



Mediterranean forest research: challenges and opportunities in a changing environment

The Mediterranean Region is defined according to its biogeography and bioclimate. Climate is characterised by mild winters and hot, dry summers. Biodiversity is rich and landscape patterns are complex. Mediterranean forests have historically been subjected to numerous threats (forest fires, over-exploitation, deforestation, degradation), today accentuated under climate and land use changes. An interdisciplinary research agenda integrated for Mediterranean forest ecosystems has been recently elaborated by a network of Euro-Mediterranean research institutions

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Ricerca sulla foresta mediterranea: sfide e opportunità in un ambiente che cambia

La regione mediterranea è caratterizzata da biogeografia e bioclima specifici: clima con inverni miti ed estati calde e secche; biodiversità ricca e paesaggi complessi. Le foreste mediterranee sono da tempo minacciate da incendi, supersfruttamento, deforestazione, degrado, oggi accentuati dai cambiamenti climatici e di uso dei terreni. Per superare i limiti che hanno finora caratterizzato la ricerca nel settore, si è costituita una rete di 50 istituti di ricerca da 18 Paesi euro-mediterranei con un'agenda da realizzare in cooperazione

Introduction

The Mediterranean Region is defined according to the biogeographic-bioclimatic definition. Climate is char-

acterised by mild winters and hot, dry summers. Rain is usually concentrated in late Autumn, Winter and early Spring but the rainfall patterns and amount are variable and different, higher on the North Coast (Europe) and lower in the South (Africa) and East coasts (Asia). Year-to-year variability in total rainfall is large and, occasionally, violent precipitation events may occur and dry winds may favour the spread of forest fires. At sea level, winter temperatures only occasionally go below 0 °C but, over the numerous mountain ranges (Alps, Apennines, Pyrenees, North African range) of the area, freezing temperature and snow are

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common in wintertime. Furthermore, the Mediterranean region is characterised by a large geographical and topographical variation related to the presence of a variable coastline and of many mountain ranges, often quite high in elevation. The climate supports Mediterranean forests, woodlands, and shrub vegetation (*macchia, maquis, dehesas*), in the Thermo-Mediterranean and Meso-Mediterranean belts, at low elevations (Quezel 1985). As the elevation increases, vegetation pass from the Supra-Mediterranean to the Montane-Mediterranean and Oro-Mediterranean zones with completely different forest types.

Forests and woodlands of the Mediterranean region cover about 80 Mha, about 9% of the region's land area; they constitute a unique world natural heritage in terms of biological diversity, hosting around 25,000 species of vascular plants, (50% are endemic species) and a high degree of tree richness and endemism (290 indigenous tree species with 201 endemics) with extraordinary genetic diversity.

Mediterranean forests provide a wide array of environmental services and products. Watershed protection, landscape quality, soil conservation, carbon sequestration and recreation resources are among some of the public goods and externalities provided by Mediterranean forests that are seldom recognised and difficult to evaluate and price (Merlo & Rojas Briales 2000, Croitoru 2007). Their conservation and appropriate management have crucial impacts on the sustainability of the region's most strategic resource: water. Currently, 60% of the water-poor-countries (with < 1,000 m³ capita⁻¹ year⁻¹) of the world are in the Mediterranean region and it is expected that, by 2050, 290 million people will face water shortages (with < 500 m³ capita⁻¹ year⁻¹).

Also, Mediterranean forests provide wood products for timber and energy as well as highly appreciated and unique non-wood products (e.g., cork, pine kernels, mushrooms, medicinal plants, etc). The latter, with appropriate forest management models and innovation frameworks, have the potential to generate innovative, high added value and eco-friendly goods to support the socioeconomic development of rural areas and improve the welfare of urban populations, thus being a key pillar in a Mediterranean knowledge-based bio-economy.

Despite their important role as primary green infra-

structure of the region, Mediterranean forests are subject to numerous threats such as forest fires, over-exploitation, deforestation and degradation. These threats, historically present, are nowadays accentuated in a context of climate and land use changes (Palahi et al. 2008). Several authors reported that, among all bioclimatic regions, the Mediterranean area appears to be the most vulnerable to global change (Sala et al. 2000, Lindner et al. 2010). In this respect, the Mediterranean area is especially sensitive to any climate change because it represents a transition zone between arid and humid regions of the world (Scarascia-Mugnozza et al. 2000). In all climate change scenarios, the increase in temperature is associated with changes in the precipitation patterns, although with a higher uncertainty. If precipitation is forecasted to increase over northern Europe, a decrease up to 20% is expected for the south of Europe, particularly in summer, with severe effects on the frequency and intensity of drought periods, affecting water resources, forestry and agriculture. Higher temperatures and lower precipitation during summer will increase the evaporative demand of the atmosphere on ecosystems that already now can transpire up to 80% of precipitation (Palahi et al. 2008). The IPCC 4th Assessment (2007) predicts, at the end of the century, an average temperature increase for the Mediterranean region of about 4-6 °C and 20-50% less rainfall during the summer months. Expected climate change will result in the expansion of Mediterranean conditions to new areas. Moreover, increased areas of unmanaged forest in the north and deforestation and overexploitation in the south will increase the level of biotic (pests and diseases) and abiotic (fires, droughts, etc.) risks reducing the possibilities for adaptation to climate change.

Forest resources in the Mediterranean Region

Patterns of land-use are different between the northern and southern parts of the Mediterranean rim. In the northern part, including Turkey, the shares among Forests, Meadows and Arable land/permanent crops are generally more balanced compared to the southern part (figure 1).

These differences in land-use patterns may pose different pressures on forest land in the Mediterranean countries, with consequent impact on forest manage-

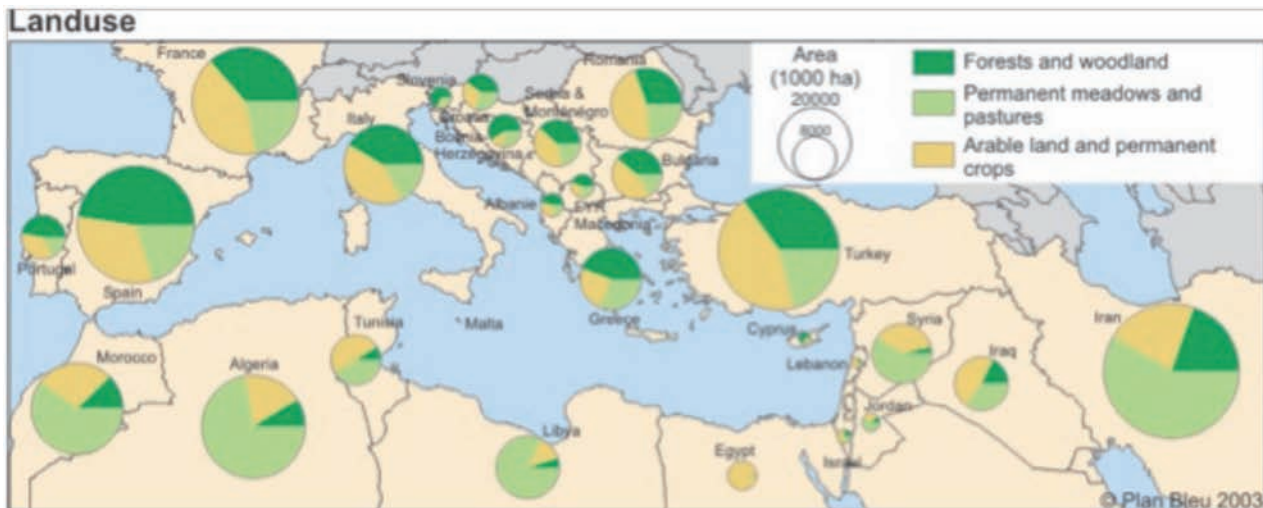


FIGURE 1 Share of land use options in Mediterranean countries. Forests and woodland, dark green; permanent meadows and pastures, pale green; Arable land and permanent crops, yellow. The size of the circles is scaled according to total area of the three land-uses that sum up to 1 (or 100%). Romania, Bulgaria, Macedonia, Iraq and Iran not included in the present analysis (source of data: FAOSTAT database, map downloaded from PlanBleu.org). In the south, permanent meadows and pastures are generally prevalent with respect to forest and arable land, with the exception of Israel, Lebanon and, partly, Tunisia. In Egypt, arable land and permanent crops are, by far, the most important land-use
 Source: FAOSTAT database

ment options. Nevertheless, forest trees represent an important component of the Mediterranean biodiversity; in the area, the number of tree species is quite large compared to those living in central Europe (100 vs. 30, respectively). Furthermore, many of the Holarctic and Eurasian tree species survived during the glacial ages in Mediterranean *refugia*, from where the continent was recolonised at the end of glaciations (Scarascia-Mugnozza et al. 2000).

Basic statistical data on forest resources in Mediterranean countries were derived by the Global Forest Resources Assessment (FAO 2006). Every five years, FAO organises an assessment of forest resources, that is based on common tables and reports provided by 229 countries, grouped in six regions.

In the Mediterranean, the forest cover (for Definitions see caption of Table 1) is nearly 80 Mha (79.153 Mha, Table 1). Most of the forest area is located in the European side of the Mediterranean (76%), while Mediterranean Africa and Asia contribute for 10 and 14%. There are also 31.5 Mha of other wooded land, to which Mediterranean Europe contributes for 57%.

In the case of Asia, it is interesting to note that other

wooded land (11.13 Mha), representing 35% of the total cover of this land use in the Mediterranean, is practically equal to that of forest (11.12 Mha). The percentage forest cover over the total land area is 9.2%, ranging from 1.4% in Africa to 32.6% in Europe. When the country-based percentage cover (third column in Table 1) is averaged for all countries, the mean is 21.1%, being 3.6, 11.2 and 33.6% respectively for Africa, Asia and Europe. Country forest cover ranges from 0.1% (Egypt and Libya) to 62.8% in Slovenia. In 2005, wood volume in Mediterranean forests sums up to 8,659 Mm³, the largest part being in Mediterranean Europe (nearly 80%, 6,832 Mm³). African and Asian countries contribute to the total growing stock by 4.7% (408 Mm³) and 16.4% (1,419 Mm³), respectively.

The average growing stock in a Mediterranean forest is 109 m³ ha⁻¹, ranging from 51 m³ ha⁻¹ in Africa to 127.6 m³ ha⁻¹ in Asia (Europe: 113 m³ ha⁻¹). The Asian value is related to the relevant hectare-based growing stock in Turkey (138 m³ ha⁻¹) and its large forest cover (see Table 1). When the unit growing stock is averaged for all countries, the mean is 107 m³ ha⁻¹, being



Country	Forest area (1000 ha)	% forest cover	Other wooded land (1000 ha)	Total area (1000 ha)
AFRICA				
Algeria	2277	1.0	1595	238174
Egypt	67	0.1	20	100145
Libyan Arab Jamahiriya	217	0.1	330	175954
Morocco	4364	9.8	406	44655
Tunisia	1056	6.8	170	16361
ASIA				
Cyprus	174	18.9	214	925
Israel	171	8.3	85	2106
Lebanon	136	13.3	106	1040
Syrian Arab Republic	461	2.5	35	18518
Turkey	10175	13.2	10689	77482
EUROPE				
Albania	794	29.0	261	2875
Bosnia and Herzegovina	2185	43.1	549	5120
Croatia	2135	38.2	346	5654
France	15554	28.3	1708	55150
Greece	3752	29.1	2780	13196
Italy	9979	33.9	1047	30134
Malta	n.s.	1.1	0	32
Portugal	3783	41.3	84	9198
Serbia and Montenegro	2694	26.4	808	10200
Slovenia	1264	62.8	44	2027
Spain	17915	35.9	10299	50599

1: Definitions: FOREST: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. OTHER WOOD-ED LAND: Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. Both categories do not include land that is predominantly under agricultural or urban land use. For France, the total forest cover is reported. However, only a part of France can be considered as effectively Mediterranean. Forest cover in the French Mediterranean Region is 2.7 Mha (18% of the total), with a percentage cover of 38%, a larger fraction compared to the national average (27-28%) (Montagné et al. 2005).

TABLE 1 Forest resources in the Mediterranean Region in 2005
Source: FRA2005 (FAO 2006)¹

60, 64 and 143 m³ ha⁻¹ respectively for Africa, Asia and Europe. Growing stock ranges from 36 m³ ha⁻¹ (Lebanon and Libya) to 238 m³ ha⁻¹ in Slovenia.

The largest part of the forests (80%) have been reported to be commercially exploitable (or already exploited). The percentage is 63,5% in Africa, 81% in Europe and 85,5% in Asia (with data from Turkey dominating the results). At country level, the wood volume of commercial value ranges from 2% of Tunisia to 100% of Morocco. In France and Slovenia wood in "commercial" forest represents more than 90% of the total wood volume of the countries.

Forest management and forest dynamics in the Mediterranean region

The Global Forest Resources Assessment (FAO 2006) collects information also on the main characteristics of forests in the world. This information is useful to understand the development of appropriate and efficient silvicultural and management practices to ensure and promote sustainable forestry. Those characteristics are linked to broad management categories (primary forest, natural, semi-natural, plantations, etc.) that may be considered as a starting point in describing the management options in Mediterranean forests. These practices are related to the structure and development of forest resources, and hence to their ability to provide services. The categories can also be connected to the degree of human impact on forest ecosystems. The characteristics reported by FRA2005 (FAO 2006) are described below (see Table 2):

Primary Forest, land of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.

Modified natural Forest: land of naturally regenerated native species where there are clearly visible indications of human activities.

Semi-natural Forest: land of native species, established through planting, seeding or assisted natural regeneration.

Productive plantation Forest: land of introduced species, and in some cases native species, established through planting or seeding mainly for production of wood or non wood goods.

Protective plantation Forest: land of native or intro-

duced species, established through planting or seeding mainly for provision of services.

Mediterranean ecosystems have been subjected to a historical long-term human influence, with both positive and negative effects (Hobbs et al. 1995). Due to this long and strong relationship with humans, the ecosystems of the Mediterranean basin have been defined as “total human ecosystems” (Naveh 1987). The long history of manipulation of trees, forests and landscapes is documented also by the current presence of planted forests of *Pinus pinea*, *Cupressus sempervirens* and *Castanea sativa* in areas where these species, introduced and extended since the Greco-Roman times, have become common components of the landscape (Scarascia-Mugnozza et al. 2000). This long history is also reflected into the very limited area of remaining primary forests (2.2 Mha, 2.8% of total forest cover). Most of the forest area is under management (modified natural or semi-natural forest, 66.7 Mha, nearly 85%), while 10.3 Mha are productive or protective plantation (13%).

It is interesting to note that there are significant differences in the shares of the management categories between the three continental groups. Whereas primary forests are nowadays totally absent in Africa, in Asia they represent 9% of the forest area (practically all located in Turkey) (Table 2).

Modified and semi-natural forests are nearly 90% in Europe, while they make up approximately 74% and 65% in Africa and Asia. Interestingly, in the countries of the latter two continents, semi-natural forests established through planting, seeding or assisted natural regeneration represent a limited percentage (around 7%) of forest cover. On the other hand, in the same ar-

eas, the percentage of forest area relating to productive and protective plantations is very relevant being greater than 26%, whilst, in Europe, the total of planted forests amounts to 8.8% (5.2 Mha), largely in the category of productive plantation.

The evaluation of changes occurring in forest cover in the Mediterranean region may provide information on the trend in forest resources and, indirectly, on the sustainability of forestry and other land-use practices in the Mediterranean.

Forest cover is increasing in almost all countries of the region and, where forest cover is not increasing at least it remains constant. Total forest cover increased from 69.13 Mha in 1990 to 76 Mha in 2000, reaching 79.15 Mha in 2005. Most of the “new” 10 Mha of forest are located in Europe (84%), 10% in Africa and only 6% in Asia. The percentage increase has been similar in Europe and Africa (around 1%) and lower in Asia (0.4%).

Approximately one third of this increase occurred because the total cover of other wooded land decreased from 34.7 Mha in 1990 to 31.6 Mha in 2005 (-9%), indicating a trend of wood encroachment (stand-level cover passed the 10% threshold or the cover of trees became predominant with respect to shrubs and bushes). Natural invasion of abandoned lands, particularly in mountainous regions, and deliberate reforestation and afforestation plans are among the other factors that can be responsible of the increase in forest cover.

Only two countries had a slight negative trend in forest cover between 1990 and 2000 (Albania and Bosnia-Herzegovina) but they reverted (Albania) or stopped (Bosnia-Herzegovina) the trend between 2000 and 2005. Among the countries with a small forest cover, Algeria, Egypt and Syria presented a rele-

Area	Primary forest (%)	Modified natural (%)	Semi-natural (%)	Productive plantation (%)	Protective plantation (%)
Africa	0.0	66.2	7.5	9.1	17.2
Asia	8.9	57.8	7.0	17.2	9.2
Europe	2.0	36.4	52.7	8.1	0.6
Total Mediterranean	2.8	42.4	41.7	9.5	3.5

TABLE 2 Importance of the different forest characteristics in the Mediterranean Region and “continental groups”. For definitions see main text



vant annual percentage increase (1.3-4.1 %/year) that generally decreased, albeit remaining above 1%, in the 2000-2005 period. In Europe, Italy, Portugal and Spain had annual increases above 1% in the whole 1990-2005 period. In Portugal, the increase in forest cover was strongly connected to afforestation policies whereas in Italy it was mainly related to recolonisation of abandoned land. Furthermore, Italy was one of the few countries where also other wooded land increased significantly in the period. In Spain, from 1990 to 2005, total forest cover increased by 4.5 Mha, while other wooded land decreased by 2.2 Mha.

The active afforestation and reforestation policies are an important factor in forest management and in shaping forestry in the different countries. In fact, on one hand, afforestation is a tool to increase forest cover in countries where for climatic or historical reasons it has decreased to very low, unsustainable levels; on the other hand, afforestation can be used to reduce the exploitation pressure on natural and semi-natural forests.

It is worth signalling that, in Asian and African Mediterranean countries, with few exceptions, forest plantations represent a significant share of total forest area, often above 25-30%. On the contrary, in Europe, only Portugal has more than 30% of forest plantations (not considering Malta).

Responding to climate change: adaptive management for Mediterranean forests

The Mediterranean basin has maybe the longest history of human presence in the earth. Humans began to modify significantly Mediterranean ecosystems 8000 thousands years ago, starting already at that time to impact global climate (Ruddiman 2003). Today, the Mediterranean can be considered a test area for studying global change (Scarascia Mugnozza et al. 2000, Palahi et al. 2008). Historically, forests have been able to adapt to slow-rate changes in mean climate variables but the current rate of changes is much faster than in the past and, furthermore, variability has increased, with higher risk of extreme weather events, such as prolonged drought, storms and floods.

Can the Mediterranean populations apply management options that may prepare or adapt forests to the expected impacts of climate change?

The degree of adaptation will depend both on the inherent adaptive capacity of trees and forest ecosystems but also on the socio-economic factors that will drive the capability to implement planned adaptation. Socio-economic factors are particularly limiting in the Mediterranean region, where large forest areas are only extensively managed or unmanaged (Fabbio et al. 2003, Lindner et al. 2010). Therefore, a dynamic conservation approach is urgently required and it should be based on sustaining the mechanisms allowing the maintenance of biodiversity (natural disturbance, gene flows, regeneration) (Palahi et al. 2008). Re-afforestation policies are necessary to ensure that forest species and their site-specific varieties are best adapted to future climatic conditions and ecosystem functioning is maintained (Resco de Dios et al. 2007). Fire prevention is also fundamental, as well as grazing control in burned and degraded areas, where the re-establishment of a minimum texture of ground vegetation and tree cover is the only feasible way of restoration (Fabbio et al 2003). Adaptive management should also try to implement solutions for reduced water use and long-term soil preservation (Palahi et al. 2008).

A research agenda for the Mediterranean forest ecosystems

Mediterranean forest and shrub ecosystems represent only 2% of the world's forest cover (FAO 2006); and yet, specific, social and environmental aspects make this region an interesting model system where the impact of global change on terrestrial ecosystems can be studied while developing and testing appropriate, land-use adaptive management. However, this framework needs new scientific knowledge based on advancing and integrating research from different scientific areas and disciplines to support decision-makers in the development of:

- new policy approaches promoting innovative economic instruments to ensure the delivery of key forest goods and services;
- new adaptive management strategies based on the understanding of forest ecosystem functions and processes, under a changing environment;
- a new paradigm in fighting forest fires; shifting from short-term driven fire control policies towards

longer-term policies aimed at acting on the structural causes of fires and integrating fire and forest management strategies.

Therefore, in order to avoid an irreversible decline of Mediterranean forests, it is urgently needed to tackle the abovementioned issues on the basis of improved and enlarged scientific knowledge. In addition, advancing science and innovation in key areas crucial to developing new forest management models and ensuring the marketing of existing and new goods and services will play an important role in creating a more structured knowledge-based bioeconomy in the region. Research and its efficient dissemination is a prerequisite for creating the basis of innovation and providing the scientific expertise to develop efficient cross-cutting policies based on the real importance of forests and forestry in relation to other strategic resources and issues, such as water, soil, energy, agriculture, biodiversity, fires and climate change. To meet these goals, forest science should adopt and adapt the most innovative developments from relevant disciplines (climatology, economics, decision science, biology, ecology, information technology and geomatics, etc.).

However, forest research in the Mediterranean region has traditionally been handicapped by its fragmentation, limited means, and occasional outdated and isolation. In addition, the weakness in coordination at European level and scattered cooperation policies are minimizing the impact of research programmes and jeopardizing their capacity to deliver efficient solutions properly. In this context, the challenge for all Mediterranean countries is, beyond enhancing their own capacities in research relevant to Mediterranean forests, to gather their national capacities through a mechanism of alignment of programmes and renewed cooperation in order to achieve the necessary critical mass. New ways to overcome the current situation must be implemented through ambitious long-term Mediterranean transnational research partnerships, networking, sharing of infrastructures and experimental sites, capacity building, and knowledge transfer measures. Furthermore, transcontinental research cooperation with other Mediterranean Climate Areas (California, Australia, South Africa, Chile) should be enhanced to share the knowledge necessary to address common scientific challenges and

needs. Such partnerships and activities should take advantage of the framework provided by the European Forest Based Sector Technology Platform (FTP) and the work of the Mediterranean Regional Office of the European Forest Institute (EFIMED), which consists of a network of 50 forest research institutions from 18 Mediterranean countries. EFIMED and the FTP jointly developed the Mediterranean Forest Research Agenda 2010-2020 (MFRA), which presents a pan-Mediterranean vision of the forestry challenges and scientific priorities relevant to all Mediterranean countries. The MFRA, structured around four strategic research priorities –selected for their intrinsic importance and significance for policy decision-making – provides a scientific framework for building joint transnational Mediterranean forest research cooperation.

The following research priorities have been identified for the Mediterranean Forest Research Agenda:

- the impact of climate and land-use change on Mediterranean forest ecosystems' functioning: assessing and monitoring the main physical and biological processes including biodiversity and water;
- the integration of the risk of forest fires in land-use and landscape planning and management;
- policy, economic and institutional aspects of sustainable provision of forest goods and services;
- forest and woodlands in the context of integrated management of land resources: models and decision systems for optimizing multi-objective and multi-actor management problems.

Advancing scientific knowledge and fostering innovation are essential steps, then, to ensure the sustainable management of Mediterranean forests and maximize the potential role of their unique goods and services in building a knowledge-based bioeconomy in the region.

To implement this Research Agenda, while developing a strong scientific cooperation between the EU Member States and the MPCs, as well as with countries from other Mediterranean Climate Areas, the European Commission has just launched a transnational EU-Mediterranean ERA-NET research programme, called FORESTERRA (Enhancing FOrest RESearch in the MediTERRanean through improved coordination and integration). The objective of this Action will be to

reinforce scientific partnership around the Mediterranean region while building new transcontinental cooperation among Mediterranean Climate Areas (California, Australia, South Africa, Chile) to reduce frag-

mentation and maximize the impact of research activities on sustainable forest management, including the management of forest resources to mitigate and adapt to climatic threats.

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