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Prescribed Burns Drive Lasting Changes in Forest Soil Nitrogen Cycling

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Ecological disturbances such as fire fundamentally alter soil physicochemical properties and restructure microbial communities, thereby reshaping Earth's biogeochemical cycles. Most research on fire-soil-microbe feedbacks has emphasized short-term responses to single, high-intensity wildfires, typically within the first-year post-burn. In contrast, the long-term effects of repeated prescribed fire—now widely used to reduce wildfire risk and promote biodiversity—remain poorly resolved. We hypothesized that multi-decadal prescribed fire imprints a persistent geochemical signature on soils, fundamentally reshaping microbiome function. To test this, we examined two fire-managed ecosystems in the eastern United States. At the Albany Pine Bush (Albany, NY, USA), long-term fire management significantly depleted soil total nitrogen, particularly nitrate, likely due to volatilization, leaching, and stabilization into recalcitrant pyrogenic organic matter. Metagenomic analyses revealed reduced genetic potential for dissimilatory nitrate reduction and denitrification in repeatedly burned soils. At the Catoosa Wildlife Management Area (Crossville, TN, USA), we evaluated how fire history influences soil reactive nitrogen (NO and HONO) emissions by microbial populations in restored shortleaf pine-oak savannas. Laboratory incubations of surface soils (0-5 cm) from control, intermediate restoration (*i.e.,* fire-managed), and advanced restoration sites were conducted to test HONO-N and NO-N emissions as a function of moisture and temperature. Intermediate restoration soils exhibited the highest NO-N fluxes (6.21 ± 0.48 μg N kg^{-1} soil), followed by control soils (3.00 ± 0.29 μg N kg^{-1}). Advanced fire-managed soils produced negligible NO-N fluxes across conditions tested. NO-N emissions were positively correlated with ambient temperature. Peak HONO-N fluxes did not differ significantly between intermediate and control soils, while HONO emissions were undetectable in advanced soils under the temperature and moisture conditions examined. HONO-N fluxes were positively correlated with soil moisture. These changes in HONO and NO emissions were associated with shifts in both soil hydrology and microbial community. On-going isotopic analyses are being used to attribute the specific microbial sources of these emissions. In summary, we find that long-term, repeated application of prescribed fire fundamentally reshapes soil nitrogen cycling.