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Spatial constraints on ocean alkalinity enhancement through coastal enhanced silicate weathering

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Coastal enhanced silicate weathering (CESW) is a CO_2 removal technology that targets the enhanced dissolution of silicate minerals in the coastal zone, leading to ocean alkalinity enhancement that increases the seawater's capacity to store CO_2. Different CESW deployment scenarios have been proposed, which depend on the ambient sediment grain size. Silicate mineral dissolution can potentially be increased through (1) natural particle grinding in energetic areas (gravel application), and flushing the sediment via (2) physical advection (permeable sediment application) or by (3) bioirrigation (cohesive sediment application), which removes dissolution products from the pore water and lowers the sediment pH by promoting oxic mineralisation. Hence, different approaches will be executed in different coastal environments. However, the amount of seafloor available for these different types of CESW applications has not been assessed.

To quantify the total seafloor area compatible with CESW and estimate the CO_2 sequestration potential upon large-scale application, we performed a "virtual" field trial, in which we apply olivine-based CESW to the whole the French coastal zone. Maps of environmental parameters were used to calculate olivine dissolution rates in different sediment types and quantify the resulting alkalinity release and CO_2 sequestration efficiency. For a one-time deployment of 20 kg olivine m^{-2}, the highest CO_2 sequestration rate (5-year average) was found for the gravel application (0.67 $kgCO_2\ m^{-2}\ yr^{-1}$, 11 Mt total France), followed by the cohesive sediment application (0.37 $kgCO_2\ m^{-2}\ yr^{-1}$, 3.0 Mt total) and the permeable sand application (0.032 $kgCO_2\ m^{-2}\ yr^{-1}$, 0.80 Mt total). The application type is thus a key parameter for the CO_2 sequestration rate as it controls the size of the added olivine grains and the pH in which olivine dissolves. Furthermore, many of the sites where olivine dissolution is predicted to be most efficient overlap with nature conservation areas. The limited extent of seafloor where CESW is efficient, combined with competing interests in the coastal zone, means that the potential application area for CESW could be smaller than previously anticipated.