Modelling bacterial degradation after disturbances

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Microbial degradation of soil pollutants is an important ecosystem function. However, as soil systems are constantly exposed to disturbances of different intensities and frequencies, their ability to recover the biodegradation function is crucial.

We applied a numerical simulation model considering growth, degradation and chemotactic movement of bacteria to analyze bacterial degradation performance in response to different disturbance regimes comprising single or multiple disturbance events. The recovery of the degradation rate and its spatiotemporal dynamics were observed. To investigate the influence of bacterial distribution on recovery, we simulated different spatial configurations of the disturbances with various degrees of fragmentations. Furthermore, we considered bacterial dispersal networks in the model to simulate the bacterial movement along fungal networks in soil.

We found that biodegradation recovery is split into a phase of initial recovery driven by spatial processes (bacterial dispersal and substrate diffusion) and a subsequent phase of long-term recovery driven by the nonspatial process of bacterial growth. Therefore, after highly fragmented disturbances where the bacteria are relatively homogeneous distributed the degradation rate fully recovers already in the initial phase. By contrast, in scenarios with heterogeneous bacterial distributions (i.e. after disturbances occuring in a clustered pattern) the second phase and, hence, bacterial growth becomes much more important. In those scenarios, the degradation rate after the disturbance is drastically enhanced (up to 38%) by bacterial dispersal networks compared to scenarios without networks. This effect is caused by an increase of efficiency of the spatial process of bacterial dispersal as these networks enhance accessibility of remote disturbed areas. However, if the bacteria are already homogeneously distributed additional dispersal networks increased the recovery rate only by up to 10 % at most in moderate frequented disturbance regimes.

Our simulation results show the importance of spatial processes for functional recovery of degradation after disturbances. Especially in ecosystems where the the mobility of chemical species and bacterial cells is limited, bacterial dispersal networks that overcome these hindrances may be highly beneficial for stabilizing the systems function biodegradation.