Climate Change in the Mediterranean

The Economic Impacts of Climate Change in the Mediterranean

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Climate Change is arguably the greatest challenge faced by humanity. Its potentially devastating consequences pose a threat to human activities and to human life itself. It follows that we should act immediately to contain global warming and to curb the emissions of greenhouse gases.

To adopt the appropriate climate policies, we have to get to know the phenomenon and its characteristics as accurately as possible and obtain as complete a picture as possible of its damages.

Three fundamental features of climate change have to be taken into consideration. First, while it is a global phenomenon affecting the whole world, environmental and socio-economic impulses and responses are radically different across regions. So, everybody is responsible for it, but the consequences – the impacts – differ greatly across space. Second, climate change is a long-term phenomenon. Assessing impacts on environmental and socio-economic systems requires a long-term perspective. Third, the knowledge of environmental and socio-economic dynamics, and of the feedback between the two, is still affected by a large amount of uncertainty.

In this article we focus on the consequences of climate change for a specific region of the world: the Mediterranean. As we have just argued, a knowledge of impacts that are region-specific is essential for the design of the appropriate policies to cope with a changing climate, especially from the point of view of vulnerabilities and the necessary adaptation measures.

To determine whether and to what extent to act, the economist's approach is to determine the costs and the benefits of policies, including the cost of inaction. This requires a careful quantification of benefits, which here correspond to the avoided damages of climate change. This is only possible by first determining the economic impacts of climate change as thoroughly as possible. To that end three steps are needed.

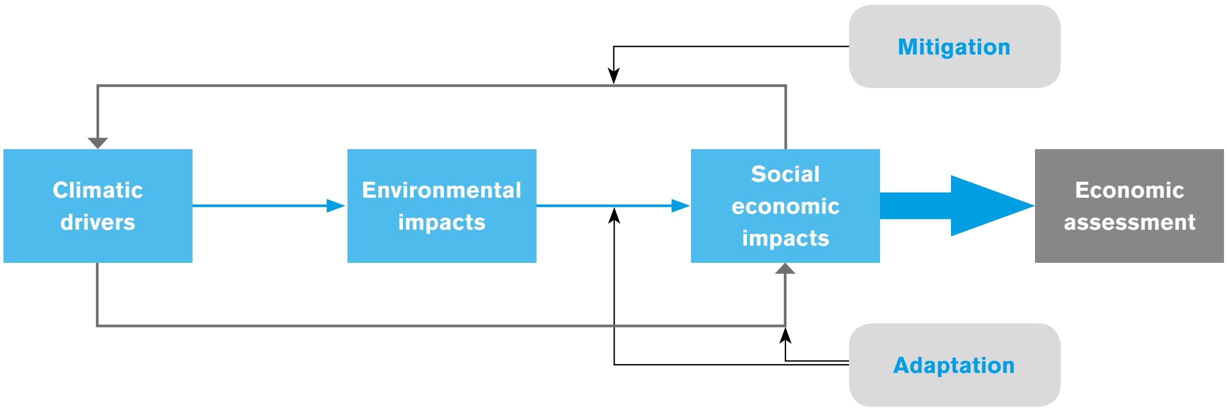
The starting point is the knowledge of the alterations to the climate system that are likely to occur at some point in a given region. As said, climate change is taking place globally, but there can be local effects which it is vitally important to be aware of. The second section is devoted to an illustration of this aspect, and notes that the Mediterranean is considered a "hotspot" of climate change.

The second aspect is that changes in climate determine environmental impacts, i.e. physical impacts on a number of areas and sectors, often mapped into the impact categories of human health, the natural environment and natural resources. A fourth category of impacts is usually added, which is the economy. The situation is depicted in Chart 1 and the illustration of the physical impacts in the Mediterranean region is given in the third section of the article.

Once knowledge of the environmental impacts is obtained, an economic evaluation is necessary for an appropriate cost-benefit exercise to be undertaken. To that end, the simplest method to assess the economic impacts of climate change is a direct costing approach that does not take into account the feedback that an economic perturbation in a sector or activity exerts on the rest of the system. Direct costing techniques can be roughly described as the following process:

> Economic cost of the change = ["Quantity with the change" – "Quantity without the change"] x "Price"

CHART 5 **Analysis of the Impacts of Climate Change**



This approach is widely used in economic assessments of climate change. Its strength is the relatively small number of assumptions regarding economic dynamics compared with a general equilibrium approach. Moreover, it is often the only viable approach when non-market values – e.g. biodiversity conservation – are involved. Its shortcoming is that it cannot measure possible rebounds on overall economic activity that a changing economic context can trigger.

The systemic perspective necessary to capture these feedbacks is provided by Computable General Equilibrium (CGE) models. A notable feature of CGE models is market interdependence. All markets are interrelated, as in response to price signals, utility-maximizing consumers and cost-minimizing producers readjust their demands and supplies across all markets. Eventually, CGE models can capture and describe the propagation mechanism induced by a localized shock in the global context and vice versa (see Chart 5). The final impact on national GDP summarizes these "higher order" effects, which are usually very different from the initial impacts.

In the fourth section, we report on the existing environmental economic literature that applies the above methods to assess the economic impacts of climate change in the Mediterranean. Given the complexity of CGE models, such literature is relatively small when it comes to the Mediterranean and considers a limited number of sectors/areas, typically focusing on portions of the whole region.

The Mediterranean: A "Hot Spot" of Climate Change

The Mediterranean region is characterized by a complex morphology of mountain chains and strong land-sea contrasts, a dense and growing human population and various environmental pressures. In general, climate trends in the Mediterranean Basin exceed global ones for most variables (EIB, 2008). Annual mean temperatures are now 1.4°C above late 19th century levels, particularly during the summer months. Heat waves now occur more frequently, and the frequency and intensity of droughts have increased since 1950. During each of the recent decades, the surface of the Mediterranean Sea has warmed by around 0.4°C. During the past two decades, sea levels have risen by about 3cm per decade, a sharp increase if compared to the period 1945-2000 (+0.7mm/year) and to 1970-2006 (1.1mm/year). Mediterranean seawater pH is currently decreasing by 0.018 to 0.028 pH units per decade.

During the 21st century, climate experts anticipate:

- An increase in air temperature between 2.2C° and 5.1C° for the countries of southern Europe and the Mediterranean region over the period 2080-2099 with respect to the period 1980-1999;
- A significant decrease in rainfall, ranging from between -4 and -27% for the countries of southern Europe and the Mediterranean region (while

the countries of northern Europe will report a rise of between 0 and 16%);

- An increase in periods of drought, represented by a high frequency of days during which the temperature would exceed 30°C;
- A higher frequency and intensity of extreme events, such as heat waves, droughts or floods;
- An increase in sea levels, which could be around 35cm by the end of the century. This would result from global sea level trends and the transport of water through the Strait of Gibraltar, although the precise contribution is still uncertain due to a lack of knowledge of specific processes. This would induce local differences in sea-surface height of up to 10cm. In southern Italy, substantial coastal inundation is expected by 2100. Significant shoreline modifications are also expected elsewhere, such as in the Balearic Islands.
- By 2100, a CO_2 uptake by the oceans is expected to lead to global acidification of 0.15-0.41 pH units below 1870-1899 levels, and similar rates should be expected for the Mediterranean;
- Even under a "Paris-compliant" global warming of 1.5°C, a 2.2°C increase in regional daytime maxima is likely. This increase is expected to be associated with more frequent high-temperature events and heat waves. In the eastern Mediterranean, heatwave return periods may change from once every two years to multiple occurrences per year. A global atmospheric temperature increase of 2°C will probably be accompanied by a reduction in summer precipitation of around 10-15% in southern France, northwestern Spain and the Balkans, and up to 30% in Turkey and Portugal.

The impacts of climate change on people, infrastructure and ecosystems occur in combination with other trends of environmental change, including population growth and urbanization. The southern and eastern Mediterranean countries appear to be more vulnerable to climate change than their northern Mediterranean counterparts. On the one hand, they are more exposed to accelerated desertification, soil aridity and water scarcity and, on the other hand, they present economic structures more strongly dependent on natural resources, as well as limited technical and financial capacities to help implement large-scale adaptation options. The more vulnerable Mediterranean areas will be those of North Africa adjacent to desert areas, the major deltas (like those of the Nile in Egypt, the Po in Italy, and the Rhone in France), the coastal areas (northern rim and southern rim of the Mediterranean Basin), as well as areas of high demographic growth and those that are socially vulnerable (southern and eastern rim, densely populated cities and suburbs).

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Physical Impacts

The impacts of climate change on the Mediterranean environment especially relate to: (i) water, via a change of its cycle due to a rise in evaporation and a decrease in rainfall; this water problem will be of crucial importance with respect to the issue of sustainable development in the region; (ii) soil, via the acceleration of already existing desertification phenomena; (iii) land and marine biological diversity (animal and plant), via a displacement northwards and in altitude of certain species, extinction of less mobile or more climate sensitive species and emergence of new species; (iv) forests, via a rise in fire hazards and parasite risks.

These impacts will exacerbate already existing pressures on the natural environment connected with anthropogenic activities. The main domains where climate change will have an impact are water resources, food security, ecosystems, coastal zones and human health (Cramer et al., 2018). Impacts and expected risks differ for each of them, and the vulnerability to combined risks is unlikely to be a sum of the vulnerability to each separate risk. Instead, their combination may exacerbate the magnitude of the impact or may produce successive, more frequent stress periods, which the least resilient countries will find difficult to cope with.

Water Resources

Among Mediterranean countries, water resources are unevenly distributed with critical limitations in the southern and eastern part of the Basin. Mediterranean societies will face the double challenge of meeting higher water demands from all sectors with less available freshwater water resources. Owing to climate change (enhanced evapotranspiration and reduced rainfall) alone, fresh water availability is likely to decrease substantially (by 2-15% for every 2°C of warming), among the largest decreases in the world, with significant increases in the length of meteorological dry spells and droughts. River flow will generally be reduced, particularly in the south and the east where water is in critically short supply. The median reduction in runoff almost doubles from about 9% at 1.5°C to 17% at 2°C. Water levels in lakes and reservoirs will probably decline. For example, the largest Mediterranean lake, Beyşehir in Turkey, may dry out by the 2040s if its outflow regime is not modified.
Other challenges to water availability and quality in coastal areas will probably arise from saltwater intrusion driven by enhanced extraction and sea level rise, and increasing water pollution on the southern and eastern shores, from new industries, urban sprawl, tourism development, migration and population growth. Recharge of groundwater will be diminished, affecting most of the region.
The general increase in water scarcity as a consequence of climate change is enhanced by the increasing demand for irrigated agriculture to stabilize production and maintain food security. Irrigation demands in the Mediterranean region are projected to increase between 4 and 18% by the end of the century due to climate change alone (for 2°C and 5°C warming, respectively). Population growth and increased demand may escalate these numbers to between 22 and 74%.
The Mediterranean region is regularly affected by flash floods, which are a consequence of short and local heavy rains in small catchments, many of them near the coast in densely populated areas. Flood risk, associated with extreme rainfall events, will increase due to climate change.

Food Production and Security

Food production from agriculture and fisheries across the Mediterranean region is changing due to social, economic and environmental changes. Although human population growth and increased affluence in some regions, along with changing diets, will lead to higher demand for food products, crop, fish and livestock yields are projected to decline in many areas due to climatic and other stress factors. In addition to the effects of drought, extreme events such as heat waves, frost or heavy rainfall may bring unexpected losses due to crop diseases, yield reductions and increased yield variability.
Yields for many winter and spring crops are expected to decrease due to climate change, especially in the South (legume production, sunflowers, tuber crops, olive production, grapevines, fruit trees, vegetables). Pests and diseases, as well as mycotoxins, could also represent a serious threat under unfavourable climate conditions. Sea level rise, combined with land subsidence, may significantly reduce the area available for agriculture in some areas.
The impacts of climate change on livestock production potential, combined with the growing demand for animal products will increase the food-import dependence of south Mediterranean countries in the coming decades (estimated at around 50% for all food products in the Maghreb).
Fisheries and aquaculture, crucial for food security and the economy of the Mediterranean, are currently impacted most by overfishing and coastal development. Ocean warming and acidification are very likely to impact fisheries more significantly during the coming decades, with more than 20% of exploited fish and marine invertebrates expected to become locally extinct by around 2050. By 2070-2099, more than half of the 75 endemic Mediterranean species are expected to qualify for the IUCN Red List of Threatened Species, and 14 more could have become extinct.
Overall, expected climate and socio-economic changes pose threats for food safety and security in the Mediterranean region. These pressures will not be homogeneous across the region and its production sectors, creating further regional imbalances and disputes. Thus, trade will be a key factor in maintaining food security.

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Natural and Managed Ecosystems

Forests, wetlands, coastal and marine ecosystems in the Mediterranean Basin will be affected by mean and seasonal changes in temperature and precipitation, as well as the changes in extremes. The increase in aridity (mainly due to reduced rainfall, but also to higher temperatures) is probably the main threat to the diversity and survival of Mediterranean land ecosystems. Higher fire risk, longer fire seasons and more frequent large, severe fires are also expected as a result of increasing heat waves in combination with drought and land-use change. Falling water levels and reduced water quality are also impacting wildlife in Mediterranean inland wetlands and freshwater ecosystems.

Shifts in the geographic distribution of a great diversity of native species have been linked to warming trends. The widening of the Suez Canal and the transport of alien species through ballast water from ships worsen the situation. More than 700 non-indigenous marine plant and animal species have been recorded so far in the Mediterranean, many of them are favoured by the warmer conditions. More than 50% of these have entered through the Suez Canal. Ocean acidification is expected to have a significant impact on a wide array of organisms that produce carbonate shells and skeletons.

These ecological changes on land and in the ocean lead to an overall biodiversity loss. They may also compromise the numerous benefits and services that Mediterranean ecosystems provide, including renewable natural resources (such as food, medicines, timber), environmental services (maintenance of biodiversity, soils and water, regulation of air quality and climate, carbon storage, for example) and social services (such as opportunities for recreational, educational and leisure uses, traditional cultural values)

Coastal Areas

In the Mediterranean, one-third of the population (about 150 million people) lives close to the sea. A small tidal range and relatively limited storm surges have led to the development of coastal infrastructure, land-use systems and human settlements that are very close to mean sea level. Sea level rise, which may well exceed recent IPCC estimates, will have considerable impact on Mediterranean coastal hazards, especially along the southern and eastern shores, where adaptive capacity is generally limited by weaker economic and institutional conditions. Port cities with more than one million inhabitants are considered to be at increasing risk from severe storm-surge flooding, rising sea level and local land subsidence.

By 2050, for the lower sea level rise scenarios and current adaptation measures, cities in the Mediterranean will account for half of the 20 global cities with the highest increase in average annual damages. Those areas at extremely high risk are predominantly located in the southern and eastern Mediterranean region, including Morocco, Algeria, Libya, Egypt, Palestine and Syria, most of which are presently subject to political instability and thus less able to deal with additional environmental pressures. Coastal areas suffer from saltwater intrusion and this will increase as the sea level rises.

Droughts or changes in ecosystem service supply may also aggravate social conflict and trigger forced migration. Due to its cultural, geopolitical and economic complexity, the Mediterranean Basin has historically been a region of social and political instability. The additional climate-related stressors create increased risks to human security in the region, make communities in the Mediterranean Basin more vulnerable and hence increase human insecurity.

Human Health

Climate change is one of many drivers affecting health, acting directly (through heat, cold, drought, storms and other forces) or indirectly (through changes in food provision and quality, air pollution or other aspects of the social and cultural environments).

Impacts vary in magnitude and timing based on the local environmental conditions and the vulnerability of the human population. In the Mediterranean Basin, regions with particularly strong changes in temperature and notable heat waves exist along the coasts and in densely populated urban centres. Heat-related illnesses and fatalities can occur when high ambient temperatures (particularly when combined with a high relative humidity) exceed the body's natural ability to dissipate heat. Although most Mediterranean populations are relatively acclimatized to high temperatures, an increase in the intensity and frequency of heat waves, or a shift in seasonality, pose significant health risks for vulnerable population groups, including those who live in poverty with substandard housing and restricted access to air-conditioned spaces. The degree to which heat-related morbidity and mortality rates will increase in the next few decades will depend on the adaptive capacity of Mediterranean population groups through acclimatization, adaptation of the urban environment to reduce heat-island effects, implementation of public education programmes and the preparedness of the healthcare system.

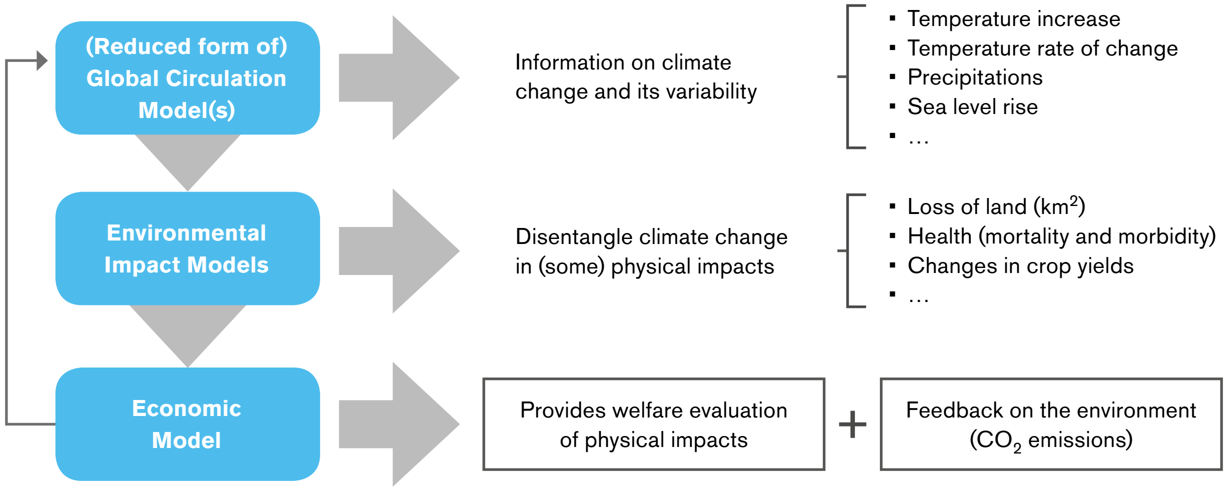
In recent years, several outbreaks of different vector-borne diseases have been documented in the Mediterranean region. There is a high chance that the recently observed climatic trends will contribute to the future transmission potential of vector –, food- and water-borne diseases in the region. Predicting the consequences of climate change for the severity of infectious diseases and distributions remains a challenge, particularly for vector-borne human infections, which are compounded by the complex interactions between hosts, pathogens and vectors or intermediate hosts that make the cumulative influence of climate change on disease outcomes elusive.

Economic Impacts

It was argued above that the physical or environmental impacts of climate change have to be translated into economic impacts for any cost-benefit analysis of climate policies, whether focused on mitigation or adaptation measures, to be appropriately designed given the limited financial resources that characterize any country. This follows the steps represented in Chart 6. Because a climate shock affects more than one sector or area of socio-economic activity, climate economists have developed models of how the economic system works with a sectoral and regional detail that enables them to use the system to trace the effects of climate alterations, taking into account the complex interdependencies of economic activities. The ultimate goal is to quantify the changes as a measure of wellbeing – typically agents' welfare (utility) or GDP – brought about by a given climate shock. Thus, the appropriate models to evaluate the economic impacts of climate change are multi-sector, multi-country, computable general equilibrium models (CGE). An added feature possessed by some, but not all, CGEs is that of being dynamic, i.e. also tracing the shocks through time.

One important limitation that characterizes the evaluation of economic impacts of climate change along

CHART 6 Example of a Climate Change Impact (Integrated) Assessment Modelling Exercise



the above-described lines is that the assessment is generally confined to market impacts, as a CGE model only describes market transactions. The existence of option values not directly influencing agents' demand and supply schedules are outside the descriptive range of these models, as they are not part of "national accounting," the usual database for CGE models. This is typically the case of impacts related to human health, biodiversity loss and ecosystems.

In the case of the economic impacts of climate change specifically in the Mediterranean region, the literature does not offer comprehensive CGE studies embracing all impacts and/or all countries of the region. Below is a succinct report on the results of the most recent studies.

The Ciscar et al. (2011) Study

Ciscar et al. (2011) report the main results of PESETA, a project of the EU Joint Research Centre, and one of the few studies which has systematically analysed climate impacts in Europe. For five alternative warming scenarios, the physical impacts on agriculture, river floods, coastal systems and tourism are investigated for up to 2080.[1] The model differentiates across European regions: southern Europe, central Europe south, central Europe north, the British Isles, and northern Europe.[2]

The physical impact results are used in a CGE modelling exercise aimed at quantifying the economic consequences of climate change. The consequences can be valued in monetary terms (GDP) as they directly affect sectoral markets and – via cross-sector linkages – the overall economy. They also influence the consumption behaviour of households and therefore household welfare.

In all 2080 scenarios, most regions would undergo welfare losses, with the exception of northern Europe, where gains in a range of 0.5-0.8% per year are driven largely by the improvement in agricultural yields. Southern Europe would be severely affected by climate change, with annual welfare losses of around 1.4% for the warmest 5.4 °C scenario (0.25% for the 2.5 °C scenario). In terms of GDP, the loss for the region would exceed 40 billion euros (6bn euro in the 2.5 °C scenario).

The sectoral and geographical decomposition of welfare changes under the 2.5 °C scenario shows that aggregated European costs of climate change are much higher for agriculture, river flooding, and coastal systems than for tourism. The British Isles, central Europe north, and southern Europe appear to be the most sensitive areas. Moreover, moving from a European climate scenario of 2.5 °C to one of 3.9 °C aggravates the three noted impacts in almost all European regions.

The Galeotti and Roson (2012) Study

Galeotti and Roson (2012) use a dynamic recursive CGE model called ENVISAGE, developed at the World Bank, to evaluate an increase in the number of impacts; namely, agricultural yields, sea level rise, water availability, tourist arrivals, energy demand (cooling/heating), health effects and heat-related labour productivity.

The study focuses on Italy, but the results are compared to those of Spain, a country similar to Italy in terms of development, and to those of the Middle East and North Africa region (MENA), a composite aggregate of countries that include the southern Mediterranean region.[3]

The annualized damage in Italian real GDP in 2050 is found to be 0.18% and 0.07% with a 1% and 3% discount rate respectively. The variation in Spain's real GDP shows some differences relative to Italy, due to sea level rise – nearly absent in Spain – and agriculture – where impacts are more serious in Spain. For MENA, the overall loss in real GDP is about six-fold in 2050 and nine-fold in 2100, relative to Spain. These proportions should be further multiplied by a factor of three, if comparison is made with Italy. Impacts of climate change, therefore, are much more severe on the southern shore of the Mediterranean, confirming that much of the (economic) burden of climate change is likely to be felt in developing countries. In the MENA region, individual impacts

[1] The physical impacts are presented in Table 2 of Ciscar et al. (2011).
[2] The region that is of interest to this chapter is southern Europe, which includes Portugal, Spain, Italy, Greece and Bulgaria.
[3] The authors note that available data and the model disaggregation scale did not allow them to conduct a more disaggregated country-level analysis.

on GDP are all negative: in addition to a negative effect on agriculture, the most serious impact is on labour productivity, but also sea level rise and tourism contribute to the drop in GDP.

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The Bosello and Eboli (2013) Study

MEDPRO stands for MEDiterranean PROspects, and is a project funded under the EU's 7th Framework Programme, coordinated by the Centre for European Policy Studies (CEPS). Within it Bosello and Eboli (2013) focus on the potential economic impacts of climate change on 11 southern and eastern Mediterranean countries through the effects of changes on the coastal ecosystem and on agriculture.[4] The impacts are quantified through bottom-up studies assessing the consequences of the deterioration of the coastal ecosystem and protected areas for tourism arrivals, and the effects on yields of major crop families by the middle of the century. These data are then used as inputs in a world CGE model called ICES, which quantifies the impact on GDP, sectoral production and prices. The results point to a generalized, albeit moderate loss in the region's GDP, ranging from -0.1% to -0.25% in 2050. The countries that are more adversely affected are Tunisia (-0.26%/-0.41% of GDP in 2050) and Morocco (-0.04%/-0.14% of GDP in 2050). High losses (-0.13%/-0.36% of GDP in 2050) are also highlighted for the "Middle East" aggregate (including, among others, Jordan, Syria, Palestine, Lebanon and Israel), which together make up 26.5% of the region's GDP. Negative impacts are more perceptible at the sectoral level. In the Reference Scenario, the average production loss for the agricultural sector is -0.5% in 2050, with a peak of -1.4% in Tunisia, while that of the service sector is -0.45% in 2050 with a peak of -0.9% in the Middle East. In general, GDP losses linked to tourism activity are greater than those related to agriculture, although this is not the case for Tunisia or Morocco.
In all, it may appear that the costs of climate change for the 11 countries could be limited. The study, however, considers the potential impacts related to changes in climatic conditions on just two sectors. Therefore, the costs highlighted are only a fraction of the losses that climate change could generate in the area.

The Szewczyk et al. (2018) Study

PESETA III is an update of the original project carried out in 2018.[5] The series of PESETA projects of the JRC aim to provide a better quantification of the possible consequences of future climate change for Europe. The goal of the JRC PESETA III project is to further improve that knowledge, narrowing uncertainty gaps. The study follows three stages: climate modelling, assessing the climate impacts for a number of impact categories and the economic analysis of the impacts. Five impact areas have been fully integrated: labour productivity, river floods, coastal floods, energy, and agriculture. A sixth integrated impact category is human mortality due to heat waves. Welfare losses (as a percentage of GDP) for the six sectoral impacts in southern Europe – the region of interest here – reach 1.8% and 4.2% in the 2°C "Paris Agreement" scenario and the "high" warming scenario, respectively. By comparison, the EU welfare loss under the high warming scenario is estimated to be around 1.9% of GDP (€240 bn) and could be reduced by approximately 2/3 in the 2°C scenario (€79 bn). The largest contributor by far is mortality in the sub-region, followed at a distance by labour productivity, coastal floods and agriculture. In terms of the relative geographical distribution of climate damages, assigning to northern Europe – the region with the lowest net welfare damage (as a share of GDP) – an index of one, southern Europe reaches eight. Finally, as one moves south, impacts appear to be

[4] The 11 countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, Tunisia and Turkey.
[5] A second update of the PESETA project was undertaken in 2014.

higher as a share of GDP: this is confirmed for agriculture, labour productivity and river floods, but not for coastal damages and energy impacts.

Conclusions

Human society has developed in tandem with the natural environment of the Mediterranean Basin over several millennia, laying the groundwork for diverse and culturally rich communities. Even if advances in technology may offer some protection from climatic shocks, the consequences of climate change for inhabitants of this region continue to depend on the long-term interplay between an array of societal and environmental factors. As documented in this article, the Mediterranean is a critical example of a region with high vulnerability and where climatic change may have sizable physical and economic impacts. Historically, various adaptation responses have emerged over time, some of them drastic, entailing migration and changes in societal structures.

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