MEDITERRANEAN FOREST ECOSYSTEM SERVICES AND THEIR VULNERABILITY

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Mediterranean Forest Ecosystem Services
and their Vulnerability *(Ver 2.0)*

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Preface

To better support the decision-making process in the forestry sector, so to also improve the resilience of integrated ecological and socio-economic systems, it is strategic to assess the impacts of climate change and management strategies on the capacity of forests to provide, both to the environment and to people, goods and functions known as Forest Ecosystem Services (FESs).

This synthesis report investigates existing key FES in the Euro-Mediterranean countries (i.e. countries encompassing the Mediterranean climate zone or biogeographical region), and how they seem currently impacted by climate change and, in some cases, by wrong management and human-related dynamics. Attention is paid to known risk hot spots and to reasons for these risks, by relying on scientific evidence from available literature and/or existing datasets.

The report is one of the Deliverables of the Climate-KIC funded Pathfinder "MADAMES - Mitigation and ADaptation Analysis for Mediterranean Ecosystem Services"[1] with the overall goal of designing a Service, benefiting of the wide and increasing availability of accessible platforms on environmental and climate data (e.g. observations, predictions and projections from the Copernicus Programme), to support stakeholders of the forestry sector (governments, regional or local administrations, private owners, etc.) to make choices and find solutions toward a forest management aimed not only at production, but aware of all aspects related to forest ecosystems, not neglecting feedbacks (synergies and trade-offs) between climate adaptation and mitigation.

Building on the present assessment, MADAMES will tailor the future Service to represent at the best some of the key FESs analyzed and also exploiting, during the design, the information collected for some potential test areas in Italy with climatic and territorial conditions typical of the Northern Mediterranean region (i.e. the Southern Europe countries bordering the Mediterranean basin).

The purpose of this document is merely to provide a comprehensive overview based on available information without claiming to be exhaustive.

[1] http://www.meeo.it/wp/projects/madames/

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1 Introduction

Traditional forest protection and management approaches, which are mainly based on existing and static habitats and ecosystems' functions, may be totally ineffective if they neglect the effects of the changing environmental conditions (Noce et al., 2017; Collalti et al., 2018). This is why, in delineating new and suitable strategies and plans for forest protection and management, it is crucial to consider the vulnerability due to combined climate change, land use transitions and human pressures over forest structure, productivity, resilience and services' provision. Forest ecosystems are in fact highly vulnerable to changes both in the mean climate, impacting the overall long-term productivity and carbon cycle, and in the climate variability, with fluctuations of extreme events that alter the phenological stages, the CO_2 exchanges, and the plants' susceptibility to disturbances and (a)biotic stresses (Lindner et al., 2014).

This is true in particular for the Mediterranean forests[2] in Southern Europe, whose threats are mainly related to climate and management, the latter especially due to general under-exploitation (weak harvest rate) against local spots of over-exploitation (Levers et al., 2014; Vizzarri et al., 2017). For this region, higher and higher temperatures (warming in summer is proceeding 40% faster than for the globe) and changes in rainfall regime (lower precipitation in summer and equal or slightly higher precipitation in winter) are expected in the future (Santini et al., 2018). The overall annual decrease in precipitation (from 2 to 7% in the short- and medium-term, 2025 and 2050 respectively) contrasts the global increase comprised between 1 and 4% (Santini et al., 2018). Future atmospheric CO_2 concentration coupled with rising temperature are expected to stimulate plant growth and carbon sequestration in natural ecosystems as well in short rotation forestry plantations (Calfapietra et al., 2015).

However, most of the climate models project more frequent, prolonged and intense either hot or dry events for the future and, despite the general drop in annual precipitation amount, also more intense rainfall episodes are expected. All that, in case of forests, reflects in reduced regeneration and growth, decrease of leaf life span in evergreen species and increase in length of growing period in deciduous species Kellomaki and Leinonen (2005). Moreover, it was observed and it is expected an increase in fire risk and water stress (Santini et al., 2014) so that, with a reduction of the soil water content, the soil organic matter decomposition rates would decrease (Kellomaki and Leinonen, 2005). Finally, the higher vulnerability of ecosystems (interacting air, plants, water and soil) could exacerbate the damages caused by insects and pathogens (Kellomaki and Leinonen, 2005).

The resilience, health, and stability of forest ecosystems are crucial to a large set of Forest Ecosystem Services (FESs), such as timber and non-timber products, habitats for wildlife, sinks to regulate and mitigate biogeochemical and hydrological cycles, and cultural and historical heritages (Vizzarri et al., 2017). In this context, the present report aims at providing a synthetic overview about the existing key FESs in the Mediterranean area, and about how they seem currently impacted by climate and, in some cases, by land use change, human pressures and/or wrong management. Attention is paid to known risk hot spots and drivers of these risks, by relying on scientific evidence from available literature and/or existing datasets.

[2] In this study "Mediterranean forests" are defined in a strictly geographical sense and include the forests of mountain areas

2 General description of the area

2.1 Environmental characteristics

The Mediterranean region is defined through both biogeographical and climatic classification. All the territories strongly linked with the Mediterranean Sea, in term of climate, geomorphology, culture, history etc. should be included in this region. Favourable climatic conditions in post-glacial age, in particular the mild winters, allowed the proliferation of rich terrestrial and marine biodiversity, key driver for the development of important civilizations (Scarascia-Mugnozza and Oswald, 2000). The socio-economic value of natural resources has been known since ancient times but exploitation and conservation have not always been in sustainable balance. However, the human presence was constant and decidedly heavy, creating varied landscape and very fragmented land cover. In this context, we must also consider the high degree of human conflicts affecting this area since centuries and that have profoundly affected ecosystems and certainly designed the current situation. Quezel (1985) states that the Mediterranean region is one of the most complex and heterogeneous areas of the world from an environmental and biogeographical point of view.

Partially revising the approach of Matteucci et al. (2013), we considered in this work 15 "Euro-Mediterranean" countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, France, Greece, Italy, Macedonia, Malta, Montenegro, Portugal, Slovenia, Spain and Turkey, for a total surface of 2.673 million sq. Km. We have included all countries partially or completely within the Mediterranean biogeographical region (European Environment Agency, EEA[3]) (Figure 1). This area is characterized by an important geological and topographic variability reflected in several mountain ranges, hilly landscapes and a very complex coastline (Matteucci et al., 2013). Altitude ranges from the sea level to the highest peaks of Mont Blanc (France/Italy - 4'808 m above sea level) and Mount Ararat (Turkey - 5'165 m a.s.l.).

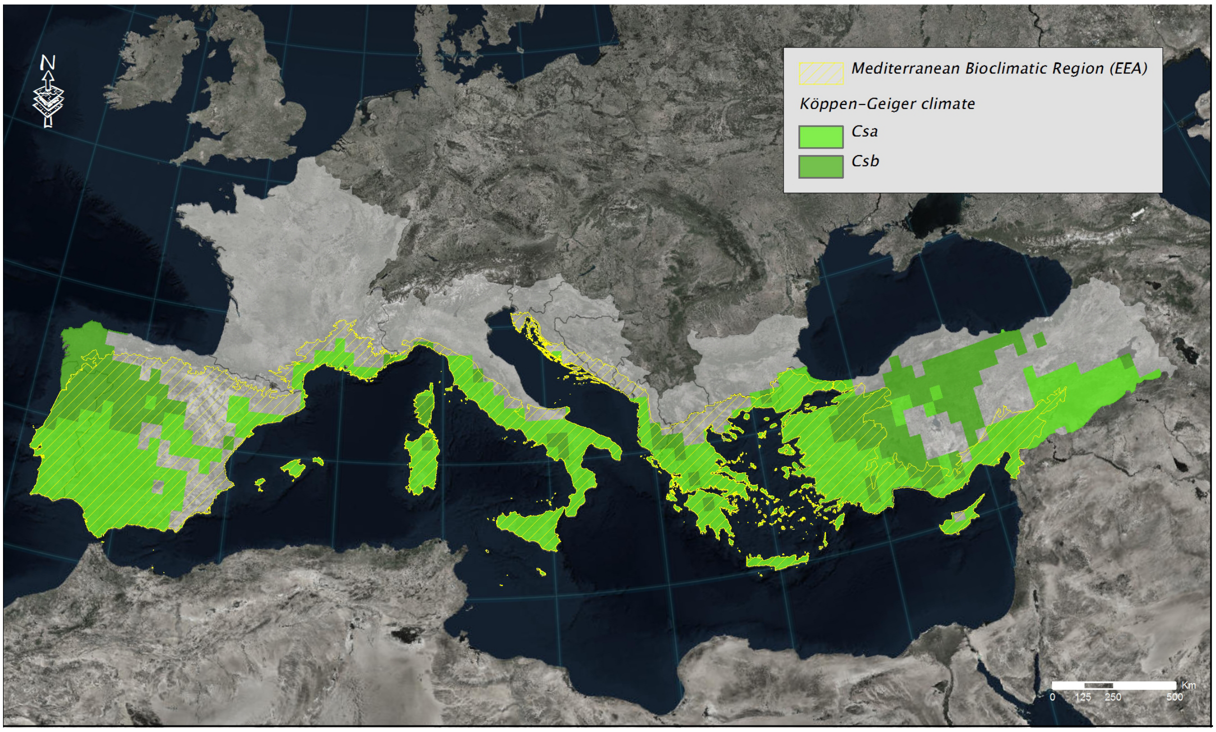

Figure 1: Study area with the 15 countries, the Mediterranean biogeographical region according to European Environment Agency (EEA) and the Mediterranean climate zone under the Köppen-Geiger classification (Csa, Csb)

[3] https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3

2.1.1 Climate

The influence of the Mediterranean Sea on the climatic characteristics of this region is obviously crucial, furthermore the location (halfway between subtropical and mid-latitude) makes the climate variability (i.e. precipitation seasonality) very strong. Moreover, the Mediterranean climate is characterized by significant inter-annual variability (for some authors "climatic infidelity", Lionello et al. (2012)) and, finally, this area is recognized one of the world's hot spots of climate change (Giorgi, 2006; IPCC, 2007b) (see also Sect 2.2).

The geomorphological complexity of the region, due to mountain belts often located in the proximity of the coastline as well as to the presence of gulfs and peninsulas, strongly influences the atmospheric circulation and consequently the regional to local climate. According to the consolidated Köppen-Geiger classification (Kottek et al., 2006) the Mediterranean climate is defined as a mid-latitude temperate one with a dry summer season, which can be either warm or hot (labeled Csa and Csb, respectively, in the Köppen-Geiger classification, Figure 1) (Lionello et al., 2012).

In this area, definitely, the limiting factors for the growth and distribution of vegetation consist in the combination of temperature and rainfall in the summer (June-July-August, JJA) season. In Figure 2 some elaborations from the E-OBS dataset[4] are reported, showing how the precipitation (in particular in summer) is irregularly distributed with considerable differences between the peninsulas (Iberian, Italian, Greek and Anatolian) and the Northernmost continental portion. According to EEA (European Environment Agency, 2012), the Southernmost territories of Spain, Italy and Greece have a moderate risk of desertification mainly due to their frequent water scarcity conditions.

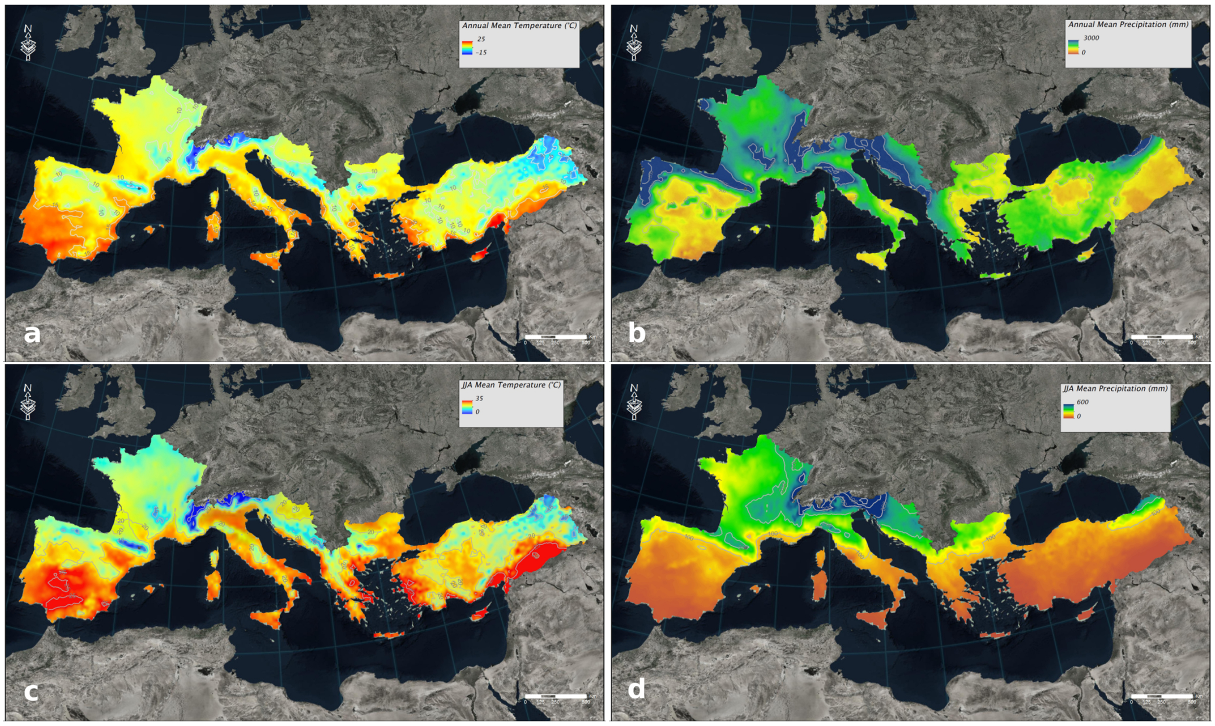

Figure 2: Authors' elaboration from E-OBS v17.0. Annual (a) and Summer (c) Mean Temperature (°C) and Annual (b) and Summer (d) accumulated precipitation (mm) along the 1965-2015 period.

2.1.2 Plant biodiversity

The Mediterranean region is considered one of the most important plant biodiversity hot spots of the world (Figure 3) and is peculiar for a plenty of endemism: 80% of all European

[4] https://www.ecad.eu/download/ensembles/download.php

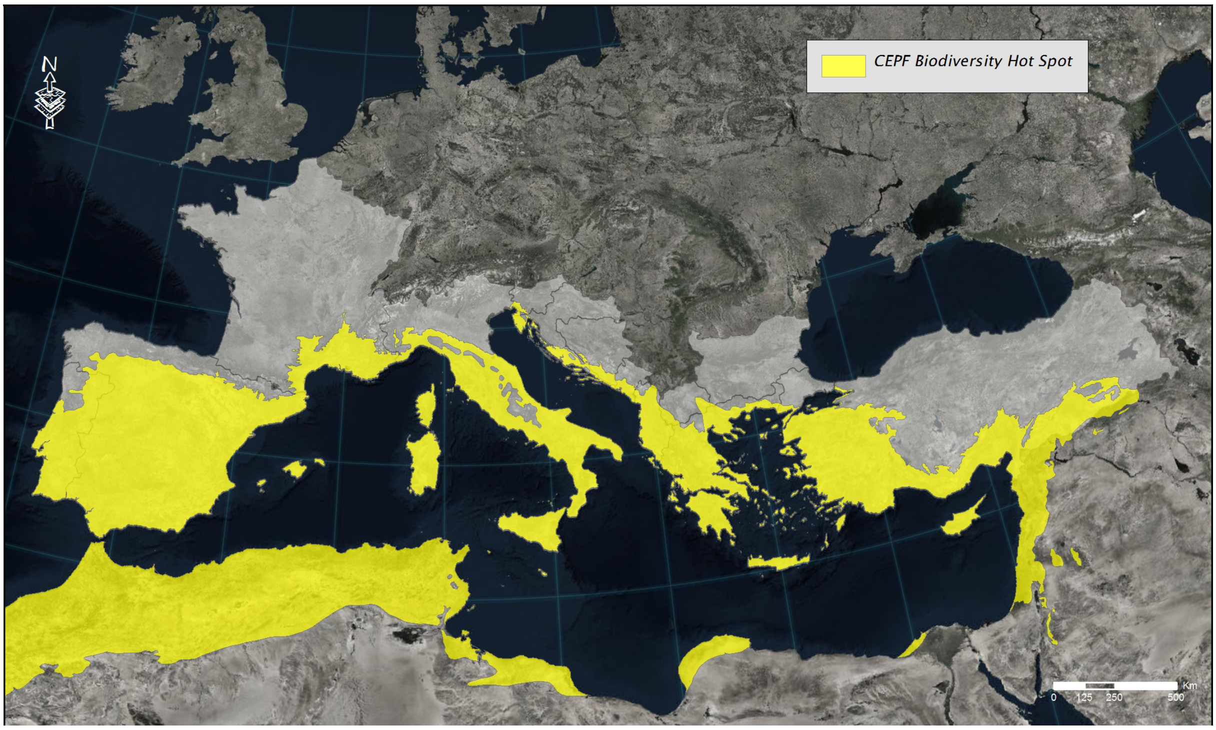

Figure 3: Mediterranean Basin Biodiversity Hot Spot. Source Critical Ecosystem Partnership Fund [5]

plant endemics are Mediterranean. Medail and Quezel (1997) estimate that the whole tropical Africa has the same plant richness (approximately 30'000 species) than the Mediterranean region in a surface area four times larger, and this richness is four time greater with respect to the Northern European region. Practically, what the Mediterranean biome lacks in size is compensated by biodiversity (Cox and Underwood, 2011).

One of the main reasons explaining this abundance is due to the refuge function for the species during the glacial age: the post-glacial colonization of the whole Europe has restarted from the Mediterranean basin, and in particular from its main peninsulas. In Medail and Quezel (1997), in particular, some sub hot spots have been identified function of plant endemism and richness: the Baetic-Rifan complex (Spain), the Maritime and Ligurian Alps (Italy, France), the Southern and Central Greece, Crete (Greece), the Tyrrenian Islands (Italy, France), Anatolia (Turkey) and Cyprus. Subsequent studies in this regard (Médail and Diadema, 2009) found a clear spatial congruence between these regions and glacial refuge areas identified from phylogeographical surveys.

Protected areas in this region, whose creation started at the beginning of the 1900s, reach today a coverage of around 10.1% of the territory[6]. It has been shown that these protection systems are effective enough to protect current biodiversity Noce et al. (2016), but it is certainly necessary to take into account future scenarios of climate change for reshaping them, for designing the new ones and in general for appropriately updating all the environmental protection policies (Noce et al., 2017).

2.2 Main pressures and threats

In addition to being one of the most important global biodiversity hot spots, the Mediterranean region is among the most vulnerable areas under a multitude of pressures and threats. According to the EEA data, approximately one-third of the Mediterranean population is concentrated along coastal zones, and in the Southern portion of the Mediterranean Europe 65%

[5] https://www.cepf.net
[6] www.protectedplanet.net

of the population lives in coastal hydrographic basins, with consequently very strong environmental pressures. The rough amount of 450 million of people inhabiting all the Mediterranean countries increases considerably in summer because of tourism, and recently also due to migration dynamics (European Environment Agency, 2012; Livi Bacci, 2018). Under increasing population density and expanding urban areas, the cause-effect relationships between these dynamics and at-risk plants and animals are evident. Underwood et al. (2009) findings demonstrate that threatened plant and mammal species increased as the size of the urban footprint and population density grew, suggesting the urgency to accelerate conservation strategies.

High population density, heavy concentration of human activities and the fragility of ecosystems are factors predisposing to further degradation of the natural environment leading to desertification. The recent increase of these threats (Skibba, 2016) is undoubtedly linked to the raising human pressure on natural resources combined to a more and more unfavourable climate. Overall, around 30% of farmland and pastures in the Northern Mediterranean are affected by desertification (Zdruli, 2001). In particular Cyprus, Crete, Central-Southern Spain, Southern Italy (especially Sicily and Sardinia) are the territories most at risk of land degradation. This phenomenon is often related to inadequate agricultural practices with consequent soil erosion, loss of organic matter and salinization effects (Santini et al., 2010), so that soils gradually lose their capacity to sustain crop production and other services. Soil degradation processes are accelerated if combined with both climate-related hazards as droughts, floods, forest fires and increasing human exploitation of lands.

It is clear how a crucial threat, also interacting with those above mentioned, is definitely the climate. Projections about the future global climate agree in identifying the Mediterranean area as one of the most vulnerable to change (Sala et al., 2000) among other biogeographical regions of the world. Also, the Mediterranean area is largely recognized as a hot spot of climate change (Giorgi, 2006; Diffenbaugh and Giorgi, 2012), expected to suffer from extreme events (Garcia-Herrera et al., 2014) and from strong negative climate-related impacts over the mid- to long-term (Santini et al., 2014; Saadi et al., 2015). For Mariotti et al. (2015) and Santini et al. (2014) the Mediterranean water cycle is particularly at risk as the 21st Century global climate gets warmer and precipitation patterns are altered in particular across the Southern drier portion of the domain. In these areas many studies predict rising temperature, decreasing summer precipitations and, consequently, increasing summer droughts (Giorgi and Lionello, 2008; Mariotti et al., 2008). In addition, Alessandri et al. (2014) suggest that the typical Mediterranean climate is expected to move Northward under the IPCC-AR5 intermediate emission scenario (namely Representative Concentration Pathway - RCP - 4.5[7]), while in the Southernmost portion more arid conditions could take place (see also Santini and di Paola (2015)). This trend was already clear in the recent decades when the mean annual temperature have increased much more than in the rest of the globe (IPCC, 2013). Analyses conducted by CMCC from the Climate Research Unit observation dataset[8] show that along 1995-2014 the global warming proceeded at 0.026°C/year, while in the Mediterranean Europe it was around 0.042°C/year (Santini et al., 2018).

Concerning extreme events, since the 1960s the mean heat wave intensity, length, and number across the eastern Mediterranean region have increased by a factor of 5 or more (Ulbrich et al., 2012). According to CMCC analyses conducted over projections from the Regional Climate Model (RCM) COSMO-CLM (Bucchignani et al., 2014), the heat and drought hazards will potentially continue to raise in the future (both over mid- and long-term projections) (Figure 4). COSMO-CLM simulations up to 2100 and under intermediate emission scenarios SRES-A1B [9] from IPCC-AR4 highlight a substantial warming of the Mediterranean region combined with a reduction of rainfall in the warm season, while an increase of precipitation over Alpine region is projected in winter (Figure 5) (Bucchignani et al., 2017). These climate impacts affect several basic ecosystem services for humans such as: provisioning (renewable natural resources such as pastures, food, medicines or consumer products such as timber); environmental (biodiversity, conservation of soils and maintenance of water or carbon storage etc.); and social (recreational, educational, tourism) (Peñuelas et al., 2017).

[7] http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html
[8] CRU TS;https://crudata.uea.ac.uk/cru/data/hrg/
[9] http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=3

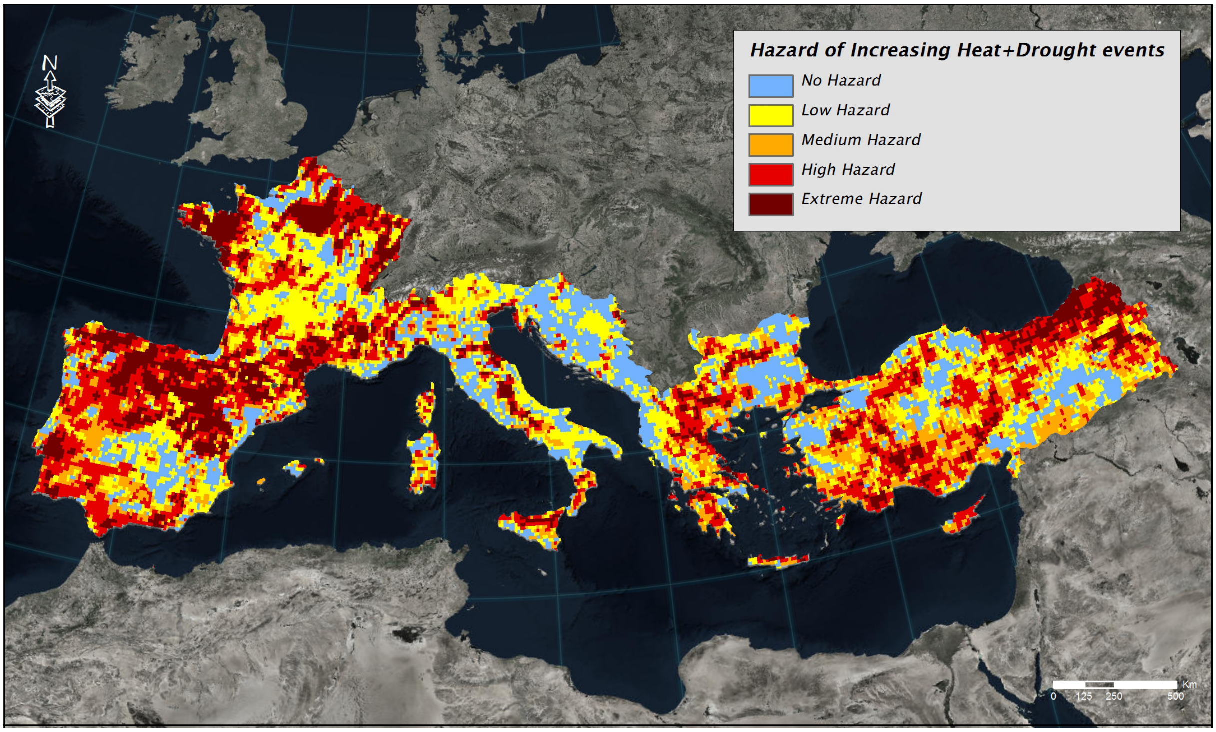

Figure 4: Heat and Droughts increasing hazard, 2030 projections. Source elaborations by authors from Bucchignani et al. (2014)

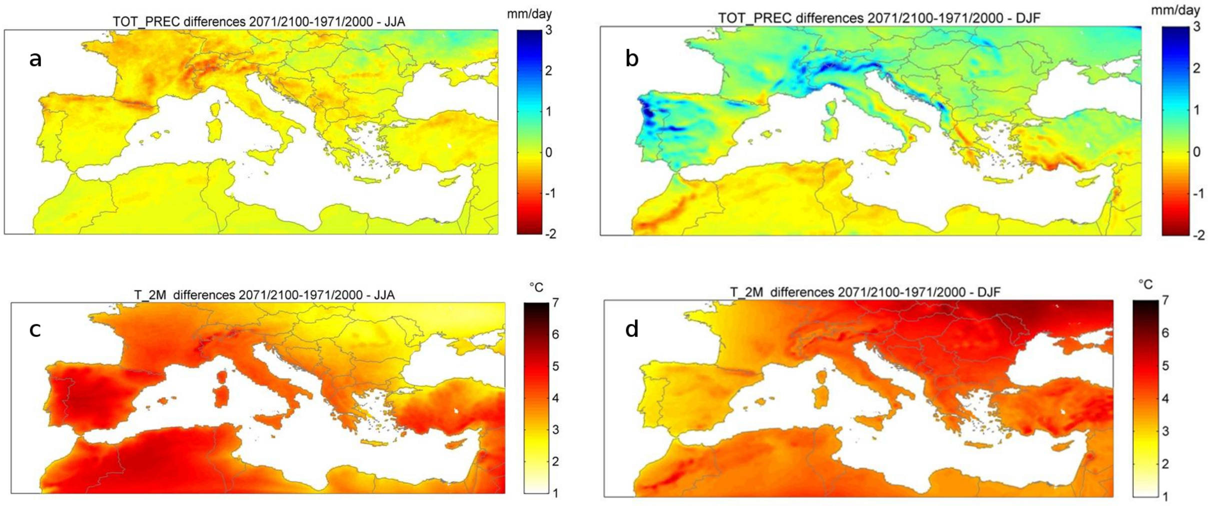

Figure 5: Anomalies in summer (a) and winter (b) precipitation and in summer (c) and winter (d) mean temperature 2071-2100 vs 1971-2000. Source Bucchignani et al. (2017)

Strictly linked to climate is the hazard of fires. Common in many forest ecosystems all over the globe, fires represent a serious environmental issue in Southern and Mediterranean Europe. Forest fires cause severe economic and environmental damages, including the loss of ecosystem services such as carbon sequestration and forest products, increase of runoff generation due to post-fire water repellency of soils (Rulli et al., 2013) and, last but not least, injuries or deaths for humans when burning occurs close to rural-urban interfaces or touristic areas (Modugno et al., 2016), as happened during summer 2018 in Greece[10]. San-Miguel-Ayanz et al. (2013) estimate that an average of about 4'500 sq. km is burned every year across

[10] https://bit.ly/2xBocjR

the Mediterranean region. The countries most affected by this threat (Rulli et al., 2013) are Spain, Portugal, Greece and Italy, secondly France especially in the Southern coastal regions and Corsica. In Figure 6 the European Environment Agency (EEA) and the Joint Research Centre (JRC) maps on the forest fire danger updated to 1981-2010 and based on long-term projections (2071-2100) are shown, suggesting how the fire hazard could be accentuated due to the expected climate regime. This theme gained strategic importance in the last few years within national and European policies so that tools and data platforms, as the Global Wildfire Information System (GWIS) or the European Forest Fire Information System (EFFIS) have been developed to provide daily forecasts on fire danger, to map events in real time and estimate damages caused by recent fires. Also, satellite products as the "Active Fires" and "Burned Areas" maps elaborated from Moderate Resolution Imaging Spectroradiometer (MODIS) sensor are continuously updated.

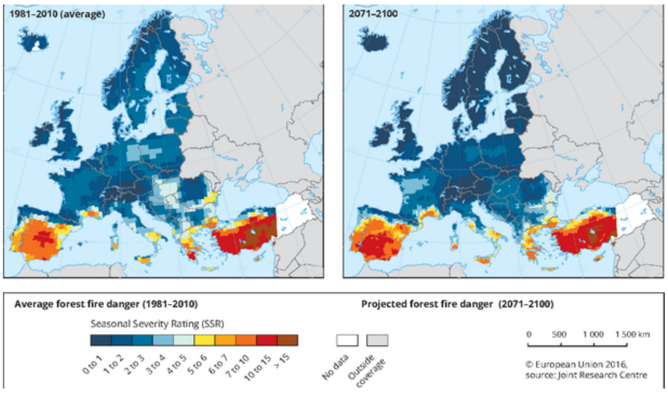

Figure 6: Current (1981-2010) and projected (2071-2100) forest fire danger. Source EEA and JRC[11]

Climate also impact invasive species, defined as "*an organism introduced outside its natural past or present distribution range by human agency, either directly or indirectly...Those alien species which cause negative impacts on biodiversity, socio-economy or human health are considered as invasive*" (CBD, 2002). Hellmann et al. (2008) identified five main nonexclusive effects of climate change on invasive species: altered transport and introduction mechanisms, establishment of new invasive species, altered impact of existing invasive species, altered distribution of existing invasive species, and altered effectiveness of control strategies. In turn, noteworthy is the impact that the invasion of alien species can have on various aspects in this region (biodiversity, ecosystem services, human health, etc.). These species, often, have capacity for growth and colonization far superior than for the native species and, given the vulnerability of the Mediterranean system, it is clear that biological invasions can have widespread effects on biodiversity and in many cases they can cause significant economic losses.

Concerning forests, species as *Ailanthus altissima* (Mill.) (Tree of heaven) and *Robinia pseudoacacia* L. (False acacia) (Enescu and Dănescu, 2013) have been introduced for multiple purposes, creating very dense woods in a very short time and even replacing the original vegetation causing a largely diffuse loss of biodiversity. *Pseudotsuga menziesii* is considered invasive in temperate European regions (Richardson and Rejmánek, 2004) where it has been extensively planted causing extensive negative effects (Schmid et al., 2014). Moreover, Broncano et al. (2005) found evidence of the ability of this conifer to invade montane Mediterranean forests in Spain if management procedures promote canopy opening and soil disturbance.

In Figure 7 the above described and additional important threats affecting Europe are illustrated, showing the fragile conditions of the Mediterranean region.

[11] https://www.eea.europa.eu/data-and-maps/indicators/forest-fire-danger-2/assessment

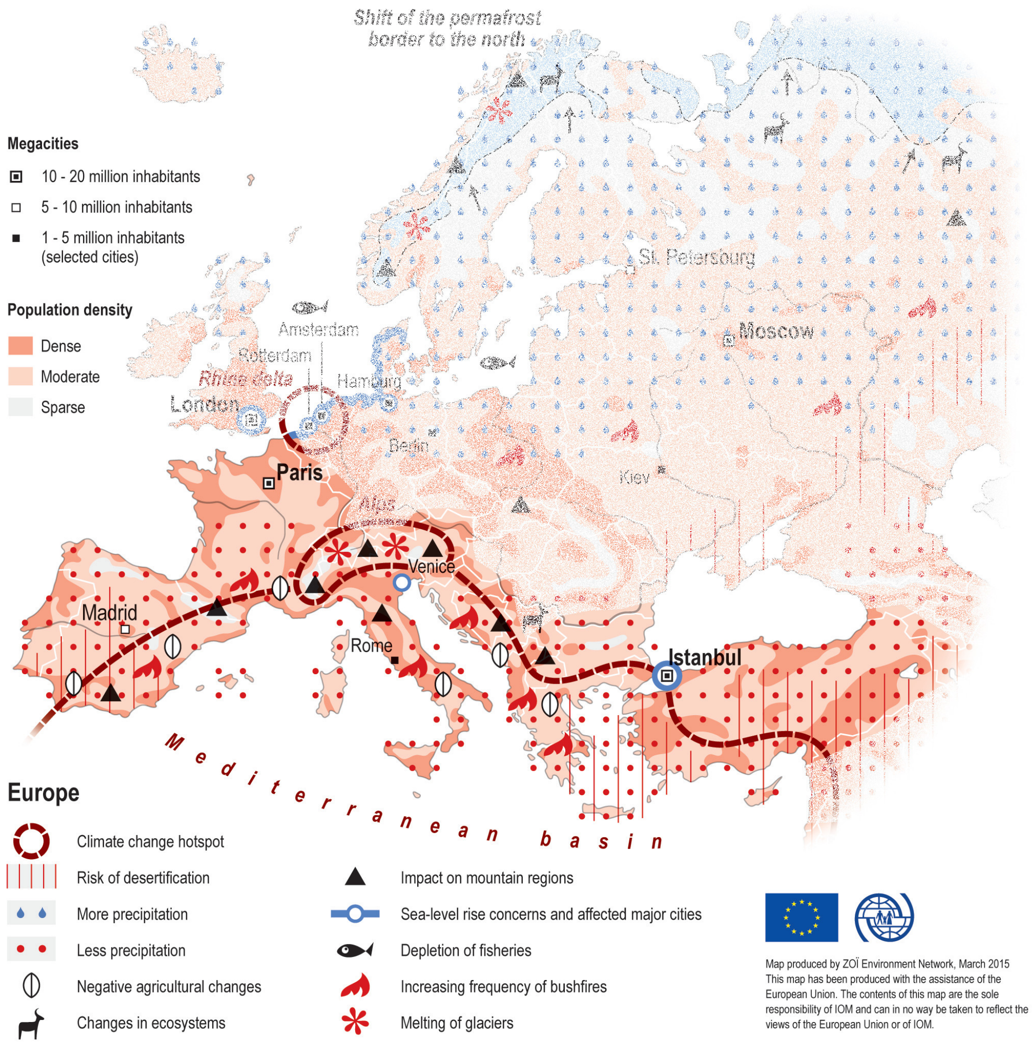

Figure 7: Threats affecting Mediterranean Europe due to climate change. Source European Union[12]

2.3 Mediterranean Forests

Mediterranean forests (Figure 8) have some peculiar traits that make them unique compared to all other types of forests. The human pressure along thousands of years and the climate characteristics of the region have reshaped the forest ecosystems leading to a very high complexity and heterogeneity on a regional and local scale. The heterogeneity is the main aspect differentiating these forests from other temperate ecosystems in Europe and in particular from the boreal ones in Northern Europe (Lefèvre and Fady, 2016). Another feature is the high degree of fragmentation of the wooded areas: as consequence, all the species that are widely distributed around the Mediterranean basin have a fragmented distribution range.

According to the estimates of FAO (2016), in the fifteen countries considered in this study the forested areas amount to approximately 744'000 sq. km, in addition 279'000 sq. km consist of other wooded areas which mostly include shrublands (see Table 1). More than 75%

[12] `http://www.environmentalmigration.iom.int/maps`

of forested areas are located in France, Italy, Spain and Turkey. The percentage of forested and other wooded areas with respect to the total country surface ranges from more than 60% in Montenegro and Slovenia to less than 35% in Albania, France, Italy and approximately 20% in Turkey (Figure 9).

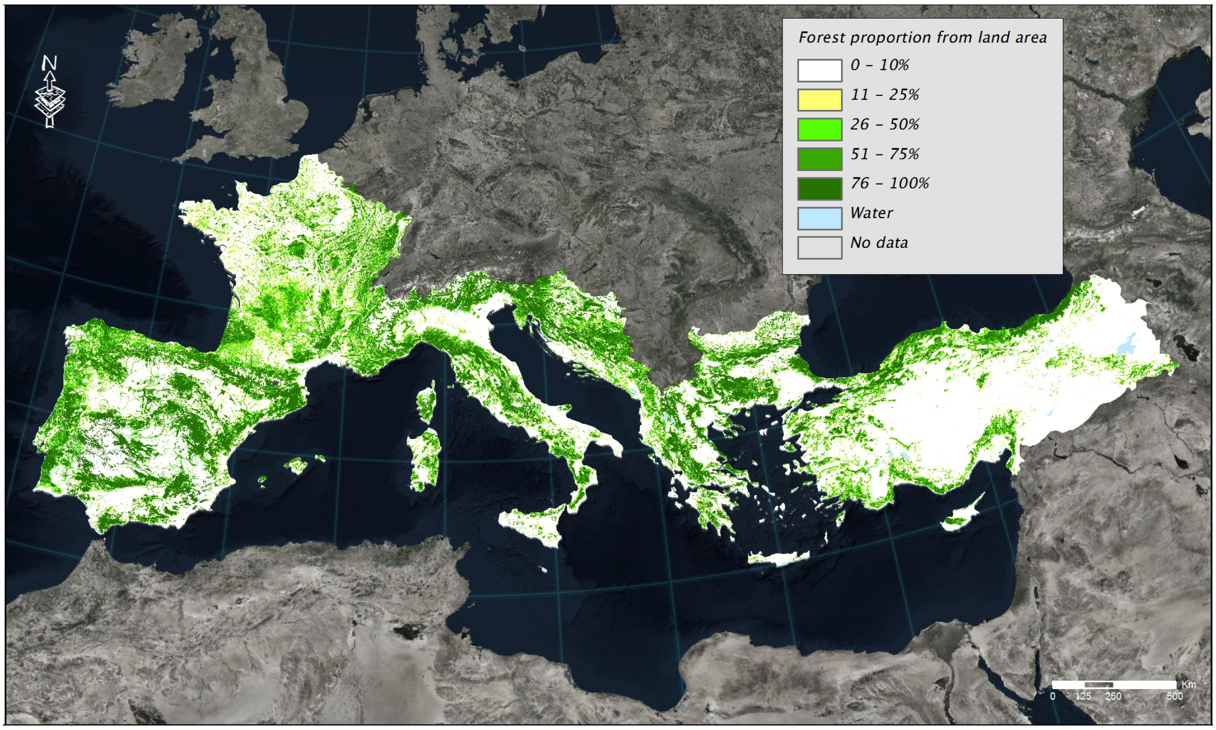

Figure 8: Forest cover map of the Joint Research Centre (Kempeneers et al., 2011)

The typical Mediterranean forests populating the study domain are composed by deciduous and evergreen broad-leaves (see also Noce et al. (2017)). In particular, the *Quercus* genus is surely the most represented with over 20 species: oak woods, due to their very high variability in terms of climatic niche and adaptability, are distributed throughout the area, from the warm Mediterranean maquis with the Holm and Cork oaks (*Quercus ilex* and *Q. suber*) to the mesophilous Sessile and English oaks (*Q. petraea* and *Q. robur*) typical of more temperate ecosystems, without neglecting the very common Downy oak (*Q. pubescens*) and Turkey oaks (*Q. cerris*). Among broad-leaves, Chestnut (*Castanea sativa*) but above all Beech (*Fagus sylvatica*) are principal species populating mountain and sub-mountain areas. These species, together with horn-beams (*Carpinus*, *Ostrya* sp.), maples (*Acer* sp.), alders (*Aluns* sp.), elms (*Ulmus* sp.), ashes (*Fraxinus* sp.), poplars (*Populus* sp.) and many species belonging to the family of *Rosaceae*, contribute to form the typical deciduous mixed forest characterized by a very high forest diversity. Several conifers compose the Mediterranean forests, and noteworthy are many species of *Pinus* as Aleppo (*P. halepensis*), Turkish (*P. brutia*) and maritime (*P. pinaster*) pine in the warmest areas, black (*P. nigra*) and Bosnian (*P. leucodermins*) pine on the mountainous areas, some species of Fir (*Abies*) with in particular the silver fir (*A.alba*), and the Lebanon cedar (*Cedrus libani)* in Turkey and Cyprus.

On the highest mountain ranges (Alps and Pyrenees) forests are characterized by strong boreal influences and coniferous such as Norway spruce (*Picea abies*), Scots pine (*P. sylvestris*), Swiss stone pine (*Pinus cembra*) and European larch (*Larix decidua*) represent the principal species in association with micro-therm trees as birch (*Betula pendula*).

According to FAO (2016), forested areas have increased their surface for approximately 20% in the considered countries along the 1990-2015 period, with an annual rate of +0.8%; in Spain and Montenegro this rate exceeds the +1% per year, being +1.2% and +1.1% respectively. In this changing context the current forest species distribution is constantly evolving and now, also as a consequence of climate change, it is modifying faster and faster. Recent studies

(Zimmermann et al., 2013; Noce et al., 2017) show that, for example, in the medium (2050) and long (2070) term scenarios, the potential distribution ranges of the thermophilous oaks (typical of the Southern side of domain) will expand northwards and a strong reduction of habitat suitability for the more mesophilous species (Sessile and English oaks) is expected, likely due to a predicted increase in temperatures not balanced by an increase in precipitation. Strong reduction of suitability is expected also for Norway spruce, European Fir and Beech in particular in the Atlantic portion of area. Further studies confirm that some shrub species highly resistant to drought could gain a competitive advantage over Holm oak, currently one of the most widespread species (Ogaya et al., 2014).

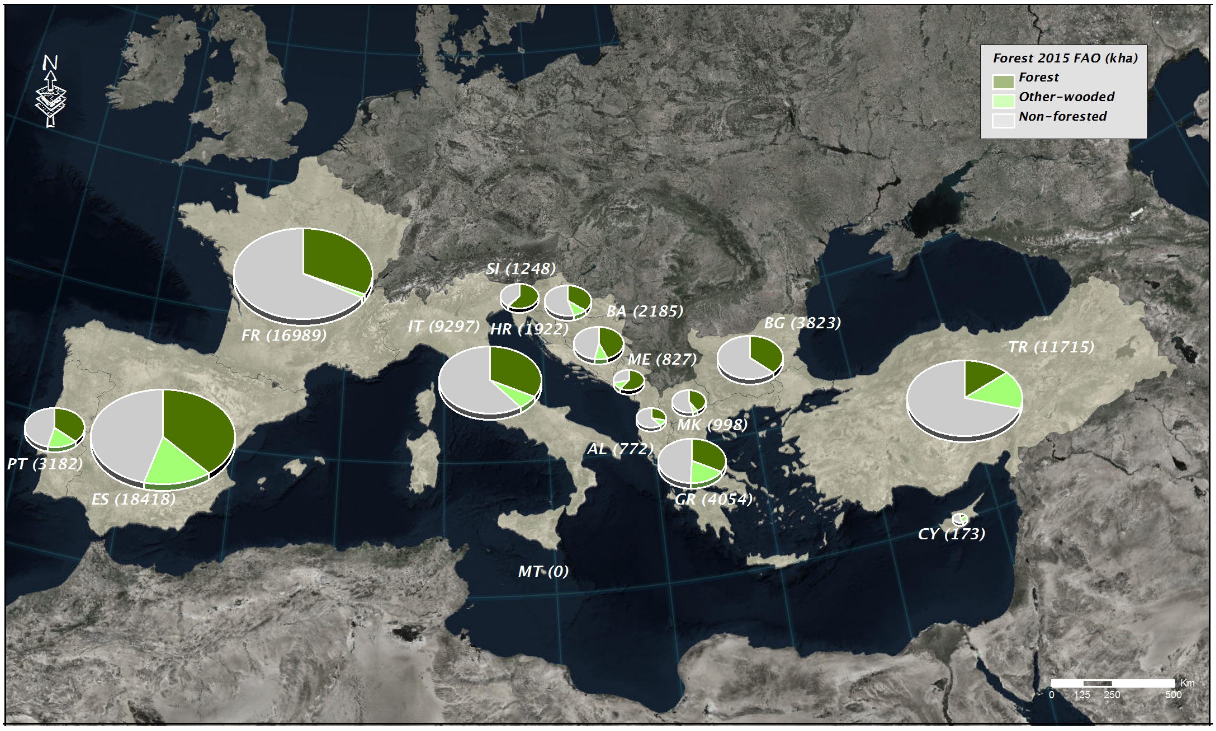

Figure 9: Surface of Forests and Other Wooded Land. Source FAO Global Forest Assessment 2015

In the Mediterranean region, forest areas are privately owned by firms, individuals, or organizations as well as publicly owned by State, communities or municipalities. The information about the ownership of forested areas is of great importance because, as stated in Marchetti (2005), private ownership (in particular at small-scale) can strongly influence the sustainable forest management and in particular implies less financial resources. Considering the whole Europe, 107 million hectares, or 52% of the whole forestland, are in hands of private owners (FOREST EUROPE, 2015) and in the subset of Countries here considered the percentage is similar (51.7% - Table 1), ranging from less than 1% (Turkey) to 97% (Portugal). Small-scale private ownership can lead to closer management and more efficient economic use of the forestry resources due to a greater sense of responsibility assumed by owners (Sizer and Counsell, 2005). In practice, if widespread and well-informed about principles like climate change mitigation and adaptation, renewable energy or biodiversity conservation, the private property can substantially contribute to a sustainable management of forestry resources (Fao and Plan Bleu, 2013). At the same time, fragmented and in some cases (i.e. Portugal and Spain) unknown property (Pulla et al., 2013) can represent a vulnerability aspect.

Table 1: Forest and other wooded areas, with private ownership information updated to 2010. Source FAO (2016)

Country	Forest 2015 (kha)	Private ownership 2010 (%)	Other wooded 2015 (kha)
Albania	772	2.1	256
Bosnia and Herz.	2185	21.4	549
Bulgaria	3823	12.1	22
Croatia	1922	28.3	569
Cyprus	173	31.2	213
France	16989	75.3	590
Greece	4054	22.5	2492
Italy	9297	66.3	1813
Macedonia	998	9.4	143
Malta	r	-	0
Montenegro	827	47.6	137
Portugal	3182	97.0	1725
Slovenia	1248	75.2	23
Spain	18418	70.7	9209
Turkey	11715	0.1	10130
Total	**75603**	**51.7**	**27916**

In this regard, several tools have been developed in the recent decades to promote sustainable forestry, whose Forest Certification is one of the most important. Oriented both to public and private actors, and in the perspective of preserving ecosystem services provided by forest also considering the climate change, certification aims at improving forest practices in environmentally sustainable and socio-economically viable ways complying with a set of principles and criteria (standards) for a correct forest management (Maesano et al., 2018). Numerous forest certification schemes exist, but the Programme for the Endorsement of Forest Certification schemes (PEFC) and the Forest Stewardship Council (FSC) are the most recognized and diffused. These two approaches are profoundly different especially regarding the concepts of forested surfaces. Table 2 shows data (updated to 2014) about the certified forests in the considered Countries: from these numbers it emerges that PEFC plays a predominant role in the investigated countries (in particular in France, Italy and Spain). Undoubtedly, the forest certification still remains a good practice adopted in particular by the Westernmost Countries of the area (Figure 10).

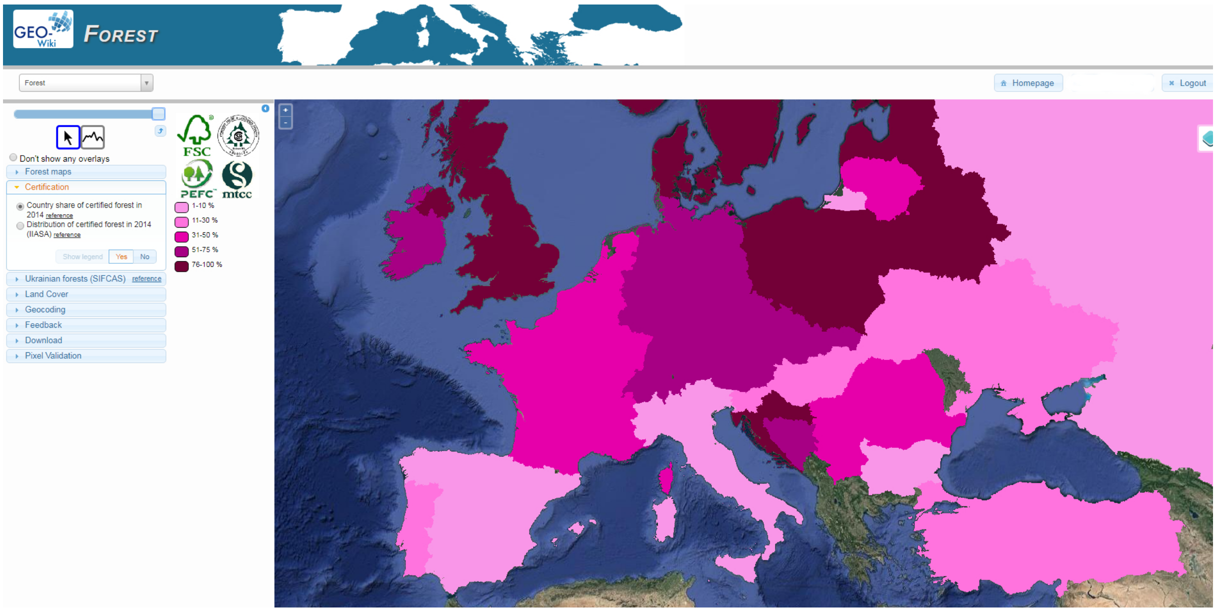

Figure 10: Country share of certified forest in 2014. Source GeoWiki[13]

Even if it is documented that the forested surface was constantly increasing in the last decades (FAO, 2016), many of threats and pressures mentioned in the previous paragraph affect the stability and vitality of forest ecosystems. Increasing forest fires in combination with the rising of summer heat waves and drought events certainly have severe impacts on plant communities and on the capacity of the forest ecosystems to regenerate itself; in some cases this capacity has been irreparably damaged. Excessive grazing and resource overexploitation are also very important destabilizing factors.

Table 2: Certified forest area for each country. Source Maesano et al. (2018)

Country	**FSC (kha)**	**PEFC (kha)**
Albania	na	na
Bosnia and Herz.	1519	0
Bulgaria	410	0
Croatia	2038	0
Cyprus	na	na
France	20	7930
Greece	na	na
Italy	51	778
Macedonia	na	na
Malta	na	na
Montenegro	na	na
Portugal	337	236
Slovenia	250	10
Spain	194	1690
Turkey	2909	0
Total	**7728**	**10644**

It is worth also mentioning the influence that pests and diseases have on the Mediterranean forests health. FAO (2010) estimates that, in 2005, 347 and 591 thousands ha of forest in Italy were affected by insects and disease respectively, while in Portugal insects caused damage in 604 thousands ha of forest. Particularly important is the oak decline, its incidence seems to spread over larger areas in Southern Europe and in particular in Spain and Italy. This phenomenon is due to multiple causes divided in predisposing (i.e. drought, thin soils), triggering (i.e. insect attack) and contributing factors (i.e. rot agents), that occur slowly over several years, even if mortality can suddenly follow the decline (Gentilesca et al., 2017).

The fact that, recently, there has been a strong increase in protected forest areas deserves attention. Protected forests increased for about 500’000 hectares per year across the whole Europe in the fifteen-year period 2000 - 2015, reaching peaks of more than 30% (reference 2015) of forest areas per country under protection. Certainly, some countries are forward in this protection process (i.e. Italy 32.5%, Portugal 22%, Montenegro 20% and Spain 19%), while others still are a step backward (i.e. Bosnia and Herzegovina 2% and Bulgaria 4%) (FOREST EUROPE, 2015).

[13] `https://www.geo-wiki.org/Application/index.php`

3 Key ecosystem services of the Mediterranean Forests

3.1 Overview

Mediterranean forests are typical examples of the multipurpose forest management in terms of production, protection and recreation, and in this sense the concept of Forest Ecosystem Services (FESs), intended as the direct and indirect contributions to human well-being by ecosystems, gained attention (Millenium Ecosystem Assessment, 2010; Aznar-Sánchez et al., 2018). Other authors (Lockie, 2013; Mori et al., 2017; Nichiforel et al., 2018) explain the FES concept as everything that allows to provide environmental services and economic benefits, both strictly commercial traded in the market (i.e. timber, firewood etc.), and non-strictly commercial (i.e. biodiversity conservation, recreational, drinking water etc.).

Three main approaches to classify ESs has been developed: Millenium Ecosystem Assessment (2005) (MEA) groups ESs in *Provisioning*, *Regulating*, *Cultural* and *Supporting* (see Figure 11); The Economics of Ecosystems and Biodiversity (TEEB, 2010) differentiates the services in *Provisioning*, *Regulating*, *Habitat* and *Cultural and Amenity*; and finally the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013) concentrates in *Provisioning*, *Regulation & Maintenance* and *Cultural*. In this work we describe a subset of key Mediterranean FESs according to MEA classification and the related impacts from climate change (Millenium Ecosystem Assessment, 2005; FOREST EUROPE, 2014) as described in Table 3.

Table 3: Key Mediterranean Forest Ecosystem Services (FESs). Source Millenium Ecosystem Assessment (2005) partially modified

Key FES
Provisioning
WFP (Wood Forest Products) and Fuelwood
Non-WFP
Regulating
Water regulation and purification
Soil protection (erosion regulation)
Climate regulation (incl. carbon sequestration)
Biodiversity repository
Cultural
Recreation (incl. ecotourism, cultural, spiritual etc.)
Fishing and Hunting
Supporting
Nutrient cycling and Primary Production

3.2 Provisioning

3.2.1 Wood Forest Products (WFPs)

Today FAO (2010) defines as Wood Forest Products (WFPs) all forestry products referable to roundwood, sawnwood, wood-based panels, wood pulp, paper and paperboard, and fuelwood (or firewood) that, according to FAO (2015b), is the wood removed for energy production purposes (i.e. charcoal, chips, sheets, pellets, sawdust, etc.), regardless whether for industrial, commercial or domestic use. Undoubtedly WFPs are the main *provisioning* services by Mediterranean forests (Fao and Plan Bleu, 2013); the economic value of these FESs is currently superior to any other (Vizzarri et al., 2017) and, above all, it is easily measurable because definitely these are commercial goods.

For example, according to FAO (2010), in 2005 the global wood production amounted to 3.4 billion cubic meters, and estimates for Southern Europe (FOREST EUROPE, 2015) show that from the forestry sector (wood, pulp and paper industry) there was a gross value added of over 22 billion euro in 2010, equal to 0.8% of the total GDP of the area. In the FAO (2016) estimates for 2011, a total of 125 and 48 million cubic meters of wood and fuelwood, respectively, have been removed from the forests within the here addressed countries (with the exclusion of Croatia and Macedonia), with the 44% of total wood and the 56% of total fuelwood removed in France. During the twenty years 1990-2010, in the Mediterranean basin (comprehensive of North Africa) the total wood production slightly decreased (-3%) as the net result of a 7% increase in timber and 10% decrease in fuelwood, and the estimated total value for roundwood

Figure 11: Ecosystem services. Source Wunder and Thorsen (2014)

production in the region reached 9'440 million euro in 2010, 76% of which is industrial timber with an average unit value of 136.28 €/ha, corresponding to 104.17€/ha and 32.11 €/ha for industrial timber and firewood, respectively (Masiero et al., 2016). The rate of forest harvesting intensity in the area is very heterogeneous and, although it reaches the highest levels in South-West France, it remains far from the values found in Northern Europe (i.e. Sweden, Finland) (Levers et al., 2014).

From the climate change mitigation perspective it is also very important to stress that fuel-wood can substitute fossil fuels, and timber products can substitute other more energy- and emissions-intensive materials.

Impacts of climate change Contrasting scientific results can be found concerning the future conditions of forest production. While the still debated CO_2 fertilization effect has the potential to increase primary production of ecosystems (Santini et al., 2014), for Ding et al. (2016) the tree growth is expected to decrease due to increasing drought stress in particular in Mediterranean mountain ranges leading, inevitably, to negative impacts on forest production. European forest lands, according to model projections up to 2100, will be suitable only for a

Mediterranean oak forest type, with low economic returns for forest owners, and will have a strong reduction of suitability for species with high commercial value as Norway spruce, silver fir and sessile oak (Hanewinkel et al., 2013; Noce et al., 2017). This scenario will be even more alarming considering that the Mediterranean area represents the Southernmost portion (and consequently more sensitive to warming conditions) of the distribution range of these species.

Hanewinkel et al. (2013) developed an approach to evaluate the current and future "Land expectation value" (LEV) for the whole Europe: this value (expressed in €/hectare of forest) is a summary of various factors (species, price, quality and quantity of timber). Thus, analyzing the future suitability of some group of timber species (Norway Spruce, Beech, Pines and Oaks of medium productivity and Mediterranean Oaks with very low productivity) they projected the economic effects of climate change over the mid- and long-term under three emission scenarios from the lower emission one (SRES-B2[9]), to the intermediate (SRES-A1B[9]) up to the *fossil-intensive* (SRES-A1FI[9]). Their results (Figure 12) suggest that climate-induced ranges' shifts of major timber species in Europe may reduce the LEV (from 20 to 35% for the long-term time frame with respect to 2010), with consequences for the income to forest owners and the delivery of raw material to the downstream timber industry.

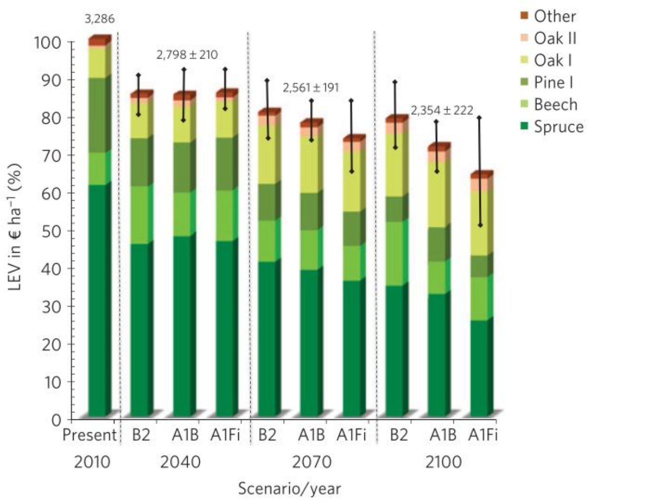

Figure 12: Land expectation value (LEV) projections under different IPCC-AR4 emission scenarios. Oak I are the medium productivity Oaks like Sessile Oak, Oak II are the Med Oaks with very low pr. like Turkey Oak. Source Hanewinkel et al. (2013)

Slightly different were the results of Ding et al. (2010b): these authors confirmed that the productivity of most of the wood products in Mediterranean Europe will be negatively affected by climate change (up to 2050), but for some forest products (i.e. sawnwood and industrial roundwood) they observed some possible positive impacts probably related to a substantial predicted increase of forest area in lower emission scenarios (SRES-B1 and B2). Moreover, an other important aspect to be highlighted is that forest management is crucial to obtain high quality timber, especially under changing climatic conditions (Duncker et al., 2012; Collalti et al., 2018).

3.2.2 Non-Wood Forest Products (NWFPs)

Today According to FAO definition, Non-Wood Forest Products (NWFPs) are all "goods of biological origin other than wood derived from forests, other wooded land and trees outside forests". Belong to these FESs berry harvesting, honey production and all wild products resulting from collection of edible plants, mushrooms etc. or parts thereof, growing naturally in forests or agro-forested areas. Albeit marginal in this region, plant and animal products used for medicinal or cultural purposes are NWFPs. These services contribute to create and consolidate employment in rural areas (Fao and Plan Bleu, 2013), to improve the attractiveness of rural areas for residents and tourists, and to promote the utilization of wood potentialities in order to develop multi-functionality and diversification of farm and forest companies.

Croitoru (2007) identified some major groups of NWFPs in Mediterranean region: cork, fodder, mushrooms, honey and other (berries, medicinal plants, pine nuts, chestnuts etc.). This study also highlighted the insufficient knowledge about the importance and the value of these services at the beginning of the 2000s: nowadays, their high potential to build up the economic exchanges of rural economies particularly in regions where wood is not the most valuable for-

est product appears still not fully explored. Masiero et al. (2016) estimate that the total value of NWFPs in Mediterranean countries was in 2010 almost the 8% of the total value of forest products and services with an average unit value of 12€/ha. Thus, NWFPs can be considered as a great opportunity to be explored and developed.
Croitoru (2007), probably not by chance, identified as first NWFP the cork. APCOR (2018) estimates that in the main producer countries (Spain, Portugal and secondarily France and Italy) the annual cork production is about 172 ktons on a surface of approx 1'441 kha. France and Portugal in 2016 have exported cork for a total of 1'189 million euros (over 80% of the total world value). Fodder for grazing is another important service provide by forests in particular in Eastern countries (Albania, Greece and Turkey). Furthermore, collection of wild mushrooms contributes to a variety of ecosystem services in the Mediterranean Basin: it represents an important food source and may be regarded as a key NWFP (Karavani et al., 2018). In conclusion, although less important, honey (especially in Slovenia, Cyprus and Greece) and other NWFPs like pine nuts deserve a mention.

Impacts of climate change Scientific literature still lacks of wide and consolidated information about the impacts of climate change on the NWFPs. Even if Cork oak is a highly adapted species to warm temperatures and droughts, in Fao and Plan Bleu (2013) it is highlighted that some climate models predict a fragmentation of the potential distribution range in the Southernmost areas (i.e. Andalusia) and at the same time a Northward shift, and moreover Costa et al. (2016) demonstrate that prolonged droughts events (expected to increase on the mid- and long-term) are currently causing strong decreases of cork growth in Portugal. Regarding mushrooms collection, a recent study (Karavani et al., 2018) conducted in Iberian Peninsula over the 2008-2015 period stated that there is no negative ongoing effect on productivity, but rather the opposite (predicted median productivity of marketed mushrooms for 2016–2100 was 23–93% higher), maybe due to an elongation of the fruiting season arising from the combined effect of increased precipitation at the beginning of the season and warmer temperatures at the end.

3.3 Regulating

3.3.1 Water regulation and purification

Today According to Brauman (2015) "*water is often discussed as a provisioning service, presumably because people generally experience water as coming from a watershed. However, ecosystems do not create water but move and modify flows, so research and management may be better served by considering terrestrial water-related services to be regulating services*". Water-related services are generally indicated as hydrological services, i.e. a subset of ESs. FAO (2018) states that forests are integral part of the water cycle, thus understanding the impacts of forest management on water resources is necessary to delineate effective measures for a more sustainable both forest and water management. However, hydrological services provided by forests still remain undervalued due to their complexity, and an important review work on their economic value (Ojea and martin Ortega, 2015) clearly stated that definitions and classifications about these services are nowadays highly inconsistent.

The regulation of water quantity and quality is among the most important FESs in many regions around the world. In the Mediterranean area, forests plays a crucial role in the mitigation of hydrogeological hazards, in the regulation of groundwater recharge and in the purification of water (Fao and Plan Bleu, 2013). Forests and forest soils can minimize flood and landslide hazards by contrasting both the strength of rainfall when reaching the soil, through intermediary canopy interception, and the speed of runoff when routed downstream and converted into river discharge. Forest tree roots stabilize ridges, hills and mountain slopes and help preventing movements of land mass, in fact landslides occur less often in densely forested areas, all other territorial factors being equal.

At the same time, forest floor/soils, formed by highly porous, loose, semi-decomposed organic material, can favour good infiltration conditions for precipitation water. This is relevant not only for groundwater recharge by purified water, but also for soil water storage and the mitigation of surface flow. Moreover, forest ecosystem structure is important for snow storage, which can support the prolongation of the snow ablation period, contributing again e.g. to a more controlled surface flow, more balanced groundwater recharge, and lower avalanche hazards.

Any transformation of forest cover leads to alterations in drinking water supply and purification, flood control, landslide exposure, regulation of streamflow as well as provision of recreational opportunities from forest resources and water bodies (e.g. Holmes et al. (2017)). For Ellison et al. (2017), the loss of tree cover and/or the conversion in other land use alter surface water availability, infiltration and water storage capacity of soil, and groundwater recharge.

According to the Millenium Ecosystem Assessment (2005), over 75% of the world's accessible freshwater comes from forested watersheds. These water resources are important also in the production of energy, especially hydropower from (usually forested) mountain catchments and valleys. Then, forested watersheds regulate the quality and abundance of freshwater in rivers, lake and wetlands, and consequently sustain the well being and biodiversity of aquatic and terrestrial species.

The above described ability to intercept precipitation, regulate infiltration and reduce runoff is an important service (e.g. Wunder and Jellersmark Thorsen (2014)) especially over steep slopes of mountains prone to flash floods or to instabilities as rock-fall, landslides or snow avalanches. These hazards implies costs due to damages for infrastructures or productive croplands, residential property, environment and human health, or costs associated with sedimentation or wood debris deposition/floating in rivers and lakes, increasing siltation and obstruction processes and decreasing the quality and operation efficiency for the multipurpose (drinking water, irrigation, hydropower) reservoirs.

Impacts of climate change More information is needed about the forest-water relationships for different ecosystems and at different scales (spatial and temporal) in the face of climate change. A recent study (Peñuelas et al., 2017) clearly stated that the decrease in precipitation and increase in evapotranspiration due to raising temperature, reasonably, could decrease the movement of blue water from the forests to downstream ecosystems in the Mediterranean region. This reduction trend has already been found in some European rivers of Southern and Eastern sub-region (Stahl et al., 2010) and it could amplify in the future Schneider et al. (2013). All that will turn groundwater into the main source of freshwater for the society. However, with the expected reduction of rainfall amount and of the antecedent soil moisture due to climate change, the deep percolation and aquifer recharge will also decrease. The vegetation can thus play a more important role, with forest adaptive management (e.g. thinning) having the potential to increase the blue water by reducing interception (Vicente-Serrano et al., 2014). Similarly, adaptive management of headwater forests (e.g. planting pine forests) can help increasing the groundwater recharge (Garcia-Prats et al., 2016). In high alpine watersheds, rising temperatures will bring less snow accumulation and/or earlier snow-melt (Barnett et al., 2005), thus limiting summer water supply, when water is more needed. In case of forestland conversion in the upstream area of freshwater bodies, decline in flow could lead to disappearing of native aquatic species (Otero et al., 2011).

3.3.2 Soil protection (erosion regulation)

Today The principal driving forces of soil erosion are rain splash and overland water flow (for water erosion) and wind speed (for wind erosion). Vegetated, and in particular forested areas, are strategic for reducing the erosive impact of precipitation and wind, and in regulating the role of other environmental predisposing or accelerating factors that determine the soil erodibility (e.g. slope, dryness). Forests, and their complex system with herbs, shrubs and trees contribute considerably in reducing the rate of erosion by: protecting the soil from the impact of raindrop, wind, sun; inhibiting the overland surface flow; and blinding soil over hillslopes thanks to their root systems, guaranteeing a better soil structure and humidity thus preventing drying and cracking.

Furthermore, while tree cover and forest conditions deteriorate, soil and water quality also worsen due to increased erosion, degradation and missed purification processes (see above paragraph). Thus adopting good forest management, restoration and conservation practices with a view to sustainability can help improving the efficiency of soil protection, especially in areas at high risk of land degradation and desertification.

In particular, Mediterranean soils on hard bedrock are generally thin (few tens of cm), have sandy or silty texture with a high rock fragment contents and in most cases they are located on very steep slopes. All factors that determine a strong vulnerability to erosion. Such soils occupy more than 60% of the Northern Mediterranean territory, particularly in mountainous areas (FAO, 2018). Furthermore, several studies suggest a significant positive and rapid feedback between plant cover and soil properties linked to fertility (water-storing capacity, permeability, nutrient availability, depth) (Gallardo et al., 2000; Castaldi et al., 2009; Sardans and Peñuelas, 2013). In the last 50 years, land use transitions in the Mediterranean area have been very considerable, in particular the forest cover has changed very much, both in terms of surface extent, continuity and characteristics, and this has had unavoidably impacts on the capacity to control soil erosion. A general trend of reduction of forested surface caused an acceleration of soil erosion by water with cascading consequences as land and environmental degradation (Jones et al., 2012; Anaya-Romero et al., 2016).

Impacts of climate change It is not easy to estimate the effects of current and future climate change on the soil protection service by forests, as direct and indirect relationships can be considered. For example, while the link between climate change and erosion is unclear and uncertain, and mostly related to the change in the annual amount, frequency and intensity of rainfall events, the influence of climate change on the forest health and production is evident because the reduction of canopy cover or wood biomass will have serious effects on the vulnerability to erosion. Alteration of tree cover has necessarily consequences on the soil erodibility in terms of accumulation of the nutrients due to lower organic matter inputs; this, in addition to increasing photodegradation of litter and the soil exposure to atmospheric agents (rainfall erosivity), induces reduction in soil fertility, structure and overall stability (Barnes et al., 2012). The increasing frequency and intensity of droughts alters the ability of plants to accumulate nutrients in the biomass, along with the decrease in soil mineralization, favouring the accumulation of nutrients in the soil and consequently in the downstream flowing water. The study of Peñuelas et al. (2017) evidences a trend toward the reduction of aboveground cover and the accumulation of recalcitrant nutrient compounds in soil, suggesting a potential increase in nutrient losses related to a higher frequency and intensity of torrential rains.

Another indirect effect of climate change on the forest soil protection service could be the fact that the predicted increasing frequency of forest fires can increase successive soil predisposition to erosion due to enhanced hydrophobicity (Certini, 2005; Rulli et al., 2013) and reduced plant regeneration (Delitti et al., 2005), and this could accelerate desertification processes in already dry areas. In Anaya-Romero et al. (2015) it is stated that climate change projections suggest increasing soil erosion rates due to decreasing yearly amount and increasing intensity of rainfall (less rain but more concentrated over time) and to changes (reduction or degradation) in the canopy cover and biomass.

3.3.3 Climate regulation (including carbon sequestration)

Today Nowadays it is well known that forests and forest management have significant feedbacks with climate (IPCC, 2007a), and this climate regulating FES is crucial and more complex than the simple carbon storage.

Forests play a very important function in influencing the climate at local, regional and continental scales, interacting with the atmosphere through biophysical processes linked to evapotranspiration, albedo and roughness. The scientific community recognizes these climate-cooling effects of forests in the tropical and to some extent in the temperate regions; these effects will become strategic for all climate change mitigation and adaptation policies in addition to the consideration of the carbon sequestration potential (Perugini et al., 2017).

From a biogeochemical processes point of view, forests were officially recognized in the last decade by United Nations Framework Convention on Climate Change (UNFCCC) (e.g. REDD+ programme) of interest for the policy in order to stabilize Greenhouse Gas (GHG) emissions and thus for combating (*mitigating*) climate change. Trees, during photosynthesis and growth, absorb CO_2 (Carbon dioxide) from the atmosphere, storing it as carbon in leaves, trunks, branches and roots. In addition, the carbon stored in forest soils has to be considered. Nabuurs et al. (2018) stated that within European Union the current annual mitigation effect (capturing CO_2) amounts to 569 $MtCO_2$/yr representing the 13% of the total EU greenhouse gas emissions.

However, as well stated by *The Guardian* in February 2011, *"... the most important thing about forests is not that they reduce the amount of CO_2, but that they are huge reservoirs of stored carbon. If such a forest is burned or cleared then much of that carbon is released back into the atmosphere, adding to atmospheric CO_2 levels"*. If the land use is converted from forest to other vegetation or land use types, the carbon stored in the soil and in the vegetation biomass decreases significantly and is transferred to other ecosystem components.

For this FES, and in particular for carbon sequestration, several studies provide information about the forest carbon budget (Nolè et al., 2015) and the economic value (Ding et al., 2010a; Anaya-Romero et al., 2016; Lefèvre and Fady, 2016). Moreover, Vizzarri et al. (2017) implemented and tested in a large area of Southern Italy a new approach to evaluate ecosystem services in economic terms (in particular timber production and social cost of carbon) comparing the effects of some forest management strategies (wood production oriented, nature conservation and business-as-usual). For these authors, the total ecosystem services value (expressed in euros per hectare) increases sensibly from business-as-usual scenario (1128 €/ha, of which 421 €/ha estimated as Social Cost of Carbon - SCC) when a more conservative forest management is applied (up to 1894 €/ha, 1540 €/ha SCC).

Impacts of climate change If, as Lefèvre and Fady (2016) clearly state, only healthy forests play a role in carbon sequestration both in the current and future time, it is likely that this FES is highly vulnerable under climate change. Only with an appropriate management it is possible to preserve this FES from the negative impacts of climate change so that Mediterranean forests can give an important contribution to the regional carbon cycle (Collalti et al., 2018). They are actually a net sink and they are projected to continue to be so (Schröter et al., 2005) but, if disturbed, or bad managed, they can easily become a carbon source. However, the expected rise in extreme events magnitude and frequency (heat waves, droughts) could decrease the carbon sequestration potential (Ciais et al., 2005).

To give some examples of processes already under way, in the work of Peñuelas et al. (2017) it is demonstrated that the drought intensification is strongly affecting the mineralization of organic matter in Mediterranean soils, which is critical because soils are the main carbon sinks and a decrease in the absorption of CO_2 in prolonged dry periods is probable. At the same time, the evolution of these processes on a medium- and long-term are not fully clear. In the Fekete et al. (2017) analyses on oak stands (Sessile and Turkey) there are evidences of a strong reduction of biomass stored in the 1971-2014 period concomitantly with a significant decrease in precipitation and an increase in average annual temperatures. Broad-scale forest mortality events due to drought and heat with consequent loss of biomass stored in Spain, Italy, Greece and France are well documented in Allen et al. (2010).

3.3.4 Biodiversity repository

Today Among the various services provided by the Mediterranean forests, the maintenance of biodiversity and habitat supply for native flora and fauna are certainly among the most important. This FES reveals even more its vulnerability to climate change impacts if we consider, as previously described, that the forests living in the study domain are at the same time integral part and guardians of a very high biodiversity, significantly superior to many other ecosystems of the world. Due to their structural complexity, Mediterranean forests provide a lot of habitats for numerous plant and animal species and a refuge for large carnivores (top of the trophic chain). Moreover, the function performed by forests in the biodiversity conservation can be considered a *cross-service*: for example, as well described in Bredhal Jacobsen et al. (2014), biodiversity *supports* decomposition, it is itself a *cultural* value because it acts as a tourist attractive, it *regulates* the water and carbon cycle as a whole and it *provides* variety of products (such as timber).

Noteworthy, in the Mediterranean region and in particular in Bosnia and Herzegovina and Bulgaria, the primary forests are still present. According to FAO (2015a), these are naturally regenerated forests of native species with no clearly visible indication of human activities, and ecological process are not significantly disturbed. Furthermore, although very few and fragmented they play a unique role in terms of biodiversity conservation, ecological functioning and provisioning of ecosystem services (Sabatini et al., 2018).

For centuries, the management and exploitation of forests in this area did not take biodiversity into account, but in the last decades this function has started to have an economic value as well. In fact, recently, the markets have begun to put pressure on forest managers to conduct a careful management for the preservation of biodiversity (Bengtsson et al., 2000).

In this context, the European Union (EU) Biodiversity Strategy, launched in 2011, aims at halting the loss of biodiversity and ecosystem services in the EU, reflecting the commitments taken by the same EU in 2010, within the International Convention on Biological Diversity. Furthermore, in the EU Forest Strategy is emphasized the concept of multifunctionality.

Impacts of climate change Similarly to carbon sequestration and biomass, increasing drought in this area is causing a decrease of species diversity, as documented since the beginning of the 2000s (Walther et al., 2002) and projected by using climate models (Thuiller et al., 2005). Furthermore, the mortality due to heat waves and droughts, while causing a loss of forest biomass, also determines a sharp reduction in the amount of litter, consequently leading to a decrease of both biomass and diversity of the soil biota.

In Noce et al. (2017), mid- and long-term projections (up to 2070) show a potential widespread loss of forest diversity throughout Southern Europe with the exception of Alpine areas. These findings, however, do not take into consideration the possible substitution of native species by alien invasive species. These species are partially still replacing local ones and, as said previously, they negatively affect the cover of natural vegetation and change the species compositions reducing local species diversity (Benesperi et al., 2012; Lazzaro et al., 2014; Peñuelas et al., 2017).

In addition, if the increase in desertification risk is taken for granted in many areas of the Mediterranean, it is therefore reasonable to foresee a strong loss of plant biodiversity during land degradation processes.

3.4 Cultural

3.4.1 Recreation (including ecotourism, cultural, spiritual)

Today In a region where tourism is of crucial importance, the most relevant cultural services provided by Mediterranean forests are the recreational, educational and leisure uses, opportunities for research, the traditional values and the aesthetics of pleasant landscapes, which give rise to economic activities such as tourism and hiking (ecotourism) (Bonan, 2008; Gios and Clauser, 2009). For FAO (2018) forests "*ensure healthy lives and promote well-being for all at all ages*". With the increasing demand for recreational activities and tourism, these FESs become more and more important (Palahi et al., 2008; Wiersum et al., 2018). These services are not traded in markets and no market price is directly available from national or international databases but, through specific non-market valuation approaches, it is possible to estimate the externalities of these FESs (Bellù et al., 1997; Ding et al., 2016).

Impacts of climate change Ding et al. (2016) findings show that climate change could have positive effects in terms of economic value per hectare in the future (around year 2050) on the marginal recreational values of Mediterranean forests under all the emission scenarios but in particular under the intermediate ones (SRES-B1/B2). However, if an increase in fire regimes (frequency) is projected, this may result in changes in dominating ecosystem type towards shrub-dominated landscapes with potential negative impacts on recreational functions (Matteucci et al., 2013). Moreover, the recreational value of forest landscapes can be strongly diminished by disturbance events since dead trees (i.e. due to fires, droughts or pests) are frequently perceived as less scenic than live stands and can also create hazards for tourists (Seidl et al., 2016).

3.4.2 Fishing and hunting

Today Fishing and hunting are not always included in the *Cultural* macro class of FESs. Some authors insert them within NWFPs (Croitoru, 2007; Paletto et al., 2015), others in the *Provisioning* class in general (Martín-López et al., 2012). Based also on the indication in Millennium Ecosystem Assessment (2003), fishing and hunting are here considered cultural services linked to a *provisioning* service: this because in the Mediterranean forests these activities are mainly carried out on a small or very small scale, mostly by private individuals for recreational purposes (Martínez-Jauregui et al., 2016). It should however be stressed that, unlike other *cultural* services, these FESs provide tangible goods with a commercial value that can be traded on the markets. In this regard Croitoru (2007) estimated that in this region hunting generally ranges within 1-6% of the total economic value of the forests (approx. 4-8€/ha). Fishing at the rivers or lakes belonging to forested watersheds is a predominantly sporting activity.

Impacts of climate change Climate change, having impacts on forest ecosystems, undoubtedly also affects these services. Climate change has impacts on the demography, spatial ranges and phenology of the animal species causing shifts in the timing of life stage or of migration (Kovach et al., 2016; Socolar et al., 2017). Moreover changes in forest structure and composition can modify the habitat suitable for many hunted species (Ratcliffe et al., 2017). Warming waters, shorter winters, longer droughts, invasive species and shifting vegetation have been identified by United States National Wildlife Federation as dangerous elements for hunting and fishing heritage[14]: it is reasonable to think that they are also an hazard in the Mediterranean region.

3.5 Supporting

3.5.1 Nutrient cycling

Today This FES is strictly related to the others (in particular to the carbon sequestration), but considered separately as, according to FAO (2018), forests have the potential (mostly undervalued) to enhance agricultural production through supporting the nutrient circulation. This function can be considered as a crucial biogeochemical process in maintaining the conditions for life on Earth because large quantities of nutrients are retained in both living and dead (in particular deadwood) organic material and subsequently made available for terrestrial and marine organisms (Bastrup-Birk et al., 2016). In these terms it is shown that different types of forest resource management correspond to different levels of nutrient losses in the ecosystem (Wunder and Thorsen, 2014).

Impacts of climate change Increasing drought events can correspond to a decrease of total ecosystem nutrient content and to changes in the allocation of nutrients from leaves to roots and consequently from plants to soils (Sardans and Peñuelas, 2013; Peñuelas et al., 2017). Field studies simulating climate change have found decreases in the contents and concentrations of macro- and micro-nutrients in Mediterranean forests (Sardans and Peñuelas, 2007). Another synthesis work (Peñuelas, 2018) states that the reduction of the capacity to retain nutrients by vegetation is accompanied by an increase in nutrient contents due to a decrease in the enzymatic capacity and mineralization of soil. This, with the projected increase of torrential rainfalls, introduces uncertain changes in soil fertility as well as in nutrient cycle and fluxes.

[14] http://blog.nwf.org/2015/11/game-changers-climate-impacts-to-americas-hunting-and-fishing-heritage/

4 Conclusions: needs and way forwards

Mediterranean forests suffer from numerous threats due to climate and wrong management (i.e. scattered over- and under-exploitation). All that, influencing vegetation growth, health, productivity and diversity, determines the quantity and quality of Forest Ecosystem Services (FESs). In this report, the main FESs, as well as pressures and drivers of their vulnerability with special focus on climate change, are analyzed for the Euro-Mediterranean countries. Several FESs are considered, ranging from provisioning (wood and non-wood products) to regulating (of water, soil and climate dynamics), cultural (tourism, sports) and supporting (nutrient cycling) services.

Due to the complex processes and interactions among plants, soil, water and air, it is evident how the FESs are strictly interconnected one another and are first of all function of the evolving forest conditions within the surrounding landscape. Thus, improving the capacity and making available tools for forest status monitoring, early warning, predictions (months to years onwards) and projections (decades to century onwards) can contribute to increase the awareness about the likely future reliability and resilience of FESs.

In this context, while monitoring and early warning can be facilitated by measurements via near real-time both *in-situ* and remote sensing technologies, medium-term predictions to long-term projections of climate variables, either translated into biological/ecological indicators or fed into empirical to process-based Forest Ecosystem Models (FEMs), allow knowing in advance the likely evolution of forest habitats and conditions. Concerning indicators, these are focus of extensive literature and many initiatives are ongoing to produce those proxies of climate anomalies and extreme events' indices (e.g. WorldClim[15], ETCCDI[16], ECAD[17]) that can be used to identify more or less suitable territories for specific ecosystems, as well as if in these areas the environmental conditions can ensure vigorous - or determine weakening - forests stands. Concerning empirical to process-based FEMs, they allow more detailed reproduction of within-ecosystem processes, at plant to stand level, to simulate how not only climate but also management can influence ecosystem dynamics like changes in productivity and/or in the carbon sequestration/sink potential, from which more robust assumptions about the fate of cascading FESs can be formulated.

By regulating the energy and water exchanges between air, plants and soil, climate variables are crucial inputs to FEMs. Such variables can derive from observations (meteorological station networks), modelling (of the global atmospheric-ocean circulation, Earth system, regional climate) and/or reanalysis (modelling forced by observations). All these data are usually accessible at the producing Centres, or collected and made available through Data Portals of international coordinated experiments, initiatives and Programmes, as in case of information currently populating the Copernicus Climate Data Store (CDS[18]). Two main requirements must be considered to effectively exploit these data: i) they need a varying complexity and customized post-processing according to the coarse or fine spatio-temporal resolution for either indicators or models' application; and ii) ensemble approaches are highly valuable to take into account the uncertainty of predictions and projections, due e.g. to different emission scenarios, climate model physics, resolution, initialization.

Under the above premises, the MADAMES project aims at evaluating the feasibility of a Service supporting the forestry sector and related stakeholders and decision makers. It is expected that the Service will be based on a FEM able to reproduce - under current to future climate conditions and alternative management options - biomass growth, carbon and water cycles within Mediterranean forests. The FEM will be driven by last-generation and updated climate data ensemble as those available on the Copernicus (or similar) CDSs. Moreover, the Service will implement the proper chain of post-processing steps for bias-correcting and/or downscaling climate data to be used as direct input of the FEM that, simulating forest growth and productivity, has the potential to provide significant information about FESs. Finally, not only climate variables but also other ancillary information (e.g. topography, hydrography) or

[15]http://www.worldclim.org/
[16]https://www.wcrp-climate.org/data-etccdi
[17]https://www.ecad.eu/indicesextremes/
[18]https://climate.copernicus.eu/climate-data-store

land monitoring data (satellite-based land cover and vegetation indices) can derive from the same Copernicus Programme or other multi-thematic Data Portals, with the final aim of including the Service in innovative platforms of Services as the Copernicus Data and Information Access Services (DIAS[19]).

Thanks to a preliminary Service design, MADAMES wants to identify those basic characteristics and functions able to represent at the best some of the key FESs analyzed, with focus on those related to WFPs and climate/water regulation. Such a Service's tailoring process will also rely on the information collected for three potential test areas (managed forests and parks) in Italy with climatic and territorial conditions typical of the Northern Mediterranean region: from the Northernmost boundaries of the Mediterranean climate zone (Emilia Romagna region) to the Central Italy (Tuscany region) to the usually drier South (Basilicata region).

At the end, MADAMES can provide a stimulating contribution in the context of both adaptation and mitigation actions. The adaptation component is due to the fact that the Service conceived for exploiting climate data into the forest ecosystem modelling will allow to anticipate the knowledge about the potential climate impacts on forests, and about how these impacts can be reduced or avoided, and the forest resilience increased, thanks to appropriate single or combined management options, i.e. those expected having the best performances under the most likely scenario(s), or having good performances under as many scenarios as possible. Mitigation is related to the fact that any adaptive management option under the new climate regime will be evaluated also in terms of its potential to maintain and maximize obtainable FESs, first of all biomass production, CO_2 uptake and carbon sequestration/storage, to foster the sustainability of the forestry sector for the economy, the environment and the climate.

[19] http://copernicus.eu/news/upcoming-copernicus-data-and-information-access-services-dias

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