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Microbially Mediated Carbon and Nitrogen Cycling after Prescribed Fire

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Prescribed fires are effective tools for mitigating catastrophic wildfires and inducing positive ecological changes, but their impacts on soil biogeochemistry, particularly C and N cycling, remain poorly resolved. Post-fire trajectories of these nutrients are strongly governed by soil microbial communities, whose composition and functional potential are also altered by burning and subject to successional dynamics. These low intensity fires likely cause less direct microbial mortality, leaving viable communities poised for rapid processing of ash-derived C and N. While previous studies show prescribed fires can shift community composition and increase soil organic matter pools, few couple microbial community dynamics with geochemical transformations at high temporal resolution.

Here, we investigate interactions between microbial community assembly and ash-derived C and N transformation over time after prescribed pile burns in California chaparral and coast live oak woodland soils. Using an approach that integrates high-resolution temporal measurements of soil geochemistry (soluble organic matter pools, inorganic N speciation, pH), in-field CO_2 flux measurements, and 16S amplicon sequencing, we observe significant changes to soluble organic C and N pools and community composition immediately post-fire. In the months following, both gradually recovered, with acceleration during the following wet season, returning to baseline conditions within one year, in contrast to decadal wildfire legacies. Shifts in microbial functional potential coincided with measured changes in N speciation and ash-derived C loss; however, these processes appear to be strongly modulated by post-fire moisture dynamics. We complemented this year-long field study with a controlled laboratory incubation, revealing that under optimal moisture conditions, burned soils exhibited higher respiration rates and greater declines in soluble C and N compared to low-moisture and unburned controls.

Collectively, these findings demonstrate the potential for post-fire microbial succession to rapidly regulate C and N cycling after prescribed fires, mediated by a changing moisture regime. Our findings provide essential insights for evaluating the ecological impacts of prescribed fire and guiding land management practices.