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Vegetation as a weathering agent in young landscapes

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Where fresh rock is exposed to surface conditions, it undergoes rapid weathering during the incipient stages of soil development. In tandem, these young landscapes are commonly subject to rapid colonization by vascular plants, which directly impacts the rate and pathways of chemical weathering through transpiration, nutrient uptake, and rhizodeposition. Disentangling and ultimately predicting the influence of biology on weathering rates remains an outstanding challenge. Young systems still stabilizing in their elemental export budgets offer a unique window into the collective onset of vegetation and soil development. Here we utilize major element and silicon stable isotope ratios ($\delta^{30}Si$) from a series of climate-regulated flow-through columns packed with fresh basalt and planted with alfalfa seedlings at the Ecotron Île-de-France facility. The columns were divided into sets of (1) controls with no vegetation, (2) alfalfa seedlings with no amendments, and (3) alfalfa seedlings amended with K_2HPO_4 and $MgSO_4$ fertilizer. The presence of rapidly growing alfalfa significantly altered both the water balance and solution chemistry of discharge from the columns. Columns hosting alfalfa without fertilizer had lower efflux than the control, yet, due to higher porewater concentrations, still produced a larger total base cation efflux. However, the larger biomass in the fertilized columns reduced discharge to the point that the resulting base cation flux was lower than that of the control. Water exiting the fertilized columns exhibited the greatest enrichment in $\delta^{30}Si$ above the bedrock: 1.49±0.09‰, relative to 1.08±0.20‰ in the unfertilized columns and 1.03±0.03‰ in the control. We use $\delta^{30}Si$ of discharge and biomass to disentangle the ways vegetation is creating these observed changes in discharge chemistry through a plant-enabled weathering model. As the plants raise pore space CO_2 concentrations and disproportionally remove certain elements, the relative rates of dissolution and precipitation vary, resulting in characteristic shifts in $\delta^{30}Si$ ratios. By incorporating $\delta^{30}Si$ and concentration data, this modeling approach allows us to interrogate the relative influence of plant nutrient uptake vs changes in the balance of mineral dissolution and precipitation rates on overall mass fluxes. This work is particularly relevant to afforestation efforts in freshly deglaciated landscapes and freshly emplaced volcanic terrain.