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Mechanisms controlling the emission and stabilization of carbon during soil drying-rewetting

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Terrestrial ecosystems are continuously exposed to dry periods and rainfall events. These cycles of drying-rewetting cause strong variations in biochemical processes that alter the balance of soil carbon (C), affecting both its inputs and losses. The rewetting of dry soils results in large pulses of C dioxide to the atmosphere that can constitute a major fraction of the annual emissions in some ecosystems and, at the same time, promotes the sequestration of C into growing microorganisms. After rewetting, microbial growth and respiration can follow decoupled patterns depending on the intensity of the rewetting and the physiological status of the microbes—in turn, this decoupling can lead to contrasting fates of C between emission and stabilization into soil organic matter. Moreover, these patterns can be classified as either 'resilient' or 'sensitive', depending on the way C is used over time. Despite the significance of these dynamics for the C budget, the mechanisms controlling them are still not well understood.

To shed some light on this challenging problem, we simulated the soil-microbial response to drying-rewetting by using the process-based model EcoSMMARTS. The results indicated that the history of soil moisture affected the responses to rewetting by promoting microbial groups with specific survival strategies. The soils regularly exposed to 'severe' conditions (e.g., shallow horizons in semi-arid or Mediterranean ecosystems) exhibited resilient responses, whereas sensitive responses were obtained in soils from 'milder' environments (e.g., humid climates and deep horizons). The resilient responses were obtained when soil microbial communities could cope well with water-stress and could started synthesizing new biomass right after rewetting, which also triggered large respiration peaks induced via osmoregulation. In contrast, sensitive responses were found in communities that could not withstand the effects of drying-rewetting, which led to a delay in microbial growth and sustained C mineralization by cell residues. The disruption of soil aggregates during drying-rewetting was also identified as the major contributor of the C sources fuelling the rewetting responses. By allowing us to attribute rewetting responses to individual processes (physiological, physical, or ecological), these model results improve our understanding of the mechanisms that govern the emission and stabilization of C in soils during drying-rewetting.