# Frontiers for forest conservation: securing the future ecosystem services balance

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## FOREST CONSERVATION: CHOICE OR NEED?

### Why forest ecosystems need to be preserved

Forests are important sources of biodiversity and ecosystem services (ES) from the local to the global scale. Forest ecosystems sustain human well-being by providing timber and non-timber products, and fresh water; regulating biogeochemical cycles (climate mitigation, regulation of hydrological regimes); hosting habitats for wildlife; and protecting cultural and recreational values (national parks in Italy; Vizzarri et al., 2015a). The diversity of species and habitats is strictly related to the functionality of (forest) ecosystems, and to ecological resilience, and directly influences the provision of ES. However, during the last decades, human-induced transformations, mainly land-use change (LUC) and climate-derived effects, have led to a widespread loss of biodiversity and the erosion of important ES. As a consequence, the health and stability of (forest) ecosystems have been also undermined. On the one hand climate change increases the vulnerability of forest ecosystems to other disturbances (e.g. introduction of alien species, wildfires and windstorms), and on the other hand deforestation, overexploitation (i.e. unsustainable forestry), and LUC-related processes threaten forest biodiversity and habitat functionality, as well as the provision of ES (e.g. Meyfroidt and Lambin, 2011).

The human-induced degradation of forest ecosystems, and of associated landscapes, leads to a 'loss of resilience that prevents natural recovery of the pre-disturbance state' (Ghazoul et al., 2015, p. 624). Continuing with the current trends of human impacts, species extinction will increase and key habitats will consequently reduce, resulting in new species assemblages and large transformations of vegetation types (e.g. novel ecosystems; Lindenmayer et al., 2008). This aspect is particularly amplified in the Mediterranean basin, where the conservation of biodiversity and habitats is at high risk. In Mediterranean landscapes, where the resilience of forest ecosystems is often compromised by low utilisation rates (due to the abandonment of grazing and forestry practices), LUC and climate-related issues, forest management is called on to reconcile the maintenance of high ecological levels (in terms of best balances between forest ecosystem functionality, biodiversity and ES availability) while improving local communities' well-being. In fact, forest harvesting was found to have different implications on biodiversity conservation in tropical forests (e.g. reduced logging; Bicknell et al., 2015) and temperate and boreal forests (e.g. active management in set-aside forests; Bernes et al., 2015). Moreover, the conservation of traditional (forestry) practices is important to maintain a certain landscape diversification and limit the possible consequences of human-induced changes, such as water shortages, hydrological risks, increased frequency of forest fires, loss of native species and reduced agricultural productivity (e.g. Agnoletti, 2014; Schröter et al., 2005). At landscape scale, adaptive forest governance is demonstrated to be an effective strategy to orient decision-making processes towards balancing the ecological constraints (ecosystem functionality) with social-ecological needs (expected ES) (e.g. Vizzarri et al., 2015b). As a consequence, a deeper knowledge of the interplay between ecologic and

social-economic systems over space and time is required in order to identify the role of biodiversity in the availability and distribution of ES stocks and flows, along with the associated benefits for local communities, and whether currently adopted strategies are able to cope with such dynamics (e.g. Bennett et al., 2015). Accordingly, this work contributes to bridging the current knowledge gap in forest conservation science by highlighting the main linkages between biodiversity conservation, ES availability and forest management, with particular regard to Mediterranean landscapes, the social-ecological resilience of which needs to be maximised in order to face the emerging global sustainability challenges, such as atmospheric and water pollution, energy and food security and biodiversity loss (e.g. Liu et al., 2015).

### From conservation science to adaptive forest governance

Conservation science is a discipline aiming to jointly maximise the benefits to people (i.e. human health; similarly to environmental science) and to ecosystems (i.e. biological diversity; similarly to conservation biology; e.g. Kareiva and Marvier, 2012). More recently, conservation concepts have evolved towards incorporating the values that people attribute to nature in order to consider the complexity of coupled human–nature interactions (i.e. 'nature for itself' vs 'nature for people'; Mace, 2014). Biodiversity conservation encompasses different approaches, ranging from actions targeted at preserving the status of species and habitats at a smaller scale to the creation of habitats or restoration opportunities at a broader scale. How are such conservation approaches properly translated into forest management strategies? In the case of forest resources, conservation actions should maintain habitat connectivity and landscape heterogeneity, the integrity of forest-associated aquatic ecosystems and stand structural complexity, according to a dynamic perception of forest ecosystems over time (Lindenmayer et al., 2006). In this way, the management of complex adaptive systems, such as forest ecosystems, requires a resilience-based approach (Vizzarri et al., 2015b). Figure 1 depicts the linkages between forest management and planning and conservation-based approaches, in relation to threats to both ecosystem functionality and resilience. With particular regard to threats to biodiversity and ecosystem functioning (centred circled arrows, Figure 1), forest biodiversity, reflecting the ecosystem structures and processes, is strongly undermined over a range of increased complexity, from individual organisms, species assemblages and key habitats to the landscape scale. The shrinkage of forest ecosystem resilience (red circle arrow, Figure 1) leads to reduced capacity of adaptive systems to face external perturbations, mostly human driven. As a consequence, the loss of species and habitats (dark green circled arrow, at the top,

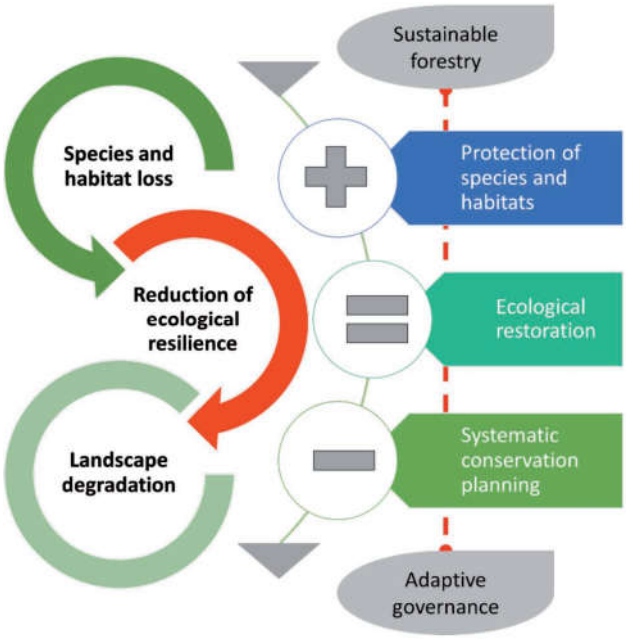


Figure 1

Chart representing the linkages between the different threats to biodiversity and ecosystem functioning (circled arrows on the left side), forest management approaches (grey boxes on the centre-right side) and alternative conservation strategies (coloured boxes on the right), in response to decreasing levels of complexity (mathematical symbols, from top to bottom).

Figure 1) increases the impact of external changes on ecosystem stability and efficiency, thus affecting the balanced connections between ecosystems and habitats at a broader scale (i.e. landscape; light green circle, at the bottom, Figure 1). The reduction of forest ecosystem resilience may negatively influence the future delivery of goods and services. Alternative conservation strategies currently exist, and may be targeted at threatened or endangered species and habitats (e.g. the establishment of protected areas), and at complex landscapes (i.e. systematic conservation planning) (coloured boxes on the right, Figure 1). Furthermore, ecological restoration may be an effective approach to recover the resilience and stability of forest ecosystems in the short term, and after an external perturbation (e.g. wildfires). Forest management and planning approaches with conservation purposes range from sustainable forestry practices (close-to-nature silviculture, selective logging, etc.) at stand level to adaptive strategies at landscape level (grey boxes on the centre-right side, Figure 1). Considering that sustainable forestry represents an integrated part of adaptive governance, the connections between these two approaches involve different ecosystem processes and functions that vary across spatial and temporal scales (red dashed line, Figure 1).

## TOWARDS CONSERVATION STRATEGIES FOR MEDITERRANEAN FORESTS

### Review exercise

During the last century, the land abandonment phenomenon, in conjunction with climate-induced changes (e.g. drought), profoundly altered Mediterranean forest landscapes, whose assets and structure became simplified and degraded. These aspects led to a large decrease in the adaptive capacity of Mediterranean forest ecosystems, including the strictly correlated ecosystem services provision, and the well-being of local communities. Deeper scientific knowledge in that sense is also required to improve the bioeconomy in the Mediterranean region (e.g. Nardi et al., 2016). Accordingly, the review exercise mainly aims at investigating how forest management can improve the conservation strategies in Mediterranean forests, with particular regard to the conservation of biodiversity and the preservation of their adaptive capacity. The literature review outlines to what extent the conservation approaches and mechanisms are linked to forest ecosystem resilience (including the provision of ES) within the scientific debate, from global to Mediterranean, and at the Italian scale. Further details about the methodology used for performing the literature review are reported in Box 1.

The main results reveal that the number of publications on forest conservation greatly increased from 1992, with similar trends among the three spatial scales considered. However, the number of publications concerning forest conservation in the Mediterranean area, and in Italy, represents a very small portion of that available at the global scale (2.36 % and 0.04 %, respectively). This seems something of a mismatch with the conservation priorities in Mediterranean forests as biodiversity hotspots (e.g. Hoekstra et al., 2005). This contradictory aspect is particularly amplified in Italy, where the conservation of biodiversity and the maximisation of associated ES would require more support from research, at least for the management of protected areas (PAs). Similarly, very few records were found when searching for the topics ‘forest compensation and offset mechanisms’ (16, 1 and 0 units at global, Mediterranean and Italian scales, respectively), ‘conservation and forest ecosystem resilience’ (26 and 5 units at Mediterranean and Italian scales, respectively) and ‘conservation, ES and forest ecosystem resilience’ (4 and 1 unit(s) at Mediterranean and Italian scales, respectively). Intuitively, these findings may denote that research focusing on linking forest management with biodiversity conservation is still needed in the Mediterranean area, and in Italy. Moreover, no records were found when searching for the topic ‘forest resilience,

**Box 1. Review exercise — methods**

The literature review is based on a keyword-based search (title, abstract and keywords) of published scientific material in the Scopus database, from 1992 to 2015. The review is structured into five steps, according to different topics, such as forest conservation, ecosystem services, resilience and compensation/offset mechanisms, and has three different levels of detail representing the spatial scale (i.e. global, Mediterranean and Italian). The table below reports the search strengths and the keywords used in the review exercise.

| Topic | First spatial level | Second spatial level | Third spatial level |
|---|---|---|---|
| **Forest conservation** | 'Conservation' AND 'forest*' OR 'forest ecosystem*' | 'Conservation' AND 'forest*' OR 'forest ecosystem*' AND 'Mediterranean' | 'Conservation' AND 'forest*' OR 'forest ecosystem*' AND 'Italy' |
| **Forest conservation and ES** | 'Conservation' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' | 'Conservation' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' AND 'Mediterranean' | Conservation' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' AND 'Italy' |
| **Forest compensation/offset mechanisms** | 'Conservation' AND 'biodiversity compensation*' OR 'biodiversity offset*' AND 'forest*' OR 'forest ecosystem*' | 'Conservation' AND 'biodiversity compensation*' OR 'biodiversity offset*' AND 'forest*' OR 'forest ecosystem*' AND 'Mediterranean' | Conservation' AND 'biodiversity compensation*' OR 'biodiversity offset*' AND 'forest*' OR 'forest ecosystem*' AND 'Italy' |
| **Conservation and forest ecosystem resilience** | 'Conservation' AND 'resilience' AND 'forest*' OR 'forest ecosystem*' | 'Conservation' AND 'resilience' AND 'forest*' OR 'forest ecosystem*' AND 'Mediterranean' | 'Conservation' AND 'resilience' AND 'forest*' OR 'forest ecosystem*' AND 'Italy' |
| **Conservation, ES and forest ecosystem resilience** | 'Conservation' AND 'resilience' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' | Conservation' AND 'resilience' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' AND 'Mediterranean' | 'Conservation' AND 'resilience' AND 'ecosystem services' AND 'forest*' OR 'forest ecosystem*' AND 'Italy' |

and compensation/offset mechanisms'. This may derive from the fact that the concept of resilience is still weakly correlated to practical biodiversity compensation and offset mechanisms.

### Linking conservation strategies with forest management approaches

The conservation strategies may be correlated to the resilience-based approaches in forest management (see Table 1).

Establishment, maintenance and management of the PA network remain some of the most effective strategies to pursue biodiversity conservation, especially considering that a large part of the total global forest area is

Table 1

Examples of the correlation between forest management approaches and conservation strategies at different identified spatial scales.

<table>
<tr><th>Forest management and planning approaches</th><th colspan="2">Conservation strategies</th><th>Spatial scale</th></tr>
<tr><td>Sustainable forestry practices</td><td colspan="2">Conservation of species and habitats</td><td rowspan="4">Local to landscape</td></tr>
<tr><td>Retention forestry</td><td rowspan="3">Biodiversity and ecosystem functioning (BEF) framework</td><td rowspan="3">Ecological restoration (standard approaches)</td></tr>
<tr><td>Resilience-based practices</td></tr>
<tr><td>Ecological-based forestry</td></tr>
<tr><td>Integrated forest management and planning—adaptive governance</td><td colspan="2">(Systematic) conservation planning</td><td>Landscape to regional</td></tr>
</table>

currently comprised in the network of PAs (16.3 %; Morales-Hidalgo et al., 2015). Nevertheless, conservation effectiveness in PAs is largely weak, due to high pressures and threats in the surrounding areas and to the lack of integrated management measures (e.g. PA management planning). Also, outside PA boundaries, the effectiveness of conservation management may be improved by adopting a 'learning-by-doing' approach, which enables forestry interventions to cope with natural dynamics and to balance the conservation of particular species and habitats with the provision of ES. At stand scale, one of the most effective approaches to guarantee the biodiversity conservation and important ES over space and time is resilience-based forestry (e.g. the *silvosistemica* discipline; Ciancio, 2016). In addition, ecological restoration may be adopted to shorten the duration for the natural recovery of a degraded forest area (e.g. burnt or cleared). This also facilitates the reestablishment of the functioning and resilience of the forest to a pre-disturbance state, as well as the associated social and economic benefits over the short term. In particular, Chazdon (2008) proposed different management approaches to restore degraded forests at different time steps, and financial investments such as: (i) rehabilitation, to improve soil fertility for agricultural or forestry use; (ii) agroforestry and reforestation (commercial or with native trees), to balance the goods and services obtained; and (iii) natural and/or assisted regeneration, to shorten the time needed to recover the biodiversity and other ES. At a broader scale, conservation planning supports the selection of areas particularly suited to conservation, and integrates the anthropogenic impacts with the planned management interventions. Translating conservation planning into adaptive governance would also mean balancing segregated and integrated conservation instruments across a complex forest landscape. Through a segregative approach to forestry only a portion of the landscape is allocated for nature conservation (e.g. national parks, forest reserves), while through an integrative approach the ecological, social and economic elements of the whole forest area are combined at the same time (e.g. biosphere reserves; Bollmann and Braunisch, 2013).

### Balancing biodiversity conservation with the provision of ES in Mediterranean forests

Resilience-based forest management is focused on maximising the capacity of forest ecosystems to face external changes while guaranteeing the benefits for people. Accordingly, trying to incorporate external disturbances (LUC and climate, at first), and adapting the forest management to natural responses in

Mediterranean landscapes, currently represent big challenges. This is particularly important when considering that Mediterranean forests show higher biodiversity risks than tropical forests, as they represent the least protected biomes at the global scale (e.g. Hoekstra et al., 2005). Low-impact and small-scale forestry practices (derived from an accurate structural analysis) are preferred, mainly to stimulate natural regeneration and structural diversification, and should be followed by monitoring activities aimed at assessing the stand reaction, and consistently adjusting future interventions (Nocentini and Coll, 2013). In fact, monitoring forest biodiversity and resilience (including the implications derived by the forestry interventions adopted) is extremely important for conservation purposes. In this way, the implementation of simulation models may facilitate a deeper understanding of how management practices affect the complex forest ecosystem dynamics, and the associated ES trade-offs, over time and across different spatial scales (from stand scale to a broader scale; e.g. the Mimose approach; Bottalico et al., 2016). Simulation tools may be further developed by including alternative social- and economic-oriented scenarios in order to consider the influence of several land-use and climate changes on forest biodiversity and resilience during the analysis. Moreover, when balancing biodiversity conservation with other provision of ES, it is extremely important to consider the revenue losses due to, for example, lowering the availability of marketed forest products, or reducing production-oriented forest areas. Tools such as payments for ecosystem services (PES) may improve the effectiveness of biodiversity conservation, and not only within the boundaries of PAs. Finally, the resilience-based management of Mediterranean landscapes, with the main purposes of maintaining healthy and stable forest ecosystems, while enhancing the integration between ecological, social and economic features, is also strictly dependent on raising the awareness of local communities and facilitating their participation in local management and planning initiatives (Vizzarri et al., 2015b).

### Adopting effective policy measures for forest conservation in the Mediterranean

Several policies supporting the conservation of forest biodiversity also in the Mediterranean area are currently available at global and European scales. At global scale, at least three Aichi biodiversity targets specifically aim at reducing the loss of habitats, including their degradation and fragmentation, and at managing natural systems in more sustainable and integrated ways (Targets 5, 7 and 11; UNEP/CBD/COP/DEC/X/2). Considering that the same aims for conservation are promoted at the EU level (the birds and habitats directives, Directives 2009/147/EC and 92/43/EC respectively; and the EU biodiversity strategy to 2020, COM(2011) 244), the future management of natural ecosystems in general needs to carefully take into account ES trade-offs (also in a spatially explicit way) in order to guarantee the respect of ecosystem functionality and that the objectives for biodiversity conservation will be reached in the near future (e.g. Maes et al., 2012). For example, the WWF's Green Belt Programme aims at establishing a network of forest reserves across the Mediterranean countries and promoting effective participatory management measures in order to preserve habitats and reduce biodiversity threats. In addition to the Biodiversity Finance Initiative (Biofin) and Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects for developing countries, the adoption of proper compensatory mitigation mechanisms also in Europe may further enhance biodiversity gain and compensate for impacts and threats (Madsen et al., 2010). Although compensatory measures regulated by the Habitats Directive in Europe are available, the lack of standardised regulations among Member States and the low levels of voluntary activities greatly compromise their effectiveness (Madsen et al., 2010). For example, habitat banking can potentially be used to reach the 'no net loss' initiative at the EU scale (Madsen et al., 2010). In general, proper policy measures to reduce both the administrative and the financial gaps need to be developed, and not only in the Mediterranean area.

## FINAL REMARKS

Forest conservation refers to enhancing the functionality and resilience of forest ecosystems over space and time, especially where biodiversity and the provision of ES are increasingly impacted by anthropogenic pressures. Accordingly, forest management and planning are required to face the complex dynamics of coupled human and natural systems, by adopting a resilience-based approach. This aspect needs to be particularly emphasised in Mediterranean landscapes, where recent LUC phenomena (e.g. abandonment of rural practices in mountain areas) and climate effects (e.g. warming and drought) are increasingly forcing forest ecosystems towards their health and stability thresholds. In particular, resilience-based forest management should be oriented to: (i) maintain native (or threatened) species and habitats by means of an integrated approach, thus preserving the forest structure while maximising their ability to provide additional goods and services (marketed and non-marketed ES) and enhance the well-being of local communities; (ii) further develop resilience-based practical approaches (i.e. forest management systems) and integrated assessment tools (i.e. forest ecosystem models, decision support systems) in order to simulate and monitor forest ecosystem dynamics, including their final and intermediate outcomes over different temporal and spatial scales, and to better support decision-making processes; (iii) implement adaptation measures in forest landscape planning, and conservation policies at a broader scale, by, for example, balancing conservation areas with more productive ones, or stimulating the adoption of investments and offset mechanisms; and (iv) improve the exchange of information between managers, researchers, policymakers and stakeholders to increase the effectiveness of conservation strategies. Finally, the management of natural resources (not only of forest ecosystems) should consider that conservation targets are met only if the resilience of the whole social-ecological system is improved. Resilience-based management requires a better understanding of the complexity of natural and semi-natural systems (in ecological, economic and social terms; e.g. McAfee et al., 2010), along with the strengthening of transdisciplinary collaborations at various scales to face multiple management challenges and objectives, such as nature conservation and human well-being (e.g. conservation in the Anthropocene; Corlett, 2015).

Snag and saproxylic fungi as key elements for biodiversity conservation in a European beech forest in Molise region, central Italy.

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