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Harnessing *Cannabis sativa* (Hemp) for Phytoremediation and Phytomining in Agricultural Enhanced Rock Weathering (ERW) Systems

CHLOE KENT[1], JAKE THOMPSON[1], BENJAMIN KOCAR[2] AND NOAH J. PLANAVSKY[1]

[1]Yale University

[2]U.S. Army Engineer Research and Development Center

There is an urgent need for both significant emissions reductions and large-scale deployment of negative emissions technologies to mitigate climate change. Agricultural enhanced rock weathering (ERW) is a promising, low-cost carbon dioxide removal (CDR) strategy that enhances the natural weathering of silicate rocks, such as basalt and dunite, to sequester atmospheric CO_2. Beyond its CDR potential, ERW offers additional agronomic benefits, including improved soil fertility and increased crop yields. However, the feedstocks with the highest CDR potential, particularly dunite and other ultramafic rocks, contain elevated concentrations of bioavailable heavy metals, such as Ni and Cr, which pose environmental toxicity risks. These concerns have restricted their widespread application, as ultramafic feedstocks can only be applied in limited quantities with infrequent reapplications, thereby constraining their overall CDR potential. More widely used mafic feedstocks, such as basalt, face similar albeit smaller limitations, further restricting ERW scalability.

To address these challenges and enhance the long-term viability of ERW, in-situ soil remediation techniques—including hyperaccumulator crops and biochar amendments—were evaluated in mesocosm experiments to assess their efficacy in removing or immobilizing toxic elements in both basalt and dunite amended soils. Plant, soil, and water samples were collected throughout the experiment to determine heavy metal mobility and bioavailability. *C. sativa* emerged as an effective phytoremediator, demonstrating substantial uptake of Ni and other heavy metals. Additionally, this study presents the first-ever synchrotron-based X-ray fluorescence microprobe (XFM) maps of heavy metal accumulation in *C. sativa*, offering novel insights into its metal sequestration mechanisms.

These findings suggest that integrating *C. sativa* into ERW systems could mitigate the environmental risks associated with heavy metal accumulation, enabling the safer and more extensive application of both ultramafic and mafic feedstocks. By addressing key barriers to ERW scalability, this approach has the potential to significantly enhance its CDR capacity while concurrently managing soil contamination, reinforcing ERW's role as a critical negative emissions technology.