Does nutrient demand control rock weathering? A model analysis

KATE MAHER[1*], FRIEDHELM VON BLANCKENBURG[2]

[1]Dept. of Earth System Sciences, Stanford University, Stanford, CA 94305, USA (*kmaher@stanford.edu)
[2]Earth Surface Geochemistry, GFZ German Research Centre for Geosciences, Potsdam, Germany

Photoysnthesis, and the respiration it allows, constitutes the largest transfer of energy on Earth, outpacing tectonic and geomorphic processes. Given that the biosphere constitues such a massive energy flux, and requires rock-derived nutrients for cell reproduction and mainenance, it is often assumed that the biosphere exerts a substantial influence on regolith evolution and chemical weathering rates. However, ecoystems are also efficient recylers: for mineral nutrients, such as P, plants recyle approximately 90-100% globally. Field data from ecosystems where both nutrient supply from regolith and recycling have been quantified shows that recycling increases with ecologic element demand, and decreases with erosion rate. Thus, although the extreme nutrient demands of ecosystems may far outpace the rates of regolith supply, seemingly requiring aggressive nutrient acquisition strategies, ecosystems also armor themselves against nutrient limitations using a variety of retention and recycling strategies. Do ecosystems impose feedbacks that alter the balance of fluxes in the regolith or adapt passively to their weathering environment?

To evaluate this question, we coupled a plant model that drives growth according to foliar P levels to a weathering model that acounts for erosion, water flow, regolith thickness, mineral solubilization rates, secondary minerals, and nutrient storage in organic and mineral phases. For equivalent total biomass at steady state, reduced foliar P levels at low erosion rates correspond to slow growth rates. Conversely, at high erosion rates enchanced mineral P supply drives faster growth and recycling. Numerical experiments simulating different plant nutrient acquisition strategies reveal that rock solubilization becomes self-limiting and is less efective than recyling mechanisms at increasing plant growth. Importantly, “bioweathering” and recycling strategies do not impact the overall chemical weathering flux. The only plant-driven parameters that change regolith weathering rates are found to be changes in water flux and changes in belowground CO_2, and both are only important at high erosion rates. These results thus provide constraints on the potential role of plants in influencing the geologic carbon cycle and may further aid in interpretting the drivers and consequences of land plant evolution.