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Long-term legacy effects of wildfires on soil organic carbon stability in French Mediterranean forests

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Wildfires are natural disturbances that strongly affect soil organic carbon (SOC) stocks and chemistry in Mediterranean forests, with a common decrease in SOC stocks and a relative increase in aromatic carbon. Little is known on the long-term effects of Mediterranean wildfires on SOC stability and the size of SOC kinetic pools, which would improve our understanding of SOC dynamics in Mediterranean regions.

In this study, we aim at providing qualitative information on SOC stability as well as quantitative estimates of the size of the centennially persistent SOC (CPsoc) pool under contrasted Mediterranean wildfire disturbance regimes.

We sampled soils from 25 oak forest plots with different wildfire histories over six decades, but similar pedoclimates (Dystric Cambisol to Dystric Leptosol) in a French Mediterranean region (Maures mountains). A wildfire history index (WHI) is used to represent the number and the age of fires for each forest plot, high WHI values characterizing plots with more frequent and recent fires. At each plot we collected topsoils (0-5 cm depth) and soil biogenic structures (earthworm casts) that are known to be hotspots of soil biological processes. Qualitative proxies of SOC stability and quantitative estimates of the size of the CPsoc pool are obtained with Rock-Eval 6, a thermal analysis technique consisting in the sequential pyrolysis (200-650°C) and oxidation (300-850°C) of SOC. The bulk chemistry of SOC is assessed by mid-infrared spectroscopy.

SOC stability approximated as the proportion of SOC resistant to pyrolysis at 650°C increases with WHI and is higher in topsoils than in soil biogenic structures under all wildfire disturbance regimes. Similarly, the temperature at which 50% of the carbon resulting from the SOC pyrolysis has thermally evolved (T50_PYR) increases with WHI and is higher in topsoil than in earthworm casts. Conversely, the temperature at which 50% of the carbon resulting from the SOC oxidation has thermally evolved (T50_OX) is not altered by wildfire disturbance or biological processing by earthworms. The size of the CPsoc pool is estimated by a regression model using Rock-Eval 6 parameters as predictors, which was calibrated in long-term experimental sites in Northwestern Europe. Thermal characteristics of our Mediterranean samples are within or close to the thermal application range of the model. The percentage of CPsoc increases significantly with WHI, from 25-30% of SOC in forest topsoils not burnt since 1950 to 40-50% of SOC in topsoils experiencing frequent and recent wildfires. The percentage of CPsoc is also higher in topsoils than in earthworm casts. SOC stability proxies and the size of the CPsoc pool are positively related to aromatic carbon and negatively related to the degree of oxidation of SOC.

Our study demonstrates the long-term legacy effects of Mediterranean wildfires on SOC stability that are visible in topsoils and soil biogenic structures. Wildfire disturbances increase the size of the centennially persistent SOC pool due to newly formed pyrogenic carbon. Long-term (>50 years) SOC recovery after wildfire disturbances is thus accompanied by a decrease in SOC stability as new and unstable carbon progressively accumulates in topsoil.