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Too big or too narrow? Disturbance characteristics determine the functional resilience in virtual microbial ecosystems

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In general ecology, there is an ongoing debate about the influence of fragmentation on extinction thresholds. Whether this influence is positive or negative depends on the considered type of fragmentation: whereas habitat fragmentation often has a negative influence on population extinction thresholds, spatially fragmented disturbances are observed to have mostly positive effects on the extinction probability. Besides preventing population extinction, in soil systems ecology we are interested in analyzing how ecosystem functions are maintained despite disturbance events. Here, we analyzed the influence of disturbance size and fragmentation on the functional resilience of a microbial soil ecosystem. As soil is a highly heterogeneous environment exposed to disturbances of different spatial configurations, the identification of critical disturbance characteristics for maintaining its functions is crucial.

We used the numerical simulation model eColony considering bacterial growth, degradation and dispersal for analyzing the dynamic response of biodegradation examplary for an important microbial ecosystem service to disturbance events of different spatial configurations. We systematically varied the size and the degree of fragmentation of the affected area (disturbance pattern).

We found that the influence of the disturbance size on functional recovery and biodegradation performance highly depends on the spatial fragmentation of the disturbance. Generally, biodegradation performance decreases with increasing clumpedness and increasing size of the affected area.

After spatially correlated disturbance events, biodegradation performance decreases linear with increasing disturbance size. After spatially fragmented disturbance events, on the other hand, an increase in disturbance size has no influence on the biodegradation performance until a critical disturbance size is reached. Is the affected area bigger than this critical size, the functional performance decreases dramatically. Under recurrent disturbance events, this threshold is shifted to lower disturbance sizes. The more frequent disturbances are recurring, the lower is the critical disturbance size.

Our simulation results indicate the importance of spatial characteristics of disturbance events for the functional resilience of microbial ecosystems. Critical values for disturbance size and fragmentation emerge from an interplay between both characteristics. In consequence, a precise definition of the specific disturbance regime is necessary for analysing functional resilience.

With this study, we show that we need to consider the influence of fragmentation in terrestrial environments not only on population extincions but also on the resilience of ecosystem functions. Moreover, spatial disturbance characteristics - which are widely discussed on landscape scale - are an important factor on smaller scales, too.