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The Effect of Soil Water-Repellency on CO_2 Flux Upon Rewetting

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Rewetting of dry soil results in a well-known short-term pulse of CO_2 from soil to the atmosphere known as the 'Birch effect'. The displacement of CO_2 in air-filled pores with water during wetting has been recognised as one of the sources of this pulse. The Birch effect has been extensively reported under wettable soil conditions, but some studies report a lack of such response, suggesting soil water repellency (SWR) as a potential cause. SWR restricts infiltration and affects soil water distribution. Preferential flow paths and increased overland flow are common patterns in water-repellent soils, leaving extensive areas of the soil dry even after substantial rainfall. Future climate scenarios will likely enhance the development and persistence of SWR. Despite this, the effect of SWR on CO_2 efflux upon rewetting has never been tested and remains poorly understood.

The aim of this research was to test the hypothesis that SWR suppresses CO_2 pulse after rewetting. A field study was conducted in a burnt pine stand in Portugal, before the first natural rainfall event, and in an unburnt grassland in South Wales (UK) during the 2018 European drought. All sites were severely repellent during the field campaigns. Forest fires are known to induce changes in SWR, often increasing its severity and persistence. The study plots were rewetted with water and water mixed with a wetting agent (Revolution®, Aquatrols) to simulate inhibited and non-inhibited infiltration, respectively. CO_2 efflux in response to wetting was monitored before and several times after the rewetting event, using the soil gas flux system along with changes in soil water content, infiltration and runoff. The effect of SWR reduced the CO_2 pulse after wetting in all sites.
In the lab, intact core samples were rewetted following the same methodology used in the field to simulate wettable and water-repellent conditions. CO_2 efflux in response to wetting was continuously monitored using the LI-COR Li-8100A Soil Gas Flux system. Severely reduced infiltration and preferential flow was observed under water-repellent conditions. Typical Birch effect observed under wettable conditions was not detected in water-repellent soils.

The main conclusion from the experiment is that the hydrological response of water-repellent soils to wetting have an impact on CO_2 fluxes. Hence SWR becomes an important parameter to consider in monitoring and modelling of gas fluxes.

Keywords: soil water repellency, hydrophobicity, CO_2 efflux, CO_2 pulse, Birch effect, wildfires, forest fires.