8.2. Design and monitoring of a post-fire restoration

Zamora, R.[1]; Bollullos, C.[2]; Aspizua, R.[2]; Cabezas-Arcas, F.M.[1]; Castro, J.[3] and Navarro, J.[4]

[1] Andalusian Institute for Earth System Research. University of Granada [2] Environment and Water Agency of Andalusia [3] University of Granada

[4] Andalusian Regional Ministry of Environment and Spatial Planning

Panoramic view from the burnt area of the municipality of Lanjarón. In the foreground the *Thymus-Brachypodium* thicket can be seen recolonizing the burnt terrain.

Abstract

In September 2005 a fire in Sierra Nevada affected more than 1,100 ha of reforested pines. Afterwards, an ambitious restoration programme was implemented by researchers from the University of Granada in collaboration with the managers of the Sierra Nevada Protected Area. The design of this project applies the most recent scientific knowledge to promote a new model of ecosystem restoration. The key points of this restoration are: 1) promoting spatial heterogeneity, 2) encouraging functional diversity, and 3) promoting the natural recovery capacity.

Aims and methodology

The restoration project designed after the fire takes advantage of natural succession dynamics, promoting both the spatial heterogeneity as well as the species diversity. The objective is to favour a more heterogeneous and diverse landscape, able to resist possible catastrophes (pests, forest decay, fires) with a greater adaptive capacity to climatic change.

In the project, different restoration techniques were applied, such as using pioneer shrubs and vegetation debris as planting microsites, and creating dispersal core areas to strengthen the recuperation of the most degraded areas after the fire. For the creation of these new core areas, shrubland species of rapid growth and reproduction were used, such as, *Rosa canina, Crataegus monogyna, Prunus ramburii, P. spinosa*, and *Berberis hispanica*. In addition, planting takes advantage of pioneer shrubs that appeared spontaneously after the fire, mainly *Adenocarpus decorticans, Ulex parviflorus, Genista versicolor*. These species can act as nurse plants, enhancing the survival of reforested seedlings. This novel technique of restoration has been tested in Sierra Nevada, with very positive results [6].

Furthermore, in a sector of the burnt area, some experimental plots were established with three treatments differing in the management of the burnt wood: the traditional removal of all trees standing after the fire, no intervention (leaving all trees standing with no action), and an intermediate action of felling and cutting up 90% of the trees but leaving the entire biomass *in situ*. Since then, several variables have been monitored, these being related either to vegetation regeneration (survival, growth, herbivory damage) or to ecosystem functioning (recuperation of species diversity, carbon sequestering, burnt-wood decomposition, etc.).

Holm oak seedling growing under the remains of burnt wood left after the fire in the experimental plots.

Results

The presence of pioneer shrubs have generally favoured the survival and growth of most of the introduced species, although it has had a markedly different effect on survival depending on the species. The thorny species formed by *Ulex parviflorus* and *Genista versicolor* have facilitated the restoration, improving the survival rates of all the species by substantially reducing ungulate herbivory.

On the contrary, the effect of *Adenocarpus decorticans* on the survival of *B. hispanica, C. monogyna, P. spinosa* or *Q. ilex* has not been beneficial (see Table 1).

The survival and growth of seedlings was also affected by elevation, this generally being greater at high altitudes for *Q. ilex* and *B. hispanica*, while the other species prospered better at low elevations.

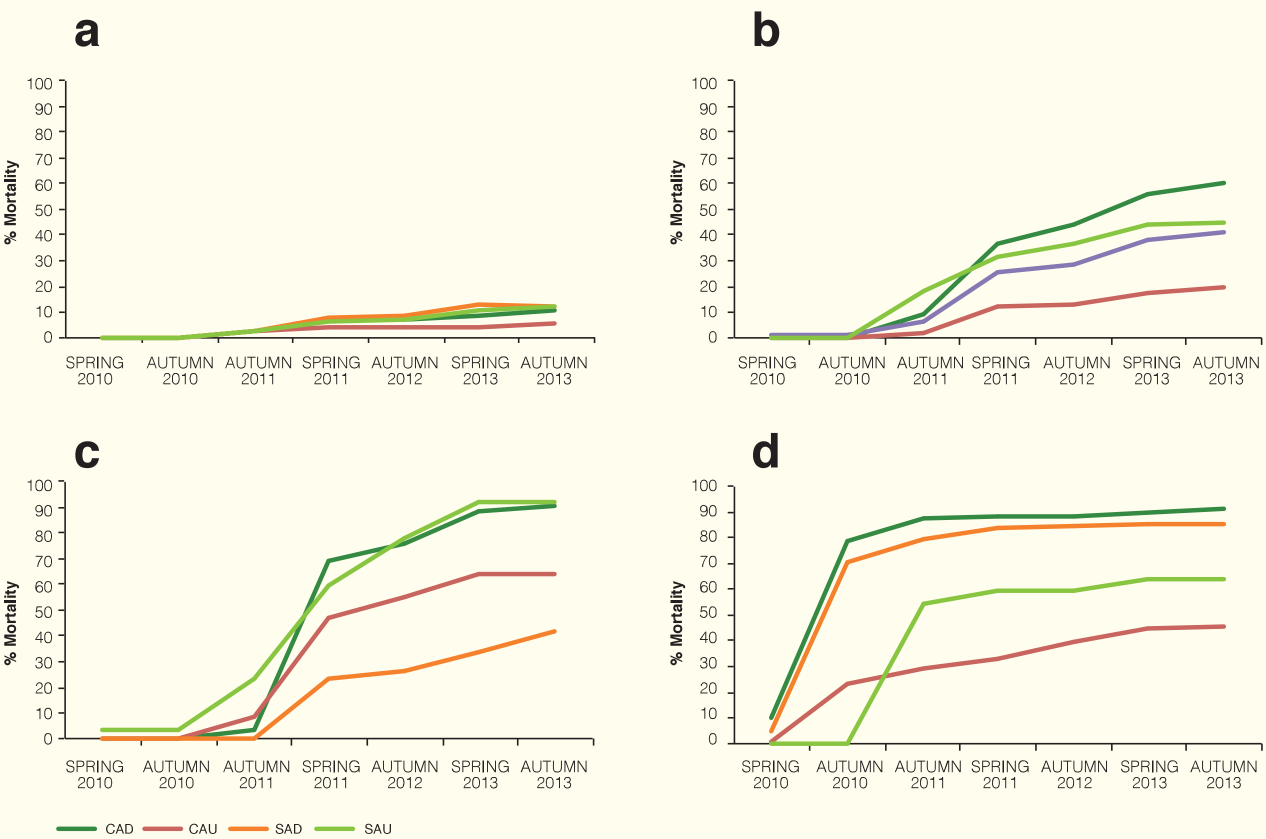
C. monogyna and *R. canina* were the species that showed the highest survival rate. The tree species that survived best were *P. pinaster* at low and *Q. ilex* at high elevations. In general, shrubby species adapted better than tree species did.

Table 1

SURVIVAL	With *Adenocarpus*	With *Ulex/Genista*	Without *Adenocarpus*	Without *Ulex*
Berberis hispanica	≈	+	+	-
Crataegus monogyna	-	+	+	-
Prunus ramburii	-	+	+	-
Rosa canina	≈	≈	≈	≈
Pinus sp.	≈	+	≈	-
Quercus ilex	-	+	+	-

Effect of pioneer shrubs (*Adenocarpus* and *Ulex/Genista*) on the survival rate of species introduced in the restoration. The positive and negative signs correspond to the higher and lower statistically significant percentages of survival, respectively.

Figure 1



Accumulated mortality rate of *Rosa canina* (a), *Crataegus monogyna* (b), *Quercus ilex* (c), and *Pinus sp.* (d) in the biennial monitoring conducted between spring 2010 and autumn 2013 with *Adenocarpus* (CAD), with *Ulex* (CAU), without *Adenocarpus* (SAD) and without *Ulex* (SAU).

Discussion and conclusions

A number of restoration actions have been designed to enhance vegetation diversity, both of species and structure, thereby improving the capacity to adapt to climatic change and extreme events. Perhaps the most novel of these actions has been the combination of different types of treatments according to the ecological characteristics and the history of management in the area. In order to promote natural regeneration, stands have been planted with irregular shape and different species composition. The stands have been combined with plantations by dispersal core areas, using a mixture of shrub and tree species. In every scenario, shrub species have shown better results than the trees have.

Specifically, the species that have shown the greatest percentage of survival rate have been wild rose (*R. canina*), hawthorn (*C. monogyna*), especially at low elevations. The barberry (*B. hispanica*) and Holm oak (*Q. ilex*) are the species that best responded at the high elevations. This diversity of responses to different ecological conditions is the basis for recovering a more resilient vegetation adapted to new climatic conditions.

The results for the experimental plots indicate that the burnt trunks and branches act as nurse structures, reducing soil temperatures and alleviating the water stress of the plants [7]. The burnt wood also acts as a major reservoir of nutrients that are gradually transferred to the soil [8]. Also, the structural complexity that the trunks and branches generate by being scattered over the ground protect the juvenile woody-plant species against ungulate herbivores. This translates as a higher recruitment rate and more vigorous growth of saplings, whether natural or planted [9]. On the other hand, the removal of wood also affects the ecosystem carbon balance [10] (see Chapter 7.1.). Soil respiration was greater in the presence of burnt woody remains, probably due to the greater microbial biomass and nutrient availability registered in the soil within this scenario [8]. Thus, wood cannot be considered the only option for post-fire management, whatever the characteristics of the area. There is an ample gradient of management possibilities for burnt wood, ranging from removal to non-intervention, which may include different degrees of removal, considering of different sensitivity to environmental factors (herbivory pressure, disease risk).

Aerial view of experimental plots one year after the fire (September 2006). The three plots without intervention can be distinguished (darker tone), three plots of 90% measuring and cutting up of the trunks, without removal (intermediate tone), and the traditional treatment (lightertone, similar to the rest of the area treated).