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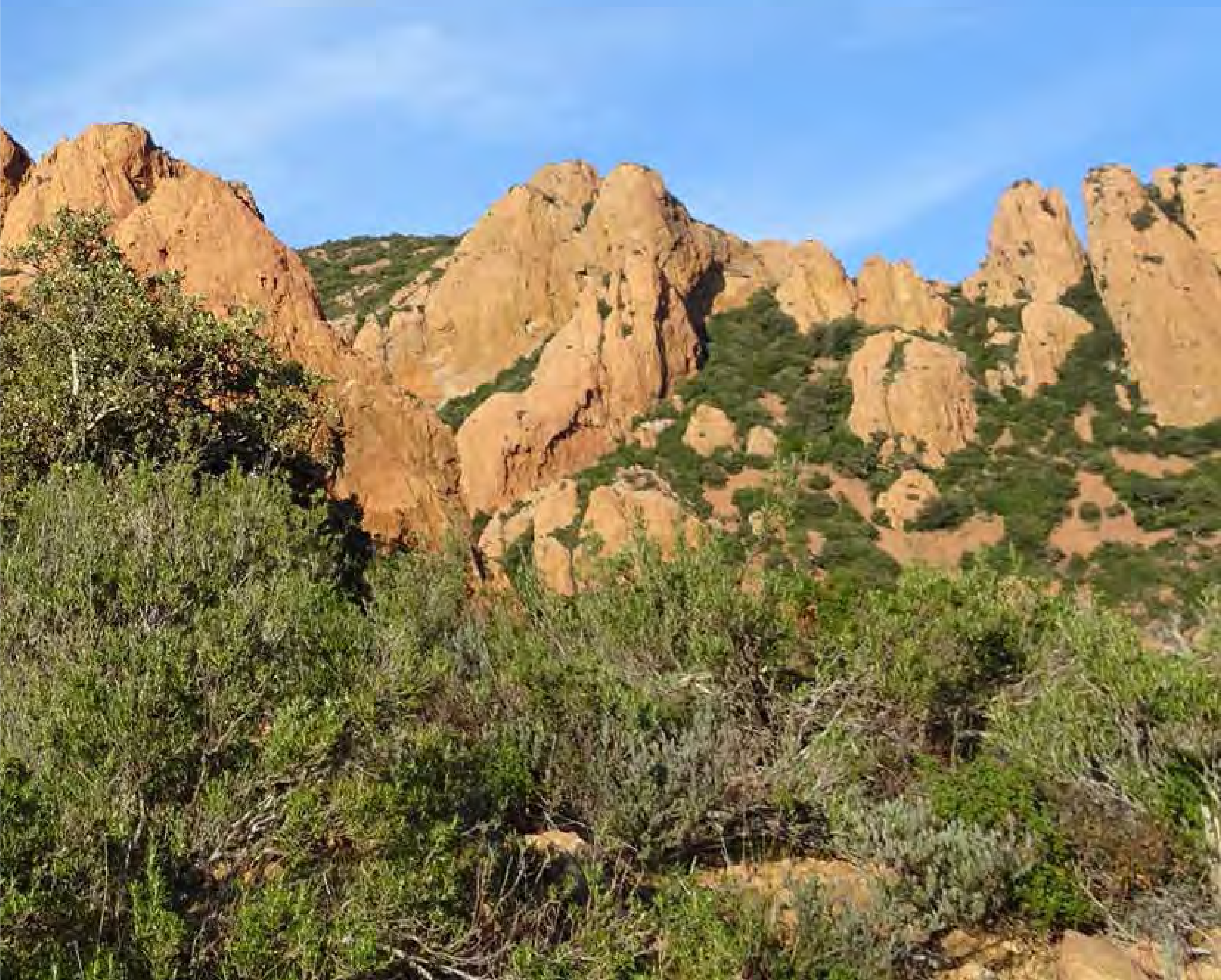

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5 Drivers of degradation and other threats

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Introduction: Mediterranean forests at stake

Forests in the Mediterranean region have been subject to environmental changes since time immemorial. The region's geography and location has made it a conducive environment between biomes, resulting in significant biodiversity. Since the beginning of human history, forests have adapted to pressures caused by human development, resulting in a complex socio-ecological balance. These pressures, however, have never been more extreme than they are today.

Global change, understood as the wide range of global forces resulting from human activity, is affecting the entire Mediterranean basin (Doblas-Miranda *et al.*, 2017). The threats caused by global change pose particular risks to the principal characteristics of Mediterranean forests and forested habitats described in previous chapters:

1. Mediterranean forests and shrublands are highly sensitive to global atmospheric changes due to their proximity to arid regions;
2. a long history of land-use change may result in more frequent and intense fires, water scarcity and land degradation and;
3. a singular biota is linked to a higher vulnerability to global change-induced extinction.

Moreover, the wide range of socioeconomic conditions and government policies that characterize the Mediterranean basin affect the intensity and dynamics of these threats.

This chapter outlines the different threats to Mediterranean forest landscapes, structured according to indirect and direct causes of degradation. The anthropogenic origin of current global changes directly affecting Mediterranean forests is considered the underlying cause of degradation. Although in many cases these human forces have a global impact (such as greenhouse gas emissions caused by climate change), this chapter will consider their effect on the Mediterranean region in particular. This chapter will also consider the consequences of direct and indirect threats and the combination of both.

Underlying (indirect) causes of degradation

Local and regional policies

The Mediterranean region is located at the intersection of three continents. Mediterranean countries do not share a common forest strategy recognizing the many functions and values of Mediterranean forests, particularly in view of global changes. As a consequence, forest governance remains the responsibility of national authorities. In some cases, national forest laws and regulations help forest owners to promote sustainable forest management (Box 2.4). At a sub-national level, however, forest policies can easily lose their flexibility and in some cases may inadvertently promote (by not preventing) causes of degradation that are not only environmental but also economic and social (e.g. land abandonment and fuel accumulation, see Box 2.5).

Box 2.4. The Regional Center for Forest Ownership of the Provence-Alpes-Côte d'Azur Region, France

The Regional Center for Forest Ownership is a public establishment created under the supervision of the French Ministry of Agriculture to promote sustainable silvicultural management among private owners. Its forestry technicians meet private owners' needs, personalizing technical, legal, economic and financial support. The main aim of this Regional Center is to facilitate and promote the sustainable management of common causes of degradation through technical assistance and training.

Despite the fragmentation that characterizes regional governance in this area, several and ongoing regional efforts have been undertaken. A scientific Mediterranean Forest Research Agenda was developed for the period 2007-2020, based on a shared and common vision of Mediterranean challenges. It aims to protect the sustainability of Mediterranean forests by sharing and advancing knowledge about how forest ecosystems function and developing new tools for management and governance in the context of global change. Scientific advancement should form the backbone of more structured knowledge-based governance; it is a prerequisite for providing the scientific expertise with which to develop more efficient policies to establish a common Mediterranean vision.

At a policy level, the regional project "Adapting the framework for forestry policy to meet the needs of climate change in the MENA region" (with the support of the German Development Cooperation (GIZ) and under the Collaborative Partnership on Mediterranean Forests (CPMF)), has increased the capacity of national decision-makers to design forest conservation policy. It has also involved additional actors, motivating them to actively cooperate with other sectors. It will only be possible to overcome current challenges associated with global change through improved understanding and recognition of the economic (tourism, livestock farming, water, etc.) and social value of forests, including through better stakeholder coordination. Other initiatives go one step further, by also proposing participatory modes of governance (Box 2.6).

An additional regional tool promoting new policies and initiatives to mitigate Mediterranean forest degradation is the Strategic Framework on Mediterranean Forests (SFMF), adopted at the Third Mediterranean Forest Week (Tlemcen, Algeria, 2013). It calls for improved governance of policy development, implementation and monitoring, particularly by fostering the participation of all stakeholders at the landscape/territory level. The SFMF has rapidly been integrated in national initiatives. In Algeria, for example, it was considered during the formulation of the country's National Forest Plan. It nevertheless requires further translation and implementation in practice. The initiatives above are only few examples of several activities already undertaken in the Mediterranean region. Nevertheless, more work is still needed to develop a regional strategy supporting the development of revised and common Mediterranean forest policies. These are required to reduce degradation and maintain forest quality so that they can continue to provide various ecological and socioeconomic goods and services and contribute to socioeconomic development, based on integrated landscape planning.

Box 2.5. Wildfires and policies in the Mediterranean

The increased and extended risk of wildfires in the region requires new policies and approaches to fire management. Suppression policies that are not properly accompanied by vegetation management, silviculture and integrated landscape-level forest management may seriously increase forest degradation due to fuel accumulation, leading to an increased risk of forest fires. This situation requires new firefighting policies, together with efficient preventive strategies, such as integrated fire and forest management planning. The aim is to establish territorial policies that allow fires to remain a part of Mediterranean ecosystems at an 'acceptable' level. National and regional strategies and policies must be reconsidered, by tackling all dimensions of the problem, including clearly identifying civil protection and forest protection objectives. Finally, priority should be given to the shift from short-term fire control policies to longer-term policies of removing the structural causes of fires.

Micro and macroeconomy

Economy indirectly affects forest degradation. A key concept used to describe and design development policies in Mediterranean countries is the so-called "bioeconomy" (Bugge *et al.*, 2016). There is no consensus in the literature (Pülzl *et al.*, 2014) on whether bioeconomy represents a paradigm, a master narrative, or simply a general concept. However, analysing the implementation of this concept in the forestry sector, we find that there are two opposite views and different underlying perspectives on the role forest resources can play in rural development policies: a technological approach vs. a social approach to the concept of bio-based development. These two approaches have different consequences for Mediterranean forest ecosystems.

The technological approach to bio-based economies is based on the accepted wisdom of externality correction (i.e. "getting prices right" or applying a true value to resources, thus reducing the consumption of natural capital). This "old wine in new bottles" strategy gives technological change a central role, synergizing the food and raw materials produced by forests (e.g. biomass and cork) with agriculture and fisheries for use in new and expanding markets. Biotechnology innovations are the engine for growth in this regard. Bio-refineries are a reference model for this approach in the Mediterranean forest sector (Box 2.7). In seeking to increase the scale of production, companies have tended to focus on supply chain organization (often associated with quite large financial investments) and labour intensive production (raw material procurement is generally based on very large quantities of low quality commodities).

By comparison, a social approach to the bio-based economy (as defined both by OECD, 2011 and UNEP, 2011), emphasizes both the protection of natural capital and the importance of addressing equality and social inclusion to protect the sustainability of socio-ecological systems. This strategy focuses on the forest sector's social dimensions, in which the most critical innovations relate to land tenure organization and the provision of advisory and other supporting services in rural communities, such as micro-credit, e-marketing, job creation and social inclusiveness (Box 2.8).

Box 2.6. Practices to promote participatory approaches and the sustainable development of Mediterranean forest ecosystems in the Maâmora forest (Morocco)

Under the regional project "Maximize the production of goods and services of Mediterranean forest ecosystems in the context of global change" (funded by the French Global Environment Facility), two practical guides were created to facilitate the implementation of "win-win" partnerships in forested areas in Maghreb countries, especially in the Maâmora region. The Maâmora forest is the largest cork oak forest held by a single owner in the world. Despite this, its forest surface has decreased from 132 000 ha to 55 000 ha since the beginning of the nineteenth century. The main identified causes of this decrease are forest degradation and deforestation caused by strong anthropogenic pressure (grazing, pruning, resource withdrawal by local populations depending on those resources) and a failure of forest management to adapt to both this pressure and climate change. The initiatives in Figure 2.20 present options to encourage cork oak conversion and regeneration by involving local populations in responsible and sustainable resource management.

Before

- Illicit acorn collection, inadequate harvesting methods
- Degradation, regeneration of threatened cork oaks
- Necessity of importing seeds from outside

Actions implemented with users

- Forming cooperatives and associations
- Raising awareness and education
- Win-win contracts between managers and populations: 60% of acorns to users/ 20% to plant nurseries/ 20% for natural regeneration

After

- Partnership between managers and users for the benefit of the general public
- Improving revenues of local populations
- Value chain control
- Accountability of users adopting good management practices in a legal context
- Seed traceability (nurseries) and availability
- Reduced pressure on forest resources

Figure 2.20. Suggestions for the promotion of participatory approaches to reduce degradation in Maâmora Forest

The social approach more effectively supports job expansion and added value in rural areas than a purely technological focus (Table 2.10). Unfortunately, the social approach has limited political visibility. It is based on a constellation of niche markets in which products and services are promoted via investments in technical assistance, new contractual agreements and networking services. In many Mediterranean countries, these services are often the most vulnerable to public budget cuts.

Box 2.7. The technological approach to the bioeconomy: the thermic central of Gardanne Province (France)

The thermic central of Gardanne Province, located near Marseilles (France), is a wood-based power station converted from a former coal-burning station in 2016. The plant is managed by the German company E.ON, which claims it has reduced CO_2 emissions by 600 000 tonnes a year and created new jobs, ensuring a market for the low quality woodcuts sourced from forests in the surrounding region (even where importation of some portion may still be required). Annual demand for industrial wood (855 000 tonnes at the plant's full capacity) will, according to E.ON, have several indirect positive impacts. These include increasing active management of local forests, thus reducing the likelihood of abandonment and risk of forest fires. The environmental consequences of such enormous annual wood consumption, however, remain unexplored.

Moreover, the diversification of small-scale forest activities has led to increased integration with the farming, tourism and recreational sectors. This has created monitoring and evaluation problems, as limited statistical data is available. Finally, social innovations associated with increased social capital do not attract as much private sector attention as large-scale investments that require significant financial and technological capital. With a view to long-term sustainability, stronger private-public partnerships, focused on protecting and enhancing the non-market functions of the Mediterranean forestry sector, would result in greater balance between these social and technological approaches to managing forest resources in the region.

Box 2.8. The social approach to the bioeconomy: the Borgotaro Consortium in Parma Province (Italy)

The Borgotaro Consortium manages 13 000 ha of forest owned by local forest communities ("Comunalie"). The Consortium was created in 1957 to regulate and manage the rights of local residents to grazing, harvesting wood for fuel, tap water distribution and wild mushroom picking. Over time, wild mushrooms became the most important income source for local forest communities and in 1964 the first mushroom reserve was created, allowing communities to grant daily picking permits. In 1996 the local mushroom ("Porcino di Borgotaro") obtained EC Protected Geographical Indication status, leading to the creation of an economy based on wild mushrooms. The "Porcino" supports a variety of local activities: 100 000 pickers generate an annual revenue of EUR 5 million, which is in turn linked to the revenue of 15 agro-tourism farms, 12 small hotels, eight bed and breakfasts, nine cheese, sausage and grape growing and wine production factories, two didactic farms, three museums and private collections, 30 restaurants and 26 shops selling local traditional products. These activities are inter-connected by a "wild mushroom trial" ("La strada del fungo") and promoted by a web site (http://www.fungodiborgotaro.com/).

Cultural and technological factors

Mediterranean forest dynamics depend on interactions between environmental factors and anthropogenic activities, which form a complex feedback pattern and continuous landscape transformation. The modification of landscapes and, consequently, the structure of forests, began when humans first harnessed the use of fire, followed by the commencement of agricultural production and the domestication of livestock.

Pollen and charcoal evidence from the Bronze Age (around 4000 BC) suggests anthropogenic wildfires

Table 2.10. The technological vs. social approach to developing the bioeconomy: a broad comparison

	Technological approach to bio-based economy	Social approach to bio-based economy
Focus	Technological innovations, large scale investments	Social innovations, small scale, added-value products and services (→ low risk)
Vertical vs. horizontal relations	Value chain perspective; sectoral development; vertical integration	Network economy, inter-sectoral development; horizontal integration
Diversification of outputs and inputs	Wood as a unique raw material; diversification in outputs	Diversification in the use of inputs (industrial wood, biomass, non-wood forest products, ecosystem services)
Market power	Increased market power of industrial companies controlling advanced technologies (→ high risks connected to the company's consolidation trends)	Balanced market power among the various diversified operators (→ reduced risk due to diversification)
Examples	Innovation assessment approach by the EU Eco Innovation Observatory (http://www.eco-innovation.eu/)	Local Action Groups (Leader+ approach – http://enrd.ec.europa.eu/enrd-static/leader/en/leader_en.html)
Drivers	Patented (private) R&D initiatives, with public support	Public-private initiatives in education, training and non-patented innovations

in Italy led to the replacement of *Quercus ilex* forests with shrub-lands (Vannière *et al.*, 2008). Similarly, the interaction between climatic changes and human pastoral activities resulted in a transition from maquis forests to steppe vegetation in Mediterranean France (Henry *et al.*, 2010). It is believed that forest clearing was primarily driven by increasing demand for livestock pasture and crop land. Williams (2000) notes that as time progressed and technology evolved, deforestation increased as a result of timber requirements for ship construction, metal smelting and wood as an energy source. During the Middle Ages, a growing human population and subsequent increase in demand led to extensive land degradation and soil erosion.

Although traditional uses of forests persisted during the twentieth century (especially with regard to burning practices; Box 2.9), described trends were reversed in the Mediterranean basin. Accelerated urbanization led to a decreased rural population. During the 1950s the urban population of northern Mediterranean basin countries accounted for about 40 percent of the total, whereas in 2010 it rose to more than 60 percent (Antrop, 2004). In Maghreb countries, urban populations accounted for about 30 percent of the total in 1960, increasing to almost 70 percent in 2015 (World Bank, 2015b). Urbanization and declining rural populations are accompanied by abandonment of agricultural land and marked declines in free-ranging livestock numbers (Lasanta-Martínez *et al.*, 2005). These processes initiate secondary succession and a consequent increase in forest cover.

Urbanization commonly causes the young labour force to migrate to cities, meaning rural areas remain largely populated by the elderly. This demography is less likely to adopt new farming technologies or modern practices. Low income yields have made many small farms in remote, rural areas unprofitable, accelerating abandonment of agricultural practices (MacDonald *et al.*, 2000). In some regions, traditional local populations have been replaced by foreigners and residents from a high socioeconomic class who commute daily to large cities (Sluiter and de Jong, 2007). Rey Benayas *et al.* (2007) have shown that countries with lower population growth rates and higher Gross Domestic Product (GDP) are associated with higher land conversion rates.

In North Africa, forests have gradually declined at a rate of 126 thousand ha/yr over the last 50 years (Keenan *et al.*, 2015). This decline is driven by population growth but also by direct demand for

Box 2.9. Integral Forest Fire Prevention Teams in Cantabria (Spain)

Over the past few decades, wildfires have become one of the Iberian Peninsula's most critical environmental problems. However, in northwest Spain burning is still used as a traditional tool during the winter in order to create grasslands for extensive livestock farming. Despite bans on this process, rural populations take advantage of favourable weather conditions to eliminate bushland, spreading fires which cannot be controlled.

The Spanish Ministry of Agriculture and Fisheries, Food and Environment (MAPAMA) supports Autonomous Communities that experience high numbers of wildfires through its "Equipos de prevención integral de incendios forestales" (EPRIF)'s programme (Integral Forest Fire Prevention Teams). Prevention activitives developed by the EPRIF focus on making livestock farming practices compatible with the environment. The Cantabrian Autonomous Region team in the Pas and Cabuérniga Counties was one of the first to adopt these preventative measures. The EPRIF developed a programme of prescribed fires with different typologies and degrees of difficulty. Highly complex controlled fires were developed in collaboration with Cantabria's fire fighters and MAPAMA's Preventative Labour Brigades. The EPRIF's work consists of complementary environmental education programmes and activities to further improve these grasslands.

In some Cantabrian municipalities the EPRIF has been working continuously since 2013. Its programmes have led to a reduction in the number of wildfires related to the creation of agricultural pasture from an average of 50 wildfires burning 350-400 hectares per year in 2013, to less than 10 fires burning only 50 hectares in 2016. Over time, the EPRIF has been integrated into the standard practice of the region's rural population, evinced by an increased number of burning requests. Its awareness-raising efforts have also been met with approval by the Region's administrators and educational institutions.

fuelwood, food and fibre, which often leads to overgrazing, overexploitation and forest clearing (Palahi *et al.*, 2008). There is also considerable forest expansion in some areas of the south due to afforestation programmes (Hansen and DeFries, 2004), and most of the countries in the southern Mediterranean are reporting stable or slightly increasing forest areas (FAO, 2015a and Table 2.3). These complex socioeconomic interactions and transitions have, over time, resulted in the current Mediterranean landscape.

Demographic patterns and migration

Population increase in many Mediterranean countries is one of the principal factors affecting forest ecosystems throughout the region. While the southern European population is expected to increase slightly to 155 million people by 2050, the North African population is expected to increase by 50 percent to 328 million people over the same period (DESA, 2009). Although depicting population growth as the principal cause of erosion, desertification, deforestation, pest and diseases, pollution and decreased water resources may be a simplification of more complex processes (Auclair *et al.*, 2001), it is undeniably implicated in these environmental threats.

Apart from the migration of local populations from rural to urban areas (resulting in ageing populations) described above, regional migration across the Mediterranean also creates an imbalance between human populations and the environment. Migration is in part a consequence of environmental degradation in countries of origin, and causes a risk that the overexploitation of resources is passed through to countries of arrival (FAO, 2016b).

Morocco provides a good example of this issue. Annual forest loss in Morocco is the result of a

Table 2.11. Demographic changes in Morocco from the first and the latest general population census

Year	Total population	Rural population		Urban population	
		in thousands	% of total	in thousands	% of total
1961	11 897	8 350	70.2	3 547	29.8
2014	33 770	13 417	39.7	20 353	60.3

combination of different elements which either affect the quality of vegetation cover or lead to reduced prevalence of hardwood or natural species. Population increases in Morocco in the last few decades have placed pressure on the country's natural resources, especially forests. The annual total population growth rate changed from 2.25 percent in 1961 to 1.17 percent in 2014, showing an almost two-fold decrease in around 50 years (Table 2.11). However, in absolute terms, urban populations experienced a five-fold increase over the same period while rural populations "only" increased by 60 percent. On the one hand, the country's population increase has necessitated significant urban development, resulting in devitalization of large crop and forest areas and ongoing land demands for construction purposes. On the other hand, forest degradation is also the direct result of grazing, agricultural, building or artisanal activities carried out by rural populations. Excessive wood gathering, in places such as the Middle Atlas cedar forests, has resulted in the loss of vast forest areas (HCEFLCD, 2005). Overgrazing, evinced by the disappearance of pasture plains, prevents forest regeneration. Ecosystem simplification increases vulnerability and decreases vegetation cover, exposing soil surfaces to desiccation and ultimately rainfall erosion, which accelerates soil degradation. This, combined with reduced water reserves, leads to desertification to the south and east of the Atlas Mountains.

Direct causes of degradation and principal agents

Climate change: climate warming, drought and other extreme climatic events

Throughout the Earth's history, its climate has been characterized by frequent fluctuations between periods of relative warmth and relative cold. However, unusual increases in global temperatures have occurred over the last century and the Mediterranean basin shows no sign of escaping this unequivocal climatic change. Recent data indicates a temperature increase of about 0.85°C globally and 1.3°C in the Mediterranean area in the last century, compared to temperatures recorded over the period 1880-1920 (Solomou *et al.*, 2017). The Mediterranean climate is expected to become drier and warmer, with decreasing water available for plants and increasing evapotranspiration (IPCC, 2007b).

The Mediterranean's vegetative cover is the result of a long, slow evolutionary process influenced by the climatic factors characterizing the region (Valladares *et al.*, 2014). However, socioeconomic pressures have historically affected Mediterranean forests, leading to innumerable anthropogenic afflictions, unsustainable forest practices and neglect of forested lands. Climate change has exacerbated those pressures, adversely affecting forested lands in the region. The current rate of climatic change is much faster than previously and has an attendant higher risk of extreme weather events, such as prolonged periods of drought, frequent and severe storms, flooding and increased extreme heat events (Scarascia-Mugnozza *et al.*, 2000). While Mediterranean plant communities have adapted to survive long, hot summer droughts and prolonged wet winter periods, the current change poses risks to forests' adaptability and increases their susceptibility to pressures and risks in the absence of adaptive management (Box 2.10).

The combination of climate change, anthropogenic disturbances (overexploitation of forest resources, human-induced fires and deforestation) and other aspects of global change (particularly land use and pollution) will have an effect on Mediterranean forest vegetation (Peñuelas *et al.*, 2010). Impacts are expected to affect the structure and operation of Mediterranean forest ecosystems, as well as the services they currently provide (Table 2.12).

Alteration of wildfire patterns

As outlined above, Mediterranean ecosystems, having evolved in the context of environmental disturbances and centuries of human influences, are undergoing change as a result of extensive rural migrations and land abandonment.

The most productive lands are used intensively, while less productive areas are abandoned or subject to less intensive use and afforestation. Fire systems result from interactions between climate, topography, local micro-environments at smaller spatial and temporal scales, as well as land use and land cover changes. Demographic shifts from rural to urban areas may favour fuel build-up and, consequently, may result in large fires. Conversely, population decreases reduce the probability of human-induced fires (Moreira *et al.*, 2011). According to this hypothesis, less frequent but more intense and large fires are expected (Box 2.11). This alters the principal role of fires in the Mediterranean both as long-term landscape modifiers and as a mechanism to maintain land cover classes in fire-dependent ecosystems (Stamou *et al.*, 2016). Effects may vary from region to region due to differences in regeneration patterns among the main land cover types, topographic constraints and local fire histories (Viedma, 2008).

Box 2.10. Coping with climate change: adaptive management for Lebanon's forests

Given that Lebanon's forests and woodlands suffer from fragmentation, pest outbreaks, forest fires and unsuitable practices, adaptation measures have been established to increase their natural resilience, anticipate future changes and promote landscape management (Ministry of Environment, 2011). These measures have been mainstreamed towards the adaptive actions outlined below:

1. strengthening the legal and institutional framework to integrate climate change needs;
2. integrating landscape planning and development at local/regional levels;
3. strengthening awareness and education and supporting research; and
4. developing forest management plans for the most vulnerable ecosystems.

In tandem with these activities, the government has commenced initiatives with the ultimate objective of enabling Lebanon's forests to cope with the effects of climate change. A National Afforestation and Reforestation Programme, known as the "40 million forest trees initiative," was launched by the Ministry of Agriculture in partnership with FAO in December 2012. The initiative intends to plant 40 million forest trees to recover forest areas lost over the last decade.

The Ministry of Environment has also undertaken biodiversity conservation measures, developing and updating the National Biodiversity Strategy and Action Plan (NBSAP) for the period 2016-2030, as required under the Convention on Biological Diversity (CBD).

During the period 1985-2011, Turco *et al.* (2016) reported a broad decreasing trend in the total annual burned area in Mediterranean countries (with the exception of Portugal), due to improved fire management and prevention (or socioeconomic changes leading to more hazardous landscape configurations in the case of Portugal). Recent studies on forest fires in the Mediterranean basin, however, have recognized a shift in fire frequency and size, an extension of the fire season (Koutsias *et al.*, 2015), and indications of a relationship between increased fire activity and climate change (Moreira *et al.*, 2011; Pausas and Fernández-Muñoz, 2012; although see Bedia *et al.*, 2014 for consideration of various sources of uncertainty on this point).

Table 2.12. Effects of climate change on the Mediterranean forest vegetation

Observed effects	Cause	Consequences
Changes in forest plants' growth and health	Increased CO_2 concentrations	• Increased productivity of some species • Increased biomass production of some species: greater number of leaves, higher total leaf area per plant, larger diameter stems and branches • Reduction of growth and health of local vegetation
Changes in vegetation patterns and distribution	Drought, rainfall and extreme weather events	• Influences plant productivity and efficiency of water use • Influences seed production • Habitat and coverage losses • Loss of biodiversity • Forest distribution shifting northward and upward
Changes in plants' phenology	Decreased precipitation and increased average winter temperature	• Decrease in winter chilling requirements for flowering and seed germination • Advancement of flowering date • Increase in the length of growing season • Incomplete winter hardening • Reduction in winter cold/snow damages
Changes in wildfires	Increased dry and warm conditions	• Increased frequency of fire events • Increased forest fire intensity and length • Replacement of forest with fire-prone shrub communities • High risk for native species to fail seed regeneration • High risk of increased invasion by non-native species
Pest outbreaks	Increased winter temperatures and extreme temperature episodes	• Increased frequency and intensity of pest outbreaks • Pest location and range shifts poleward or to higher altitudes

Biological invasions

By comparing selected regions across the mainland (Chytrý *et al.*, 2008) and observing the presence of invasive plants in the Mediterranean (Vilà *et al.*, 2007) we can conclude that forests are among the least invaded habitats in Europe.

Classical forestry investigations (e.g. di Castri, 1990) suggested Mediterranean forests were particularly resistant to plant invasion due to their environmental resilience and changes over recent millennia. Other studies, however, indicate local human-induced disturbances encourage forest invasion by non-native plants (e.g. Martin *et al.*, 2009). Forest disturbances create an environment conducive to invasion by new and non-native species, yet this often takes place over a limited period while high resource availability is maintained (Pino *et al.*, 2013). Other studies have challenged this paradigm, showing that a significant subset of invasive forest species are neither dependent on disturbances nor restricted to early successional life strategies (Gilbert and Lechowicz, 2005). Thus, many foreign plant species have invaded shaded, relatively undisturbed forest undergrowth in both temperate and tropical regions around the world.

Peri-urban forests are particularly vulnerable to invasion by non-native plants due to their presence in landscapes characterized by high levels of human disturbance and propagule pressure[1] (Clotet *et al.*, 2016). The role human activity plays in encouraging foreign plant establishment in peri-urban habitats is

[1] Composite measure of the number of individuals released into a region to which they are not native (Carlton, 1996).

Box 2.11. The 2007 fires in the Peloponnese (Greece)

In 2007 catastrophic wildfires occurred in the Peloponnese, Greece. The most extreme natural disaster in the country's recent recorded history (Koutsias *et al.*, 2012), the fires led to 67 deaths. Part of those fires burned non-fire-prone ecosystems, indicating a departure from recent burning patterns. During the summer of 2007, Greece experienced three extreme heat waves from late June to the end of August and overall, the summer of 2007 was reportedly the warmest the National Observatory of Athens had ever recorded since Greek observations began. The extremely high temperatures, combined with a prolonged dry period, triggered the most extensive and destructive forest fires in Greece's modern history (Founda *et al.*, 2008).

According to the CORINE land-cover categories, areas most affected by fire are those with greater fuel accumulation through the encroachment of natural vegetation in abandoned fields, as well as changing land-use patterns (Koutsias *et al.*, 2012). Increasing levels of humid and sub-humid areas burned clearly relate to weather patterns. The relationship between fuel and weather helps explain unusually large wildfires. This change suggests established fire-systems are being altered by climate change, exacerbated by fuel accumulation. This could result in major ecological consequences, particularly given the lack of specific adaptations in place to cope with fires in non-fire-prone plant communities.

well understood (e.g. González-Moreno *et al.*, 2013). Recent studies in the Barcelona region show that species dispersed by vertebrates and introduced predominantly by horticulture are especially abundant in peri-urban forests (despite the fact that these species do not dominate the invasive species pool).

Previous studies have established that dispersal by vertebrates is an effective mechanism for invasive plant colonization and spread, but estimates of the importance of this dispersal process vary (Buckley *et al.*, 2006). Recent results point to the presence of ecological filters favouring the colonization, establishment and spread of these vertebrate dispersed species in forests (Basnou *et al.*, 2016); yet the composition of these filters is still largely unknown.

Consequences of underlying and direct causes of degradation

Alteration and pollution of water resources

Water scarcity is among the three most important long-term risks worldwide (WEF, 2015). The sustainability of freshwater resources is critical, not only for environmental reasons, but for social and economic sustainability. Several factors are related to the scarcity and quality of freshwater resources: population growth, irrational use of water resources, pollution and climatic and land-use change.

The global population, totalling 7.1 billion in 2012, is expected to grow to 8.3 billion by 2030. Urbanization is anticipated to increase alongside population growth. It is projected that about 60 percent of the world's population will live in urban areas by this time (DESA, 2009). Inequities between total water availability and its distribution throughout the population is a problem for the Mediterranean region, as is the planned use of water resources. Population growth and improved quality of life have increased demand for food, leading to an increase in water used for agricultural purposes. Excessive and uncontrolled use of groundwater is also a major problem. In some areas this has caused groundwater levels to fall between 30 and 60 metres, degrading forests that are in direct need of this resource.

The quality of water resources is rapidly deteriorating due to domestic and industrial wastewater, extreme fertilizers used in agriculture and leachate from pesticides and landfills, mining activities and geothermal activities (Box 2.12). This pollution will pass through hydrological cycles to water resources, soil, forests and vegetation, distorting ecological equilibrium. Mediterranean forests are generally located close to settlements; as a result, untreated solid waste landfills are often established in forest areas. Mining activities, when carried out without taking the necessary precautions, are a serious pollutant, as are the pesticides used to combat forest pests. In some countries, aircrafts use sea water to extinguish forest fires. This salt water, together with waste oil from machines used during forestry activities, can be harmful to forest ecosystems.

Box 2.12. Pollution of freshwater resources in Turkey

According to 2010 Turkish Statistical Institute data (www.turkstat.gov.tr/Start.do), 73 percent of Turkey's total population has access to sewer systems. In 1994, only 10 percent of the population was served by its wastewater treatment plant. By 2010, this number rose to 52 percent. More than 70 percent of Turkey's water resources are used for agriculture, while 20 and 10 percent are used for industrial and domestic purposes respectively. Nearly 90 percent of Turkey's irrigated areas are subject to surface irrigation or other means of release irrigation.

The causes of pollution to Turkey's freshwater resources are as follows (Ministry of Environment and Urbanisation, 2011): untreated or partially purified urban wastewater; leaks from sewage and solid waste piles; mixing of agricultural chemicals and chemical fertilizer residue from soil and irrigation channels with surface water and aquifers; and deforestation and inadequate agricultural practices that accelerate erosion, leading to sediment accumulation in lakes and reservoirs. Industrial wastewater amounts to about 1 percent of the total, but materials such as mercury, lead, chromium and zinc, whose composition have a high toxicity rate, constitute a great threat. The adverse effects of industrial activities are more harmful to the environment than others.

It is projected that Turkey's temperatures will increase between 3-7°C over the period 2090-2100. Warm-weather waves will also increase over the next 30 years. As a result, it is expected that snowfall areas will decrease in the winter months between 2015-2100. This reduced snow cover is expected to change the hydrological cycle of the Euphrates Dicle basin and the Eastern Anatolia Region and Eastern Taurus in particular. It is predicted that gross water potential of certain basins could be reduced by up to 60 percent between 2041 and 2070.

Over the last 25 years, precipitation has decreased in the Mediterranean basin by 20 percent. The future of water resources in catchments should, however, be assessed not only with regard to predicted temperature increases and decreased precipitation, but land-cover changes. Climatic shifts, increasing water consumption, but also encroachment of forest cover due to land abandonment, are drivers of decreasing annual trends and changes in flow regimes detected in the historical records of large catchments in southern Europe (e.g. Dahmani and Meddi, 2009; García-Ruiz *et al.*, 2011).

Land degradation and fragmentation

Land degradation is a generic term referring to a system's reduced productivity and complexity resulting from a combination of physical and anthropogenic factors. Forest fragmentation refers to the process by which forests are divided into smaller, more numerous, more distant or more isolated parts with patchy or uneven edges.

Despite the expansion of total forest area in the Mediterranean over recent decades, various factors and processes contributing to degradation pose a threat to the condition of forests in the region's northern countries. Mediterranean forests face many threats, particularly as a result of the interaction between land-use/land cover change and climate change, as well as changes to disturbance systems. Soil erosion is a major cause of forest degradation, affecting soil structure and related physical processes (e.g. runoff and flood control), organic matter content, carbon cycling, local diversity, local productivity and the resilience of the system. The degrading impact of soil erosion is more serious in Mediterranean forests where soils are thin and poor, particularly in mountain areas following disturbance events (fires, windstorms and pest outbreaks) (De Rigo *et al.*, 2016). Although precipitation in the Mediterranean is lower than in other regions, alternating drought and intense rainfall events increase the risk of severe hydric erosion in Mediterranean forests (De Rigo *et al.*, 2016). Similar processes are expected to take place in eastern and southern regions. Desertification is one possible result of large-scale land degradation in the Mediterranean basin. This is more likely to occur in the southern rim, which is subject to higher rates of current and projected environmental stress. Open cork and holm oak forests in southern Spain and Portugal are examples of Mediterranean forests vulnerable to desertification in the northern rim.

Forests in Europe are generally fragmented; woodland landscapes, which account for 70 percent of the subcontinent, are poorly connected (Estreguil *et al.*, 2013), making them more vulnerable to fragmentation. Fragmentation in Mediterranean forests is expected to follow the same trend as forest cover and forest degradation. Fragmentation statistics in Europe, however, depend on the particular methods and spatial resolution of the data used. Broadly speaking, forest fragmentation may have decreased slightly in recent years, but this trend is not spatially homogeneous across Europe (Saura *et al.*, 2011; Estreguil *et al.*, 2013). Although forest cover is expanding significantly in the Mediterranean's northern rim, there is no evidence defragmentation is following the same trend. Factors contributing to either increased or decreased fragmentation include fires (Box 2.13), agriculture, infrastructure expansion and urban sprawl. Fragmentation is likely to have increased in some countries in the southern Mediterranean due to the decrease in forest area and its relationship to habitat loss.

Box 2.13. Forest fires and soil degradation

Frequent and recurrent fires in Mediterranean forests lead to the destruction of vegetation cover and changes to soil properties, creating a "window of disturbance" during which there are enhanced conditions for surface runoff and soil erosion (Shakesby, 2011). In commercial tree plantations, this is often compounded by post-fire management operations for salvage logging and ground preparation for replanting, which create an even larger disturbance. While erosion rates in Mediterranean burnt forests are normally lower than in Australia or the United States, the underlying forest soils are generally poor (having experienced strong degradation before afforestation), and fires could lead to loss of organic matter and the support capacity for tree roots, furthering the degradation of forest soils. Repeated fires can therefore limit the soil capacity to support regeneration or replanting. Furthermore, this erosion also has an impact on water quality degradation, as ashes exported from burnt areas contain nutrients and toxic substances which can contaminate aquatic ecosystems and, eventually, pose a hazard for human health (Verkaik *et al.*, 2013).

Today, degradation in Mediterranean forests is lower than in areas used for other purposes, such as agriculture and in semi-natural areas. This is expected to remain the case into the future. Forests play a fundamental role in controlling degradation processes such as erosion and preventing desertification. Also, the expansion of forests, including plantations of exotic species in simplified forests, can reduce degradation in many areas where soil quality has been impoverished due to intensive farming or overexploitation. Forests of any kind help to conserve the presence of many species by helping to connect their habitats. The maintenance of forest cover is also essential to the supply of numerous ecosystem services on which populations depend. Maintenance of existing forest areas, in addition to expanding forest cover, is therefore a priority for conserving ecosystems and maintaining population well-being.

Forest dieback and regeneration decline

Even in the Mediterranean region, forest decline is taking place due to the combined effect of warming and drought (Allen *et al.*, 2010). Climate change is emerging as one of the most significant threats to the survival and function of Mediterranean forests (Martínez-Vilalta *et al.*, 2012). Tree species have adopted two primary mechanisms to mitigate the effects of drought: (i) drought avoidance, in which stomata close at a threshold water level to minimize further transpiration and (ii) drought tolerance, in which stomatal closure is less severe and transpiration continues at relatively high levels (McDowell *et al.*, 2008).

Trees adopting the drought tolerant approach can die through cavitation of water columns within the xylem (Gerosa *et al.*, 2009). Continuous stomatal responses through the drought avoidant approach can cause carbon starvation by shutting down photosynthesis while respiration costs continue to deplete carbon stores. Moreover, reduced cellular metabolism limits during drought may constrain the production and translocation of carbohydrates, resins and other secondary metabolites necessary for plant defence against insect attack and the colonization of fungi (McDowell *et al.*, 2008).

The combination of these factors has resulted in several instances of forest decline or dieback of oak, fir, spruce, beech and pine species in Spain, France, Italy and Greece (e.g. Peñuelas *et al.*, 2007; Landmann and Dreyer, 2006; Di Filippo *et al.*, 2010; Tsopelas *et al.*, 2004). Forest dieback has also occurred in the Mediterranean basin's southern rim, having an enormous impact on *Cedrus atlantica* in Algeria (but also other tree species including pine, oak and juniper), and especially in the drier mountains closest to the Sahara (Chenchouni *et al.*, 2008).

Dieback processes not only vary between co-occurring tree species, but will also depend on the genetic tolerance/resistance of individual specimens (Gitlin *et al.*, 2006). Dieback processes may also depend on a tree's age and stand density, characterized by delayed responses by some species. For these reasons, forest dieback is often a non-linear process. This, combined with a lack of quantitative knowledge on the mortality threshold from drought and heat stress for many species (McDowell *et al.*, 2008), significantly reduces the ability to predict rates of forest dieback at a regional and local level.

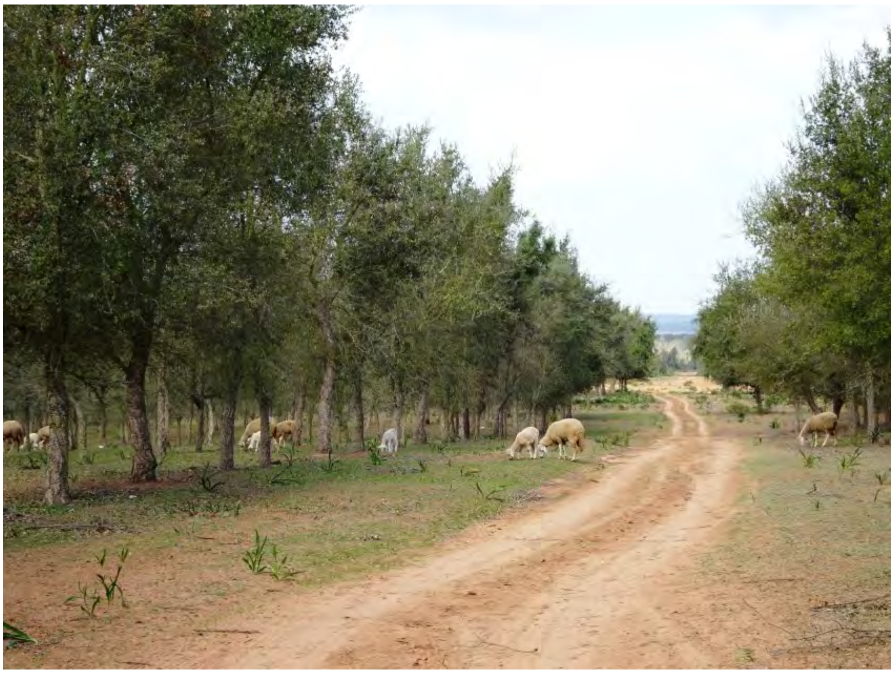

Figure 2.21. Grazing in a cork oak forest in Morocco © Nelly Bourlion

Deforestation and overgrazing

Changes in Mediterranean forest cover due to deforestation and afforestation are considered in Chapter 3, while their causes are explained in the "Cultural and technological factors" section of this Chapter. Overgrazing may also lead to forest degradation. These lands often present ageing tree populations due to a lack of natural regeneration, weakened and injured trees, decreased resilience to forest fires, shifts in the botanical composition of the undergrowth towards unpalatable species and, over the long term, loss of biodiversity (Ajbilou *et al.*, 2006) and even desertification (Le Houérou, 1990). On the other hand, Mediterranean vegetation is well adapted to grazing (Seligman and Perevolotsky, 1994). Sustainably managing forest areas for grazing can contribute to forests' economic value and control biomass accumulation, resulting in a decreased risk of major wildfires (Étienne, 2005).

Similar levels of overgrazing to those observed a few decades ago in many parts of Mediterranean Europe have now been observed in the Maghreb (Box 2.14). Even if overgrazing is still reported in some parts of Europe (e.g. Dano, 2005), the issue today is primarily related to disruptions to traditional agrosilvopastoral systems. In many Mediterranean dehesas, current breeding is characterized by a lack of synchronicity between periods of greater fodder supply provided by vegetation and periods of greater feed demand from animals, leading to the degradation of these systems (Enne *et al.*, 2004). Most often, however, the disruption of former systems has led to land abandonment and ungrazing, resulting in uncontrolled biomass accumulation and increased risks of major wildfires.

The big picture that emerges on grazing in the Mediterranean region is the duality between the region's south and north, both of which result in land degradation (Le Houérou, 1990). Provided that grazing systems are adjusted seasonally, since the availability of food and the demand from animals needs to be synchronized, grazing can be a sustainable management option for Mediterranean forests, with economic benefits and a positive impact on wildfire risk and biodiversity (Figure 2.21).

Box 2.14. Overgrazing diagnosis in Algeria, Lebanon, Morocco, Tunisia and Turkey

Local studies conducted in pilot sites under the auspices of the regional project "Maximize the production of goods and services of Mediterranean forest ecosystems in the context of global changes" identified overgrazing as a driver of forest degradation in all sites but found contrasting grazing dynamics in the Maghreb and Near East (Lefhaili, 2015). In the cork oak Maâmora forest in Morocco, grazing intensity was estimated to be three to four times higher than the load capacity of the ecosystem. This forage deficit (Table 2.13) led to an overexploitation of the fodder resources provided by forests, including tree lopping and the browsing of seedlings and saplings. Very similar deficits were observed in Algeria's Senalba forest, and Barbara district and the cork oak Tabarka Forest in northwestern Tunisia (Table 2.13; Nsibi *et al.*, 2006). By contrast, most of the forage resources in Tunisia's Siliana district were supplied by non-forest rangelands, reducing overall demand for forage in forest areas. In Turkey's Düzlerçamı Forest, grazing intensity largely exceeded the mean grazing capacity of southern Turkey's forest ecosystems (Tolunay *et al.*, 2014).

While overgrazing resulted in forest degradation in all pilot sites, it was not connected to deforestation that was driven by other factors (urbanization, land use change in agricultural lands, or transitory forest management activities). Increased forest cover was observed in Senalba and Siliana as a result of reforestation and land use change from agricultural lands respectively.

Interestingly, prospective overgrazing trends were quite different in the Maghreb and in Turkey. While overgrazing was identified as one of the primary drivers of forest vulnerability to the effects of climate change in Maâmora, Senalba, Siliana and Barbara, grazing pressure was expected to decrease in Düzlerçamı due to low market demand, migration and young people's lack of interest in rural work. Maintaining grazing activities in some areas was even seen as a positive way to prevent forest fires.

Table 2.13. Grazing pressure in different forest sites in Morocco (Maâmora Forest), Algeria (Senalba Forest), Tunisia (Siliana, Barbara and Tabarka forests) and Turkey (Düzlerçamı Forest)

Site	Forest area[a] (ha)	Forage capacity from forest area (× 10^3 FU)	Number of live-stock (SLU)[b]	Total forage demand (× 10^3 FU)	Forage supply by non-forest area[c] (× 10^3 FU)	Forage deficit (× 10^3 FU)	Deficit/ capacity ratio
Maâmora[1]	131 808	40 574[d]	789 330	236 799	51 401	144 825	3.6
Senalba[2]	68 000	24 684	335 700[e]	115 817	0[e]	91 133	3.7
Siliana[3]	65 753	16 438	241 345	87 418	78 368	0	0.0
Barbara[3]	13 526	3 382	76 385	23 605	10 101	13 504	4.0
Tabarka[4]	19 600[f]	6 860	97 635	39 054	0	32 194	4.7
Düzlerçamı[5]	2 472[f]		13 500				

Note: FU = Feed Unit = energy value (in kcal) provided by 1 kg of barley harvested at mature stage. SLU = Small Livestock Unit = number of livestock heads equivalent to the feed requirements of one sheep. [a]Including non-wooded lands within the zone classified as forest (such as fallows, etc.) [b]Considering that 1 head of cattle = 5 SLU. [c]Including external feed complement. [d]Computed using an annual forage productivity ranging between 250 and 350 FU/ha (308 FU/ha on average). [e]An equivalent number of livestock whose feeding depends entirely on grazing in forest areas (Gacemi, 2016). [f]Forest area where grazing is allowed (excluding forest protected areas or where grazing is not allowed).

Source: [1]Data from the 2013 report of the management plan of the Maâmora forest as reported by Lefhaili (2015). [2]Estimates based on 2010-2011 census data as reported by Gacemi (2016). [3]Data from the 2010 national forest and pastoral inventory of Tunisia as reported by Aloui and Tounsi (2015a,b). [4]Data from Nsibi *et al.* (2006). [5]Data from the District Directorate of Forestry of Düzlerçamı, as reported by Musaoğlu *et al.* (2014).

Pest and disease expansion

Even when scientific understanding about the nature of global climatic change was still developing, scientists were directing their attention to the possible effects of climatic change on pests and diseases. Then, as now, the scientific community agreed that climate change would favour forest pest species: while the survival of many arthropods depends on low temperature thresholds, fungi or pathogens benefit from dry conditions (e.g. Jactel *et al.*, 2012). How this general pattern will apply to specific cases is more uncertain. Increased temperatures could be very beneficial for pest populations at the upper altitudinal or latitudinal limits of their geographical distribution, since in this case low temperatures are limiting, but rear limits should also be taken into account, and in these cases could have the opposite effect. Apart from the direct effect of temperature, in Mediterranean systems, increased temperatures usually result in decreased water availability. The uncertain interaction between higher temperatures and reduced water supply makes predictions difficult. Finally, the impact of temperature and precipitation on the "humanized" landscapes of the Mediterranean will influence the manner in which disease could spread.

A good example of the insect pests common to the Mediterranean is the pine processionary moth (Box 2.15). Climatic change is expected to be conducive to the spread of other insect pests in coming years (Battisti, 2005). Many fungus pathogens are illustrative of the threats facing a large portion of Mediterranean forests due to the combination of increasing dry conditions and land use change (e.g. Bergot *et al.*, 2004; Desprez-Loustau *et al.*, 2006).

Box 2.15. The pine processionary moth *Thaumetopoea pityocampa*

As a result of its ecological, economical and medical importance, the pine processionary moth is a well-known species (Battisti, 2005). For this reason, it is frequently used as a case species for forecasting and modelling. The pine processionary moth has moved in altitude (Hódar and Zamora, 2004) and latitude (Robinet *et al.*, 2007) and is a paradigmatic case of sensitivity to global change for three reasons. First, the pine processionary moth larval development takes place during winter, rather than spring-summer, as is usually the case for Lepidoptera. As a consequence, the pine processionary moth is strongly dependent on minimum winter temperatures (Battisti *et al.*, 2015), making it highly responsive to climatic change. Second, the pine processionary moth demonstrate a high capacity for local adaptation, with some populations shifting to a summer cycle in cool areas and tolerating higher temperatures than expected in southern limits (Pimentel *et al.*, 2006). Lastly, the pine processionary moth has taken advantage of the massive afforestation of coniferous (*Pinus*) species in a significant part of its distribution area, creating extremely favourable conditions for the expansion of the species (Battisti *et al.*, 2015).

Biodiversity loss and genetic erosion

Biodiversity loss is one of the greatest environmental concerns facing mankind in the twenty-first century. Human pressure, wildfires and ecosystem fragmentation all have a detrimental effect on global biodiversity, and the Mediterranean region is no exception. Occupied since the Bronze Age, the Mediterranean has been home to many civilizations. This has had an impact on its landscape, forests and trees. In the Greco-Roman age, *Pinus pinea*, *Cupressus sempervivens* and *Castanea sativa* forests were planted throughout the Mediterranean region. These have become characteristic elements of the landscape (Scarascia-Mugnozza *et al.*, 2000).

Despite this significant human impact, the Mediterranean region is a biodiversity hotspot, with high conservation value (Myers *et al.*, 2000). Its many conifer and broadleaf species, widespread throughout central Europe, also present high genetic variability. The role of Mediterranean forests as biodiversity reservoirs has increased over recent decades as a consequence of European Union policies that have designated some forested habitats as a priority for diversity conservation in the Habitat Directive (Donoghue, 2008). Although the rate of biodiversity loss does not appear to be decreasing, it has stabilized in forests (Butchart *et al.*, 2010). Some economic improvements have also been made. Dramatic socioeconomic, environmental and land-use problems, however, remain present.

Conservation of genetic diversity – one form of biodiversity – is a fundamental concern in conservation biology. It provides the raw material for evolutionary change and thus the potential for adaptation to changing environments. The method used to regenerate forests is particularly important for forest genetic resources. The most simple and widespread system of forest regeneration following a clear cut is artificial regeneration (Ratnam *et al.*, 2014), which consists of planting seedlings raised in forest nurseries. By changing native gene pools through the use of introduced seed, this system of regeneration disrupts the continuous evolution of tree populations at a given site, disrupting natural breeding patterns, gene flow and genetic diversity. It can, however, improve site productivity through the selection of superior seed sources.

Artificial regeneration of forests, loss of forested areas and fragmentation all have a detrimental effect on their genetic pool. This can lead to genetic erosion – the loss of genetic diversity within a species caused by human activity. Population reduction and fragmentation result in a loss of gene flow (via pollen and seed) and genetic diversity, the basic element of evolution in a species. Smaller populations may experience genetic drift and inbreeding, which changes the allele frequency from one generation to the next, both creating differences between, and decreasing genetic variability within, populations.

Geographical and temporal degradation trends: facing the challenge

This chapter has sought to emphasize the geographic heterogeneity of the drivers and threats of forest degradation, influenced by differing processes in the Mediterranean's north (land abandonment, forest fires, etc.) and south/east (overgrazing, overexploitation of fuelwood, migration, etc.). These differences are the consequence of contrasting social and economic realities. Although climate change will affect both areas equally, its impact will depend on the particularities of a region's history of land use change. This leads to another important issue regarding the interaction between different causes of climatic change (Doblas-Miranda *et al.*, 2017). Population pressures, combined with fragmentation, climate change, etc., open the door to a series of new and complex reactions and consequences, which are very difficult to predict (Laczko and Aghazarm, 2009).

Increased environmental pressures are anticipated, especially in relation to climate change (temperature warming, drier conditions and, predominantly, extreme events) and derivative consequences in the form of wildfires and biological alterations (invasive species, extinctions and pest expansion), and energy, water and food requirements (IPCC, 2014b). The challenge for researchers is to understand and project new situations, interactions between threats and their effects on forest ecosystems (Doblas-Miranda *et al.*, 2015). At the same time, local and international efforts at the management and policy levels should explore smarter land use management, including regional policies which balance sustainability and development (e.g. Council of the European Union, 2006). Moreover, it is important to develop new value chains which consider and adapt to the known consequences of degradation. These must include not only those favoured by involved enterprises, but also the creation of new societal values with regard to consumption patterns (United Nations, 2015).

Maintaining Mediterranean forests and the services they provide poses an enormous challenge, but it is one we must face through the adoption of higher standards. Subsequent chapters offer potential strategies and solutions to combat the threats described above and help the Mediterranean socio-ecological system to evolve in support of a better and more sustainable future.

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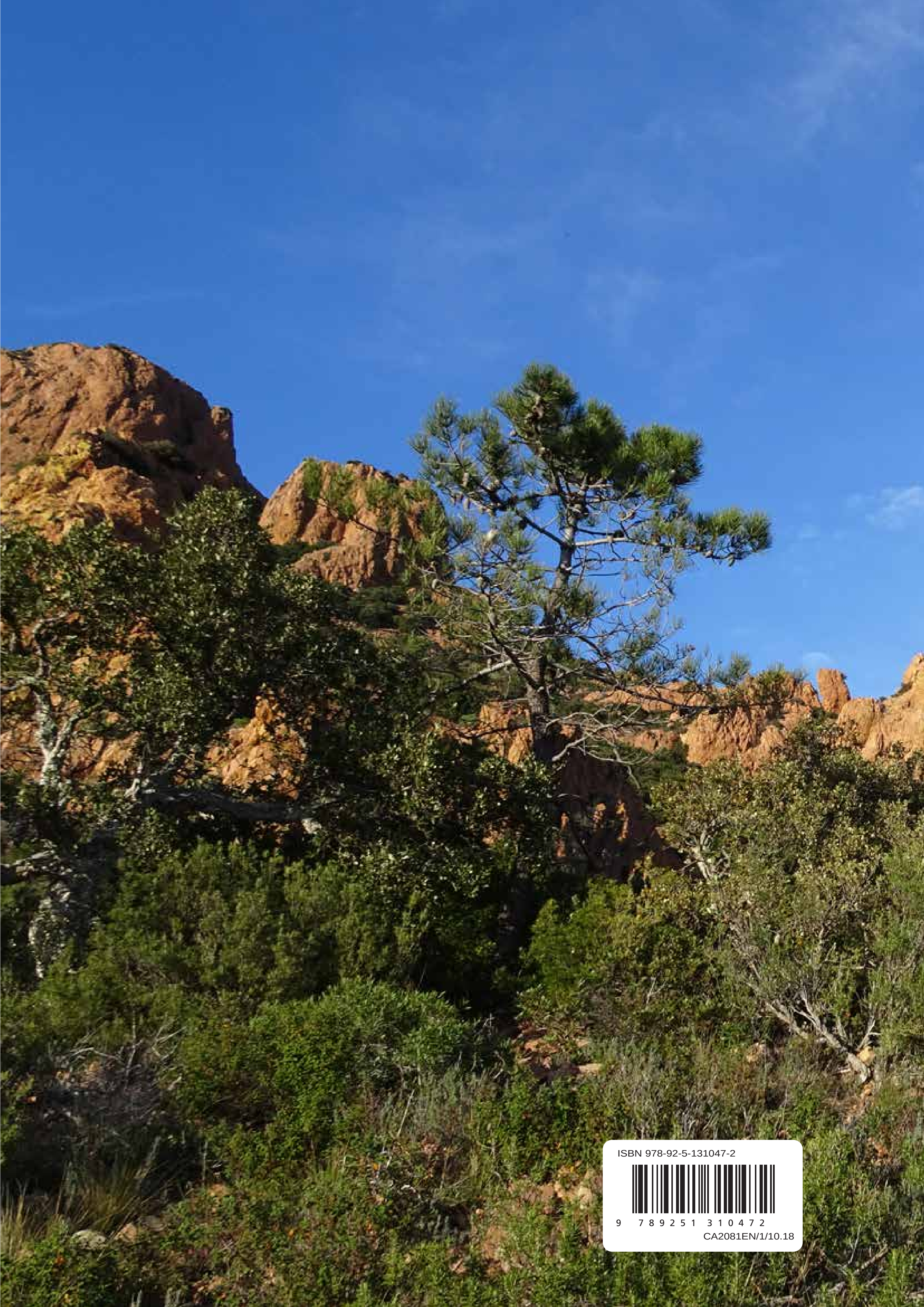

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