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Can you escape the beat? Modelling spatiotemporal biodegradation dynamics during periodic disturbances

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Biodegradation of organic compounds in soil is an important microbial ecosystem service. Soil ecosystems are constantly exposed to disturbances of different spatial configurations and frequencies, challenging their ability to recover the biodegradation function. Thus, the response to these disturbances is crucial for the soil systems' biodegradation performance. The influence of spatial aspects of the disturbance regimes on long-term biodegradation dynamics under periodic disturbances has not been examined, yet.
We applied a numerical simulation model considering bacterial growth, degradation, and dispersal to analyze the spatiotemporal biodegradation dynamics under disturbances occuring with different frequencies and with different spatial configurations.
We found biodegradation performance decreasing in response to periodic disturbances but on average approaching a new quasi steady state. This mean performance of the disturbed systems increases with both, the interval length between disturbance events and the fragmentation of the spatial disturbance patterns. A detailed spatiotemporal analysis of degradation activity reveals that under highly fragmented disturbance patterns, biodegradation still takes place in the entire disturbed area. For moderately fragmented disturbance patterns, parts of the disturbed area become completely inactive. However, areas with high degradation activity emerge at the interface between disturbed and undisturbed areas, allowing the systems to maintain a relatively high degradation performance. Further decreasing the disturbance patterns' fragmentation, fewer interfaces between disturbed and undisturbed area and, thus, fewer active habitats occur, which reduces biodegradation performances.
In additional simulations, we found that bacterial dispersal networks, as for example provided by fungal hyphae, usually increase the areas of high degradation activity and, thus, the biodegradation performance in presence of periodic disturbances. However, for some specific regimes with highly fragmented disturbance patterns, dispersal networks can in turn decrease the biodegradation performance.
Our results show that spatial aspects of the periodic disturbance regime influence the biodegradation dynamics, indicating the relevance of spatial processes for functional stability. The level of connectivity between disturbed and undisturbed areas is crucial for the local and global dynamics of the ecosystem service biodegradation. Networks enhancing bacterial dispersal may often, but not always, increase the functional stability.