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Effects of enhanced mineral weathering on soil structure and organic carbon storage

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Enhanced mineral weathering is a nature-based solution to reduce atmospheric and soil CO_2 concentrations in agricultural settings. Spreading finely grained basalt on the soil leads to subsequent chemical reactions that alters soil properties by changing soil pH, nutrient availability and particle-size distribution. Changes in these soil properties activate soil feedback mechanisms such as shifts in soil biogeochemical reactions or plant growth dynamics. Several studies have examined changes in pH and CEC after basalt application; however, basalt application may have an additional influence on the soil's structural quality and the quantity of soil organic carbon (OC). In this study, we used a long-term field trial of basalt application at the University of Illinois Energy Farm (Illinois, USA) to elucidate changes in soil structure and OC storage. The field study was launched in 2016 using a randomized block design consisting of control (n=4, no basalt application), basalt (n=4), and lime (n=3) treatments. The sampling campaign was conducted in 2022 and in each field, we sampled with stainless steel cylinders (250 cm^3) at depths of 1—6 cm and 15—20 cm. All samples were analyzed for nutrient content, OC concentration, pH, CEC and select samples were analyzed for soil water characteristic curves and aggregate-size distribution.

Basalt and lime application had a significant effect on soil pH, Ca concentration and the dominance of Ca^{2+} as an exchangeable cation, all which reflect evidence of increased soil structural quality. Indeed, soil structure, as quantified from the soil water characteristic curves using the concept of relative entropy (the Kullback-Leibler divergence), showed clear signs of enhancement after lime application. However, this was less evident for the basalt treatment. Despite improvements in soil structure, there were no effects on OC storage in either of the treatments. Aggregate characterization for OC concentration showed that the depth stratification had a greater role in carbon protection than the soil treatment itself, where the highest OC enrichment (E_{OC}>1) was observed at the lower sampling depth of 15—20 cm. The organo-mineral association in the finest fraction was not affected by the treatment because neither the aggregate size class distribution nor OC accumulation in the finest fraction differed among the control, lime,

and basalt treatments. Enhanced mineral weathering improves soil nutrient content, pH, and, potentially, soil structure; however, these changes do not directly result in higher OC storage, which underlines the complex nature of OC dynamics.