Terraforming Soil EERC: Accelerating Soil-Based Carbon Drawdown Through Advanced Genomics and Geochemistry

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To reduce the United States' net carbon dioxide (CO_2) emissions to zero and limit the impacts of global warming, it is essential to actively remove CO_2 from the atmosphere. Soils store a vast amount of carbon in organic and inorganic forms—on the order of 3000 billion tons globally—this is more carbon than is found in the atmosphere and on land combined. While the United States' 166 million hectares of agricultural soils have lost a vast amount of carbon in the past century due to cultivation and erosion, there is clear potential to reverse this trend and actively manage agricultural lands with strategies that capture CO_2 from the atmosphere. The *Terraforming Soil* Energy Earthshot Research Center (EERC) will research new bio- and geo- engineered techniques to understand, predict, and accelerate scalable and affordable CO_2 drawdown in soils, via both organic and inorganic carbon cycle pathways. The Center's overarching goal is to advance the fundamental understanding of CO_2 drawdown in soils through both organic and inorganic pathways, measuring soil C storage capacity, durability, and regional variations that have bearing on land-management practices. In Objective 1, synthetic biology tools will be used to accelerate naturally occurring plant and microbial traits that shape CO_2 fixation processes, organic matter formation and mineral dissolution. Combined genome sequencing and isotope tracing approaches will be used to quantify the fundamental mechanisms of how organic matter accrues over time and the traits of plants and microorganisms that need to be better reflected in process models. In Objective 2, the Center will focus on positive interactions that can occur during the weathering of primary minerals and the formation of organic matter-mineral complexes—together, these have dramatic potential to accelerate soil CO_2 drawdown via combined organic and inorganic pathways. But currently, the interactions between soil weathering, soil biology, and organic matter cycling are poorly understood. The Center's field and laboratory-based studies will measure how soil management approaches can be 'stacked' together, to optimize total CO_2 drawdown via co-deployment of novel engineered crops or microbes, silicate minerals, or organic amendments. Research for Objective 3 will integrate new modeling capabilities and data exploration to enable better predictions of soil CO_2 drawdown in both space and time. Novel micro- and macro-scale simulation tools will be combined with advanced modeling, machine learning, and data science approaches, allowing the Center to better forecast the potential impacts of new soil CO_2 drawdown approaches at multiple scales. The *Terraforming Soil* EERC team includes world-class experts in soil carbon cycling, photosynthesis biochemistry, plant/microbial gene engineering and genomics, mineral geochemistry, machine learning, exascale modeling and computing, additive manufacturing, and *in situ* isotope-based characterization. Throughout the research program, the Center will bridge cutting-edge analytical and computational studies with a commitment to engage with community stakeholders, exploring the technical, social, and economic implications of engineered soil CO_2 drawdown. The Center will emphasize diverse training opportunities for students and early career scientists and amplify equity and inclusion throughout the research pipeline.

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