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Post–fire management for improving soil quality and hydrological process: a case study in a Mediterranean Croatia

Domina Delač*[1]; Ivica Kisić[1]; Paulo Pereira[2]

[1]*University of Zagreb, Faculty of Agriculture, Croatia, {ddelac, ikisisc}@agr.hr*
[2]*Mykolas Romeris University, Environmental Management Laboratory, Latvia, {pereiraub@gmail.com}*

**Corresponding author*

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Abstract

Wildfires in Mediterranean Croatia have increased in recent decades, raising concerns about the adverse effects of fire and the rate of soil and water degradation. Post-fire management techniques, such as mulch application, are commonly used after high to moderate wildfire severity. Local, site-specific solutions are needed to mitigate wildfire effects in this context. This research aims to study the effect of mulches (from on-site sources) on soil and hydrological properties. We hypothesised that mulch application would increase soil quality and reduce erosion and runoff yield. During July 2019, about 900 ha of *Pinus halepensins* Mil. forest, abandoned grazing and agricultural olive groves (*Olea europea* L.) were affected by a moderate to high wildfire in the hinterland of Šibenik City (Croatia, 43°45'N 15°56'E, 105 m a.s.l.). Twenty-five days after the wildfire occurrence, unmulched (UM, control) and two mulch treatments (*Olea europea* leaves (OM) and *Pinus halepensis* needles (PM) were applied for post-fire stabilisation on *Cambisols*. One treatment covered an ~10 m^2 area with 0.5. kg m^2 mulch application which was measured on the experimental plots. Prior to mulch application, 15 (5 per treatment) metal rings (0.2 m^2) with connected plastic collectors were set up on sloped terrain (~9°) to monitor erosion and runoff yield. Soil samples were collected every three months, and erosion and runoff yield after major precipitation events during two years. The studied soil properties were: soil water repetency (SWR), soil hydraulic conductivity (SHC), mean weight diameter (MWD), water stability of aggregates (WSA), soil organic matter (SOM), total carbon (TC), total nitrogen (TN), extractable potassium (K_2O), and available (P_2O_5). Our results showed that both mulch treatments reduce runoff generation in addition to UM treatment. The erosion yield was not occurred due to natural soil conditions. A linear decreasing trend was noted for SWR in all treatments. Overall, PM was showed higher efficiency in increasing soil aggregate stability (MWD and WSA), SHC SOM, and TC. OM has mostly increased soil nutrients such as TN, P_2O_5, and K_2O. Bot mulch treatment increased soil quality, but the effect was variable due to the different chemical compositions of the material. The use of native mulch can be recommended because it improves soil quality and reduces runoff ratio. However, consideration should be given to whether they are available in the areas affected by wildfire.

1. Introduction

Wildfire is a common phenomenon and part of the Mediterranean ecosystem. However, in recent decades, the number and intensity of wildfires over the entire Mediterranean area have increased related to the long drought periods and intense high temperatures (Pausas et al., 2008). In addition, land abandonment, depopulation of rural areas, reduction of pastures, accumulations of flammable vegetation contribute to the spared of wildfires frequency and magnitude (Moreira et al., 2011; Pausas and Keeley, 2009). In the Mediterranean Croatia, such cases are often pronounced in the hinterland of large cities, especially in areas where landscape management and land use are not properly implemented (Delač et al., 2020, 2021). One of the main consequences of wildfires is the complete removal of vegetation and litter, which exposes topsoil to the risk of erosion and degradation of soil's physical and chemical properties. Soil affected by wildfire will experience degradation of primary functions, at least for some time (Certini, 2005; Pereira et al., 2019). The post-fire management is often implemented in the wildfire affected area to rehabilitate and stabilise the upper soil profile. Very often, mulch is applied to burned areas during post-fire restoration (Díaz-Raviña et al., 2012). Mulch is a common technique to inhibit soil erosion and encourage faster soil recovery after the passage of fire. Moreover, these treatments, known as emergency rehabilitation treatments, reduce rainwater's impact, favour the infiltration process, mitigate soil degradation, and prevent runoff and soil sediment removal after a wildfire. Moreover, mulching

with organic plant residues has improved the soil structure, mainly due to an increase in stability of soil aggregates, soil porosity, and improvement in soil hydraulic conductivity (De la Rosa et al., 2019). Although depending on the fire severity, soil organic matter (SOM), total carbon (TC), total nitrogen (TN) and available and extractable nutrients such as phosphorus (P) and potassium (K) can increase, decrease or remain unchanged. (Caon et al., 2014). The mulch addition and the compounds that have not been volatilised in the form of ash and charred residues are incorporated into soil increasing nutrients content (Caon et al., 2014). However, there is a lack of research about their manner after applying different types of mulch materials. In addition, there is a need to observe runoff and erosion behaviour after application on native mulch materials. This research aims to study the effect of Pinus halepensis and Olea europea mulches (from on-site sources) on soil and hydrological properties. We hypothesised that mulch application would increase soil quality and reduce erosion and runoff yield.

2. Material and method

The study was carried out in the Dalmatia region on the Adriatic coast (Croatia) in a hinterland of Šibenik City, (5 km from the Coast, 43°45'06.0"N 15°56'02.9"E.; Fig.1.). Elevation ranges between 50 and 200 m a.s.l. and the aspect is NE. According to Köppen classification, the study area's climate is Mediterranean Csa (warm temperatures with dry and warm summers). The mean annual temperature is 15.8 °C, and the annual precipitation is 800 mm (Šibenik meteorological station) (Kottek et al., 2006). The soil type is classified as *Cambisol*. Vegetation belongs mainly to *Pinus halepensis* Mil., forest and cultivated olive groves (*Olea europaea* L.) and fig tress (*Ficus carica* L.). In the study area, the wildfire occurred on 28 July 2019 and affected an area of about 900 ha (Delač et al., 2020, 2021) and it lasted three days until local firefighters stopped the fire. The first intervention to the burned area was 25 days after wildfire occurrence due to safety reasons and recommendations from local firefighters. The severity of wildfire was moderate to high, which was evident in partially burned canopy places. The area provided natural organic materials for usage and implementation. For covering burned soil surface, two different mulch treatments were applied. One was composited of *Pinus halepensis* needles (PM) the other one of mulch of *Olea europaea* leaves (OM). These mulched were used due to on-site availability and the valuable input of native plants on the soil. The mulches were applied in 0.5 kg m^2 on 10 m^2 each treatment. The erosion equipment to measure runoff and sediment yield were set-up on the same treatments. The studied soil properties were: soil water repetency (SWR), soil hydraulic conductivity (SHC), mean weight diameter (MWD), water stability of aggregates (WSA), soil organic matter (SOM), total carbon (TC), total nitrogen (TN), extractable potassium (K_2O), and available (P_2O_5). The effect of wildfire without any human intervention (unmulched, UM) was monitored next to mulch treatments to assess the impact of both mulches. The soil sampling campaign was conducted during two years: 25 days after fire (DAF), 3 months after fire (MAF), 6, 9, 12, 15, and 24 MAF. Soil samples (0–3 cm) were collected in each treatment in 5 repetitions after litter removal (105 in total). The runoff and erosion yield were collected after major precipitation events.

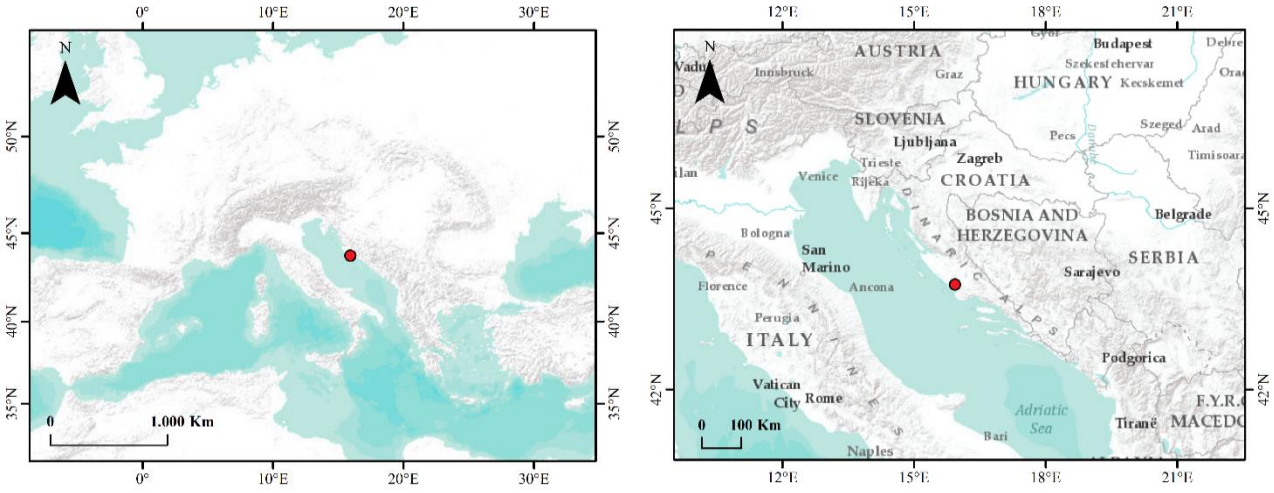

Figure 1. Study area (red dot shows experimental location)

3. Results and conclusions

Post-fire management is typically a trade-off between the cost and potential effectiveness of applied treatment and the potential damage to valuable resources from unmitigated erosion. Mulching is a technique that belongs to emergency stabilisation techniques, as it immediately stabilises the soil of the burned area and reduces additional damage to the fragile bare soil which confirmed our results. After a wildfire, there is a mosaic of low, moderate, and high soil burn severity conditions, but the cost of mulch material and the energy required to apply it must be considered. Preference should be given to local and available on-site material. Our results showed that both mulch treatments reduce runoff generation in addition to UM treatment. The erosion yield was not occurred due to natural soil conditions. A linear decreasing trend was noted for SWR in all treatments. Overall, PM was showed higher efficiency in increasing soil aggregate stability (MWD and WSA), SHC SOM, and TC. OM was mostly increased soil nutrients such as TN, P_2O_5, and K_2O. Bot mulch treatment increased soil quality, but the effect was variable due to the different chemical compositions of the material. The use of native mulch can be recommended because of its effect on improving soil quality and reducing runoff ratio, however consideration should be given to whether they are available in the areas affected by wildfire.

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