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Functional resilience of microbial ecosystems in soil: How important is a spatial analysis?

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Microbial life in soil is exposed to fluctuating environmental conditions influencing the performance of microbially mediated ecosystem services such as biodegradation of contaminants. However, as this environment is typically very heterogeneous, spatial aspects can be expected to play a major role for the ability to recover from a stress event.

To determine key processes for functional resilience, simple scenarios with varying stress intensities were simulated within a microbial simulation model and the biodegradation rate in the recovery phase monitored. Parameters including microbial growth and dispersal rates were varied over a typical range to consider microorganisms with varying properties. Besides an aggregated temporal monitoring, the explicit observation of the spatio-temporal dynamics proved essential to understand the recovery process. For a mechanistic understanding of the model system, scenarios were also simulated with selected processes being switched-off.

Results of the mechanistic and the spatial view show that the key factors for functional recovery with respect to biodegradation after a simple stress event depend on the location of the observed habitats. The limiting factors near unstressed areas are spatial processes - the mobility of the bacteria as well as substrate diffusion - the longer the distance to the unstressed region the more important becomes the process growth. Furthermore, recovery depends on the stress intensity - after a low stress event the spatial configuration has no influence on the key factors for functional resilience. To confirm these results, we repeated the stress scenarios but this time including an additional dispersal network representing a fungal network in soil. The system benefits from an increased spatial performance due to the higher mobility of the degrading microorganisms. However, this effect appears only in scenarios where the spatial distribution of the stressed area plays a role.

With these simulations we show that spatial aspects play a main role for recovering after a severe stress event in a highly heterogeneous environment such as soil, and thus the relevance of the exact distribution of the stressed area. In consequence a spatial-mechanistic view is necessary for examining the functional resilience as the aggregated temporal view alone could not have led to these conclusions.

Further research should explore the importance of a spatial view for quantifying the recovery of the ecosystem service also after more complex stress regimes.