, E., & Ziv, B. (2012). Climate of the mediterranean: Synoptic patterns, temperature, precipitation, winds, and their extremes. *In The Climate of the Mediterranean Region* (pp. 301–346). Elsevier. doi: 10.1016/B978-0-12-416042-2.00005-7

UN. (2015). The Paris Agreement. *United Nations Framework Convention on Climate Change* (UNFCCC), 60 pp. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

UN DESA. (2022). World Population Prospects 2022: Summary of Results. *United Nations Department of Economic and Social Affairs, Population Division*, UN DESA/POP/2022/TR/NO. 3.

UNEP/MAP. (2016). *Mediterranean Strategy for Sustainable Development 2016-2025.*

UNEP/MAP, & MED POL. (2011). *Hazardous substances in the Mediterranean: a spatial and temporal assessment.* United Nations Environment Programme, Mediterranean Action Plan, Athens.

UNEP/MAP, & Plan Bleu. (2020). *State of the Environment and Development in the Mediterranean.* Nairobi.

Üngör, U. Ü. (2023). Forum: Mass Violence in Syria. *Journal of Genocide Research, 25(1),* 84–88. doi: 10.1080/14623528.2021.1979907

UNWTO. (2017). Tourism statistics. *World Tourism Organization.* www.e-unwto.org/toc/unwtotfb/current

Vallauri, D. R., Aronson, J., & Barbero, M. (2002). An Analysis of Forest Restoration 120 Years after Reforestation on Badlands in the Southwestern Alps. *Restoration Ecology, 10(1),* 16–26. doi: 10.1046/j.1526-100X.2002.10102.x

Vallejo, V. R., Díaz-Fierros, F., & de la Rosa, D. (2005). Impacts on soil resources. In J. M. Moreno Rodríguez (Ed.), *A Preliminary General Assessment of the Impacts in Spain Due to the Effects of Climate Change* (pp. 345–384). Ministerio de Medio Ambiente y Universidad de Castilla La Mancha.

van der Geest, K., de Sherbinin, A., Kienberger, S., Zommers, Z., Sitati, A., Roberts, E., & James, R. (2019). The Impacts of Climate Change on Ecosystem Services and Resulting Losses and Damages to People and Society: Concepts, Methods and Policy Options. In R. Mechler, L. , Bouwer, T. Schinko, S. Surminski, & J. Linnerooth-Bayer (Eds.), Loss and Damage from Climate Change. *Climate Risk Management, Policy and Governance* (pp. 221–236). Springer, Cham. doi: 10.1007/978-3-319-72026-5_9

van Hassel, F., & Bovenkerk, B. (2023). How Should We Help Wild Animals Cope with Climate Change? The Case of the Iberian Lynx. *Animals, 13(3),* 453. doi: 10.3390/ani13030453

van Vliet, M. T. H., Vögele, S., & Rübbelke, D. (2013). Water constraints on European power supply under climate change: impacts on electricity prices. *Environmental Research Letters, 8(3),* 35010. doi: 10.1088/1748-9326/8/3/035010

van Zalk, J., & Behrens, P. (2018). The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S. *Energy Policy, 123,* 83–91. doi: 10.1016/j.enpol.2018.08.023

Vanham, D., del Pozo, S., Pekcan, A. G., Keinan-Boker, L., Trichopoulou, A., & Gawlik, B. M. (2016). Water consumption related to different diets in Mediterranean cities. *Science of The Total Environment, 573,* 96–105. doi: 10.1016/j.scitotenv.2016.08.111

Vautard, R., Gobiet, A., Sobolowski, S., Kjellström, E., Stegehuis, A., Watkiss, P., Mendlik, T., Landgren, O., Nikulin, G., Teichmann, C., & Jacob, D. (2014). The European climate under a 2°C global warming. *Environmental Research Letters, 9(3),* 034006. doi: 10.1088/1748-9326/9/3/034006

Velis, M., Conti, K. I., & Biermann, F. (2017). Groundwater and human development: synergies and trade-offs within the context of the sustainable development goals. *Sustainability Science, 12(6),* 1007–1017. doi: 10.1007/s11625-017-0490-9

Ventrella, D., Charfeddine, M., Moriondo, M., Rinaldi, M., & Bindi, M. (2012). Agronomic adaptation strategies under climate change for winter durum wheat and tomato in southern Italy: irrigation and nitrogen fertilization. *Regional Environmental Change, 12(3),* 407–419. doi: 10.1007/s10113-011-0256-3

Verner, D., Treguer, D., Redwood, J., Christensen, J., McDonnell, R., Elbert, C., & Konishi, Y. (2018). *Climate variability, drought, and drought management in Tunisia's agricultural sector.* World Bank Group, Washington, 132 pp.

Vicente-Serrano, S. M. (2007). Evaluating the Impact of Drought Using Remote Sensing in a Mediterranean, Semi-arid Region. *Natural Hazards, 40(1),* 173–208. doi: 10.1007/s11069-006-0009-7

Vicente-Serrano, S. M., Lopez-Moreno, J.-I., Beguería, S., Lorenzo-Lacruz, J., Sanchez-Lorenzo, A., García-Ruiz, J. M., Azorin-Molina, C., Morán-Tejeda, E., Revuelto, J., Trigo, R., Coelho, F., & Espejo, F. (2014). Evidence of increasing drought severity caused by temperature rise in southern Europe. *Environmental Research Letters, 9(4),* 044001. doi: 10.1088/1748-9326/9/4/044001

Vicente-Serrano, S. M., Miralles, D. G., Domínguez-Castro, F., Azorin-Molina, C., El Kenawy, A., McVicar, T. R., Tomás-Burguera, M., Beguería, S., Maneta, M., & Peña-Gallardo, M. (2018). Global Assessment of the Standardized Evapotranspiration Deficit Index (SEDI) for Drought Analysis and Monitoring. *Journal of Climate, 31(14),* 5371–5393. doi: 10.1175/JCLI-D-17-0775.1

Vicente-Serrano, S. M., Peña-Gallardo, M., Hannaford, J., Murphy, C., Lorenzo-Lacruz, J., Dominguez-Castro, F., López-Moreno, J. I., Beguería, S., Noguera, I., Harrigan, S., & Vidal, J. -P. (2019). Climate, Irrigation, and Land Cover Change Explain Streamflow Trends in Countries Bordering the Northeast Atlantic. *Geophysical Research Letters, 46(19),* 10821–10833. doi: 10.1029/2019GL084084

Vilagrosa, A., Morales, F., Abadía, A., Bellot, J., Cochard, H., & Gil-Pelegrin, E. (2010). Are symplast tolerance to intense drought conditions and xylem vulnerability to cavitation coordinated? An integrated analysis of photosynthetic, hydraulic and leaf level processes in two Mediterranean drought-resistant species. *Environmental and Experimental Botany, 69(3)*, 233–242. doi: 10.1016/j.envexpbot.2010.04.013

Vila-Traver, J., Aguilera, E., Infante-Amate, J., & González de Molina, M. (2021). Climate change and industrialization as the main drivers of Spanish agriculture water stress. *Science of The Total Environment, 760,* 143399. doi: 10.1016/j.scitotenv.2020.143399

Vogiatzakis, I. N., Mannion, A. M., & Sarris, D. (2016). Mediterranean island biodiversity and climate change: the last 10,000 years and the future. *Biodiversity and Conservation, 25(13),* 2597–2627. doi: 10.1007/s10531-016-1204-9

Wada, Y., van Beek, L. P. H., van Kempen, C. M., Reckman, J. W. T. M., Vasak, S., & Bierkens, M. F. P. (2010). Global depletion of groundwater resources. *Geophysical Research Letters, 37(20).* doi: 10.1029/2010GL044571

Waha, K., Krummenauer, L., Adams, S., Aich, V., Baarsch, F., Coumou, D., Fader, M., Hoff, H., Jobbins, G., Marcus, R., Mengel, M., Otto, I. M., Perrette, M., Rocha, M., Robinson, A., & Schleussner, C.-F. (2017). Climate change impacts in the Middle East and Northern Africa (MENA) region and their implications for vulnerable population groups. *Regional Environmental Change, 17(6),* 1623–1638. doi: 10.1007/s10113-017-1144-2

Weilgart, L. (2023). *Best Available Technology (BAT) and Best Environmental Practice (BEP) for Mitigating Three Noise Sources: Shipping, Seismic Airgun Surveys, and Pile Driving.* CMS Technical Series No. 46, 53 pp.

Winkler, D. E., Lubetkin, K. C., Carrell, A. A., Jabis, M. D., Yang, Y., & Kueppers, L. M. (2019). *Responses of alpine plant communities to climate warming. In Ecosystem Consequences of Soil Warming* (pp. 297–346). Elsevier. doi: 10.1016/B978-0-12-813493-1.00013-2

Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nature Communications, 12(1),* 2501. doi: 10.1038/s41467-021-22702-2

WMO. (2022). *State of climate services – Energy.* https://library.wmo.int/records/item/58116-2022-state-of-climate-services-energy

Wong, P. P., Losada, I. J., Gattuso, J.-P., Hinkel, J., Khattabi, A., McInnes, K. L., Saito, Y., & Sallenger, A. S. (2014). Coastal systems and low-lying areas. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 361–409). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

World Bank. (2017). *The toll of war. The economic and social consequences of the conflict in Syria.* World Bank Group, 148 pp.

World Bank. (2018). *Beyond Scarcity: Water Security in the Middle East and North Africa.* MENA Development Report, World Bank, Washington, DC.

World Bank. (2021). *World Development Indicators.* https://datatopics.worldbank.org/world-development-indicators/

Xanke, J., & Liesch, T. (2022). Quantification and possible causes of declining groundwater resources in the Euro-Mediterranean region from 2003 to 2020. *Hydrogeology Journal, 30(2),* 379–400. doi: 10.1007/s10040-021-02448-3

Xi, Y., Peng, S., Ciais, P., & Chen, Y. (2021). Future impacts of climate change on inland Ramsar wetlands. *Nature Climate Change, 11(1),* 45–51. doi: 10.1038/s41558-020-00942-2

Yang, C., Fraga, H., Ieperen, W. Van, & Santos, J. A. (2017). Assessment of irrigated maize yield response to climate change scenarios in Portugal. *Agricultural Water Management, 184,* 178–190. doi: 10.1016/j.agwat.2017.02.004

Yang, C., Fraga, H., van Ieperen, W., Trindade, H., & Santos, J. A. (2019). Effects of climate change and adaptation options on winter wheat yield under rainfed Mediterranean conditions in southern Portugal. *Climatic Change, 154(1–2),* 159–178. doi: 10.1007/s10584-019-02419-4

Yerou, H., Homrani, A., Benhanassali, A., & Boussedra, D. (2019). Typological assessment of dairy farms systems in semi-arid Mediterranean region of Western Algeria. *Biotechnology in Animal Husbandry, 35(4),* 335–346. doi: 10.2298/BAH1904335Y

Zaimes, G. N. (2020). Mediterranean Riparian Areas-Climate change implications and recommendations. *Journal of Environmental Biology, 41(5),* 957–965.

Zamora-Marín, J. M., Ruiz-Navarro, A., Oficialdegui, F. J., Anastácio, P. M., Miranda, R., García-Murillo, P., Cobo, F., Ribeiro, F., Gallardo, B., García-Berthou, E., Boix, D., Medina, L., Morcillo, F., Oscoz, J., Guillén, A., Herrero-Reyes, A. A., Aguiar, F. C., Almeida, D., Arias, A., … Oliva-Paterna, F. J. (2023). A multi-taxa assessment of aquatic non-indigenous species introduced into Iberian freshwater and transitional waters. *NeoBiota, 89,* 17–44. doi: 10.3897/neobiota.89.105994

Zapata, V., Gernaat, D. E. H. J., Yalew, S. G., Santos da Silva, S. R., Iyer, G., Hejazi, M., & van Vuuren, D. P. (2022). Climate change impacts on the energy system: a model comparison. *Environmental Research Letters, 17(3),* 034036. doi: 10.1088/1748-9326/ac5141

Zergui, A., Boudalia, S., & Joseph, M. L. (2023). Heavy metals in honey and poultry eggs as indicators of environmental pollution and potential risks to human health. *Journal of Food Composition and Analysis, 119,* 105255. doi: 10.1016/j.jfca.2023.105255

Zhang, R., Tian, D., Wang, J., & Niu, S. (2023). Critical role of multi-dimensional biodiversity in contributing to ecosystem sustainability under global change. *Geography and Sustainability, 4(3),* 232–243. doi: 10.1016/j.geosus.2023.05.002

Zhao, G., Li, Y., Zhou, L., & Gao, H. (2022). Evaporative water loss of 1.42 million global lakes. *Nature Communications, 13(1),* 3686. doi: 10.1038/s41467-022-31125-6

Zittis, G., Hadjinicolaou, P., Klangidou, M., Proestos, Y., & Lelieveld, J. (2019). A multi-model, multi-scenario, and multi-domain analysis of regional climate projections for the Mediterranean. Regional *Environmental Change, 19(8),* 2621–2635. doi: 10.1007/s10113-019-01565-w

Ziyadi, M., Dahbi, A., Aitlhaj, A., El Ouahrani, A., El Ouahidi, A., & Achtak, H. (2019). Terraced Agroforestry Systems in West Anti-Atlas (Morocco): Incidence of Climate Change and Prospects for Sustainable Development. In P. Castro, A. Azul, W. Leal Filho, & U. Azeiteiro (Eds.), *Climate Change-Resilient Agriculture and Agroforestry.* Springer, Cham.

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