

Historic Precipitation Regimes Influence Microbial Population Dynamics in Response to Seasonal Rewetting in Mediterranean-Grassland Soil

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Project Goals: Microorganisms play key roles in soil carbon turnover and stabilization of persistent organic matter via their metabolic activities, cellular biochemistry, and extracellular products. Microbial residues are the primary ingredients in soil organic matter (SOM), a pool critical to Earth's soil health and climate. We hypothesize that microbial cellular-chemistry, functional potential, and ecophysiology fundamentally shape soil carbon persistence, and we are characterizing this via stable isotope probing (SIP) of genome-resolved metagenomes and viromes. We focus on soil moisture as a 'master controller' of microbial activity and mortality, since altered precipitation regimes are predicted across the temperate U.S. *Our SFA's ultimate goal is to determine how microbial soil ecophysiology, population dynamics, and microbe-mineral-organic matter interactions regulate the persistence of microbial residues under changing moisture regimes.*

Abstract: Microbial activity is rapidly stimulated by the rewetting of dry soils, resulting in a pulse of carbon mineralization and nutrient availability. This phenomenon is important because significant portions of annual net ecosystem production can be lost through microbially driven C mineralization in a single rewetting event, and predicted climate changes in semi-arid life zones could profoundly change soil C dynamics and nutrient availability. While there has been much interest in the immediate response of indigenous communities to soil wet-up, little is known about the effects of reduced spring rainfall on subsequent microbial population responses in semi-arid soils undergoing a fall wet-up.

To determine how reduced spring rainfall affects losses of recently fixed C and taxon-specific population dynamics, we performed a wet-up experiment using soils that had been field-labeled with ¹³CO₂ by the Firestone group as part of their 'Phage and Fauna' Genomic Sciences project. Sixteen rainfall-manipulation plots were exposed to ¹³CO₂ (labeled) or ¹²CO₂ (unlabeled) for 5 days to label photosynthetic soil inputs under two precipitation regimes: the historical average water (100%) and 50% water reduction (treatment). Following the annual summer dry period, our SFA team collected and incubated soils at LLNL with four isotopic treatments (¹²C¹⁸O, ¹³C¹⁸O, ¹²C¹⁶O, ¹³C¹⁶O) in 184 microcosms. 'Heavy water' (¹⁸O-H₂O) additions were used to specifically target the active portion of the microbiome and virome. Samples were harvested at six times following rewetting (0, 3, 24, 48, 72, 168 h) for DNA-quantitative stable isotope probing (qSIP), total CO₂, and ¹³CO₂ production.

While the differences between historical precipitation treatments were minimal for both total soil C respired and newly fixed CO₂ respired, we observed a large treatment effect on microbial response. Quantitative SIP analysis of 16S rRNA genes showed the prior spring's precipitation significantly affected cumulative total community growth and death rates following the fall wet-up. Overall, growth began more rapidly and sustained higher rates for 100% precipitation soils with 4.5 times more cumulative growth during the incubation. Mortality was also more rapid for 100% precipitation soils, with cumulative mortality 5 orders of magnitude larger in the 100% treatment. Population specific response patterns also differed across treatments. Growth response was dominated by Firmicutes, Actinobacteria, and Proteobacteria in 100% precipitation soils, whereas there was very little Actinobacteria response and delayed and reduced Firmicutes response in the 50% precipitation soils. Mortality was also markedly different, with 119 ASVs (amplicon sequence variant) found to have measurable death rates in 100% precipitation treatment, while only 4 ASVs were observed as dying in 50% treatment. To investigate mechanisms of mortality we are analyzing SIP-metagenomes to characterize microbial and viral activity and functionality following wet-up. Preliminary results show active viruses responded differently to our two treatments. Our results suggest historic precipitation patterns can have a significant impact on future microbial activities, turnover, and persistence. Future work will investigate the underlying mechanisms of different responses and their impact on soil C.

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