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Noninvasive methods for dynamic mapping of microbial populations across the landscape

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Soil microorganisms drive key ecosystem processes, and yet characterizing their distribution and activity in soil has been notoriously difficult because of the heterogeneity of microbial populations in time and space that require extensive sampling to constrain. In the Landscape Evolution Observatory (LEO) in Biosphere 2, soil sampling is limited in efforts to minimize disruption to the long-term experiment that aims to characterize the interacting biological, hydrological, and geochemical processes driving soil evolution. New methods are needed to monitor soil microbial communities and their genetic potential over time. In this study, we leverage well-defined boundary conditions on hydrological flow at LEO to develop a method to nondestructively characterize in situ microbial populations. In our approach, we sample microbes from the seepage flow at the base of each of three replicate LEO hillslopes and use hydrological models to 'map back' in situ microbial populations. Over the course of a 3-month periodic rainfall experiment we collected samples from the LEO outflow for microbial community analysis. We describe changes in microbial community composition over time and use hydrological flow models to identify the changing source region of discharge water over the course of periodic rainfall pulses, thereby mapping back microbial populations onto their geographic origin in the slope. Predictions of in situ microbial populations are ground-truthed against those derived from destructive soil sampling. This method may be useful for long-term, non-destructive monitoring of the microbial communities in this large-scale model system and other systems with similar sampling limitations. Additionally, our results will inform understanding of microbial transport through soils.