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Crushed basalt application to a tropical soil alters its properties: a modelling study using Crunchflow

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Applied to cropland soils at the regional scale, enhanced silicate weathering (ESW) has increasingly been proposed as a technique that could sequestrate significant quantities of atmospheric CO_2 while also providing ancillary benefits to soil fertility and crop growth. However, the effectiveness of using silicate additions as a geoengineering technique to remove CO_2 from the atmosphere still faces uncertainties. Furthermore, the long-term impact of repeated silicate additions on soil properties and functioning is not well understood. To address these concerns, we used the reactive transport model CrunchFlow to investigate ESW in a tropical environment. We conducted simulations involving five annual additions of 50 t ha-1 of a basaltic rock powder with a known mineralogy in the topmost 20 cm of a highly weathered Oxisol. According to the modelling results, basalt weathering can reduce soil acidity, with the initial solution pH value of 5.6 increasing to 10.7 after five applications. This process also supplies Ca, Mg and K and remineralizes the Oxisol, potentially improving its chemical fertility. Our estimation indicates that instantaneous CO_2 sequestration rates increase from 0.081 t $ha^{-1}yr^{-1}$ after the initial addition of basalt to 8.75 t $ha^{-1}yr^{-1}$ after five successive additions of basalt, resulting in significant increase in the rate of carbon capture. Additionally, we highlight the likely precipitation of allophanes (up to 1.5 wt.% and mostly in the 0-20 cm soil layer) upon dissolution of the rock's glassy component and plagioclases. As inferred for volcanic soils, allophanes have a large capacity for organic carbon stabilisation. However, this variable-charge mineral also provides a large reactive surface for irreversible binding of phosphate, possibly limiting its bioavailability. Owing to the development of alkaline pH values and the release of Ca from the weathering basalt, calcite is also predicted to form, although in minoramounts (~0.1 wt.%). Overall, we have demonstrated that the deliberate application of basalt to tropical soil leads to significant changes in its properties. The knock-on effect of these changes on its functioning remains unknown. We will discuss the limitations of our model and improvements needed to increase its accuracy.