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The Role of Plants as Ecosystem Engineers in Resilience to Climate Change

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In drylands landscape structure is controlled by two ecosystem engineers, soil microphytes and shrubs. Soil microphytes adhere the soil particles by secreting polysaccharides, thus forming biogenic soil crusts. Shrubs engineer the environment above and below ground. Above ground they can form soil mounds and below ground modulate the soil properties by their roots. The two engineering modes create shrub patches in the landscape.
The two phase mosaic formed by the engineers creates a source-sink system where the crust is a source of soil, water, organic matter and nutrients while the shrub patch is the sink.
Most of the productivity and diversity of the system is concentrated in the sink patches. Climate change such as the increase in frequency and severity of droughts may affect the function of the two phase mosaic by causing shrub dieback. This can transform a shrub land into crust land by increasing leakage of resources and decreasing productivity and diversity (desertification).
Based on our long term research at LTER sites in the Northern Negev, Israel, we present two models depicting how climate change can cause state changes from shrub land to crust land and how the mode of shrub engineering can prevent this transition. Our main proposition is that the resilience of a two phase mosaic to drought depends on whether the engineering is by mound formation or by subsurface soil modulation.
When the engineering mode is mound formation, shrubs dying due to drought expose the underlying mound to erosion by rainfall and runoff. The eroded patch is then colonized by microphytes which form soil crusts. This process takes between five to ten years. To rebuild the soil mound by a shrub takes hundreds of years. Therefore, once the soil mound is eroded the area will then be transformed from shrub land to crust land and the recovery time is long. When the engineering is through the roots the system is more resilient to drought. Even if the canopy dies back the shrub patch continues to function as a sink because the roots function as tubes that channel the water to deeper soil. The patch continues to function as a shrub patch even though the shrub has been decimated. The enriched patch prevents crust encroachment and stimulates regrowth of the shrub. In this case there isn't a transformation from shrub land to crust land and the recovery rate is rapid.
Based on the two case studies we present a general model on state changes in shrub lands due to climate change. We demonstrate that a main factor in gauging state transition due to climate change is the mode by which plants engineer their environment.