SCAP
SOCIEDADE DE CIÊNCIAS AGRÁRIAS DE PORTUGAL

# The role of mosses in soil physico-chemical properties under two contrasting post-fire managements in Central Portugal

## El papel de los musgos en las propiedades físicoquímicas de suelos afectados por dos manejos postincendio en la región centro de Portugal

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**ABSTRACT**

Mosses play an important role after wildfires, acting as early colonizers before the establishment of vascular vegetation, thus stabilizing, and protecting soil against erosion. However, little is known about the effect of moss development on soil recovery after wildfires. In this work, we studied effects of mosses on soil physicho-chemical properties in a burned eucalyptus plantation under two contrasting post-fire managements in Central Portugal, six years after wildfire. Post-fire managements were applied in two separate areas from the same wildfire and consisted of salvage logging vs. mulching with standard and low application rates (8 and 2.6 Mg ha$^{-1}$, respectively). Six years after fire, for each area and management type (untreated, logged, mulched standard/low), we collected five soil samples at 0-2.5 depth with and without moss biocrusts (n=50). Soils were analysed for pH, electrical conductivity, oxidizable organic C, total N, available P, aggregate stability, macro-aggregate content, and wettability. The studied post-fire managements showed contrasting effects on soil properties in the medium-term. Whereas salvage logging did not negatively affect soils, the mulching at a standard rate increased soil fertility six years after the fire. The moss biocrust emerged after the wildfire preserved soil structure, thus decreasing the risk of soil erosion.

**Keywords:** Mosses, mulch, salvage logging, post-fire management.

**RESUMEN**

Los musgos juegan un papel importante tras los incendios forestales actuando como colonizadores tempranos, estabilizando y protegiendo así el suelo frente a la erosión. Sin embargo, se desconoce el efecto de los musgos sobre la recuperación del suelo post-incendio. En este trabajo estudiamos los efectos a medio plazo del musgo sobre las propiedades físicoquímicas del suelo en una plantación de eucalipto de la región Centro de Portugal, afectada por un incendio forestal y con diferente gestión post-fuego. Dicha gestión consistió en saca de madera vs. aplicación de mulch estándar y reducida (8 y 2.6 Mg ha$^{-1}$, respectivamente). Seis años después del incendio, para cada zona y tipo de gestión (sin tratar, saca de madera, mulch estándar/reducido), se muestrearon 5 réplicas de suelo a 0-2,5 cm de profundidad con y sin musgo (n=50). Se analizó pH, conductividad eléctrica, C orgánico oxidable, N total, P disponible, estabilidad de agregados, contenido en macroagregados y repelencia al agua. Los tratamientos post-incendio estudiados mostraron efectos contrastados sobre las propiedades del suelo a medio plazo. La saca de madera no afectó negativamente al suelo, mientras que la aplicación estándar de mulch aumentó la fertilidad edáfica. Los musgos desarrollados tras el incendio preservaron la estructura del suelo, reduciendo así el riesgo de erosión.

**Palabras clave:** musgos, mulch, saca de madera, gestión post-incendio.

## INTRODUCTION

Biological soil crusts are a community of organisms living in the soil surface composed mainly of cyanobacteria, lichens, and/or mosses, which have key roles for the health and functionality of the ecosystems, improving soil structure and stability, influencing the local hydrologic cycles, enhancing soil fertility, or increasing the biodiversity of soil microbial community (Belnap and Lange, 2013). After a wildfire, mosses are described as fast colonizers before the establishment of vascular vegetation (Esposito, 1999), suggesting a positive role in early post-fire stages. In the absence of vegetation after a wildfire, the presence of a moss biocrust stabilizes the soil surface protecting it effectively against water erosion (Silva *et al*., 2019). After wildfires in semi-arid conditions, soils covered by mosses reach higher soil fertility, boosting the ecosystem recovery (García-Carmona *et al*., 2020). However, apart from erosion control, little is known about the role for soil recovery of the early emergence of mosses, even less in climates under oceanic influence as in Portugal.

Post-fire management is an important factor that will determine the capacity of soil to recover from degradation. Salvage logging, the most common practice in Portugal, under certain circumstances can trigger erosion processes (Malvar *et al*., 2017), alter nutrient cycling (Pereg *et al*., 2018), and induce detrimental consequences for microbial diversity (García-Carmona *et al*., 2021). On the other hand, effective mitigation measures such as mulching reduce the negative impacts of post-fire erosion providing a surface cover to soils before the vegetation regrowth (Girona-García *et al*., 2021). Although the treatments' effectiveness at mitigating soil erosion is widely documented, their medium-term implications on soil physico-chemical properties recovery is partially unknown.

In this work, we studied soils under two contrasting forest managements, salvage logging and mulch application, six years after a wildfire in eucalypt plantations. Our aim was to determine the medium-term effects of fire and forest management on soil physico-chemical properties in combination with the presence of burgeoning moss biocrust patches that emerged after the fire.

## MATERIAL AND METHODS

The study area is located in Miranda do Corvo, central Portugal, affected by a moderate severity wildfire during August 2015 that burned 715 ha mainly of *Eucalyptus globulus* Labill. plantations. The climate is Mediterranean with oceanic influence characterized by mild winters and warm, dry summers, with mean annual temperatures of 12ºC and 851 mm of precipitation. Soils were characterized as an association of Epileptic Umbrisol and Cambic Umbrisol with a depth of 30 cm and loam texture. Six years after the wildfire, a developed moss biocrust covered the topsoil at several patches in the fire-affected area.

After the wildfire, two contrasting post-fire managements were applied in separate areas. One was salvage logging, without slash treatment or removal, for which a forwarder tractor made two passes, causing skid trails. The other was mulching, performed by homogeneously applying chopped eucalypt residues from the logging operations. Mulch was applied at a "standard" rate of 8.0 Mg $ha^{-1}$, effective in earlier field studies in the region (Keizer *et al*., 2018), and a "low rate" of 2.6 Mg $ha^{-1}$, effective under laboratory conditions of simulated rainfall (Prats *et al*., 2017).

Soil sampling was conducted in July 2021. For each treatment, 10 samples were collected from 0-2.5 cm depth, five replicates in soils underneath moss biocrusts and five in uncrusted soils (n=50).

Soil pH and electrical conductivity were measured in 1:2.5 and 1:5 (w/v) aqueous extracts. Soil organic carbon was determined by the potassium dichromate oxidation following the Walkley-Black method; nitrogen was analyzed following the Kjeldahl method; and available phosphorus was extracted and measured following the Olsen method. The aggregate stability and the total content of macro-aggregates were examined after an artificial rainfall of known energy (279 J $min^{-1}$ $m^{-1}$) (Roldán *et al*., 1994). Soil water repellency was assessed by the Water Drop Penetration Time (WDPT) test.

## RESULTS AND DISCUSSION

Six years after the wildfire, contrasting effects were found in relation to post-fire management and the presence of mosses in soils. Soils affected by salvage logging did not reflect negative consequences due to the management; indeed, an increment in available P was registered. Those results suggest the way the management was performed had no long-lasting effects on soil properties, results that are in accordance with Fernández and Vega, who did not find detrimental effects after logging under

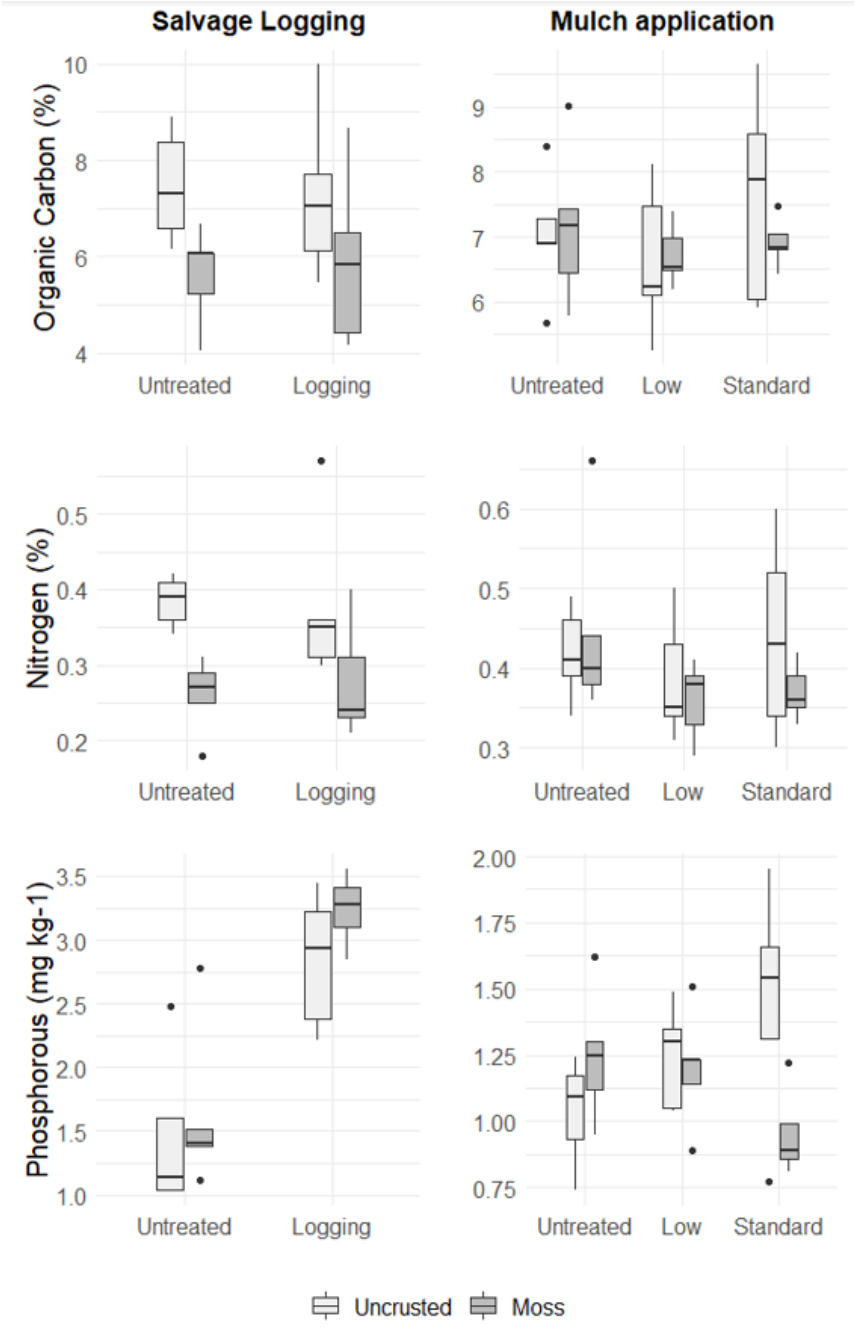


**Figure 1 -** Soil organic carbon, nitrogen and available phosphorous measured in the two contrasting forest managements, salvage logging (untreated and logging) and mulch application (untreated, low rate and standard rate), in soils under mosses and uncrusted soils.

similar climate conditions and organic carbon content. On the other hand, the lower organic carbon and nitrogen content in soils underneath mosses show the opposite trend than in drylands, where an improvement in soil fertility and nutrient cycling is expected with the presence of a moss-biocrust (Ferrenberg *et al*., 2022), even in post-fire environments, creating fertility islands (Muñoz-Rojas *et al*., 2021). A possible hypothesis may be mosses preferred to avoid establishing where the most recalcitrant organic matter concentrates after the wildfire, which would be in accordance with the higher soil hydrophobicity registered in the uncrusted soils (Doerr *et al*., 2009). The rapid recovery of vascular vegetation in the area together with the naturally high levels of organic matter apparently counteracts the effects of a moss biocrust on soil fertility in a medium-term. Nevertheless, the presence of mosses preserved soils, with a higher total content of macro-aggregates in all cases, providing better conditions to soils compared to the uncrusted ones, more exposed to degradation (Chamizo *et al*., 2012).

Mulching increased nutrients and soil organic carbon contents, although the increment was detected only in soils under the highest rate of mulch and without moss development. The direct contact of the mulch residues with the topsoil may have accelerated its decomposition, thus the increment in soil fertility, while mosses could be slowing down the decomposition process (Figure 1, Table 1).

## CONCLUSIONS

The studied post-fire forest managements showed contrasting effects on soil properties in the medium-term. Whereas salvage logging did not negatively affect soils, the mulching at a standard rate increased soil fertility six years after the fire. The moss biocrust emerged after the wildfire preserved soil structure, thus decreasing the risk of soil erosion.

**Table 1 -** Water repellency and total content of macro-aggregates measured in the two contrasting forest managements, salvage logging (untreated and logging) and mulch application (untreated, low rate and standard rate), in soils under mosses and uncrusted soils. Lowercase letters represent significant differences among treatments and moss crust (Tukey test, p-value<0.05). P-values after 3-way ANOVA: *** = <0.001; ** = <0.01; * = <0.05

| Treatment | Moss | Water Repellency | Macro- Aggregates |
|---|---|---|---|
| Untreated | Uncrusted | 10652a ± 5915 | 55.0 ± 9.7 |
| | Moss | 502b ± 758 | 59.7 ± 8.6 |
| Logging | Uncrusted | 8146a ± 6178 | 53.2 ± 4.6 |
| | Moss | 533b ± 605 | 59.0 ± 6.8 |
| Untreated | Uncrusted | 345b ± 282 | 53.5 ± 10 |
| | Moss | 647b ± 519 | 63.5 ± 6.1 |
| Low rate | Uncrusted | 372b ± 481 | 52.5 ± 9.1 |
| | Moss | 536b ± 1036 | 64.9 ± 6.9 |
| Standard rate | Uncrusted | 941b ± 1253 | 54.1 ± 10.2 |
| | Moss | 251b ± 373 | 60.2 ± 14.4 |
| *3-way ANOVA:* | | | |
| Management | | <0.001*** | 0.604 |
| Treatment | | 0.779 | 0.966 |
| Moss | | <0.001*** | 0.004** |
| Manag: Treat: Moss | | <0.001*** | 0.857 |

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