

PROMOTING DIVERSIFICATION AS A WAY TO ENHANCE THE ABILITY OF MEDITERRANEAN FOREST TO COPE WITH CHANGE

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Mediterranean forests deliver multiple goods and services to societies but are increasingly threatened by the different components of global change. In such context, management practices oriented to progressively diversify pure stands with species presenting different traits of response to disturbances should be more and more considered as a way to enhance the capacity of the stands to respond to change. The importance of promoting the natural diversification of Mediterranean forests and the main factors and mechanisms driving these processes are briefly discussed in this communication taking as example the case of long-term managed sub-Mediterranean pine stands of the Catalan Pre-Pyrenees (NE Spain), a forest type that is particularly vulnerable to wildfires. Finally, some examples of management practices that could be applied to promote the natural diversification of these stands are introduced.

Keywords: diversification, resilience, response-type diversity, post-disturbance dynamics, *Quercus-Pinus*.

Parole chiave: diversificazione, resilienza, diversità di risposta, dinamiche post-disturbo, *Quercus-Pinus*.

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1. Introduction

Forests play a key role on the welfare of societies by providing a variety of goods and services. In the Mediterranean region, they are a major component of landscapes and represent valuable assets for many economic sectors such as tourism, energy, soil protection or drinking water supply (FAO, 2013). Mediterranean forests are also one of the world's major centres for plant diversity and endemism, being recognized as a global biodiversity hotspot (Médail and Quézel, 1999). The evolution of these ecosystems has been intimately associated to the impacts of human activities for millennia, with positive and negative feedback cycles operating at different spatial and temporal scales (Nocentini and Coll, 2013). The result of these interactions, together with the inherent climatic and topographic heterogeneity of Mediterranean landscapes, has originated anthropogenic forest systems and landscapes that have reshaped ecological values in the region (Blondel *et al.*, 2010).

In recent times, the different components of global change threaten, at different temporal and spatial scales, the difficult equilibrium between the acquired anthropogenic structure and functioning of many Mediterranean forests and the future provision of ecosystem services required by human societies. The generalized land abandonment processes occurring from the second half of the 20th century, for example, have opened the door to active encroachment and self-organization processes that are progressively modifying the structure and composition of Mediterranean landscapes (Roura-Pascual *et al.*, 2005; Ameztegui *et al.*, 2010). In parallel, climate change scenarios, predict

for the Mediterranean region a notable increase in temperature (between 2 and 4°C over the next century), variations in the precipitation regimes and an increasing frequency of extreme events such as heat waves and storms (IPCC, 2007) which could induce important shifts of dominant tree species in the next decades (Valladares *et al.*, 2014). Under this context of important and rapid environmental changes, maintaining the provision of the multiple goods and services of Mediterranean forests and their singular functional and structural components constitute the main challenge for forest managers.

2. Fire and global changes

The combined effect of land-use and climatic changes are expected to modify the frequency and severity of abiotic and biotic disturbances. In the particular case of wildfires, which have historically been shaping Mediterranean natural landscapes, extensive forest recovery is leading to an overall increase of burnt areas and fire recurrence (Pausas, 2004).

The number of fire-prone days per year is also growing as a consequence of climate change (Piñol *et al.*, 1998) and there is a general consensus among the scientific community that the risk of catastrophic wildfires will raise in the Mediterranean. Under this context, advancing in the understanding of the processes that mediate the response of Mediterranean forests to wildfires is essential to define adequate ecosystem-based measures to increase the resilience of these systems against them. However assessing how Mediterranean forests respond to fire is complex because the factors and mechanisms driving these processes are varied and operate at

different spatio-temporal scales. For example, in a recent study conducted in a large *Pinus nigra* forest affected by a wildfire in the central Catalonia (NE Spain), post-fire recovery success was found to be more important in previously long-standing forests than in young stands originated from land abandonment processes (Puerta-Piñero *et al.*, 2012). This response was associated to the higher presence of individuals of species with resprouting ability (mainly oaks) in the understory of the old stands. These species, contrary to pines, show difficulties to colonize new areas but establish well under relatively closed canopies, where the seedlings find protection from direct exposure to sun. Dispersion in these cases is mediated by the Eurasian jay (*Garrulus glandarius*), a bird that naturally disperse the acorns into the pines caching them during the fall for consumption during winter (Gómez, 2003). Overall, post-fire recovery success in this area was thus related to different ecological processes and specific plant features, such as the action of a biotic disperser, the ability of some tree species to establish under shade and their capacity to resprout (Fig. 1).

In general terms, the diversity of types of responses to disturbances present in a given stand (e.g. sprouting ability, seed mobility, drought tolerance) is considered to be a good indicator of its overall resilience to change (see Puettmann, 2011). In this line, promoting the natural diversification of simplified stands in particular with species with different traits of response to change should be more and more considered by forest managers as a strategy to enhance the capacity of the systems to adapt and respond to rapid environmental changes and natural disturbances.

3. Forest management practices to enhance diversification of pure stands

Management practices oriented to enhance the natural and progressive diversification of simplified stands



Figure 1. *Quercus pubescens* sprouts in a previously dominated *Pinus nigra* forest fifteen years after the occurrence of a large wildfire near Solsona, Lleida (Spain).

might focus, first, at facilitating dispersion processes of other species from adjacent stands and, second, at improving (when needed) the site conditions for the establishment and development of these species and their future persistence. The maintenance and preservation of biological legacies such as remnant trees from past-uses or disturbances (Fig. 2) or still the retention of some trees at final harvest operations is of vital importance not only because they can act as seed source but because they can harbor biotic dispersers that play a key role for regeneration (Filotas *et al.*, 2014). At a larger scale, improving habitat conditions of dispersers might also be considered. For example, maintaining some dense and homogenous pine areas intercalated with small agricultural fields may increase jay populations and by this the dispersion of acorns inside the pines if seed sources are available (Pons and Pausas, 2008).

At stand-scale, silvicultural treatments such as thinning or selection cuttings might be applied to modify stand structure and canopy attributes and by this favor the development of dispersed species. The intensity of these interventions may depend on the light exigencies of the species, a factor that can vary along their life stages. Most Mediterranean oaks, for example, show better recruitment rates under shade but once established require light to improve growth and reach higher developmental stages (Espelta *et al.*, 1995). At larger scales, natural diversification processes can be enhanced by increasing landscape heterogeneity (Gonzalez-Moreno *et al.*, 2011). This can be addressed with the use of stand-based forest planning strategies that explicitly consider the diversity of structures and forest typologies present in the landscapes.

As mentioned in Puettmann (2011) this management practices may lead to increased cost and are probably not profitable at the short term. However in the long term they could lead to important economic savings by ensuring the persistence of forest after unexpected events and the continuous provision of precious goods and services to societies.



Figure 2. Old *Quercus pubescens* tree (reflecting past coppice management) inside a *Pinus sylvestris* stand near Solsona, Lleida (Spain).

RIASSUNTO

Promuovere la diversificazione come mezzo per aumentare la capacità delle foreste mediterranee di affrontare il cambiamento

Le foreste mediterranee forniscono molteplici beni e servizi alla società ma sono sempre più minacciate dalle diverse componenti del cambiamento globale. In tale contesto, le pratiche di gestione orientate a diversificare progressivamente i soprassuoli monospecifici con specie che presentano diverse capacità di risposta ai disturbi sempre più dovrebbero essere considerate come un modo per aumentare le capacità dei soprassuoli a reagire al cambiamento. L'importanza di promuovere la diversificazione naturale delle foreste mediterranee e i principali fattori e meccanismi che guidano questi processi vengono discussi usando come esempio il caso dei soprassuoli di pini sub-mediterranei dei Pre-Pirenei Catalani (Spagna nord orientale) gestiti da lungo tempo, e che sono particolarmente vulnerabili agli incendi. Infine vengono presentati alcuni esempi di pratiche gestionali che potrebbero essere applicate per promuovere la diversificazione naturale di questi soprassuoli.

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