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In-field carbon dioxide removal via weathering of crushed basalt applied to acidic tropical agricultural soil

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Enhanced weathering (EW) of silicate rocks such as basalt provides a potential carbon dioxide removal (CDR) technology for combatting climate change. Modelling and mesocosm studies suggest significant CDR via EW but there have been few field studies. The aim of this study was to directly measure in-field CDR via EW of basalt applied to sugarcane cultivated on acidic soil (pH 5.3, 0-0.25 m) in tropical northeastern Australia, where weathering potential is high. Basalt (< 4 mm) was applied annually from 2018 to 2022 at 0 or 50 t ha^{-1}, incorporated in the first year but not in subsequent years, with a resultant increase in soil pH but not crop yield. Soil inorganic carbon content and bicarbonate (HCO_3^-) flux to deep drainage (1.25 m depth) during the 2022-2023 year were measured to quantify CDR. Soil inorganic carbon was below detection limits. Mean HCO_3^- flux was 3.15 kmol ha^{-1} a^{-1} (SEM 0.40) in the basalt-treated plots and 2.56 kmol ha^{-1} a^{-1} (SEM 0.18) in the untreated plots but the difference (0.59 kmol ha^{-1} a^{-1} or 0.026 t CO_2 ha^{-1} a^{-1}) was not significant ($p = 0.082$), despite substantial weathering having occurred. This discrepancy is attributed to weathering by acids stronger than carbonic acid. Surface-bound protons, nitric acid and organic acids contributed similar amounts of acidity in the row, where the crop grew and fertiliser was applied. In the interrow, less nitric and organic acids were generated. These results show that in-field CDR via EW of basalt is very low where soil pH is well below the pK_a of carbonic acid (6.36). However, increased soil pH and the consumption of strong acids by weathering will eventually lead to reduced CO_2 evasion. Management that maintains soil pH close to 6.36 is likely to maximise in-field CDR via EW of applied alkaline minerals.