Natural recovery and leaf water potential after fire influenced by salvage logging and induced drought stress

D. Moya (*), J. de las Heras, F.R. López Serrano, P. Ferrandis

Escuela Técnica Superior de Ingenieros Agrónomos de Albacete. Universidad de Castilla-La Mancha, Campus Universitario s/n, 02071, Albacete, Spain
* Corresponding author: daniel.moya@uclm.es

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<th>Keywords</th>
<th>Abstract</th>
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<td>Forest management</td>
<td>Salvage logging is one of the most common emergency actions in the short-term management after a fire. Several studies have been carried out and some obtained positive results which incite to carry it out but other, found negative effects on seedling establishment and regeneration. In addition, climatic changes will have large impacts on vegetation productivity and resilience since the regional models for south-eastern Spain predicts a rainfall decrease of about 20% and temperature increase of 4.5ºC. Our aim was to determine how short-term forest management and induced drought affect the ecosystem recovery in Aleppo pine stands naturally recovered after a fire. In summer 2009, a mid-high severity fire burned 968 ha of Aleppo pine (Pinus halepensis Mill.) forest in south-eastern Spain. Six months later, a salvage logging was carried out. The Aleppo pine recruitment was negligible. During summer 2010, twelve square plots (2m x 2m) were set in the three scenarios: control, salvaged and drought induced. The surface cover and soil water availability for three dominant understory species were recorded in four field campaigns: Spring-2010, Fall-2010, Spring-2011 and Fall-2011. The season, management and the target species showed significant differences in growing and water stress. In general, Esparto grass showed lower water stress, mainly in Fall, a higher increase of total coverage. Both effects were showing their highest values in non-salvaged areas and no drought. Changes in leaf water potential and soil water content after the drought season influence the survival and development of individuals. Our results indicate that soil water content and ecosystem response can be modified by short-term silvicultural treatments. Therefore, management after fire could cause opposite effects to those initially foreseen, since they depend on fire severity, and type of ecosystem management response. So, their application must be evaluated and assessed before implementation.</td>
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<td>Leaf water potential</td>
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<td>Stipa tenacissima</td>
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1 INTRODUCTION

Forest fires are important in landscape modelling along the Mediterranean Basin, but predictions based on climate change models foresee changes in droughts and fire regimes (Flannigan et al., 2000). Temperature increases and changes in precipitation regimes (i.e., increasing drought events) have been predicted to increase wildfire frequency and intensity (Dury et al., 2011). Plant communities in Mediterranean regions have developed adaptive traits to both disturbances, wildfires and drought periods, but changes in climatic conditions may have large impacts on vegetation productivity, density and distribution. Particularly, the regional models for SE Spain are predicting a rainfall decrease of c.a. 20% and a temperature increase of c.a. 4.5 ºC (Brunnet et al., 2009).

The response of the ecosystems to forest fires depends on
several factors, mainly related to fire severity, structural patterns, weather and landform (Ryan & DeBano, 2005). Post-fire management has revealed as a key tool to enhance the natural recovery and to implement urgent actuations in areas showing high risk of flood or erosion. At short-term management after a fire, salvage logging is one of the most common emergency actions, but their ecological effects are not totally clear, particularly those referred to seeding establishment since reduction of protection by removal of dead wood has been demonstrated to increase summer mortality in Aleppo pine (Pinus halepensis Mill.) stands (Martínez-Sánchez et al., 1999).

2 Objectives

Our main objective was to determine how short-term forest management may affect the ecosystem recovery. The study was focused in Aleppo pine stands naturally recovered after a fire where salvage logging was carried out. We designed an experiment inducing drought in natural regenerated post-fire communities, in order to analyse responses in different simulated scenarios. We checked how rainfall decrease, mainly in summer, could affect the soil water content and coverage of species adapted to both disturbances: fire and drought.

3 Methodology

In summer 2009, a mid-severity fire burned over 1000 ha of Aleppo pine forest in SE Spain, close to Pozo-Lorente (Albacete). Average rainfall and temperature values from 1986 to 2011 (upon data provided by the Spanish National Meteorological Agency (AEMET)), were 367 mm and 13.6 °C, respectively. The ombroclimate was characterized as Dry, located in the Mesomediterranean belt, and the natural potential vegetation was a sclerophyllous oak forest of Quercus ilex (Bupleuro rigidii-Querceto rotundifolii sigmetum) (Rivas Martinez, 1982).

Six months after the fire, a salvage logging was carried out in the burned stand, also enclosing a control area with no treatment (uncut). After cutting, in spring 2010, three 25-m linear transects separated 5 m were established in both areas, to characterize pine seedling recruitment. Pine seedlings intercepting lines were counted and their total height recorded. In general, Aleppo pine recruitment was low but slightly higher in the uncut area.

During summer 2010, twelve square plots (2 x 2 m²) were set in the study area (30 S, 629692 E, 4322181 N; 920 masl). Four were randomly chosen as control plots in the uncut area and four were randomly set in the logged area. The later set of plots were paired to four plots, where drought was induced by reducing precipitation, using metallic structures to fix elevated plastic half-pipes and digging trenches on the sides of the plots to prevent lateral water flow. The structures were made with transparent PVC covering 20% of the surface area of the plots.

To characterize the recovery of the companion vegetation, we monitored three dominant understory species occurring in all plots: a resprouter, the esparto grass (Stipa tenacissima L.) and two bush seeders, rosemary (Rosmarinus officinalis L.) and rockrose (Cistus clusii Dunal.). All individuals were marked with numbered plastic tags. Using a field tape (accuracy 1 mm), we recorded their total coverage (width and length of crown cover) calculated by using the formula for the surface of an ellipse. We compared the relative growth of individuals calculating the increase in total coverage (ΔCTC) individually. To estimate soil water availability and water stress in the plants, a compact plant water status console, a Scholander-type pressure chamber (Soil Moisture Equipment Corp., Santa Barbara, CA, USA) was used. We recorded the maximum leaf water potential by sampling during predawn (WPD), which is related to the overall water status of the individuals. Sampling dates covered short-term pre- and post-drought periods, repeating the sampling one and two years after the fire, i.e. four field campaigns were covered: Spring-2010, Fall-2010, Spring-2011 and Fall-2011.

We developed General Linear Models (GLM) to assess an overall model for leaf water potential and coverage. The predictor variables tested in the models were: SEASON (spring or fall), TREATMENT (uncut, salvage logging, salvage logging plus drought) and SPECIES (Esparto, Rosemary and Rockrose). We used Kruskal-Wallis tests to check mean significant differences among independent variables. Significant differences between groups were tested using simple ANOVA developed with Fisher’s LSD (Least Significant Difference) method. The values were logarithm-transformed to maximize the Pearson’s correlation coefficient (r), achieving assumptions of normality and homoscedasticity. However, the values are shown untransformed along with standard error (± SE). Statistical analyses were carried out using Statgraphics CENTURION XV software and conducted using a critical p-value<0.05.
RESULTS

The GLM showed all three factors related to both variables \( \Psi_{PD} \) and \( \Delta TC \). The ANOVA for \( \Psi_{PD} \) (Figure 1) showed no significant differences for Rosemary and Rockrose but, in general, Esparto grass was lower. The pressure was lower in fall for both years but the increase was shown to be dependent on the treatment. In general, water stress was lower in individuals growing in the non-managed area and higher in drought-induced plots. We also performed an ANOVA contrasting \( \Delta TC \) values (Figure 2) which showed higher values for the Esparto grass. In general, \( \Delta TC \) values were higher in the uncut area than in the logged one. In the latter, \( \Delta TC \) did not show significant differences among species.

Water potential represents a reliable and simple method to evaluate the physiological condition of a plant, since growth and productivity are directly influenced by it (Galmés, 2006) Therefore, the regulation of plant-water relationships in response to soil water depletion may be crucial in Mediterranean species, mainly in predicted scenarios for climate change (Bates et al., 2008). Changes in leaf water potential and soil water content after the drought season influence the survival and development of individuals. The inter-specific differences found here in leaf water relations are supposed to be of adaptive value related to the root development (Moya et al., 2011). In addition, these differences are related to the water saving or recovery after drought, since drought-tolerant plants are able to maintain higher stomatal conductance at low
leaf water potentials, related to stomatal response (Galmés, 2006).

Our results indicate that ecosystem response can be modified by short-term silvicultural treatments. The soil water content is related to drought events and forest management, which influence the vegetation pattern, vulnerability and resilience under frequent wildfires and warming scenarios (Bates et al., 2012). Also, the herb and shrub coverage protect soil from erosion, floods and runoff, which could be reduced to negligible values at short term (Cerdà & Doerr, 2005). At medium term, the drought could affect more significantly to the growth and ecophysiological variables (Prieto et al., 2009).

5 CONCLUSIONS

In conclusion, silvicultural treatments could be applied as a rehabilitation tool to enrich soil and vegetation, even increasing water availability at short term (de las Heras et al., 2012) but depending on fire severity, ecosystem response and type of management, the reverse effect was obtained.

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