8.4. Naturalization of pine plantations

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Abstract

A large part of the 36,700 ha of existing pine plantations in Sierra Nevada are highly vulnerable to climate change. Therefore, a management priority is to increase their biodiversity, landscape heterogeneity as well as and functional performance. The studies made to date reflect the importance of the environmental variables (climate, altitude), landscape structure (fragmentation of the pine forest, size, density, position, and contact with the patches of native vegetation) and of past management in the composition, structure, and regeneration capacity of the reforested pine stands. Within the framework of the Sierra Nevada Global Change Observatory, the effectiveness of several types of treatments in different types of patches is being evaluated using a network of experimental plots. This monitoring results in recommendations for active management aimed at promoting the naturalization of the reforested sections over a broad range of environmental conditions, regulating competition, promoting mosaic structures of the vegetation, and preserving the individuals with high vegetative and reproductive potential. In reforested stands with intermediate density, diversifying the canopy and the structure by leaving dead wood, and fomenting the natural regeneration of woody species is recommended. Finally, in areas more than 2 kms away from patches of natural vegetation planting or sowing species adapted to the potential habitats according to current forecasts for climate change is proposed.

The largest extensions of reforested pines of Sierra Nevada appear in the Northern part of the mountain.

Aims and methodology

The aim of this work is to summarize the existing knowledge regarding the naturalization of the pine plantations in Sierra Nevada by collecting information from local experiences. For this purpose, some major aspects of the structure and regeneration capacity of the reforested pines (environmental variables, landscape structure, past management) are described. This is combined with an effectiveness assessment of different naturalization treatments applied in permanent monitoring plots distributed throughout the most representative pine forests on the massif [23].

Sierra Nevada Protected Area has more than 52,000 ha of dense tree formations, out of which 36,700 are reforested pines, planted mainly in the 1960s and 1970s over bare and eroded areas.

Although a large part of the pine forest surface area should have constituted a transition stage towards broadleaf formations or a mixture of broadleaf and pine species, the lack of forestry treatments has resulted in the practical stagnation of part of these masses. These are homogeneous, often monospecific, pine forests excessively dense. Trees in these forests have not been able to develop their crown or root system adequately due to excessive competition for water, light and nutrients. In many cases, there is no understory of woody species or it is very poor, in general of very low floristic and structural diversity. All this implies that these forests are under continuous physiological stress, which makes them highly susceptible to disturbances (drought, pests, etc.).

The strategy to improve their state (increase biodiversity, functional performance, resilience, etc.) is to reduce their density by selective thinning treatments.

One of the key issues to promote the naturalization of pine forests is to identify the most suitable places in which to apply the treatments.

Another crucial aspect is to evaluate the results of the actions taken in order to know the impact that different treatments exert on the vegetation according to the previously defined objectives.

In this chapter, an analysis is made of the way in which regeneration and floristic diversity under the pine forest are influenced by biotic and abiotic gradients, the spatial configuration of the pine forest, and finally the past land uses. The results presented here are based on a forest inventory of almost 600 plots established in Sierra Nevada in 2004, on which many studies have been published ([16-17]; see Chapter 3.6), as well as on other specific samplings made by the authors.

Results

The analysis of different sources of information (the forest inventory made in 2004, the results from the analysis of these data published in scientific journals, and the laying out of experimental plots with their respective monitoring programmes) offer valuable information on the structure and functioning of the pine plantations. These results can be used according to the following structural and functional aspects:

Gradients of abiotic factors:

- Elevation and regeneration: the plantations located at low elevations (≈1300 m.a.s.l.) or moderate ones (≈1700 m.a.s.l.) showed a diverse and abundant recruitment bank dominated by species of the genus *Quercus*, while the highest plantations (≈2100 m.a.s.l.) had monospecific recruitment banks of Scots pine (*Pinus sylvestris*)[16].

View of a pine plantation before (left) and after (right) the naturalization treatments in Cortijuela (Monachil).

- Distance to the patches of Holm oak and regeneration of this oak under pine trees: An exponential decline in recruitment of the Holm oak was found when increasing the distance to the nearest Holm oak woodland, diminishing regeneration by 50% beyond 250 m, and up to 80% beyond 1 km (see Figure 1).

Pine-forest structure and land uses:

- Density of the pine forest: regeneration was null at densities above 1,500 pines/ha, while moderate densities (500-1,000 pines/ha) showed better regeneration, both of the pines as well as of other species, in comparison with open tree canopies. Only the Aleppo pine (*Pinus halepensis*) registered the highest regeneration rates at very low densities (0-100 pines/ ha), while the greatest regeneration of Holm oak occurred at 1,100 to 1,300 pines/ha, this being consistent with the need for shade of this species in its early growth stages [16].
- Pine patches size and floristic diversity: greater floristic diversity was observed as the size of the pine patch diminished [17].
- Type of vegetation adjacent to the reforested pines: the higher the percentage of contact with natural vegetation, the more abundant were the birds that disperse pine seeds as well as seeds of zoochorous plants in their interior [18].
- Past land use: the probability of finding Holm oak regeneration on the ground is inversely proportional to the intensity of the management of land use in the past, being progressively greater in pastures, crops, mid-mountain shrublands, and *Quercus* forests (see chapter 3.6).

› Discussion and conclusions

The varied ecological gradients of the Mediterranean mountain enormously determine the regeneration dynamics of pine plantations. This forest type should be considered (and managed) as dynamic systems where the successional paths and diversity levels are determined by abiotic factors, complex balances of competition and facilitation, the spatial configuration of natural seed sources, and the characteristics and needs of each species [16].

The studies made in Sierra Nevada demonstrate that the naturalization of pine plantations depends both on the history of the stand (which determine the legacy of prior land use) as well as the current ecological characteristics. For the study of the effect of these biotic and abiotic gradients in the response of the masses to the different treatments, a network of permanent plots were monitored in Sierra Nevada. This enables the assessment of the most effective actions in each type of vegetation mass within a few years, considering the history of its prior use and its current ecological context to achieve the established aims.

Given the results described, a series of management recommendations are included here to promote the naturalization of reforested areas similar to those studied in Sierra Nevada:

I. Very dense pine plantations (>1,500 trees/ ha): regulate competition at the same time as allowing the entry of light, seeds and dispersal agents. For this:

- Different intensities thinning treatments to foster the fragmentation of pine plantations. In addition to varying the number of trees to be cut in the different copses, thinning from above can be applied (cutting trunks of larger diameters) in some places to favour latter natural perturbations and appearance of thickets. This should be done with the precaution not to encourage excessive heliophilous colonizing thickets, which would imply regressive successional dynamics and raise the fire risk.
- Leave the senescent, fallen, and dry individuals as well as those that show high vegetative and reproductive rate.

II. Middle density pine plantations (500-1,000 trees/ha): apply treatments for the diversification of the canopy to encourage mixed, irregular forests, adjusting the intensity of the thinning to the ecological conditions of the stand. For this:

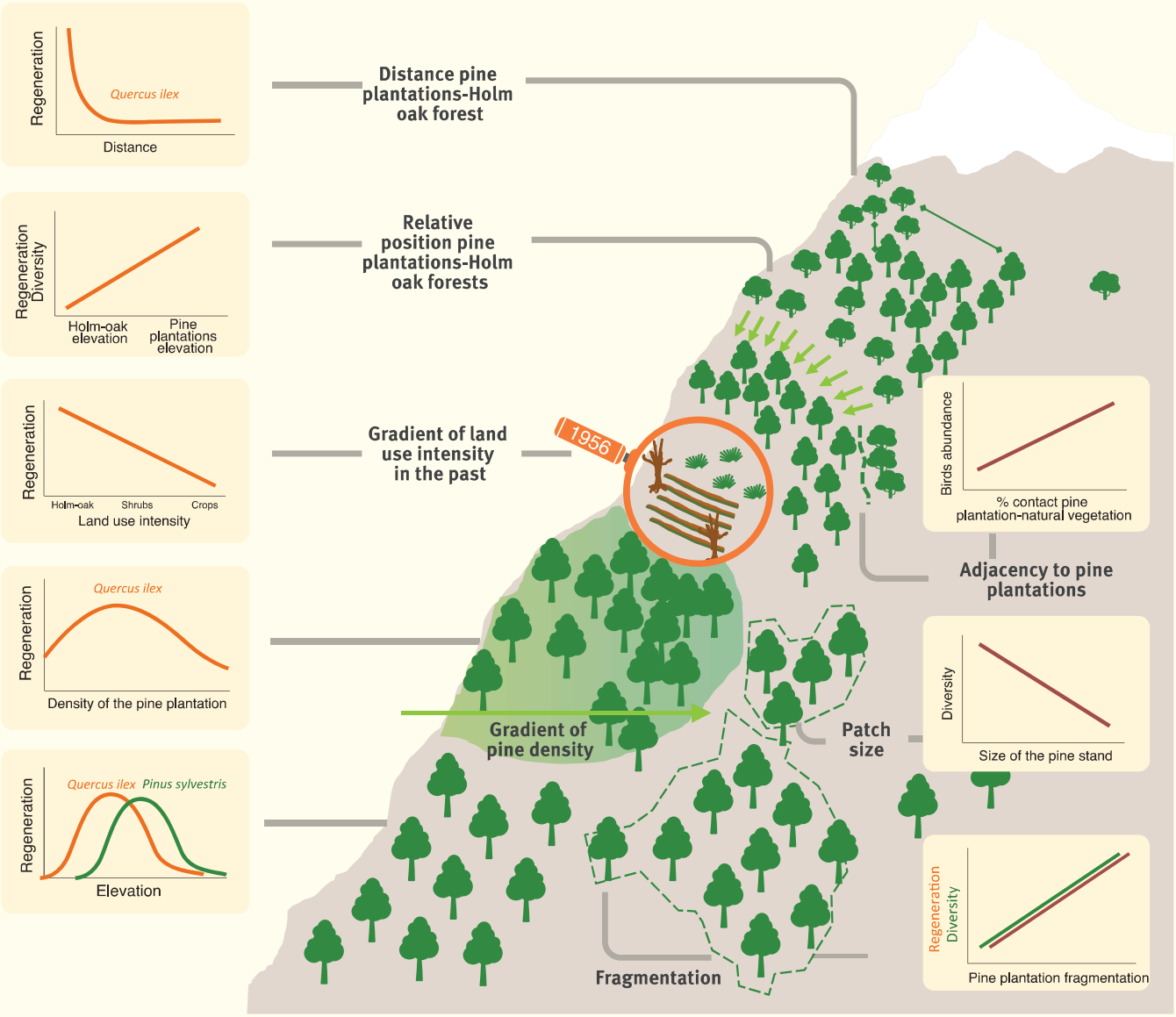
- Favour natural regeneration by the thinning of copses.
- Where regeneration of umbrofilous species is present, open the canopy proportionally to the size of the established recruits.
- Obtaining large size trees from a selection of the dominant ones and opening of space around them (some 100-150 trees/ha, of which some 50 would be kept without pruning) [19].

III. Leave dead wood (maximum of 5% of the trees) as recommended in different studies [19].

IV. Maximize the contact surface area between the plantation and natural vegetation, whether trees or shrubs, as this has demonstrated to have a positive influence on zoochorous dispersal [18].

V. Where natural recruitment is deemed very slow due to excessive distance to the natural sources of seeds or intensive use of the land in the past, it will be necessary to reinforce the populations by enrinchment seedling or planting. For this purpose, the species adapted to the potential habitats should be used according to the predictions of climatic change.

Figure 1



Schematic summary of the main results found in relation to the naturalization of reforested pines. The scheme shows the role of abiotic factors (elevation) and biotic ones (pine density, fragmentation, and size of the stands, relative position of the patches providing the acorns, source-sink distance, adjacency of natural vegetation to the pine stands and the effect of past land use).