Mediterranean forests under focus

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SUMMARY

Mediterranean forest ecosystems provide multiple goods and services, including an exceptional richness in terms of biodiversity, which are crucial for the socio-economic development of rural areas as well as for the welfare of the urban populations of the Mediterranean region. Mediterranean forests are very vulnerable and fragile to numerous threats such as forest fires, over-exploitation, deforestation, and degradation. These threats are nowadays accentuated in a context of climate and land use changes. This paper presents the main characteristics, threats and values of Mediterranean forests and discusses the main scientific challenges and policy needs required to ensure the sustainable management and provision of Mediterranean forest goods and services.

Keywords: Mediterranean forestry, forest fires, climate change, multi-objective forest planning, forest values
of magnitude of the above mentioned forest types, they have specific features which make them a unique world natural heritage. Moreover, it is expected that predicted climate and socio-economic changes will, on one hand, increase the already existing threats on Mediterranean forests, and on the other hand will contribute to the expansion of Mediterranean conditions to new areas. Therefore, time has come for raising the awareness of the forestry and scientific community as well as of the general public about the complex challenges and research needs for ensuring the sustainability of Mediterranean forests.

The present paper provides an insight on Mediterranean forests and their future. It describes briefly their current status and characteristics, and then discusses five main challenges for the Mediterranean forests selected on the basis of their intrinsic importance but also of their significance for policy decision-making. The addressed issues are as follows:

- How climate change will impact Mediterranean forest processes?
- Biodiversity in Mediterranean woodland; what is at stake?
- Living with wildfire risk
- The real values of Mediterranean forests
- The need for new Mediterranean forest management planning approaches

MEDITERRANEAN FORESTS AT A GLANCE

The Mediterranean basin constitutes a unique mosaic of terrestrial, freshwater and marine ecosystems, as a result of a distinct regional climate imprinted on a dynamic topography. Yearly rainfall varies from 100 to more than 2500 mm while the average temperature ranges from 5 to 20 °C, with an intense summer drought period. Mediterranean forest ecosystems are exposed, to pronounced and extreme climatic constraints such as wind, long drought but also heavy stormy rainfalls, high (and sometimes low) temperatures, which make them susceptible to biotic and non-biotic risks. Mediterranean flora is extremely rich with around 25,000 vascular plant species, widely distributed throughout the diverse ecosystems of the region. Climatic, geomorphic and anthropogenic factors have resulted in a mosaic-type landscape of a variety of forest types that cover an area of 73 Mha (Fig. 1), or about 8.5% of the region’s area. However, purely Mediterranean forests, garrigues and maquis cover about 56 Mha, i.e. 7.5% of the total countries land.

Mediterranean forest ecosystems provide multiple wood and non-wood forest goods and services, which are crucial for the socio-economic development of rural areas as well as for the welfare of the urban populations of the Mediterranean region. In this context, Mediterranean forests require special attention due to several reasons:

(i) They constitute a unique world natural heritage and play a key role in the welfare of urban and rural Mediterranean societies, by providing highly appreciated marketed goods (firewood, cork, pinecones, mushrooms, etc) as well as high value but non-marketed services (biodiversity conservation, soil protection, water regulation, recreation possibilities, etc.).
(ii) They represent an exceptional richness in terms of biodiversity.
(iii) They are very vulnerable to numerous factors: forest fires, over-exploitation, degradation and desertification.
(iv) Their conservation and management affects the availability of soil and water resources, this last one being a key strategic resource for Mediterranean societies.
(v) Their future (as being in a transitional zone) is seriously endangered by climate and land use changes.

The situation of Mediterranean forests is clearly different from the northern rim to the southern and eastern sub-

FIGURE 1 Mediterranean Forests and woodlands
region. In the Northern part, the socio-economic changes of the last decades, triggered by the urbanization of our society and better living standards, have increased the relevance of the ecological, recreational and landscape functions of Mediterranean forests. However, many of the non-marketed goods and services derived by these functions do not provide revenues to their forest owners. By contrast, forest management is lacking both manpower (due to rural depopulation) and profitability (high costs and low timber prices) as never before. This situation has resulted in forest land abandonment due to a low interest from forest owners in cultivating and maintaining their forests. This situation increases the risk of natural hazards such as forest fires, pests and diseases, etc.

On the other hand, forests in the eastern and southern part of the Mediterranean basin have a long history of human pressure. In the Near East, the beginnings of cultivation and animal husbandry, which affected forests in the form of clearing, date back 10,000 years. Wood was for many millennia the main material (in Latin the word “materia” meant timber) for constructing temples (the Salomon temple was build using Cedrus libani timber), palaces, ships and all kind of tools during the different civilisations that flourished in the region. Nowadays, the rapid population growth (around 2% as an average in the eastern and southern regions), the low income per capita, the marked rural density and the limited diversification of activities makes forests, Garrigues and maquis and the products they generate (firewood, grass, aromatic and medicinal plants, etc) very relevant primary resources for the subsistence of the local communities. In addition, forest environmental functions (fight against desertification, regulation of the micro-climate, regulating water resources, etc) are crucial for the sustainable development of these societies. In this context, the main threats to forest sustainability in the southern and eastern sub-regions are over exploitation of forests for fuelwood, clearing for agriculture and overgrazing. These actions combined with a dry and harsh climate, a long history of human pressure and the fact that most forest areas in southern an eastern countries are public (little incentive to conserve forests), accentuates problems linked to forest degradation and deforestation, resulting in the soil erosion and desertification or rural lands. In these countries, FAO (1994) has assessed a deforestation rate of 1.1% between 1981 and 1990 that exceeds the figure observed in tropical countries.

At a global scale, twelve out of the last 13 years (1995-2006) are among the hottest since instrumental records are available. The temperature increment from 1850-1899 to 2001-2005 has been of 0.76°C at a global scale, while in a Mediterranean country like Spain, the increment from 1971 to 2000 was of 1.53°C, which is a much higher value than the 1.2°C predicted by the climate models (Parry et al. 2000). These observations suggest that the problem in the Mediterranean can be much worst than predicted and the temperature can increase 2.5° or even 3.5°C by 2050.

In the frame of climate change, the increase of temperature is associated to important changes in the precipitation patterns. All climate models and socioeconomic scenarios concurred on increasing precipitation over much of northern Europe (between 10 and 40 per cent more rainfall) and decreasing precipitation in the south of Europe (up to 20 per cent drier), particularly in summer. This reduction predicted for southern Europe can have severe effects as, for example, the increase of frequency and intensity of the drought periods, which in turn will affect water resources, forestry and agriculture. In addition, in the Mediterranean region, water scarcity is expected to be aggravated by higher extractions per capita for irrigation and tourism (World Tourism Organization 2003).

Among all bioclimatic regions, the Mediterranean appears to be the most vulnerable to global change. Most of this vulnerability is associated to the general atmospheric circulation and the role of water as a limiting resource for Mediterranean ecosystems. The Mediterranean regions, located between 35° and 45° of latitude, are just in the frontier of the high pressure area linked to the Hadley cell (Fig. 2). Any increase in the atmospheric energy is translated into an enlargement of the Hadley cell and, as a consequence, the high pressure belt moves to higher latitudes in the northern hemisphere and to lower latitudes in the southern hemisphere, reaching the Mediterranean areas. Given that these higher pressures are associated to hot and dry air that is desiccated when ascending in the low pressure equatorial areas, the temperature increase and precipitation decrease associated to climate change in Mediterranean areas is easy to understand (see Fig. 2).

Most Mediterranean ecosystems have evolved under an almost permanent shortage of water. In a typical figure, precipitation is around half value of potential evapotranspiration (Fig. 3) and Mediterranean forests can transpire up to 80 per cent of precipitation, strongly competing for water.

Mountain forests in the Mediterranean also seem to be vulnerable because of a rise in the elevation of snow cover and altered river runoff regimes. Mediterranean and Mountains species are disproportionately sensitive to climate change as it has been corroborated with recent observations (Walther et al. 2002) and projections (Gottfried et al. 1995). In a recent study (Gracia 2007) simulations of forest growth in Europe with the GOTILWA+ process-based model (Gracia 1997, Gracià 1999, http://www.creaf.uab.es/gotilwapl) predicts an enlargement of the length of the growth period by the year 2080 of 50 days for the Mediterranean region (60 in the case
of Portugal) and, by contrast, only 33 in the Scandinavian countries. This enlargement of the forest activity will imply a greater water demand while the climate projections predict less precipitation (Fig. 4).

In this frame, the distribution of a number of typical tree species is likely to decrease in the current Mediterranean region (Sabaté et al. 2002, Schroeter et al. 2005), e.g. cork oak (*Quercus suber*), holm oak (*Q. ilex*), aleppo pine (*Pinus halepensis*) and maritime pine (*P. pinaster*), but could expand to new areas where Mediterranean like climatic conditions will appear.

Field observations and analyses have evidenced that the raised in temperatures produce an exponential increase \((Q_{10} \approx 2)\) in the respiration rates of living tissues of trees. At the same time, photosynthetic response to temperature does not increase. This results in a depletion of the reserves of mobile carbohydrates, which are used by Mediterranean trees to overcome the dry summer periods. Most of the dieback episodes observed in Mediterranean forests in recent years, are associated to the exhaustion of the reserves of carbohydrates, which can be consumed in periods of three to four consecutive dry years. Most pest attacks are the consequence of this weakening of the trees and not the origin of the dieback. In this context, the levels of carbohydrates in the trees can be used as a “marker” to detect the risk of dieback before the apparition of visual symptoms. The comprehension of the physiological mechanisms underlying the response of different Mediterranean tree species to climate change can help to define new adaptive management regimes. For example, under drier conditions, a moderate reduction of tree densities can improve the balance of photosynthesis/respiration as it has been experimentally demonstrated in the case of evergreen holm oak (*Quercus ilex*) in Spain (López 2003, Gracia et al. 2005). Adaptive management strategies, to reduced water use or to ensure a long-term soil preservation, requires further understanding of the physiological mechanisms as well as the interplay between stakeholders and the environment.

**BIOLOGICAL DIVERSITY IN MEDITERRANEAN WOODLANDS: WHAT IS AT STAKE?**

**A unique value… but under threat**

In the Mediterranean, biological diversity (understood as the sum of the diversity of genes, species and ecosystems) in forests, *garrigues* and *maquis* has, compared to other eco-regions, a number of singular features in terms of high species number and endemism rate (Fig. 5), and extraordinary genetic diversity both between and within populations (intraspecific) (Médail and Myers, Fady 2005).

This biological richness results from evolutionary processes acting in the context of a distinctive geographical and topographical diversity, with high mountain ranges,
peninsulas, and one of the largest archipelagos in the world (the Mediterranean sea, including several hundred islands) resulting in a wide range of local climates; it is also related to paleo-history (refugia in ice periods) and anthropogenic influences such as land uses and creation of mosaic-like landscapes.

The flora of the Mediterranean basin consists of around 25,000 species of vascular plants, which includes 13,000 endemic species (Quézel 1985) that comprises a complex mixture and assemblage in terms of their taxonomic affinities, biology, habitat requirements and distribution (Verdú et al. 2003). The Mediterranean region also harbours a high degree of tree richness and endemism (290 indigenous tree species with 201 endemics) (Quézel and Médail 2003).
As with other Mediterranean-climate hotspots, diversity and endemism among vertebrates is much lower that for plants (Blondel and Aronson 1999). The mammal and bird fauna being largely derived from extra-Mediterranean biogeographical zones while the reptile and amphibians faunas comprise mainly Mediterranean species, and have higher levels of endemism.

The Mediterranean Basin Hotspot, therefore, emerges as one of the hottest, having exceptionally high plant endemism, and one of the lowest percentages of natural vegetation remaining in pristine condition (no more than 5%) of any hotspot.

The regressive evolution affecting Mediterranean forests as mentioned above is jeopardizing biodiversity in the sense that radical changes in communities’ composition and in extinction of local populations are observed.

**FIGURE 5** Wealth in woody species: comparison between Europe, Mediterranean California and the Mediterranean basin (in Quezel et al. 2000); endemic (black), broad distribution (dark grey), total wealth (grey)

<table>
<thead>
<tr>
<th>Region</th>
<th>Endemic</th>
<th>Broad Distribution</th>
<th>Total Wealth</th>
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</thead>
<tbody>
<tr>
<td>Europe</td>
<td>46</td>
<td>89</td>
<td>135</td>
</tr>
<tr>
<td>California</td>
<td>76</td>
<td>94</td>
<td>170</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>158</td>
<td>89</td>
<td>247</td>
</tr>
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Using -and acting on- evolutionary processes, the key for maintaining biodiversity

The precautionary principle, the common sense and empiricism applied to preserving biodiversity have led to designing and implementing policies based on protective measures. This is illustrated by the protected areas of various status and nature, such as the EU Habitats Directive (92/43) which aims at the creation of a protected areas network (Natura 2000; in the Mediterranean region only 4% under a reserve status), as well as the EUFORGEN network for the conservation of Forest Genetic Resources. Although this approach appears adequate and needed, it is far to be efficient and sufficient, because rapidly changing environmental conditions will impact on species composition and distribution in an unforeseeable manner, so that their preservation is questionable on medium or long term. Therefore in extensively managed forests (as many Mediterranean forests), a dynamic conservation approach is urgently required; it should be based on sustaining the mechanisms allowing the maintenance of biodiversity (natural disturbance, gene flows, regeneration). However, using and acting on evolutionary processes, is a challenge in itself and implies a sufficient knowledge on their scientific basis.

**Improving the knowledge in conservation biology: a pre-requisite**

Conservation biology, interpreted as the scientific study of the phenomena that affect the maintenance, loss and restoration of biological diversity is thought to be a major area for increased research efforts, especially in the Mediterranean context. It is crucial to better understand the adaptive response of species and their migratory capacity, in regard to environmental changes and various forest management scenarios. As the speed of expected changes is fast, approaches based on modelling of the demographic, ecological and genetic aspects of the communities’ evolution should be clearly among the future research priorities (Dreyfus et al. 2005).

**LIVING WITH WILDFIRE RISK**

Over the last decades, the wildfires issue has proven to be a subject of growing concern for the Mediterranean Region. Woodlands, rangelands, maquis and garrigue in rural areas or at the interface with urban areas still continue to burn with significant environmental, social and economic impacts, in particular in case of increased frequency of fire. Although the European statistics show in average a real efficiency of policies and measures related to fire prevention and suppression, the occurrence of extreme climatic conditions (2003 in Western Europe, 2007 in Eastern Europe) resulted in catastrophic and huge fires, as those undergone by Portugal and Greece, whose impact, including political ones, was tremendous.

The number of wildfires has doubled since the 1970s with about 50 000 outbreaks every year resulting in an area of 600 000 ha burnt annually. On an average the mean area burnt in a fire has markedly decreased over the last decades, due to the efficiency of prevention and suppression measures. However, a few fires affect huge areas and are responsible of catastrophic damage (see Fig. 6). In economic terms, the losses due to fire have been estimated at a level of 1 billion euro annually.

Although the occurrence of severe wildfires has been affecting mainly the northern rim of the Mediterranean Basin, some significant changes in climate and land use, are already taking place and will most likely result in an expansion of fire threatened areas. For example, Syria, Lebanon and Algeria have recently been exposed to catastrophic wildfires, and, in a near future, new areas in the north will be concerned by a shift of Mediterranean like ecological conditions. This raises the question: how to anticipate these evolutions?

As any risks, wildfires can not and should not be
eradicated, and anyhow, managing fire risk through prevention and suppression has a cost. Therefore, in the context of finite financial resources and increased areas subject to fire, the appropriate response can not be just to «continue business as usual», as it will require a dramatic increase in the means and equipments allocated to fire management. The issue at stake is rather to set up integrated strategies and policies that provide «reasonable» trade-offs between environmental, social and economic elements, and allow to «live with wildfire risk». This new approach definitely calls for a profound rethink of these strategies and policies at national and European level, by tackling the problem in all dimensions, including a clear identification of civil protection and forest protection objectives, as they have been in the past quite often mixed up.

FIGURE 6 Raging fires in Spain and Portugal; Credits: ESA - ID number: SEMC79JZBQE

Today, the causes of wildfires are rather well understood and documented (Velez 2002). Among them, three issues related to policy aspects have to be emphasized. First, the rural abandonment in the northern rim of the Mediterranean basin has resulted in vast and uniform vegetation areas without any horizontal and vertical structuring, very susceptible to wildfires. Second, the development of the wildland-urban interface, due to a lack of control on housing, has led to a dramatic increase of fire risk. Third, the available data show that the behaviour of the public is still reflecting a lack of awareness about fire risk. This gives room for acting on the causes through improved policies, respectively on integrated land use planning, building permits allocation and education.

The increase in the risk of forest fires due to climate change and its extension to new areas call for policies anticipating these evolutions. It will be of primary importance to adopt spatially explicit planning (see chapter below) by compartmentalising the landscape (fuel-breaks, vineyards, orchards, etc.) in order to prevent large scale fires. In addition, environmental friendly vegetation management techniques, able to reduce the fuel load, such as prescribed burning, could be applied on larger scale (Rego et al. 2007).

New opportunities of using the biomass extracted from vegetation/fuel reduction operations for energy purposes should also be considered.

Recent scientific advances open the way to major applications, in particular to the areas as follows:

- assessment in time and space of fire risk related to vegetation structure and dynamics (Fig. 7), and its interactions with urban areas through geo-information methods, including remote sensing and LIDAR technologies (Deshayes et al. 2004);
- integration of fire risk into forest planning (Gonzalez 2006);
- modeling fire behaviour and propagation (Morvan et al. 2006) using deterministic physical models. Current and future applications of such models are numerous: vegetation/fuel management, risk assessment, fire suppression, training forest managers and firemen, etc.

THE REAL VALUES OF MEDITERRANEAN FORESTS

Forests in the Mediterranean region are not only important because of their high ecological value, but also due to their contribution to the human welfare in the region. The multifunctional nature of these forests has since long been recognised. Already in the 15th century, in some parts of the Mediterranean region, the forests were mainly managed for soil and water conservation and only secondary for wood production.

Also in the present, the Mediterranean forests are appreciated, not only for producing wood forest products, but rather for the provision of non-wood forest products and services.

Non-wood forest products (NWP), such as, cork, fodder, mushrooms, fruits, pharmaceutical and aromatic plants, can contribute significantly to the local or national economies. For example, for the southern Mediterranean area it is estimated, that grazing gives almost three times as much benefit, per hectare, as wood forest products. Another example is cork, which in Portugal accounts for 35% of the estimated total benefits obtained from forests (Merlo and Croitoru 2005).

Another important aspect of forests in the Mediterranean region is also their notable role in soil protection, watershed management, water quality, biodiversity enhancement and climate change mitigation by carbon sequestration and micro-climate amelioration. Even if these effects can not be valued

\[1\] According to Merlo & Croitoru (2005) this area includes Morrocco, Algeria, Tunisia and Egypt.
through market prices, they without doubts contribute to the welfare of the populations benefiting from them. Merlo and Croitoru (2005) reported that approximately 40% of the total economic value of Italian forests can be ascribed to watershed protection. Recreation, tourism and landscape aesthetics are further services offered by Mediterranean forests. With the increasing demand for recreational activities and tourism\(^2\) these services are getting more important. There have been several studies conducted for valuing forest recreation. Such studies reported estimated values ranging from 2.5 – 11€/visit (e.g., Scherrer 2002, Bellu and Cistulli 1997).

The estimated values of different Mediterranean forest goods and services by Merlo & Croitoru (2005) presented an average total economic value of Mediterranean forests of about 133€ per hectare of forests or in other words almost 50€ per year and capita. Only some 35% of this value can be ascribed to wood forest products (see Fig. 8). The estimate should not be taken as fixed value, since it can vary significantly in magnitude and composition between different countries.

\(^2\) Plan Blue (2008) reports, that the number of tourists, visiting the Mediterranean region, increased from 153 million in 1990 to 228 million in 2002.
economic principle and the target is to achieve a regulated forest ensuring a sustained yield of wood.

In a Mediterranean context, it is very seldom that wood is the only objective or even the most important. The production of non-wood products (mushrooms, pine kernels, acorns, etc), the minimization of the risk of fires, the provision of recreation possibilities and landscape beauty or the maximization of the quality and quantity of water resources are often the most important objectives, and therefore they need to be explicitly considered as management objectives in forest planning.

This situation calls for multi-objective numerical forest planning. In multi-objective forest planning, forest plans are evaluated using various multiple criteria decision support methods and multi-objective optimization algorithms (see Pukkala and Kangas 1993). The ranking of alternatives depends on the preferences of the decision maker, and therefore preference analysis is a key step of multi-objective planning. Another key step is the generation of alternative plans. Such task requires advanced growth and yield models (Palahi 2002) too simulate different management schedules for each forest stand compartment. Since numerical information for all goals is required, models measures and metrics for different objectives (recreation, risk of fires, mushrooms, pinecones, grazing, water yield, etc) need to be developed (Pukkala 2002b) and implemented. Such models (see Kangas et al. 1993, Silvennoinen et al. 2001, Gonzalez et al. 2006, Calama and Montero 2007, Bonet et al. 2008) are required to predict the effect of different forest stand characteristics and management schedules in the different management objectives (see Figs. 7 and 9 as examples).

The next step in multi-objective planning is to develop a planning model that accommodates the multiple planning objectives. Such task can be done using different approaches; linear programming, goal programming, penalty functions or multi-attribute utility theory. Different planning models require different solving techniques; mathematical programming is used in linear or goal programming, while

Further, it should be acknowledged that due to lack of consistent and reliable data, this value might be an underestimation of the true economic value of Mediterranean forests. In a Spanish study, in which the value of different non-market benefits from afforestation of marginal agricultural land were estimated, the results indicated that the annual economic value would vary between 464€ and 4100€ per hectare of additional forests (Mavsar and Riera 2007).

THE NEED FOR NEW MEDITERRANEAN FOREST MANAGEMENT PLANNING APPROACHES

The characteristics of Mediterranean forests (see above) present many different challenges to forest management, which can be summarized as follows:

From wood-based to multi-objective Mediterranean forest planning

Despite the acknowledge multifunctionality of Mediterranean forests in providing multiple and valuable goods and services to society (see previous chapter), traditional forest planning approaches in the Mediterranean region have been wood based (and still are in management practice) (Madrigal 1994, Palahí 2002, Baskent 2007). Examples of these approaches are the various forest regulation methods and cutting budget formulas develop in Central Europe in XIX century or the more recent stand-based economy approaches. Stand-based methods are based on stand-level evaluations and decisions to select a prescription which maximizes wood production individually for each stand. In forest regulation methods, stability and regularity of wood supply is the overriding economic principle and the target is to achieve a regulated forest ensuring a sustained yield of wood.

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FIGURE 8 Composition of the Total Economic Value of Mediterranean Forests (source: Merlo & Croitoru 2005)
NWP: non wood forest products; WFP wood forest products; non-use: bequest and existence value

FIGURE 9 Wild mushroom production for different basal areas and expositions in Scots pine forests in Catalonia (Spain) as predicted by the empirical model developed by Bonet et al. 2008

Altitude 1240m, Slope 24%

North
East
West
South

Total fresh weight, kg ha⁻¹

0 50 100 150 200 250 300 350 400

0 10 20 30 40

Basal area, m²ha⁻¹
heuristic techniques are used to solve models based on
penalty functions or utility theory models (Pukkala 2002a).
The use of heuristic optimization (see Reeves 1993, Pukkala
and Kangas 1993) has gained popularity in forest planning
along the increasing importance of ecological forest
management goals, which are often described spatially
through landscape metrics (see Palahí et al. 2004). Such
complex spatial problems (see below) are more easily solve
using heuristic techniques like genetic algorithms, simulated
annealing or tabú search. Such optimization techniques,
seek to approximate an optimal solution at a reasonable
computational cost, without being table to guarantee
optimality (Borges 2007). The benefit of using heuristics is
to the possibility of solving more realistic and less
rigid forest planning problems than when using mathematical
programming.

Finally, in order to implement advanced simulation
models and numerical multi-objective optimization
techniques, they need to be programmed, integrated and
used within computer-based decision systems (see Reynolds
et al. 2007). Examples of forest planning decision support
systems (DSSS) developed in a Mediterranean context,
exist in Portugal (the SADIFOR system, see Borges et al.
2003) and Spain (MONTE system, see Pukkala 2003).
Such systems have demonstrated that the utility of DSS goes
beyond their complex problem solving capabilities, since
they also provide important insights to the understanding,
structuring and effective analysis of options and implications
of alternative management approaches to forest ecosystems
and the provision of their multiple goods and services.

From a single scale forest planning to a multi-scale
landscape planning

In Mediterranean forestry, many management objectives
cannot be evaluated at the stand-level or even at forest holding
level. Sound ecological planning (Forman 1995, Mazzeroni
and Villard 1999) as well as effective fire prevention (Loehle
2004), watershed management or improving recreation
requires consideration of areas larger than the forest holding.
In ecological planning, for instance, the habitat quality of
many species should be evaluated at the landscape level
(e.g., capercaillie) (Palahí et al. 2004) and might required as
well information from other adjacent land uses (e.g. Iberian
lynx) (see Palomares et al. 2000). Effective and efficient
fire prevention (see Loehle 2004, Gonzalez et al. 2005a)
requires coordinating forest management in different stands
and forest holdings in order to design a resistant landscape
to fire spread. Forest recreation and scenic beauty are other
objectives that need to be addressed at the landscape level
(see Pukkala et al. 1995, Pukkala 2002b).

Therefore, landscape level forest and rangeland planning
is required to address many important management
objectives. Landscape planning does not mean replacing the
forest holding level by the landscape level because the forest
holdings are the decision makers and their acceptance and
commitment is crucial for the implementation of the plans.
Instead landscape planning should integrate the different
levels of forest management; stand-, forest and landscape
to find an optimal composition and configuration of the
landscape with respect to landscape objectives (habitat
requirements, fire prevention, recreation, hunting, water
yield, etc). Such planning approach is in principle feasible
with the current knowledge, methods and tools (based recent
scientific findings, simulation tools, geographic information
systems and optimization techniques) and the computing
technology available. However, a multi-disciplinary effort
involving ecologists, foresters, agronomists, economists,
geographers, and hydrologists needs to be undertaken to
synthesize information from different disciplines and build
up integrated decision support systems.

It is nowadays clear that Mediterranean forest planning
requires simultaneous evaluations at different scales because
different objectives require different spatial frameworks.
The mosaic-like structure of Mediterranean forests, the
type of management objectives and the fragmented forest
ownership require a multi-scale stand- to landscape forest
planning approach. In such context, advanced simulation
tools, which can calculate landscape level metrics to predict
the effects of a certain management on different landscape
objectives (habitat suitability, fire resistance, scenic beauty,
water yield, etc) and spatial optimization techniques are
crucial for designing optimal landscapes based bottom up
(stand-, forest-, landscape) information.

From static to adaptive forest planning

The increasing risk and uncertainty involved in Mediterranean
forestry decision making is one of the greatest challenges in
forest planning. On one hand, climate change (as it has been
presented above) will continue to be a source of uncertainty
in relation to forest dynamics, to increasing the risk of forest
fires and droughts as well as to the spread of new diseases
or plagues. On the other hand, in a context of a globalize
economy, the future demand and value of different forest
goods and services will be affected by a high degree of
uncertainty.

There are several ways to respond to this increased
uncertainty. The first option is to convert current static
periodical planning into a dynamic continuous process which
allows up-dating or re-planning when something makes the
plan obsolete (a fire, a change in the management objectives,
etc) or no longer justified. Another way to address risk and
uncertainty is to accommodate them explicitly in the forestry
decision making process (see Gonzalez et al. 2005b). This can
be done by analyzing the outcome of different management
plans under different scenarios with known or unknown
probabilities. Such approach converts deterministic planning
into stochastic analysis, providing information about the
alternative plans through the probability distributions of
the objective variables (Gonzalez et al. 2005b). Stochastic
planning allows for considering the attitude of decision-
makers towards risk and uncertainty.

Finally, a new approach to react to risk and uncertainty
is adaptive planning. In adaptive planning, decision-
makers can adapt their plan according to the changing
CONCLUSIONS: TOWARDS MORE EFFICIENT FOREST-RELATED POLICIES THROUGH STRENGTHENED COOPERATION

Although the future of Mediterranean forests seems today not totally clear due to major ongoing and upcoming environmental and social changes, and various risks and uncertainties, the challenges to meet are increasingly better understood and identified, as those presented above. The worse for Mediterranean forests is to be recurrently associated to negative values, which make their profile unattractive, and leads the public opinion to indifference. Without denying the actual threats on Mediterranean forests, one should also emphasize their value for human societies and the opportunities for improved future management.

The estimates of the economic values of Mediterranean forests provided in a previous chapter give an idea of their multifunctionality and the relative importance of non-marketed forest goods and services (mainly public goods and externalities). However, the economic nature of this type of goods (characterised by undefined property rights and lack of markets) causes important market failures that prevent the producers of those goods (forest owners who bear the cost of forest management) from internalising their value. As a consequence, forest owners do not receive the financial incentives to manage their forests in a way that ensures the sustainable and socially optimal provision of non-marketed goods and services. This situation, together with the lack of profitability of timber management has led, in the northern Mediterranean sub-region, to the abandonment of forestry and therefore to the increase of continuous areas of forest biomass, susceptible to be burnt by forest fires. In the southern and eastern Mediterranean sub-regions, the difficult socio-economic conditions, the land tenure systems (mainly public forests) and again the lack of internalization of key non-marketed forest services (soil protection, grazing possibilities, etc) do not provide the necessary incentives to the local populations to manage forests in a sustainable way or to protect them from being converted to agricultural land.

This situation requires two types of actions. The first is to improve the information regarding all non-market forest benefits, characterizing their economic nature, assigning values and positioning them within a total economic value framework. The second action, based on the first, consists of designing and implementing an appropriate mix of policy instruments (e.g., juridical, financial, market-based or persuasive measures) at different scales (local, regional, national and international) to correct the existing market failures related to the provision and internalization of non-marketed forest services. In a Mediterranean context, institutional reforms are also crucial if policy instruments are to be effectively implemented, since poor and weak administration services might prevent the correct application of the various instruments. Finally, it is important to remark that any forest policy or measure should be designed and implemented within the framework of wider rural development strategies and policies. Mediterranean forests cannot be seen in an isolated context. More than in other regions, they require a joint territorial approach between all concerned parties: agriculture and rural development, urban societies, tourism, industry, environment, transport, etc.

The trans-boundary nature of number of issues related to Mediterranean forests, and the fragmented and limited human resources allocated to this sector in terms of management, research and education also call for an increased international cooperation around the Mediterranean basin. It is crucial to share knowledge, know-how and experience. Advancing knowledge through joint research is also seen as a priority, as it becomes obvious that we are already in a knowledge-based era.

To a large extent, the future of Mediterranean forests depends on the collective political willingness and commitment to tackle the problems. Is it unrealistic to envisage a permanent high political process on Mediterranean forests such as the European one (MCPFE), for example within the future Euro-Mediterranean framework?

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