The dependance of plant nutrient cycles on rock weathering

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We suggest that in slowly eroding mountaneous landscapes nutrient-bearing mineral grains in the regolith are depleted so that plants are nourished by recycling and by atmospheric inputs. In fast regimes, permanent natural erosion rejuvenates the weathering zone such that nutrient uplift from the weathered rock beneath soil roots and soil takes place by microbes that decrease the rhizospheric pH through respiration of CO_2, or by assimilation through the symbiosis of roots with mycorrhizal fungi.

We have tested these hypotheses in two forested mountain ecosystems using metal isotopes of nutritive elements and geochemical mass balances. In the slowly eroding tropical highlands of Sri Lanka, weathering has run to completion and in the top of the weathering zone the mineral nutrients K, Ca, P, and most of the Mg are fully depleted. Radiogenic $^{87}Sr/^{86}Sr$ ratios show that nutrient sources in soil are atmospheric and are decoupled from the weathering zone. We measured $^{26}Mg/^{24}Mg$ stable isotope ratios. Uptake of Mg by plants is associated with isotopic fractionation relative to the soil and soil pore water. Because we find no isotope ratio shift between trees and soil water, isotope mass balance requires complete uptake of Mg into trees. Given this efficient Mg utilisation the recycling rate is high and loss of Mg from the ecosystem is minimal. In the fast-eroding mountain forest of the Southern Sierra Critical Zone Observatory, California, primary feldspar and biotite have been only partially dissolved. Mg stable isotope mass balances show that Mg is highly bio-utilised: 50-100 % of the Mg released by chemical weathering is taken up by forest trees. The comparison of weathering flux with bio-uptake shows that other bio-utilised elements (K, Ca, P and Si) are also highly bio-utilised, and recycling rates are low. P is enriched towards the surface, hinting at nutrient uplift. Mg stable isotopes further show that Mg can be taken up by Ponderosa Pine at a depth of up to 7m. Mass balances shows that after uptake by forest trees, loss of these nutrients occurs in eroded plant debris and recycling is minimal.

The slow Sri Lanka data confirms the absence of deep nutrient uptake, the importance of atmospheric sources, and the high degree of nutrient recycling. The fast eroding Sierra Nevada data confirms the hypotheses of a rapid nutrient turnover after deep, biogenically stimulated weathering.