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Extreme precipitation event timing can determine boreal forest soil carbon response to climate change

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Boreal forests store ~30% of the global forest soil organic carbon (SOC) stock[1]. These regions are experiencing enhanced soil drying via evapotranspiration and extreme autumn precipitation events, yet SOC response is unclear. In the mineral horizon, Al organo-metal complexes (Al_{OMC}) precipitate with dissolved organic carbon (DOC) to stabilize SOC. Geological parent material and climate influence Al_{OMC} via metal availability, hydrology, and DOC input[2]. Extreme precipitation should limit Al_{OMC} precipitation. Yet, the impact of antecedent soil moisture on SOC response to such events is unclear and could indicate event timing importance (i.e. different response to dry late summer events versus wetter autumn).

We aim to understand SOC response to short-term climate change by experimentally measuring DOC uptake into or loss from mineral soils at high-water flux with varying antecedent soil moisture. Soils were collected across a mesic boreal forest climate transect with parent material of varying Al in Eastern Canada. We find C saturation of Al_{OMC} ($C:Al_{OMC}$) and soil moisture control DOC change regardless of climate and parent material (Fig.1). This suggests surficial DOC exchange with extant Al_{OMC} is a dominant mechanism at high water-flux. As $C:Al_{OMC}$ decreases with depth, shallow saturated soils exhibited DOC loss while deeper undersaturated soils (below ~30cm) experienced significant DOC uptake indicating SOC storage potential (Fig.2). Deep soils are likely limited by a DOC source; however, increased infiltration could enhance subsoil SOC accrual.

Dry soils exhibited greater DOC loss and reduced the $C:Al_{OMC}$ threshold for DOC uptake. Using these results, we present a simple model predicting extreme event SOC response which demonstrates the increasing depth of SOC vulnerability to loss with drying (Fig.2). This indicates that precipitation event timing is key, as extreme precipitation on dry late summer soils should promote greater DOC loss relative to wetter soils later in autumn. These results suggest shallow mesic boreal forest mineral soils may experience SOC reductions with short-term climate change, while deep SOC depends on how infiltration depth is impacted.

1. Scharlemann et al. (2014). *Carbon Management*, 5(1), 81-91.
2. Slessarev (2021). *Biogeochemistry*, 157(1), 1-13.

Figure 1.

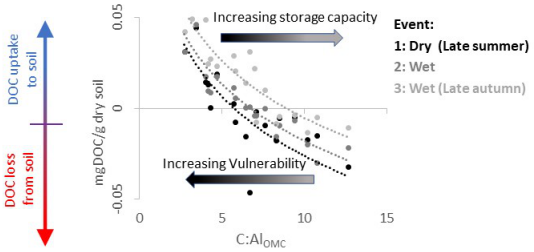

Figure 2.