3 Importance of Mediterranean forests

Pablo Martín-Ortega, *UPM*
Nicolas Picard, *FAO*
Luis G. García-Montero, *UPM*
Sara del Río, *ULE*
Ángel Penas, *ULE*
Marco Marchetti, *UNIMOL*
Bruno Lasserre, *UNIMOL*
Eray Özdemir, *Ministry of Forestry and Water Affairs of Turkey*
Fernando García-Robredo, *UPM*
Cristina Pascual, *UPM*
Carlos Calderón-Guerrero, *UPM*
Iciar Alberdi, *INIA*
Isabel Cañellas, *INIA*
Silvia Guerrero, *INIA*
Laura Hernández, *INIA*
María Martínez-Jauregui, *INIA*
Alfonso San Miguel, *UPM*
Roberto Vallejo, *MAPAMA*
Nicole Sibelet, *CIRAD*
Salvador Rivas-Martínez, *CIF*

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This chapter aims to demonstrate the importance of Mediterranean forests with regard to forest resources. It will review different definitions of the "Mediterranean region," compiling forest statistics from Mediterranean countries (with regional aggregates) found in the Global Forest Resources Assessment of FAO. Many Mediterranean countries undertake national forest inventories (NFI) including regular monitoring. Theoretically, these country-level statistics could be extrapolated to the regional level. However, the lack of consistency between NFIs across countries makes it difficult to get a consistent regional picture, and using the results of regional studies such as the FAO's Global Dryland Assessment may still be a preferable means of establishing an overall regional picture of the extent of forest cover.

This chapter provides a snapshot of the state of Mediterranean forests in terms of area, growing stock, carbon stock and land use. It will predominantly base its analysis on the FAO definition of forests in Mediterranean countries, but other definitions will be included. The different figures obtained provide a complementary snapshot of Mediterranean forests captured from different angles.

The extent of the Mediterranean region

Even if a common definition of the core circum-Mediterranean Sea region existed, it is likely the precise extent of the region would differ depending on the emphasis placed on geographical, climatic, ecological or political factors.

All of these factors are relevant in the case of forests. A purely political (e.g. the number of countries containing a Mediterranean coastline) or geographical definition (e.g. the water catchment of the Mediterranean Sea) would exclude large areas with a Mediterranean bioclimate (e.g. Portugal, based on the two definitions given above). Conversely, such definitions could include large areas that do not have a Mediterranean bioclimate (e.g. most French territory, based on a political definition, or a large part of the Alps, based on a water catchment definition).

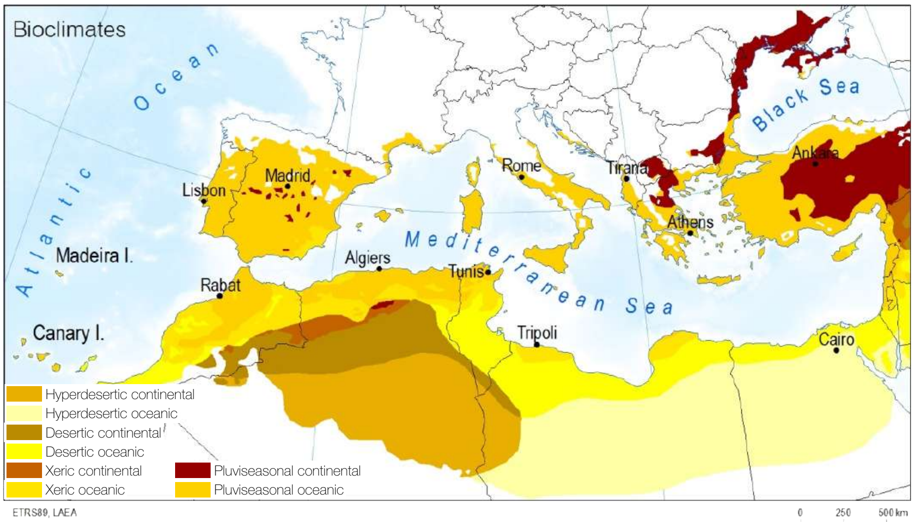

Figure 2.2. Mediterranean bioclimates in the area of study
Source: Rivas-Martínez *et al.* (2011).

Biogeography combines disciplines such as biology, climatology, ecology, edafology, evolution and geology to explain the distribution of animal and plant species. Biogeographic approaches to the definition of the Mediterranean region have mostly been based on factors such as vegetation, landform, soil and especially climate variables (i.e. bioclimatic) that influence vegetation growth and survival (FAO, 1999).

Two definitions of the Mediterranean region are based exclusively on bioclimatic variables. The region is characterized by a climate consisting of mild, rainy winters and hot, dry summers, and vegetation typified by forests, woodlands and scrubs. Again, the exact parameters of these definitions will depend on how climatic and biotic criteria are applied (Quézel, 1982). On the other hand, altitude and soil type have been less central to biogeographic approaches (Table 2.2). Among early attempts to delimit the Mediterranean bioclimate, Emberger's diagram using the mean minimum temperatures of the coldest month (m, in °C) in abscissa and the bioclimatic coefficient $Q = 2000P/(M^2 - m^2)$ (where P is the annual rainfall in mm, M the mean maximum temperatures of the hottest month in K, and m in K) has been a fruitful approach (Daget, 1977). Inspired by this approach, the UNESCO and FAO (1963) bioclimatic map of the Mediterranean region was based on a classification of ombrothermic diagrams and a xerothermic index (i.e. the index of hot weather drought).

Subsequent global applications of these bioclimatic approaches involved a larger set of bioclimatic variables and multivariate statistical analyses such as cluster analysis. Rivas-Martínez *et al.* (2011) designed a detailed bioclimatic classification system based on an extensive set of bioclimatic variables. This system classifies the world into five macrobioclimates, including a Mediterranean macrobioclimate divided into eight bioclimates.

The Mediterranean macrobioclimate is one of the largest typological units of the Rivas-Martínez *et al.* (2011) bioclimatic classification system. This macrobioclimate applies to all extra tropical regions of the Earth at any altitude and with any continentality value belonging to the subtropical and eutemperate zones (23° to 52°N & S), in which there are at least two consecutive arid months during the warmest part of the year, in which the value in millimetres of the average rainfall of the hottest two months of the summer quarter Ps_2 is less than twice the average temperature of the hottest two months of the summer quarter Ts_2 expressed in degrees centigrade ($Ps_2 < 2Ts_2$).

The Mediterranean macrobioclimate is composed of eight bioclimates: hyperdesertic-oceanic (26.8 percent), pluviseasonal-oceanic (24.9 percent), hyperdesertic-continental (12.9 percent), desertic-oceanic (11.8 percent), pluviseasonal-continental (8.12 percent), desertic-continental (6.96

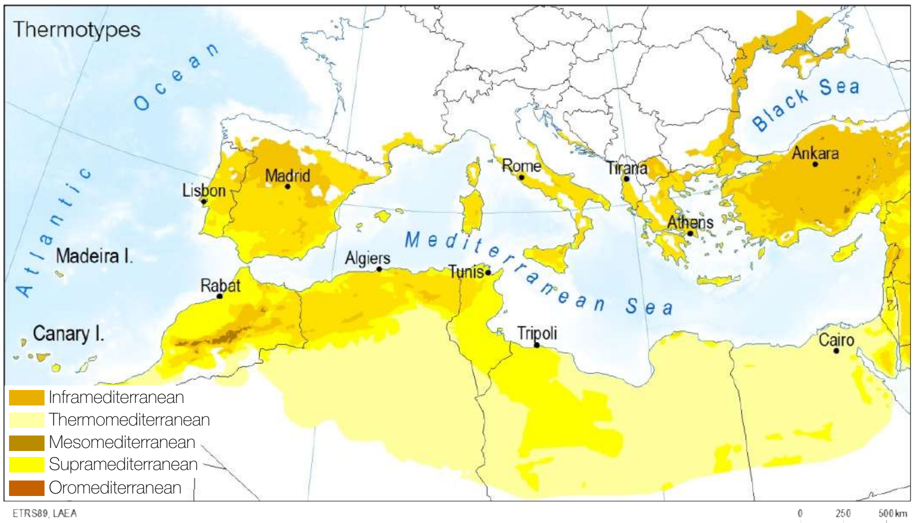

Figure 2.3. Thermotypes in the Mediterranean macrobioclimate in the study area
Source: Rivas-Martínez *et al.* (2011).

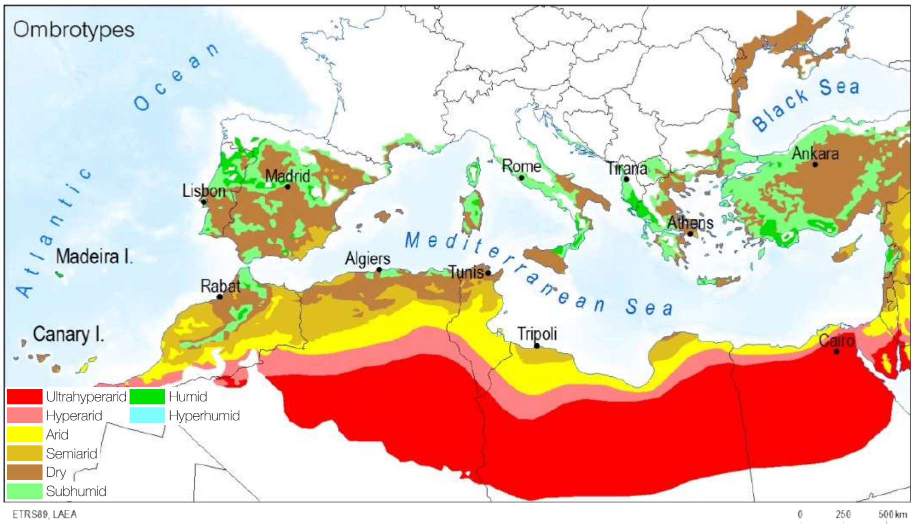

Figure 2.4. Ombrotypes in the Mediterranean macrobioclimate
Source: Rivas-Martínez *et al.* (2011).

percent) and xeric-continental (1.75 percent) (Figure 2.2). Forests cannot grow in desertic-oceanic, desertic-continental, hyperdesertic-oceanic or hyperdesertic-continental bioclimates.

A "thermotype" refers to a climate's thermic category, taking into account various temperature parameters and indices such as the thermicity index (It), the compensated thermicity index (Itc) and the positive annual temperature (Tp). In order to account for regional climatic and vegetation differences, an altitudinal or latitudinal sequence of thermotypes (thermostages) is recognized in each of the macrobioclimates (including the Mediterranean bioclimate, see Figure 2.3).

Ombrotypes categorize precipitation rates. Because of their predictive value in the relationship between the climate and vegetation, the annual ombrothermic index (Io), monthly ombrothermic index (Iom) and summer ombrothermic indices (Ios) are the most widely used. The recognized ombric types are: ultrahyperarid, hyperarid, arid, semiarid, dry, subhumid, humid, hyperhumid and ultrahyperhumid (Figure 2.4).

Finally, bioclimatic stages refer to bioclimatic types conditioned by altitude or latitude. They are delimited according to thermoclimatic (thermotypes, It, Itc, Tp) and ombroclimatic factors (ombrotypes, Io). Each bioclimatic stage contains specific plant formations and communities, giving rise to the expression

Table 2.1. Bioclimatic stages representing combinations of thermotypes and ombrotypes where forest can exist

Thermotype	Ombrotype								
	Uha	Ha	A	Sa	D	Sh	H	Hh	Uhu
Inframediterranean	-	-	-	•	•	-	-	-	-
Thermomediterranean	-	-	-	-	•	•	-	-	-
Mesomediterraean	-	-	-	-	•	•	•	-	-
Suprameditерraean	-	-	-	-	•	•	•	•	-
Oromediterraean	-	-	-	-	-	-	•	•	-
Crioromediterranean	-	-	-	-	-	-	-	-	-

Note: Uha = Ultrahyperarid; Ha = Hyperarid; A = Arid; Sa = Semiarid; D = Dry; Sh = Subhumid; H = Humid; Hh = Hyperhumid; Uhu = Ultrahyperhumid.

Source: Data sourced by authors.

"vegetation stages." Although the phenomenon of zoning is universally applicable, thermoclimatic thresholds (It, Itc, Tp) differ in the majority of macrobioclimates. Table 2.1 shows bioclimatic stages in the territory under study, including bioclimates where forests can grow.

Metzger *et al.* (2013) used 42 bioclimatic variables and hierarchical cluster analysis to classify the world into seven biomes, 18 global environmental zones and 125 global environmental strata.

The Global Ecological Zones (GEZ) of FAO (1999, 2012b) were based primarily on the Köppen-Trewartha climate map but also used vegetation maps to refine the global map and link it to vegetation types. These included the UNESCO and FAO Mediterranean vegetation map for the Middle East 1970. Although the GEZ did not identify a specific Mediterranean zone, instead classifying the world into five domains subdivided into 20 zones, the GEZ is the ecological classification adopted by the Intergovernmental Panel on Climate Change (IPCC) (Eggleston *et al.*, 2006) to define default values (Tier 1 value in IPCC tiered approach), and thus is important for UNFCCC greenhouse gas inventories. Sörensen (2007) is another worldwide classification system that relied on bioclimate variables (mean annual precipitation and mean annual potential evapotranspiration) to define levels of aridity within drylands. Like FAO's GEZ, this classification did not specifically identify the Mediterranean region but is relevant to the CBD and the UNCCD.

Other worldwide approaches have attempted to integrate more than bioclimactic information. Based on a worldwide compilation of biogeographic maps, Olson *et al.* (2001) identified the "Mediterranean forests, woodlands and scrub" biome, including 22 ecoregions around the Mediterranean Sea. Building on Metzger *et al.*'s map of bioclimates and adding information on landform, lithology and land cover, Sayre *et al.* (2014) identified 3 923 global ecological land units, several of which fall within the Mediterranean region.

All of the above classifications are consistent to some extent. Figure 2.5, for instance, compares the Palearctic component of the Mediterranean biome of Olson *et al.* (2001) with the drylands of Sörensen (2007) following removal of the hyperarid and arid zones (but including the presumed drylands). The two maps are largely consistent in their classification of the western Mediterranean. In the east, however, large areas of Turkey and Eastern Europe are classified as drylands by Sörensen, but excluded from the Mediterranean biome by Olson *et al.* The Mediterranean biome of Olson *et al.* (2001) is also similar in the western Mediterranean to the subtropical zones of the GEZ of FAO (2012b) when excluding subtropical deserts (Figure 2.6). In the east, large areas of Turkey and the Middle East are again classified as subtropical GEZ but excluded from the Mediterranean biome by Olson *et al.*.

The definition used for the Mediterranean region will ultimately determine its size and classification. With the growing availability of worldwide maps containing most bioclimatic, landform, geological, soil and land cover variables, it is likely that defining the Mediterranean region according to threshold values based on these variables will become less and less relevant. The current method used to predict the

Table 2.2. Maps of the Mediterranean region based on biogeographic and bioclimatic approaches. The column on the far right indicates whether a specific Mediterranean unit was identified among the different mapped units

Reference	Approach	Main variables	Scale	Units	Med. unit?
UNESCO and FAO (1963)	Bioclimate	Precipitation, temperature, humidity	Mediter-ranean	7 hot climates, 31 bioclimates	Yes
UNESCO and FAO (1970)	Biogeographic	Climate, vegetation physiognomy, soil and introduced vegetation	Mediter-ranean	105 vegetation types	Yes
Olson *et al.* (2001)	Biogeographic	Landform, vegetation and climate	Global	8 realms, 14 biomes, 867 ecoregions	Yes
Sörensen (2007)	Biogeographic	Precipitation, evapotranspiration, vegetation	Global	5 aridity zones	No
Rivas-Martínez *et al.* (2011)	Bioclimate	Precipitation, temperature, seasonality, evapotranspiration	Global	5 macrobiocli-mates, 28 bioclimates	Yes
FAO (1999, 2012b)	Bioclimate and vegetation Biogeographic	Climate, soil, landform, vegetation	Global	5 domains, 20 ecological zones	No
Metzger *et al.* (2013)	Bioclimate	Precipitation, temperature, seasonality and humidity	Global	7 biomes, 18 environmental zones, 125 environmental strata	No
Sayre *et al.* (2014)	Biogeographic	Bioclimate, landform, lithology and land cover	Global	3923 ecological land units	No

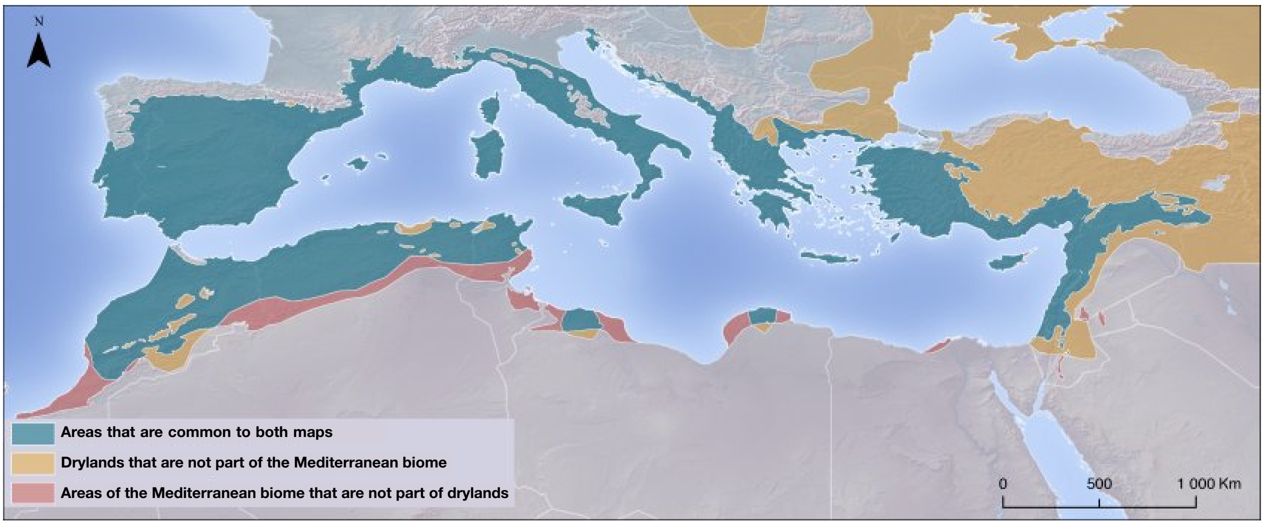

Figure 2.5. Comparison between the Palearctic component of the Mediterranean biome of Olson *et al.* (2001) and the drylands of Sörensen (2007) after removing the hyperarid and arid zones (but including the presumed drylands)

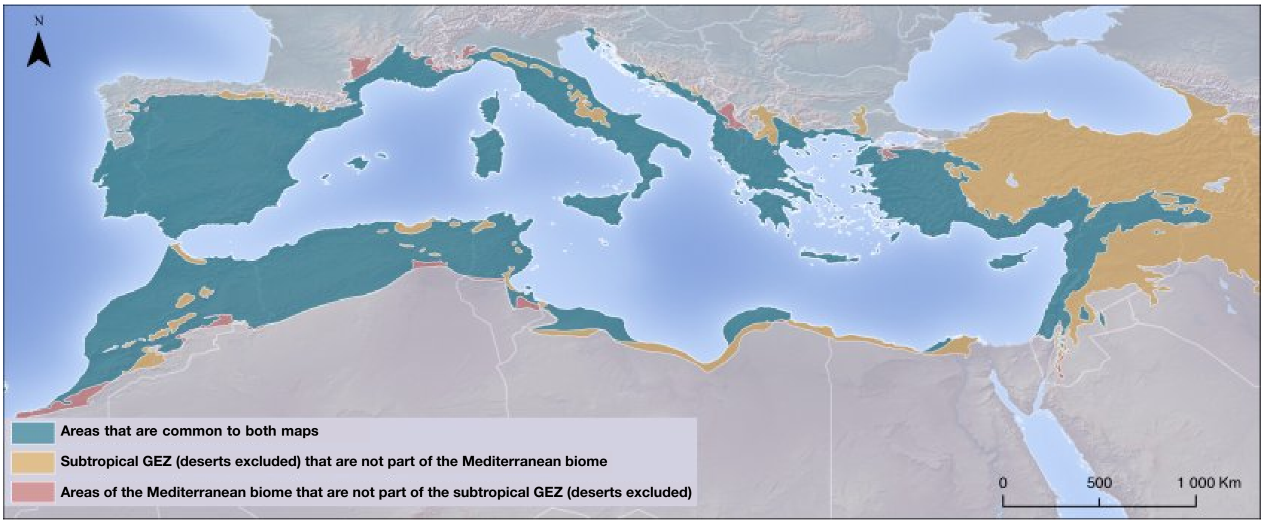

Figure 2.6. Comparison between the Palearctic component of the Mediterranean biome of Olson *et al.* (2001) and the Global Ecological Zones (GEZ) of FAO (2012b) when including all the subtropical zones except subtropical deserts

impact of climate change on the abundance and distribution of Mediterranean tree species, for instance, is to apply species distribution models using large sets of environmental variables but without reference to any specific definition of the Mediterranean basin (Benito Garzón *et al.*, 2008; Attorre *et al.*, 2011). Such definition-free approaches will become increasingly relevant, as it is expected tree species will respond in different ways to climate change rather than as part of a vegetation community. This means the vegetation communities typically associated with Mediterranean ecosystems will shift in composition in response to climate change, thus calling into question the previously accepted definition of "typical" Mediterranean vegetation.

Forest definitions and definition of the Mediterranean forest

In phytosociology, Mediterranean forests refer to typical assemblages of tree species specific to the Mediterranean region, resulting from the interaction between tree species' ecological requirements and abiotic factors. An alternative to this ecological approach would be to apply a general definition of forests within a region defined as "the Mediterranean." There are hundreds of country-specific definitions of forests, combining administrative, land use and land cover criteria (Lund, 1999). The FAO Global Forest Resource Assessment (FRA) (FAO, 2012a) provides a general definition of forests:

Forest: Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.

Other wooded land: Land not defined as "forest," spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5-10 percent, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

Other land with tree cover: Land considered as "other land" that is predominantly agricultural or urban and has patches of tree cover spanning more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 metres at maturity. It includes both forest and non-forest

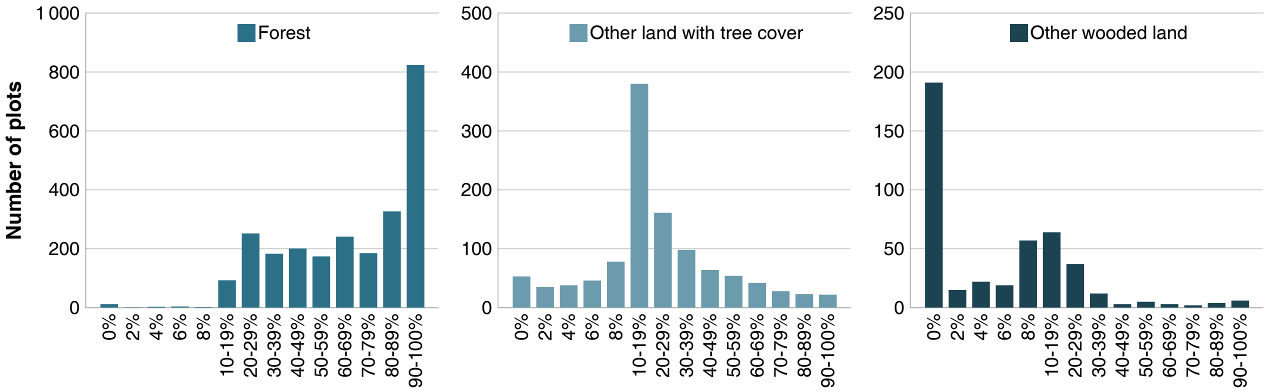

Figure 2.7. Classes of tree cover in percentage and frequency of plots for each class of each FRA definition
Source: Data sourced by authors.

tree species.

Applying a general definition of forests across the Mediterranean raises two additional questions, namely: (a) What is the definition of the Mediterranean region? (b) How to disaggregate country-level forest data to account for Mediterranean versus non-Mediterranean forests within countries?

In this section, we will try to answer these questions using FRA definitions. Because the Mediterranean region is characterized by ongoing human-induced impacts and marked climatic and ecological factors, our interest is not only in typical forests but all areas containing trees – i.e. any type of tree cover. Information on these FRA definitions was collected in 0.5 ha plots as part of the Global Drylands Assessment (GDA) (FAO, 2016d). Tree cover within the plot area was also measured. Using the Mediterranean region defined by the FAO Global Ecological Zones (GEZ) (FAO, 2012b), we found 12 933 plots available for analysis. Among the 31.4 percent of these plots (*n* = 4 064) that corresponded with FRA definitions, 61 percent (*n* = 2 502) corresponded to land defined as forest, followed by other land with tree cover at 28 percent (*n* = 1 122) and other wooded land at 11 percent (*n* = 440).

Within areas defined as forest, tree cover most frequently ranged from 90 to 100 percent. There was, however, great variability of tree cover ranging from 10 to 89 percent, which together represented most forest plots (66 percent) (Figure 2.7, left). Other land with tree cover frequently presented tree cover ranging from 10 to 29 percent, while other tree cover was minimal (Figure 2.7, middle). Finally, other wooded lands are frequently treeless, although some plots had between 8 and 30 percent tree cover (Figure 2.7, right).

Forest land has the highest percentage of tree cover. When compared against existing datasets such as Globcover 2009, these plots might correspond to intact patches of closed forests, but also to secondary forests and reforested areas. Here, we found the most open (15-40 percent tree cover) to closed (>40 percent tree cover) conifer evergreen forests and broadleaved deciduous forests as classified by Bontemps *et al.* (2011). Further comparisons demonstrate additional similarities: using maps developed by Bontemps *et al.* (2011), closed forests occupy 18 percent of the Mediterranean region, whereas our dataset indicates the presence of forest in 19.4 percent of all plots.

Other land with tree cover and other wooded land, which together represent 12 percent of all plots, were more difficult to classify. The abundance of other land with tree cover indicates the importance of trees in human environments, such as settlements or agricultural areas. They also represent most agroforestry open woodlands, olive groves or rain-fed tree crops which so characterize the Mediterranean landscape. Finally, other wooded land could correspond to Mediterranean shrublands or grasslands, both of which contain a sparse number of trees. Bontemps *et al.* (2011) found mosaics of forest, grassland and shrublands and sparse tree cover across 17.7 percent of the Mediterranean region, which could correspond to these definitions. However, these must include important vegetative formations such as open oak woodlands of *Quercus* species (known as “Dehesa” in Spain and “Montado” in Portugal).

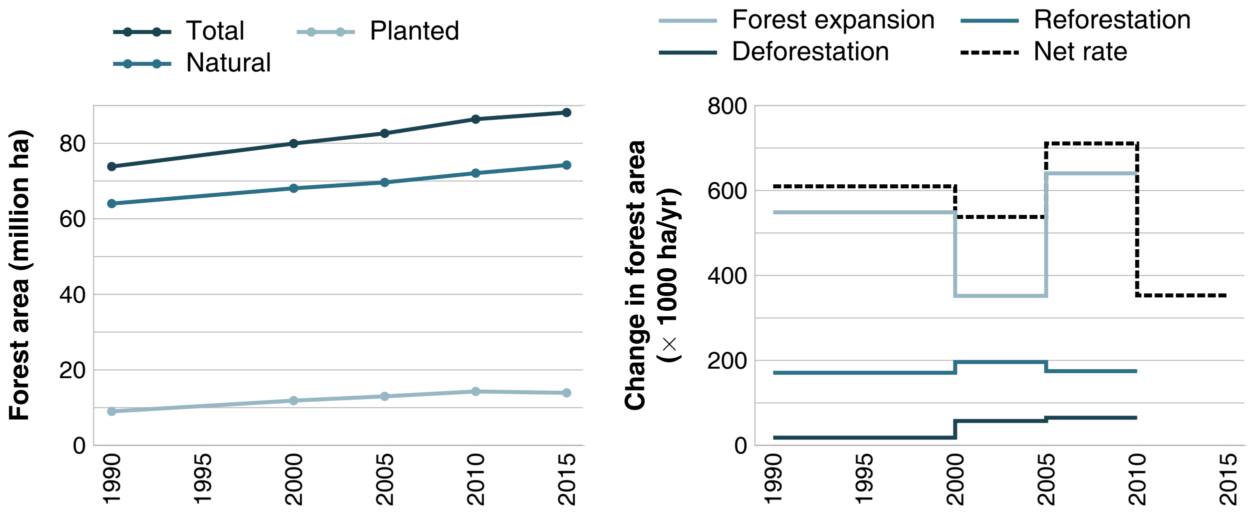

Figure 2.8. Total forest area growth for Mediterranean countries and average annual rate of change in forest area
Source: Adapted from FAO (2015a).

While these species might also have their place in these definitions, they could be included in lands classified as forests with medium to low tree cover.

Forest resources in the Mediterranean

Forest area

Based on the FAO definition of forests, there were an estimated 88 million ha of forest area in Mediterranean countries[1] in 2015 (Table 2.3), representing 2.20 percent of the world's total forest area (FAO, 2015a). Forest area in Mediterranean countries has been increasing since 1990 (Figure 2.8). The 0.85 percent/yr net increase in forest area between 1990 and 2010 has largely been the result of forest expansion (0.67 percent/yr), with reforestation contributing 0.23 percent/yr and deforestation remaining at a low level of 0.05 percent/yr (though it is trending upwards). In 2015, forests occupied 10.04 percent of the total area of Mediterranean countries, equivalent to the combined size of Spain and Morocco. Only four countries – Spain, France, Turkey and Italy – make up about 64 percent of the region's overall forest area. Between 2010 and 2015, total forest area increased by 2.04 percent, a new forest area (1.8 million ha) almost the size of Slovenia. Between 2000 and 2015, there has been a 8 million ha increase in forest area, equivalent to 0.93 percent of the total combined area of Mediterranean countries.

The increase in forest size is both the result of the European Common Agriculture Policy (as in the case of Spain) and forest regeneration in rural areas following abandonment, which can be seen in several Mediterranean countries (Fernández Nogueira and Corbelle Rico, 2017). Because statistics are provided at country level and not according to biogeographical region, a fraction of forest growth has taken place outside the Mediterranean region as defined above, thus accounting for vegetation growth in northern Atlantic regions such as northern Spain or France. In contrast with country-level forest statistics, remote sensing studies focusing on the Mediterranean region show that forest area in the Mediterranean region remains stable (see Section "Land use change" below). Moreover, a stable or increasing forest area according to the FAO definition of forests tells us nothing about forest degradation (see Chapter 5).

To complement the above snapshot using the FAO definition of forests, the Global Forest Watch definition, based on tree cover alone, indicates 85 million ha of land in Mediterranean countries has tree cover $\geq$ 10 percent and 81 million ha with tree cover $\geq$ 30 percent (rightmost columns of Table 2.3). Tree cover refers to the biophysical presence of trees, which may be a part of natural forests, plantations,

[1] Same list of 27 countries as in Chapter 1, cf. page 2.

Table 2.3. Forest area, percentage of forested area (with respect to land area or to total forest area), forest area growth and area of other wooded lands in Mediterranean countries

Country	Data extracted from FAO (2015a)					Data extracted from Global Forest Watch	
	Forest area 2015 (× 10^3 ha)	Land area with forest 2015 (%)	Share of regional forest area 2015 (%)	Change in forest area 2010-2015 (%)	Other wooded land area (× 10^3 ha)	Area with tree cover ≥ 10% (× 10^3 ha)	Area with tree cover ≥ 30% (× 10^3 ha)
Albania	772	28.16	0.88	−0.62	256	839	777
Algeria	1 956	0.82	2.22	1.98	2 569	1 690	1 472
Bosnia and Herzegovina	2 185	42.68	2.48	0.00	549	2 900	2 814
Bulgaria	3 823	35.19	4.34	2.30	22	4 461	4 377
Croatia	1 922	34.37	2.18	0.10	569	2 691	2 613
Cyprus	173	18.69	0.20	−0.17	213	154	132
Egypt	73	0.07	0.08	4.29	20	952	898
France	16 989	30.88	19.27	3.44	590	18 355	17 831
Greece	4 054	31.45	4.60	3.87	2 492	4 767	4 430
Israel	165	7.62	0.19	7.14	60	50	42
Italy	9 297	31.61	10.55	2.98	1 813	10 449	10 152
Jordan	98	1.10	0.11	−0.51	51	4	3
Lebanon	137	13.42	0.16	0.22	106	94	65
Libya	217	0.12	0.25	0.00	330	24	16
Malta	n.a.	1.10	n.a.	n.a.	0	0	0
Monaco	0	0.00	0.00	n.a.	0	0	0
Montenegro	827	61.49	0.94	0.00	137	692	667
Morocco	5 632	12.62	6.39	−0.71	580	1 113	892
Palestine	9	1.50	0.01	0.00	0	2	1
Portugal	3 182	35.25	3.61	−1.76	1 725	3 006	2 756
Serbia	2 720	31.10	3.09	0.26	508	3 026	2 943
Slovenia	1 248	61.97	1.42	0.08	23	1 342	1 324
Spain	18 418	36.90	20.90	0.94	9 209	14 326	13 061
Syrian Arab Republic	491	2.67	0.56	0.00	35	147	132
The former Yugoslav Republic of Macedonia	998	39.24	1.13	0.00	143	911	864
Tunisia	1 041	6.70	1.18	5.15	293	286	257
Turkey	11 715	15.22	13.29	4.57	10 130	12 909	11 968
All countries	88 141	10.04	100.00	2.04	32 423	85 192	80 507

Source: FAO (2015a) and Hansen *et al.* (2013).

agroforestry systems, or parks within cities. A definition based on tree cover may disregard burnt forests or clear-cut forests (which are included in the FAO definition) but may include agroforestry systems if their tree cover is large enough, even if the land is predominantly used for crops. Differences between the Global Forest Resources Assessment of FAO and Global Forest Watch estimates may also result from methodological limits in assessing tree cover, particularly the use of low-resolution satellite images in areas where tree cover is low (Bastin *et al.*, 2017) and where tree height is around the minimum height of 5 m used by the FAO definition.

Growing stock

The stem volume of living trees, known as "growing stock," is a basic variable in forest inventory. Its change over time provides basic information for the assessment of the sustainability of forest management. Growing stock information is also used as a basis for estimating the amount of carbon accumulated in living trees and allows forest managers to assess harvesting possibilities and risks of disturbance.

Figures for forest growing stock in almost all countries are available in the Global Forest Resources Assessment of FAO for the years 1990, 2000, 2005, 2010 and 2015. Most countries with data available provided figures on growing stock composition by coniferous and broadleaved tree species in forests. The total growing stock of Mediterranean forests is 10.3 billion m^3 (Table 2.4). Palestine, Portugal and the Syrian Arab Republic failed to provide growing stock data for 2015. The reported total growing stock

Table 2.4. Growing stock in forests and other wooded lands, Mediterranean countries, 2015 (million m^3)

Country	Coniferous	Broadleaved	Total Forest	Total OWL
Albania	19	57	76	8
Algeria	30	59	89	10
Bosnia and Herzegovina	135	223	358	n.a.
Bulgaria	315	384	699	n.a.
Croatia	54	361	415	6
Cyprus	11	0	11	n.a.
Egypt	n.a.	n.a.	9	0
France	1 043	1 892	2 935	n.a.
Greece	83	110	193	n.a.
Israel	3	3	6	n.a.
Italy	544	841	1 385	n.a.
Jordan	n.a.	n.a.	3	n.a.
Lebanon	4	2	5	1
Libya	n.a.	n.a.	8	4
Malta	0	0	0	0
Monaco	0	0	0	0
Montenegro	49	73	121	0
Morocco	52	102	154	1
Portugal	n.a.	n.a.	186	n.a.
Serbia	48	370	418	37
Slovenia	197	234	432	1
Spain	635	577	1 212	2
The former Yugoslav Republic of Macedonia	8	69	76	n.a.
Tunisia	17	11	27	1
Turkey	991	515	1 506	72
Total	4 238	5 881	10 325	143

Note: OWL = other wooded land. Data is not available for Palestine and the Syrian Arab Republic. Portugal did not report for 2015 so the figure for 2010 is included here.

Source: FAO (2015a).

of other wooded land amounted to 143 million m^3 in 2015, noting that only half of the Mediterranean countries provided data for this year. When interpreting the data for growing stock on other wooded land, it is important to keep in mind that it refers only to the volume of trees; the volume of shrubs is excluded. On the other hand, the definition of other wooded land includes various types of stock, including shrubs. Together with a relatively high percentage of unavailable growing stock data for the other wooded land category (due to high measurement costs and low demand for this information at national levels), there is lower reported growing stock in other wooded land than may actually be the case.

The average growing stock density in Mediterranean forests is 117 m^3/ha. But variability between countries is high. Slovenia has the highest density, with 346 m^3/ha, followed by Croatia with 216 m^3/ha. Bulgaria, France, Bosnia and Herzegovina and Serbia reported data in the range of 150-200 m^3/ha, while Morocco and Tunisia have the lowest reported stock density at 25 m^3/ha (Figure 2.9). High growing stock densities can be explained mainly by ecological conditions favouring tree growth, forest protection measures, management practices and local terrain conditions hindering the possibility of harvest.

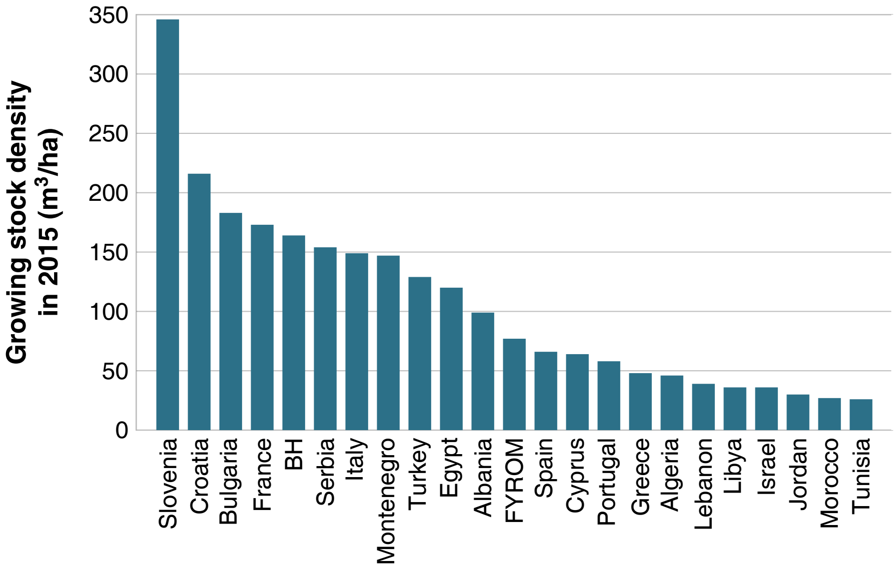

Figure 2.9. Growing stock density, Mediterranean countries, 2015

Note: BH = Bosnia and Herzegovina, FYROM = The former Yugoslav Republic of Macedonia. Data is not available for Malta, Monaco, Palestine and the Syrian Arab Republic.

Source: FAO (2015a).

Broadleaved tree species account for 58 percent, or 5.9 billion m^3, of Mediterranean growing stock in forests. The growing stock of coniferous tree species amounts to 4.2 billion m^3. The stem volume of living trees in Mediterranean forests is more or less evenly distributed between broadleaved and coniferous tree species in almost all countries.

Over the past 25 years, growing stock in Mediterranean forests has increased by 137 million m^3 per year. This corresponds to an annual rate of change of 2.0 percent (Table 2.5). The total growing stock in forests did not decrease in any Mediterranean country during the reporting period.[2] Some reported a constant growing stock between 1990 and 2015, which may be due to lack of data from more than one forest inventory. In absolute terms, the increase in total growing stock was highest in France, reaching an average of 34 million m^3 per year over the past 25 years, followed by Spain, with an average increase of 22 million m^3 per year and Italy with an increase of 21 million m^3 per year. Over the same period, the relative rate of growing stock accumulation in forests was highest in Spain, with an average yearly increase of 3.3 percent and Serbia, with an average yearly increase of 3.1 percent. The increase in growing stock may in part be due to the introduction of new sampling-based inventory systems, particularly in several countries in the east, but also to the expansion of forest area in most

[2] The decrease shown for Portugal is calculated over the period 1990-2010.

Table 2.5. Annual change in total growing stock in forests, Mediterranean countries, 1990-2015

Country	Total growing stock in forest (million m^3)					Annual change of growing stock 1990-2015		Annual change of growing stock 2005-2015	
	1990	2000	2005	2010	2015	million m^3/yr	%/yr	million m^3/yr	%/yr
Albania	75	76	74	75	76	0.04	0.06	0.19	0.26
Algeria	76	72	70	88	89	0.52	0.68	1.90	2.71
Bosnia and Herzegovina	291	358	358	358	358	2.68	0.92	0.00	0.00
Bulgaria	405	526	591	645	699	11.76	2.90	10.8	1.83
Croatia	310	360	385	406	415	4.18	1.35	2.99	0.78
Cyprus	7	8	8	10	11	0.15	2.01	0.27	3.27
Egypt	5	7	8	8	9	0.14	2.64	0.07	0.90
France	2 077	2 254	2 512	2 649	2 935	34.32	1.65	42.3	1.68
Greece	156	170	177	185	193	1.48	0.95	1.60	0.90
Israel	6	6	6	6	6	0.00	0.00	0.02	0.35
Italy	855	1 068	1 174	1 279	1 385	21.20	2.48	21.1	1.80
Jordan	3	3	3	3	3	0.00	0.00	0.00	0.00
Lebanon	-	-	5	5	5	-	-	0.05	1.00
Libya	8	8	8	8	8	0.00	0.00	0.00	0.00
Malta	0	0	0	0	0	0.00	0.00	0.00	0.00
Monaco	0	0	0	0	0	0.00	-	0.00	-
Montenegro	-	73	73	121	121	-	-	4.88	6.72
Morocco	128	143	152	150	154	1.04	0.81	0.20	0.13
Portugal	203	198	185	186	186	−0.68	−0.33	0.10	0.05
Serbia	235	250	298	415	418	7.32	3.11	12.00	4.03
Slovenia	273	333	374	406	432	6.33	2.32	5.75	1.54
Spain	664	906	1 027	1 120	1 212	21.93	3.30	18.47	1.80
The former Yugoslav Republic of Macedonia	76	79	76	76	76	0.00	0.01	0.00	0.00
Tunisia	17	22	24	26	27	0.40	2.35	0.30	1.25
Turkey	1 021	1 132	1 209	1 347	1 506	19.40	1.90	29.70	2.46
Total	6 892	8 051	8 798	9 573	10 325	137.29	1.99	152.70	1.74

Note: Data is not available for Palestine and the Syrian Arab Republic. Portugal did not report for 2015 so the figure of 2010 is reported for 2015.

Source: FAO (2015a).

regions. However, the relative increase in growing stock in forests (2.0 percent/year) was higher than the expansion of forest area during the period 1990 to 2015 (0.78 percent/year).

The reasons for growing stock accumulation in Mediterranean forests are many and complex, and of varying importance. The combined effects of CO_2 concentration and nitrogen deposition can lead to increased growth rates and low levels of harvesting activity (compared to growth) that could be the result of market conditions, increased societal awareness of the multi-functional role of forests, and more effective management of forests aimed at optimal and sustainable development of the goods and services provided by forest ecosystems.

Across the Mediterranean region, the rate of growing stock accumulation in forests was largely stable over the entire period 1990-2015 compared to the period 2005-2015.

Carbon stock

While growing, trees sequester carbon in their biomass. Forests, therefore, contain large stores of carbon in dead organic matter, soil and understorey. The total amount of forest carbon will change depending on forest management practices and climatic conditions. Forests can therefore mitigate or contribute to climate change by acting as a sink for or a source of atmospheric carbon.

On the other hand, changes in climate have had an impact on forest carbon stocks. According to the Working Group II contribution to the Fifth Assessment Report of the IPCC (2014a): "Recent indications are that temperate forests and trees are beginning to show signs of climate stress, including a reversal of tree growth enhancement in some regions (North America: Silva *et al.*, 2010; Silva and Anand, 2013, Europe: Charru *et al.*, 2010; Bontemps *et al.*, 2011; Kint *et al.*, 2012), increasing tree mortality (Allen *et al.*, 2010), and changes in fire regimes, insect outbreaks, and pathogen attacks (Adams *et al.*, 2012; Edburg *et al.*, 2012)."

Based on data in the Global Forest Resources Assessment of FAO, forests in the Mediterranean region stored 5 066 billion tonnes of carbon in 2015, equivalent to 1.7 percent of global forest carbon. Between them, France, Turkey, Italy and Spain stored 67.6 percent of total forest carbon stock in the Mediterranean region (Figure 2.10 and Table 2.6).

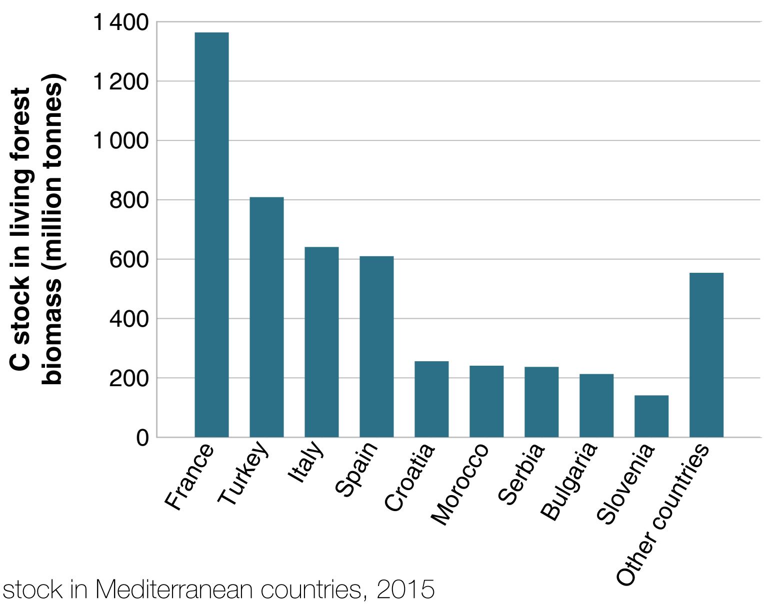

Figure 2.10. Carbon stock in Mediterranean countries, 2015

Note: Others = Albania, Algeria, Bosnia and Herzegovina, Cyprus, Egypt, Greece, Israel, Jordan, Lebanon, Libya, Monaco, Montenegro, Portugal, the former Yugoslav Republic of Macedonia and Tunisia. Data is not available for Malta, Palestine and the Syrian Arab republic.

Source: FAO (2015a).

Table 2.6. Carbon stocks in forests of Mediterranean countries in 1990, 2000, 2005, 2010 and 2015

Country	Forest carbon stock (× 10^6 Mg), 2015			Total biomass carbon in forests (× 10^6 Mg)				
	Above-ground biomass	Below-ground biomass	Dead wood	1990	2000	2005	2010	2015
Albania	38	12	14	49	49	48	49	50
Algeria	31	17	-	42	39	39	48	48
Bosnia and Herzegovina	95	23	-	96	118	118	118	118
Bulgaria	167	46	-	127	161	182	197	213
Croatia	196	60	-	190	221	237	250	256
Cyprus	3	1	-	3	3	3	3	4
Egypt	6	1	1	4	6	7	7	7
France	1 056	308	-	965	1 049	1 165	1 247	1 364
Greece	64	18	-	67	73	76	79	82
Israel	4	1	-	5	4	4	4	5
Italy	514	127	29	400	496	545	593	641
Jordan	2	1	-	2	2	2	2	3
Lebanon	1	0	-	-	-	2	2	1
Libya	5	1	1	6	6	6	6	6
Monaco	0	0	0	0	0	0	0	0
Montenegro	48	8	4	-	33	33	56	56
Morocco	184	57	1	203	227	240	239	241
Portugal	75	30	-	112	109	102	102	105
Serbia	185	52	33	122	138	147	235	237
Slovenia	115	26	6	88	107	121	132	141
Spain	458	151	-	325	454	518	564	610
The former Yugoslav Republic of Macedonia	48	13	-	60	62	60	60	60
Tunisia	7	2	-	6	8	8	9	9
Turkey	639	170	6	546	604	645	720	809
Total	3 941	1 125	95	3 418	3 969	4 308	4 722	5 066

Notes: 2015 carbon stock of Portugal is estimated with FAOSTAT data (FAO, 2017). Data is not available for Malta, Palestine and the Syrian Arab republic.
Source: FAO (2015a).

Forest carbon stock in the Mediterranean region increased by about 1.65 billion tonnes between 1990 and 2015, at a rate of 1.93 percent per year.

Land use change and pressure

Land use and land use change have a strong impact on the weather and may be as important as greenhouse gases in changing climate patterns (Pielke, 2005). Anthropogenic land use activities such as the management of croplands, forests, grasslands, and changes in land cover and land use create both CO_2 sources and sinks and are the driving factor in terrestrial carbon stock change (Schulp *et al.*, 2008; Smith *et al.*, 2014).

It is anticipated that ecosystem services will be particularly vulnerable to land use and land use change. The Mediterranean region in particular will be the most negatively affected by these changes in the medium term (Metzger *et al.*, 2006; Schröter *et al.*, 2005). Increased water stress and higher temperatures will have an impact on vegetation through stronger summer droughts and reduced availability of irrigation water. This will reduce the profitability and competitiveness of Mediterranean agriculture compared to other regions in central and northwestern Europe, which will in turn lead to the extensification and abandonment of agricultural lands (Holman *et al.*, 2017).

This section has a particular focus on Mediterranean forests and forestry. While it is known that annual mean temperatures are projected to increase in the order of 3-4°C and yearly rainfall is expected to drop by up to 20 percent in Mediterranean forests, less is known about how Mediterranean forests will adapt to these conditions. Schröter *et al.* (2005) found these changes would have negative effects on vegetation, especially as a result of increased drought, in projected scenarios. In most of these scenarios the burnt area resulting from forest fires would increase and the distribution of typical tree species such as holm oak (*Quercus ilex* L.) or Aleppo pine (*Pinus halepensis* Mill.) would likely be reduced or forced to shift northwards. Additionally, drought could be a major driver in replacing forest with shrubland or steppe vegetation (Hickler *et al.*, 2012).

Because socioeconomic factors affect land use and land use change, it is interesting to analyse trends in this regard, particularly since the adaptive capacity of forests and forestry is limited in the Mediterranean region, with large forest areas extensively managed or even unmanaged (Lindner *et al.*, 2010; Metzger *et al.*, 2006). Some authors predict that the abandonment of farmland and grazing lands will provide an opportunity for forest and shrub expansion in most Mediterranean mountain areas (e.g. García-Ruiz *et al.*, 2011).

In order to analyse these changes in land use, we examined current land use and land use change using data from two different datasets: (i) the Global Dryland Assessment (GDA) developed by FAO, spanning 2000 to 2015 (15 years), analysing and comparing data from a Global Forest Survey (GFS) of the Mediterranean, Euro-Siberian and other contiguous and/or comparable regions (such as some areas located in northern Europe, Russia, and North America); and (ii) the Human Footprint Index (HFP) by Venter *et al.* (2016) spanning 1993 to 2009 (16 years) in the Mediterranean.

- The GDA was developed by FAO. It systematically surveyed 213 783 square plots, each with an area of 0.5 ha, using Google Earth and Collect Earth Technologies (Bey *et al.*, 2016) in order to better understand the characteristics and health of forest ecosystems at a regional/biome level (i.e. independently of country borders). Besides variables related to forest characteristics, information about land use and land use change was also collected following the IPCC guidelines described in Bickel *et al.* (2006). The GDA analysis used the FAO GEZ (FAO, 2012b) definition of the Mediterranean region. The number of plots available for analysis using this approach totaled 12 933 in the Mediterranean region and 27 851 in the Euro-Siberian and other contiguous and/or comparable regions (García-Montero *et al.*, 2015, 2016).
- The HFP index is an attempt to quantify human pressure, which measures the impact of eight typical human activities, namely: (1) extent of built environments; (2) cropland; (3) pasture land; (4) human population density; (5) night-time lights; (6) railways; (7) roads; and (8) navigable waterways.

The HFP index by Venter *et al.* (2016) was used here. The cumulative human activities over a given area of 10^6 ha are weighted and added together, resulting in a standardized index ranging from 0 to 50, with 0 indicating very low or no human impact and 50 very high human impact. The HFP map was calculated for the years 1993 and 2009. When the difference between these two years is computed, the resulting map can be interpreted as a trend showing an increase or decrease in the HFP over a 16-year period. Our approach is to use the HFP index as a proxy to validate land use change by interpreting changes found in the GFS plots.

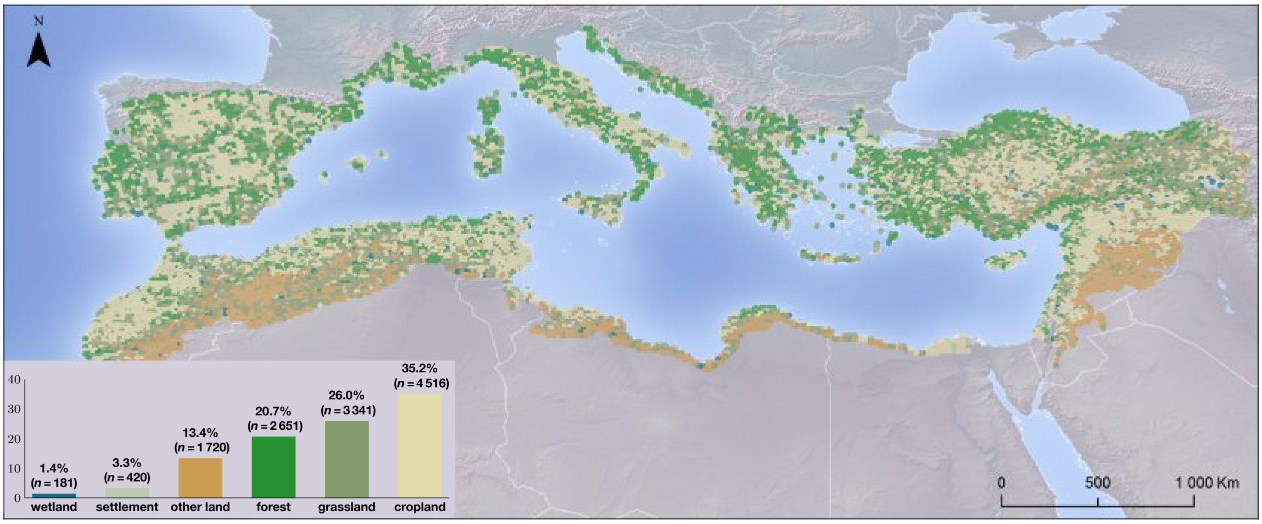

Figure 2.11. Map of GDA plots showing current land use (2015) as classified by the IPCC
Source: Data sourced by authors.

Current land use

In 2015 and referring to the IPCC land use categories, most of the plots surveyed across the Mediterranean region were classified as cropland (35.2 percent). Grassland was the second most common land use detected (26 percent of plots), followed by forest (20.7 percent) and other lands (13.4 percent). Settlement and wetlands accounted for the smallest number of plots, with 3.3 percent and 1.4 percent respectively (Figure 2.11).

Some of the maps used to build the HFP in 2009 showed similar results, reporting 31.2 percent of the region occupied by cropland, 21.5 percent by grassland and 7.3 percent by settlement. The differences found between datasets could be further explained with reference to spatial and temporal resolution. Nevertheless, these results seem to confirm the usefulness and accuracy of both datasets at a regional level.

Regarding the GFS inventory in the Euro-Siberian and other regions contiguous and/or comparable to the Mediterranean, García-Montero *et al.* (2015, 2016) reported the following patterns: (i) in the drylands of Europe and Russia, 33.83 percent of plots were classified as croplands, 17.71 percent as grasslands, 38.32 percent as forests, 3.42 percent as other lands, 2.56 percent as settlements and 4.15 percent as wetlands; (ii) In the European Euro Siberian region, 36.11 percent of plots were classified as croplands, 11.86 percent as grasslands, 41.37 percent as forests, 1.62 percent as other lands, 7.62 percent as settlements and 1.42 percent as wetlands; and (iii) in the North American region, 15.20 percent of plots were classified as croplands, 5.98 percent as grasslands, 66.91 percent as forests, 1.14 percent as other lands, 2.81 percent as settlements and 7.96 percent as wetlands.

Land use change

Overall land use in most of the plots surveyed (99.03 percent) did not change during the period 2000 to 2015. Only 0.97 percent of all 12 933 plots (n = 126) changed from one land use to another. While there were losses to grassland and other land (−0.23 percent and −0.10 percent respectively), there were net gains to croplands by an increment of 0.04 percent, followed by forest land and wetland which both increased by 0.02 percent (Figure 2.12a). The 0.02 increase in Mediterranean forest area between 2000 and 2015 contrasts with the reported increase of 0.93 percent for the same period according to the Global Forest Resources Assessment of FAO (see Section "Forest area"). This difference could either result from methodological differences, illustrating the difficulty in capturing small trends in forest changes; or it could mean that most of the increased forest area in Mediterranean countries actually

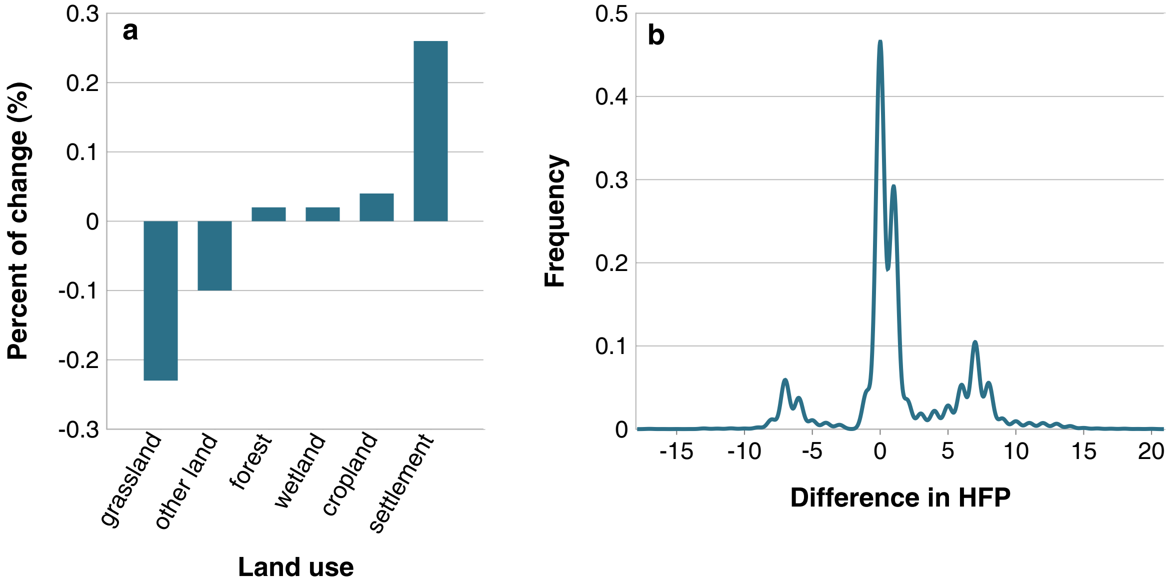

Figure 2.12. (a) Net change in the land use of plots inside the Mediterranean region surveyed between the years 2000-2015. (b) Density plot showing the frequency of the differences in the HFP index between the years 1993-2009. Negative values show a decrease in the HFP index, whereas positive values reflect an increase.

occurred outside the part of those countries defined as Mediterranean for the purposes of these studies. The single biggest increase in land use was in the settlement category, with an increase of 0.26 percent. Compared against the HFP index, most plots showed central values (61.4 percent of the values between −1 and 1) during the years 1993 and 2009, meaning that no important changes in the HFP index were detected on those plots. However, 28.2 percent showed an increased HFP index, while 10.4 percent showed a reduction (Figure 2.12b).

When comparing HFP maps, the data shows similar positive and negative trends in land use change: grassland decreased by 4.4 percent, settlement increased by 1.7 percent and cropland increased by about 8 percent.

Analysis of land use change in the Mediterranean against other contiguous and/or comparable regions between 2000 and 2015 showed similar results (García-Montero *et al.*, 2015, 2016):

- In countries located in the Euro-Siberian region, 2.10 percent of plots underwent changes of land use in the 15 years surveyed: 0.71 percent of plots transformed from various types of land use into forests, compared with a transformation of 0.35 percent of forest areas into different land uses;
- In plots located in the North American region, 1 percent of plots underwent changes of use in the 15 years surveyed, transforming 0.14 percent of area of various types of land use into forests, compared with a transformation of 0.64 percent of forests into various land uses and;
- In the drylands of Europe and Russia, 1.18 percent of the territory underwent change, transforming 0.28 percent of the plots subject to various types of land use into forests, compared with a transformation of 0.20 percent of forests into different land uses.

In summary, the Mediterranean region showed an increase in the number of new plots containing cropland which, contrary to Holman *et al.* (2017) and Schulp *et al.* (2008), shows a positive trend towards expansion. This expansion seems to be particularly evident in Spain, France, Turkey and North African countries. New plots containing settlements occurred concurrently with this regional expansion in cropland as a result of urbanization and tourism. Forest gains and losses were detected where forests were more abundant, mostly in Spain, France and Turkey (Figure 2.13).

Although we detected an increase in forest plots, mostly due to the colonization of abandoned settlements and croplands, the increase of human environments was greater still. Forests occupy 20.7

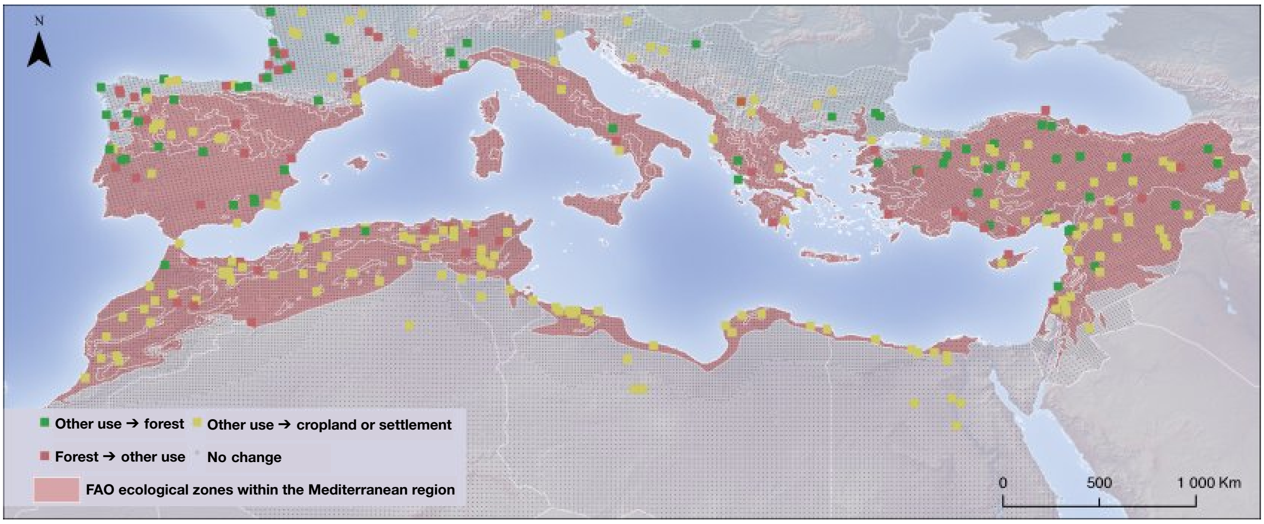

Figure 2.13. Map of GDA plots showing main changes in land use over the years 2000 to 2015. Non-forest land uses are shown in green. Land use shifting from forests to other uses are showed in red. Changes from other land use to cropland and settlement are shown in yellow. Plots that did not change are shown in black.

percent of the region and it is possible that abandoned grasslands in mountainous and rural areas could be colonized by forests in future. Although we detected movement in this direction, it was occurring at a very slow pace.

Overall, land use in the Mediterranean region is characterized by its stability. The reason small land use changes have been detected, as in other parts of the world, could be the result of temporal or spatial factors. The 15-16 year survey period may also be too small to detect important changes in our study area. Most climate change projections and scenarios are for the years 2040-2100. However, our analysis shows the importance of monitoring and classifying land use to validate longterm predictions or trends.

Conclusions

There is a moderate but stable trend towards increased forest area across the Mediterranean, with a corresponding increase in growing stock and carbon storage. The precise extent of this increase will depend on the definition used to define both forests and the Mediterranean region. To a large extent, it will also depend on the methodologies used to assess forest resources. Countries like Spain have shown an increase in forest area partly as a result of the European Union Common Agricultural Policy, but also resulting from the abandonment of rural areas. Forested areas are at great risk of forest fires and other natural disasters, as predicted in projected climate change scenarios. Moreover, the fragmentation of forested areas can lead to biodiversity loss. The Mediterranean region in particular is at risk of soil erosion and desertification.

Consideration of different approaches such as remote sensing and field-based inventories is a useful way to obtain complementary views on the state of Mediterranean forests. This calls for robust and transparent National Forest Inventories (NFI) that would allow for disaggregation of forest statistics from the country level to the sub-regional Mediterranean level. Some countries have already integrated the multidimensional scope of inventories and collect data on the various dimensions of the forests (see Box 2.3 on Spanish NFI). Harmonization of NFIs at the regional level would be a useful addition for the purposes of obtaining consistent regional data on Mediterranean forests.

Surveying forest area in the Mediterranean region over time has allowed us to conclude there has been a slight net increase in overall forest area at the regional level, even though deforestation may have occurred locally in some Mediterranean countries. This conclusion must be moderated by several questions that will be addressed in subsequent chapters: Will this slight increase in forest area continue in the future in the context of global changes? Is forest degradation occurring in the Mediterranean region? This latter question is trickier to address than assessing forest areas, as it requires a precise assessment of the state of tree populations and forest structures in areas classified as forests.

Box 2.3. The multi-objective Spanish national forest inventory

Over recent decades, the objectives of forestry and forest management in Europe have shifted from being primarily focused on wood production towards a focus on sustainable ecosystem management. The availability of appropriate forest information is essential to the decision-making process undertaken by forest managers and policy makers. In order to meet these increased information requirements, the scope of National Forest Inventories, which constitute the primary data source for national and large-area assessments, has been expanded to include new variables.

Following the Third Cycle of the Spanish National Forest Inventory (SNFI3, 1997-2007), a decision was taken to design an appropriate methodology to estimate forest biodiversity. The Fourth Cycle (SNFI4) therefore turned into a multiple objective inventory like many other European National Forest Inventories. The primary aims of the SNFI4 can be summarized as follows: estimating wood resources, biomass and carbon stocks, forest biodiversity, conservation status and the production of non-wood forest products. The methodology was developed by taking into account national forest characteristics, along with international requirements and new initiatives.

Assessment of these indicators is conducted according to the national features classification system (Alberdi *et al.*, 2014) applied to different forest types (Figure 2.14):

- Groundcover: Measuring the percentage of the sample units corresponding to different types of ground cover (bare soil, litter, rocks, etc.). Many indicators can be derived from field cover estimation such as average cover, number of plots containing more than 75 percent of one specific component and the Shannon-Weaver index (Shannon, 1948), among others.
- Presence of invasive species: A list of invasive species likely to be found in forested areas of each monitored province is devised. These invasive tree, shrub and herbaceous species are then recorded in 10 m, 5 m and 1 m radius subplots respectively. In addition, the presence of these species in the 25 m radius NFI plot is registered.
- Vegetation cover life forms: The total cover of herbaceous plants, ferns and three different shrub layers are recorded to define the vertical structure of the undergrowth.
- Complementary stand structure measurements: Due to the concentric circle plot design (which depends on tree diameters and distance to the plot centre), not all trees are measured. Additional tree location measurements and species identification of at least 20 trees are therefore recorded. This additional information allows for estimation of many horizontal, vertical and combined indicators together with neighbouring indices.
- Dead wood: SNFI records eight categories of dead wood as follows: dead standing trees (including snags, dbh > 7.5 cm, height > 1.3 m), dead downed trees (dbh > 7.5 cm), dead standing and downed saplings (2.5 < dbh < 7.5 cm), downed coarse wood pieces/downed branches (diameter at the thinner > 7.5 cm, length > 30 cm), stumps/snags (diameter at mid-height > 7.5 cm, total height < 1.3 m), coppice stumps

(representative diameter at mid-height > 7.5 cm, total height < 1.3 m) and accumulation (diameter > 7.5 cm of a representative branch at half length). The inventory considered the five classes of decay proposed by Hunter Jr (1990) and Guby and Dobbertin (1996) and defined two additional classes of dead wood: hollow dead wood (to avoid overestimation of volume) and recently cut (to deduce the probable amount of deadwood removed). Using this information, the volume and biomass of deadwood can be established.

- Micro-sites: Identifies and records elements indicating naturalness, such as nests, and others showing human activity, such as the presence of cattle, in each plot.
- Impact of browsing: SNFI records browsing impact data within a 10 m radius subplot for trees, saplings and shrub species and a 5 m radius for tree regeneration. Crown cover is used as a proxy to estimate browse availability for each species with 1 percent precision. Average browsing degree, indicating browse utilization, is also recorded by species according to the 6-rank classification method proposed by Fernández-Olalla *et al.* (2006).
- Stand age: In each plot, tree age and incremental diameter growth of the measured dominant tree are determined by means of core extraction at a height of 0.5 m above ground level. This information can be used to establish diameter-age models of dominant tree species and identify old growth trees (Alberdi *et al.*, 2013).

In addition, the SNFI has developed a new field protocol to estimate quantity and quality of cork based on SNFI measurements.

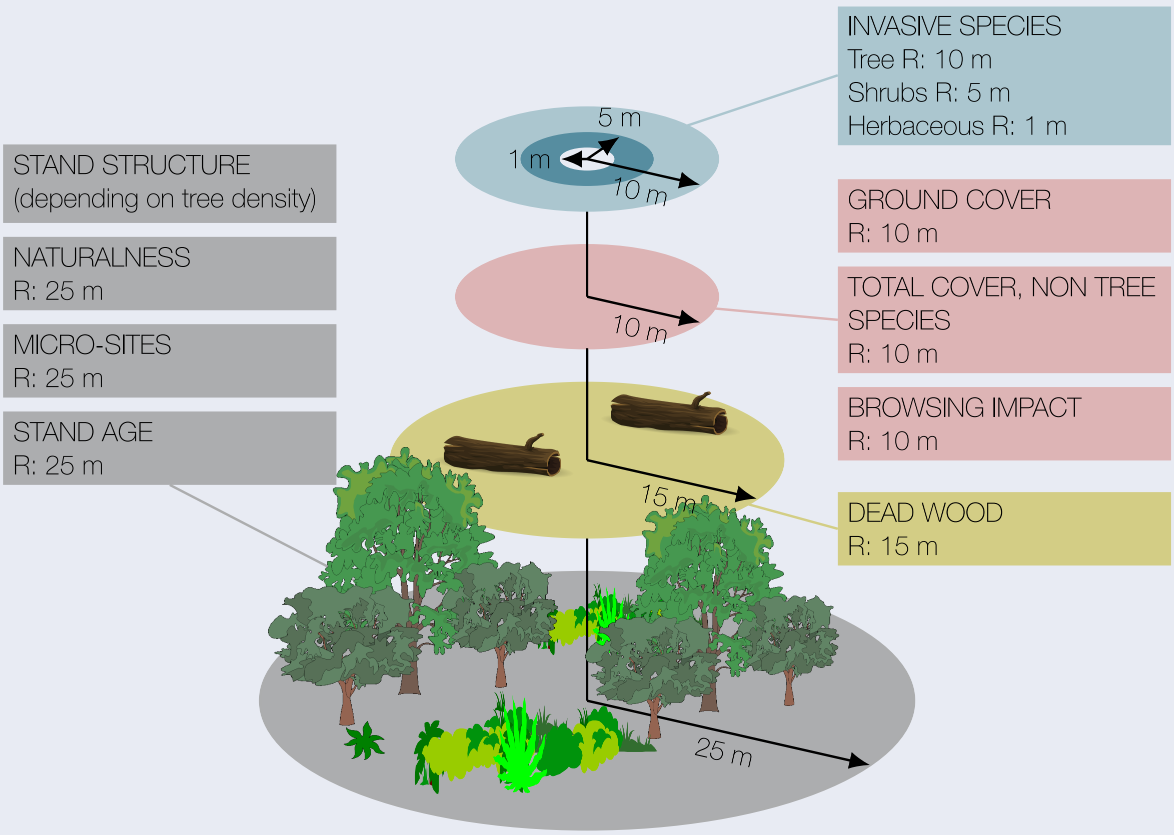

Figure 2.14. Spanish National Forest Inventory monitoring plots using new measurements