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Can understorey native woodland plant species regenerate under exotic pine plantations using natural succession?

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ABSTRACT

Forestry industry in many European countries has begun to focus on sustainable forest management practices, and consequently, a greater emphasis is now being placed on the restoration and enhancement of native woodlands in places where intensive forestry is nowadays not highly profitable. In this context, we evaluate the natural regeneration of native oak woodland vegetation under cultivated stands of *Pinus radiata* in the Biscay region, Northern Iberian Peninsula. We compared vegetation composition and diversity on 60 stands representing the three commonly observed habitats: regenerating *Quercus robur* woodlands, old-growth native *Q. robur* woodlands, and their adjacent *P. radiata* plantations at different successional stages. The aim was to assess the potential of natural successional processes to restore the native oak woodland species under pine plantations, determining whether natural regeneration is sufficient or some management interventions are needed. The results reveal significant differences in understorey species composition between pine plantations and oak habitats. However, these understorey compositional differences were reduced during natural successional process (from young to old age plantations), being especially important in the case of tree and fern growth-forms. The successional trends are driven by an increase of tree, fern and native species cover during pine plantations succession, although the richness was always higher in plantations mainly by the presence of a great number of generalist and opportunistic species. Nevertheless, some typical woodland species, such as *Ulmus minor* and *Lamiastrum galeobdolon*, did not appear in plantations. Here, the natural successional process produced a slowly convergence in understorey species composition between plantations and oak habitats. However, the old pine plantations and oak habitats still differed considerably in understorey composition, suggesting that using only natural succession a much longer time frame is needed to achieve our ecological restoration objective. Natural succession could be used to achieve the restoration objectives at relatively low costs almost for tree and fern growth-forms, although in the case of ancient woodland species especial actions would be needed. The reorientation of pine plantations towards species compositional states that are more similar to native oak habitats could be faster using adaptive forest management practices (e.g. single tree selection).

1. Introduction

In many regions of Western Europe, the native forest area has diminished dramatically over the past several centuries as a consequence of human impacts (Calviño-Cancela et al., 2012). Forests are becoming increasingly fragmented, typically resulting in numerous small patches isolated by different land uses (Rudd et al., 2002), as a result, loses of biodiversity, ecological functions and ecosystem services are produced (Onaindia et al., 2013). Simultaneously, during the last decades one of the most endangered activities for native forest is the expansion of tree plantations, and specially those of fast growing exotic tree species (Bremer and Farley, 2010). Towards the end of the last century, the forestry industry in many European countries began to focus on sustainable forest management practices, and consequently, a greater emphasis is now being placed on the restoration and enhancement of native woodlands (Mason, 2007), especially in places where intensive forestry is not highly profitable.

The effect of intensive forestry practices on native species is a cause of great concern and a source of controversy. The conservation of native plant species and biodiversity for forest landscapes dominated by plantations has become an increasingly important topic, and opportunities to maintain or enhance biodiversity

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within these forests need to be recognized and applied (Perry et al., 2011). The expansion of intensive managed plantations has raised concerns amongst forest managers and general public over the implications of these trends for sustainable production and native species conservation (Carnus et al., 2006). Some authors consider plantations to be valuable habitats for flora and fauna, and they suggest that they can catalyze the regeneration of native understorey species and thus, contribute to biodiversity conservation (Lugo, 1997; Carnus et al., 2006). In contrast, other authors showed neutral or even negative effects of plantation on native species and biodiversity (see reviews of Stephens and Wagner (2007), and Bremer and Farley (2010)). This lack of consensus around the ecological impacts of forest plantations can arise from the scarcity of studies that examine plantations along their successional gradients (Brockerhoff et al., 2008). It is well known that age and structure of the stands (e.g. canopy closure, tree height) determine the ability of plantations to harbor biodiversity (Lindenmayer and Hobbs, 2004). At the same time, comparisons between plantations and target communities should be made considering the potential vegetation stage after natural succession. The consideration of these aspects in the analysis helps to identify the plantations potential to restore native-forest species composition and diversity.

In the Biscay region (Northern of the Iberian Peninsula), native forests have suffered substantial degradation from the fifteenth to the nineteenth century, due to wood demand for charcoal and timber productions. As a result, at the beginning of the twentieth century, native mixed-oak forests, dominated by *Quercus robur*, were highly fragmented. In the 1950s, industrialization in the area initiated a crisis in the rural regions that resulted in farm abandonment and the spread of rapid growth and fast turnover *Pinus radiata* plantations (35–40 years rotations). Even if pine plantations were once highly profitable, the reduction in prices of timber over the last ten years has reduced their profitability. Thus, in the near future this economical change might give rise to silvicultural policies and practices that allow for increasing consideration towards native forest restoration and biodiversity conservation.

The links between succession and restoration have emphasized the potential of natural processes to achieve native forest restoration. In this context, the use of pine plantations as passive restoration tool of native oak forest, relying on natural succession, is an important aspect to be considered. Fast-growing pines represent an intermediate successional stage between the transitional shrubs communities and the mature tree communities (Gómez-Aparicio et al., 2009); as a consequence the spontaneously regenerated vegetation (most frequently shrubs and broadleaved trees) plays an important role in restoring natural conditions in plantations (Onaindia and Mitxelena, 2009). Studies from temperate zone plantations have found evidence that plantations can promote habitat conditions for establishment of mid-successional native tree species such as oaks (*Quercus* spp.) and ashes (*Fraxinus* spp.) (Truax et al., 2000; Cogliastro and Paquette, 2012), then this regeneration could be left to form a canopy after the plantation trees are harvested (Lust et al., 2001). However, since natural oak forests have been transformed into remnant patches the natural processes governing dispersal (e.g. dispersal distances) have a major influence on plant colonization (Cain et al., 2000), being fundamental factors to be considered in native forest restoration. Therefore, native woodlands close to pine plantations, which act as seed sources, produce more active recruitment and successional dynamics on plantations (Gómez-Aparicio et al., 2009), favoring the restoration of native community.

Within this context, we evaluate the natural regeneration of native oak woodland vegetation under cultivated stands of *P. radiata* in Northern of the Iberian Peninsula. To achieve this, we compared vegetation composition and diversity changes on three commonly observed habitats: regenerating *Q. robur* woodlands, old-growth native *Q. robur* woodlands; both acting as seed sources and their adjacent *P. radiata* plantations at different succession stages that act as seed traps. This study can determine whether natural regeneration will be sufficient for restoring the natural woodland main species or some management interventions are needed. The aim was to assess the potential of natural successional processes as an effective tool to restore oak woodlands under pine plantations. Specifically, we tested the following questions: (1) Does the course of succession on pine plantations reduce the understorey compositional differences with natural oak communities?, and (2) what are the understorey vegetation structural and diversity changes in comparison with natural oak woodlands?

2. Methods

2.1. Study area

The study was carried out in the mountainous region of Biscay, Basque Country, Northern Iberian Peninsula (43°07′N 2°51′W). The climate is temperate Atlantic with a mean annual rainfall of 1200 mm and a mean annual temperature of 12 °C. The native vegetation in this mountainous area is composed by mixed-oak woodlands, which a canopy dominated by *Q. robur*, *Fraxinus excelsior* and *Crataegus monogyna* (Aseginolaza et al., 1988), being other characteristic tree species *Castanea sativa*, *Ulmus glabra* and *Ulmus minor*. In the Biscay region, many mixed-oak woodlands have been replaced by plantations of *P. radiata*, thus remnant native forests are highly fragmented occupying only 3.5% of the area (Schmitz et al., 1998). Therefore, the predominant landscape is a mosaic dominated by pine plantations with small remnants of disseminated mixed-oak woodlands with an average size of 2.20 ha (Rodríguez-Loinaz et al., 2011).

2.2. Habitat selection

The understorey plant species composition and diversity were studied in three types of habitats: (1) mixed-oak woodland (*Q. robur* and *F. excelsior*) in a regeneration process for at least 70 years ($n = 15$, Qr), (2) old-growth native *Q. robur* woodlands older than 100 years ($n = 15$, Qo), both considered target communities from a conservation viewpoint; and (3) their adjacent *P. radiata* plantations at different successional stages ($n = 30$, P). The selected stands were located at an altitude of 350–400 m a.s.l. on sandstone soils with slopes lower than 30%. The oak stands were selected first, and then the nearest pine plantation to each oak stand was selected, being the average distance between pairs of forest 199 ± 22 m (Table 1).

The sampled pine stands were sorted into four groups according to the *P. radiata* structure and age of plantation as follows: Py = young pine plantations from 1 to 10 years old ($n = 8$); Pt = teen pine plantations from 11 to 20 years old ($n = 9$); Pm = middle age pine plantations from 21 to 30 years old ($n = 7$); and Po = old-growth pine plantations >30 years old ($n = 6$). The plantation rotation is approximately 40 years, being the pine seedlings planted in a density of 1000 trees/ha. During the first half of the rotation (<20 years) different treatments such as pruning and thinning are applied, after that (>20 years) the density of the plantations is approximately 400 trees/ha, and at this stage, silvicultural activities are uncommon.

2.3. Sampling design

Sampling was performed between June and July. In each stand, one sample plot of 20 × 20 m was established in the center of the stand. In each plot, 10 sub-plots of 5 × 2 m were used to sample