Mediterranean forests and the risks linked to climate change: MedECC's contribution

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Climate change is intensifying and is aggravating the environmental problems in the countries of the Mediterranean region. Policies for sustainable development in these countries must reduce the threats and risks and envisage ways for adapting to them. However, at the present time these countries do not possess the required knowledge and information indispensable to achieving such aims, particularly in the southern parts of the Mediterranean region where systematised observation facilities and impact models are much rarer. Currently, there are targeted efforts under way within the framework of the MedECC network of experts to compile existing scientific knowledge from a range of disciplines in order to enhance understanding of the prevailing threats and risks.

Climate change entails major risks for ecosystems and for the well-being of mankind (Oppenheimer *et al.*, 2014). Over and above the direct impact of climate change, numerous other consequences exist associated to changes in environmental conditions which result from human activity: the pollution of air, water and land, the degradation of land and oceanic ecosystems linked to industrial activity, urbanisation, transport and the unsustainable use of resources. The issues arising from such changes involve several spheres, including access to natural resources (water and food), the healthy state of ecosystems, and human health and safety when faced with natural catastrophes. Here, we will briefly review the changes which affect terrestrial ecosystems around the Mediterranean Basin.

Mediterranean ecosystems are recognised as being extremely diverse, making up a combination of habitats that is unique worldwide. Their characteristics are in part the result of a co-evolution of the socio-ecosystems. Mediterranean ecosystems provide a large number of services to humankind: renewable natural resources (food, medicinal substances, wood, mushrooms), services both environmental (maintaining biodiversity, soils and water, control over air quality and climate, stocking carbon) and social (recreational, educational and leisure uses, natural and cultural heritage, tourism) (Liquette *et al.*, 2016). However, these ecosystems are faced at present with unprecedented challenges that have arisen from climatic and environmental changes deriving from human activity which in fact now threaten the availability of most of the services such ecosystems ensure.

Climate change

In the Mediterranean region the average annual temperatures are some 1.5°C above the averages for the pre-industrial era (1880 – 1899) and this regional increase is higher than the average rise worldwide. Over the last 50 years the tendency has been towards 0.03°C/year whereas worldwide it has been 0.02°C/year. Unless other limiting action is undertaken, the increase around the Mediterranean Basin forecast for 2040 will be 2.2°C. The warming will be stronger in summer than in winter. Episodes of particularly high temperatures will probably be more frequent and/or more intense (Kulitsch *et al.*, 2010; Jacob *et al.*, 2014). Human activity makes urban environments appreciably hotter than their outlying rural areas, especially at night (urban heat islands).

Rainfall levels around the Mediterranean are characterised by wide variations depending on geography and the time of year but climatic models clearly highlight a trend towards less precipitation in the coming decades (Saadi *et al.*, 2015). This drop in rainfall allied to intensified global warming together contribute to a strong tendency for soils to dry out. The frequency and intensity of droughts around the Mediterranean Rim have already worsened since 1950 (Vincente-Serrano *et al*, 2014). For example, between 2008 and 2011 the Middle East experienced a prolonged drought due to the enduring lack of rain, a situation aggravated by high evapotranspiration linked to warming (in this region the average temperature between 1931 and 2008 rose by 1°C) and by pressure on the water resource resulting from a big growth in population (Kelley *et al.,* 2015).

A 2°C rise in atmospheric temperature at a worldwide level should lead to a drop in summer rainfall of between 10% - 15% in the south of France, North-West Spain and the Balkans and a drop of 30% in Turkey (Vautard *et al.*, 2014). A rise in temperature of between 2°C - 4°C in Europe in 2080 will entail a major widespread drop in precipitation of up to 30% (Forzieri *et al.*, 2014; Lionello *et al.*, 2018). The duration of drought periods could also lengthen by 7% if global temperatures were to rise by 1.5°C (Schleussner *et al.*, 2016). Lastly, episodes of heavy rainfall could intensify by 10% - 20% in all seasons except summer (Toreti *et al.*, 2013).

The water resource

The availability of water around the Mediterranean Basin will fall on account of three factors: i) a decrease in rainfall; ii) a rise in temperatures; iii) a rise in the demand for water resulting from population growth, particularly in countries where the supply of water is inadequate. The Mediterranean region is likely to experience a significant drop in the freshwater supply (between 2% - 15% for a 2°C rise in temperature), ranking among the severest decreases worldwide (Gudmundsson *et al.* 2017). The duration of meteorologically dry periods should lengthen significantly (Schleussner *et al.*, 2016) along with the extent and intensity of droughts (Tsanis *et al.*, 2011). The populations living in the semi-arid climate of the eastern and southern parts of the Mediterranean region are especially exposed to a lack of water and to the year-to-year variations in its availability. The catchment areas of the Near and Middle East are going to experience acute water shortages, even if the hypothesis of a limited 2°C global warming is admitted. In Greece and Turkey, the per capita availability of water could fall for the first time below 1,000 m^2/yr some time before 2030 (Ludwig *et al.*, 2010). The present insufficient supply of water in South-East Spain and along the country's southern coast could well fall below 500 m^2/yr per capita (a situation of scarcity) in the near future.

The river flowrate is currently very low in the south and east of the Mediterranean where water supplies are especially low (Forzieri *et al.*, 2014). The water level in lakes and reservoirs will also drop. For example, one among the biggest lakes, Lake Beyşehir in Turkey, could well disappear by 2040 unless the catchment networks are modified (Bucaket *et al.*, 2013).

The main source of freshwater in North Africa and the Middle East is commonly-held aquifers; this source is also under threat, as is the system of aquifers in the North-West Sahara which shows a replenishment rate of only 40% of withdrawals (Goncalves *et al.*, 2013). The networks of oases which depend on these aquifers have become highly vulnerable. Intensive recourse to underground water has led to a drop in the level of the water tables in some regions (Custudio *et al.*, 2016; Moustdraf *et al.*, 2008). Not only are the water tables falling, but the quality of the water is affected on account of its overuse, pollution, urban sprawl and the infiltration of salt water as a result of the rise in sea levels (LEDUC *et al.*, 2017). The degradation in water quality is particularly striking along the southern and eastern coasts (LUDWIG *et al.*, 2010); this is due to new industries, urban growth, the expansion of tourism, immigration and the increase in population.

Some arid regions depend in large part for their freshwater supply on glacial and snow melt in the mountain ranges. For catchment areas downstream of the snow reserves (e.g. the Atlas range in Morocco and the Alps in Italy and France) climate change has caused a decline in the springtime runoff on account of melting snow (MARCHANE *et al.*, 2017) and glacial shrinkage, leading to a reduction in the available water resource.

The European Mediterranean climate domain (MCD) is often defined by reference to the distribution of emblematic species such as the olive; however a more direct definition incorporates mention of dry summers and mild winters (ROMIEUX *et al.*, 2010). The MCD is undergoing an evolution and by the end of the 21st century it could well have moved northwards and to higher altitudes (BARREDO *et al.*, 2016). The spread of the MCD is forecast from 53% to 121% of its present area, depending on two possible scenarios for the reduction in greenhouse gases — one representing moderate emissions and the other one low emissions compatible with the Paris Agreement. The extension of the MCD to the north, on the Atlantic coast (as far as Brittany), in Turkey, the north of the Black Sea, will be partly balanced out by an extension of aridity towards the south (into Spain, the south of Italy, Greece). But the territory newly won over by the MCD will only be able to provide opportunities for Mediterranean species insofar as interactions between types of habitat and biotopes permit them (GARCIA *et al.*, 2014).

Land-based ecosystems

The Mediterranean region, which occupies a mere 1.8% of the world's forested area, is home to 290 forest species whereas the rest of Europe contains just 135 (GAUQUELIN *et al.,* 2016). There are also many endemic species. Land-based ecosystems are affected not only by the direct impact of climate change (warming, drought) but also by changes linked to the use of soils (including the abandonment of grazing and extensive agriculture in certain isolated or mountain regions) and to urbanisation which leads to the fragmenting of landscapes (PENUELAS *et al.,* 2017). Other factors that affect the situation are pollution, unsustainable tourism, over-use of resources e.g. overgrazing, and wildfire.

The combined effect of climate warming and drought should lead to a generalised increase in aridity and, consequently, to the desertification of several terrestrial ecosystems around the Mediterranean. Over the course of past centuries, these ecosystems have already adapted well to high levels of fluctuation in the climate but a warming of 2°C or more above the pre-industrial average is likely to generate climatic conditions that numerous of these Mediterranean terrestrial ecosystems will never have experienced over the last 10,000 years. Deserts will spread into southern Spain and Portugal, northern Morocco, Algeria and Tunisia, into Sicily, the south of Turkey and into a part of Syria (GUIOT & CRAMER, 2016).

Forests, particularly in the south of Europe, play an important role as carbon sinks, i.e. they absorb more carbon than they emit. If average global temperatures remain within a range of 2°C above the pre-industrial average, most Mediterranean forests should withstand global warming (except for some coniferous forests). However, higher temperatures will likely reduce the fertilising effect of CO_2. On the other hand, if no unexpected physiological adaptation takes place (GEA-IZQUIERDO G. *et al.*, 2017), large sections of forests in the western part of the Mediterranean region will remain vulnerable to a rise of 2°C above the pre-industrial average. Such a change will entail not only the loss of numerous forest resources but also their function as a carbon sink, especially during drought years (RAMBAL *et al.,* 2014; MUNOZ-ROJAS *et al.*, 2017).

Mediterranean forests are home to certain species that are especially at risk from climate change. With the evergreen holm oak, currently the most widespread species around the Mediterranean Basin, a drop in productivity as well as an increase in mortality and defoliation (leaves falling) have been recorded (Liu *et al.,* 2015). Hungarian oak stands in the south of Italy have been showing signs of decline for more than 30 years (Gentilesca *et al.*, 2017). In arid and semi-arid areas, droughts have caused a rise in the mortality of forest species and brought on a degradation and a shrinking of area for all forest ecosystems, notably among the Atlas cedars in the Moroccan Atlas (Linares *et al.*, 2011) and in Algeria (Slimani *et al.*, 2011).

The majority of plants and animals adapt to some degree to climate change by changing their phenology (the times of the various periodic events in their life cycles, for example in plants, their flowering or the appearance of foliage). Over recent decades, an advance in spring phenology of about 2.8 days per decade for plants and animals living in most of the ecosystems in the Northern Hemisphere has been observed and this has been attributed to climate change (Settele *et al.,* 2014). But adaptation can have deleterious effects: there is a real risk of a plant's responses becoming disassociated from the organisms it interacts with, for example with pollenating insects, or heightened risk from frost damage in the early days of spring (Duputié *et al.*, 2015).

Forests, wetlands and coastal ecosystems around the Mediterranean Basin are also affected by climate changes linked to extreme temperatures and drought (Gouveia *et al.*, 2017; Santonja *et al.*, 2017). Lengthy droughts and heatwaves increase the risk of wildfire and lead to modifications in land management and cause longer seasons of wildfire risk with fires more frequent and serious (Duguy *et al.*, 2013; Turco *et al.*, 2014; Ruffault *et al.*, 2016). Such wildfires are generally the result of an accumulation of inflammable material during the wet season and drought during the dry season, though human activity, whether deliberate and criminal or involuntary, often triggers the event. Over recent decades in some Mediterranean countries, mega-wildfires set off by heat waves have broken the records for the extent of burnt-our areas (Ruffault *et al.*, 2016; Ganteaume *et al.*, 2013).

MedECC: towards a science-policy interface around the Mediterranean Basin

A preliminary analysis has revealed that around the Mediterranean Rim major risks are associated with climatic and environmental changes (Cramer *et al.*, 2018). The challenges involved in mitigating such environmental changes and adapting to any impacts that cannot be avoided are a priority for both public and private decision-makers preoccupied by the future of the Mediterranean region. Political responses to climate change must be based on scientific evidence.

Much scientific knowledge is available today and research efforts have been intensified in recent years via a range of studies and major collaborative projects (MISTRALS; MedCLIVAR, CIRCE or Med-Cordex). However, decision-makers often appear not to have ready access to the results of scientific research. From this fact comes the necessity to produce a detailed synthesis and an assessment of recent trends, as well as forecasts for possible developments and the consequences of environmental change on natural ecosystems, the economy and human well-being. The efforts deployed in the fields of research, of data monitoring and of knowledge accumulated on climatic change and evolution are not sufficiently coordinated. Some of the most vulnerable regions and certain economic sectors suffer from a lack of sufficient research, notably to the south and the east of the Mediterranean. The goal of the MedECC network is to rectify these weak points.

MedECC's work relies on the application of the strictest scientific norms along with the participation of experts from all the regions and scientific disciplines involved. Its inspiration comes from the Intergovernmental Panel on Climate Change -IPCC- whose aim is to provide to the countries of the world an objective analysis based on scientific observation of climate change and its political and economic consequences. MedECC involves 600 research scientists from 35 countries whose brief is to write a first assessment report on the state of the Mediterranean region faced with climate change. It is to be published at mid-2020.

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Summary

Mediterranean forests and the risks linked to climate change: MedECC's contribution

For some time, climate change has intensified and exacerbated the environmental problems of the Mediterranean basin caused by the combined effects of changes in land use, increased pollution and biodiversity loss. In most impact domains, and in particular terrestrial ecosystems, current and future scenarios consistently reveal significant increased risks in the coming decades. In particular, warming is already 20% faster than the global average. Water resources will decrease significantly, especially in the south and east. The Mediterranean climate domain will extend to the north while the southern regions will become more arid. The risk of forest fires due to heat waves will also increase. The sustainable development policies of the Mediterranean countries must reduce these risks and consider adaptation options. However, they do not currently have the necessary information to do so, especially in the most vulnerable regions of the southern Mediterranean where systematic observation systems and impact modelling are less developed. Specific efforts are being made to compile existing scientific knowledge in different disciplines to better understand the risks involved. These efforts are coordinated by the Mediterranean Expert Network on Climate and Environmental Change (MedECC).

Résumé

Depuis quelques temps, les changements climatiques s'intensifient et exacerbent les problèmes environnementaux du bassin méditerranéen qui sont causés par les effets combinés des modifications de l'utilisation des sols, de l'augmentation de la pollution et de la dégradation de la biodiversité. Dans la plupart des domaines d'impact, et en particulier les écosystèmes terrestres, les changements actuels et les futurs scénarios révèlent systématiquement d'importants risques accrus dans les décennies à venir. En particulier le réchauffement y est déjà 20% plus rapide que la moyenne planétaire. Les ressources en eau vont diminuer significativement surtout au sud et à l'est. Le domaine du climat méditerranéen va s'étendre vers le nord pendant que les régions sud vont devenir plus arides. Le risque d'incendie de forêts dû aux vagues de chaleurs va également s'accroître. Les politiques de développement durable des pays méditerranéens doivent réduire ces risques et envisager des options d'adaptation. Cependant, ces derniers ne disposent pas actuellement des informations nécessaires pour le faire, notamment dans les régions les plus vulnérables du sud de la Méditerranée où les systèmes d'observation systématique et les modèles d'impact sont plus rares. Des efforts spécifiques sont actuellement mis en œuvre pour compiler les connaissances scientifiques existantes dans différentes disciplines afin de mieux comprendre les risques encourus. Ces efforts sont coordonnés par le réseau d'experts méditerranéens sur les changements climatiques et environnementaux (MedECC).