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Cation uptake by biochar reduces carbon removal efficiency

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Production of biochar—an organic carbon-rich material produced by pyrolyzing biomass—may be a scalable and cost-effective means of atmospheric carbon dioxide removal. Biochar has been estimated to be able to remove billions of tons of carbon dioxide from the atmosphere annually, be stable for centuries, and can directly benefit farmers as a soil amendment by increasing soil fertility. There has been an >8000% increase in CDR sales from 2020 to 2023 (see CDR.fyi). However, we are still developing a framework for quantifying the effectiveness of this process. The high-temperature pyrolysis process of biochar increases the proportion of carbon locked in stable (e.g., aromatic) structures resistant to oxidation. This process also creates high surface areas (that are very reactive), leading to binding of metals. Although biochar cation sorption can have positive agronomic benefits, this process will also affect the carbon fluxes within an agroecosystem and subsequently the CDR efficiency of biochar. Specifically, cations (Ca^{2+} and Mg^{2+}) removed from soil because of reactive surfaces in biochar decrease the cation efflux from the soil profile (and compost site where biochar is aged). In most surface waters, aqueous charge balance is maintained by re-equilibration of the carbonic acid system. Therefore, a decrease in the Ca^{2+} or Mg^{2+} flux from soils translates to decreased bicarbonate export from soils. We will introduce a framework for quantifying the effect of this process on biochar CDR projects and make a case that when biochar is being sold as a means of carbon removal, cation binding needs to be incorporated into the monitoring, reporting, and verification framework.