Abstract

In drylands, wind-driven soil erosion is a major driver of desertification. Desertification is characterized by reduced soil stability and accelerated land degradation, both of which damage local infrastructure and ecosystems. Conventional soil stabilization methods, such as those that rely on cement, polymers, or mechanical vibration, are often energy-intensive and environmentally unfriendly. Microbially induced calcium carbonate precipitation (MICP) offers a bio-mediated alternative by binding soil particles with calcite. Unfortunately, urease-mediated MICP generates ammonia as a byproduct, conferring phytotoxic risks that limit its large-scale application. Thus, this project proposes a low-cost engineered biocrust based on carbonic-anhydrase-mediated MICP, which mitigates ammonia release. Our biocrust comprises primary cells that conduct carbonic-anhydrase-mediated MICP and helper cells that secrete exopolysaccharides (EPS). Together, the co-culture is intended to be deployed into dryland regions and independently form the biocrust in designated areas. However, our design has limitations. Although the carbonic anhydrase in our system is highly efficient, our system can only conduct MICP under basic and calcium-rich conditions. By inducing carbonic anhydrase expression in wild soil bacteria, this system achieves regulated and enhanced calcite precipitation, forming a thin, erosion-resistant surface crust. Further development of this project may yield a carbon-sequestering, scalable, and programmable method to mitigate desertification sustainably.