Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37020

How do REE hyperaccumulators shape rare earth element cycling and soil carbon stabilization at mineral–organic–microbe interfaces?

EMMELINE D'INCAU[1], WENSHEN LIU[1], JEAN-LOUIS MOREL[2], YETAO TANG[1] AND RONGLIANG QIU[1,3]

[1]Sun Yat-sen University
[2]Université de Lorraine
[3]South China Agricultural University

Rare earth element (REE) mining from ion-adsorption deposits has caused severe ecosystem degradation in southern China, characterized by nutrient depletion, low organic matter content, and altered biogeochemical functioning [1,2]. Although REE-hyperaccumulator plants are increasingly used in phytoremediation and phytomining [3,4], their role in shaping coupled REE cycling and soil carbon stabilization at mineral–organic–microbe interfaces remains poorly constrained, particularly regarding the contribution of plant litter production and decomposition to REE redistribution and long-term carbon preservation [5].

This study investigates how the REE-hyperaccumulator fern *Dicranopteris linearis* modulates coupled REE and carbon cycling within soil–plant systems, focusing on mineral–organic–microbe interactions controlling element mobility, carbon turnover, and organic matter stabilization. Field investigations are conducted across contrasting ecosystems, including REE mining sites and naturally REE-enriched forest soils; results presented here primarily focus on the forest ecosystem.

REE and carbon stocks are quantified across ecosystem compartments (soil profiles, plant biomass, plant litter, soil solution, and microbial biomass) using integrated field inventories. Litter-mediated processes are assessed using standardized litter decomposition experiments (tea-bag approach), while biogeochemical monitoring stations track temporal REE and carbon fluxes within the soil–plant system.

Preliminary results indicate selective biological fractionation between light (LREE) and heavy rare earth elements (HREE), with LREE showing higher bioconcentration factors in fern tissues and litter compared to HREE. REE accumulation in fresh and decomposing litter suggests active biological redistribution through plant-mediated cycling. Concurrently, soils colonized by *D. linearis* exhibit higher total carbon concentrations in the organic horizon (+14%), pointing toward enhanced surface carbon accumulation associated with litter inputs and organo-mineral interactions.

By integrating ecosystem-scale observations with process-based biogeochemical measurements, this work provides new insights into how REE hyperaccumulators shape biogeochemical processes controlling both REE cycling and soil carbon stabilization, with implications for sustainable REE recycling, mine rehabilitation, and climate-relevant ecosystem restoration.

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