Ecology & Evolution | Nov 17, 2026 | 5 min read | By Bryan White

Out of Amazonia: Neotropical Fern Biogeography Links Young Rainforest Species to Andean Uplift and Soil Shifts

Environment * Climate Change * Atmospheric Physics

New biogeographical research led by scientists at the University of Turku and Aarhus University challenges the classic assumption that tropical rainforests owe their extraordinary biodiversity solely to millions of years of uninterrupted climatic stability. Published in Frontiers of Biogeography under the title Out of Amazonia: Biogeography of a Neotropical fern radiation , the study by Venni Keskiniva, Samuli Lehtonen, Laura Kragh Frederiksen, and Hanna Tuomisto demonstrates that while Neotropical fern lineages are ancient, many of their individual living species are surprisingly young -- forged by dramatic geological and environmental upheavals including Andean mountain uplift, shifting soil chemistry, and coastal drying.

For decades, evolutionary biologists debated whether tropical rainforests function primarily as evolutionary "museums" that preserve old species undisturbed by temperate ice ages, or as active "cradles" where rapid speciation continually generates new taxa. By reconstructing the spatial and evolutionary history of a Neotropical fern radiation across South and Central America, Keskiniva and colleagues show how geological dynamism inside and around Amazonia repeatedly triggered recent bursts of speciation.

Ancient Lineages Versus Young Rainforest Species

A key insight from the Frontiers of Biogeography analysis is the distinction between lineage age and species age. Higher taxonomic clades of tropical ferns trace their origins deep into geological time, surviving across millions of years in warm, humid lowland habitats. Yet when researchers examined phylogenetic branching tips across modern species, they found that many distinct species diverged far more recently than the ancient lineages to which they belong.

Rather than persisting unchanged inside a static equatorial refuge, tropical fern populations experienced repeated ecological disruption. As landscapes transformed across the Neotropics, ancestral lowland populations encountered newly created elevation bands, altered mineral soils, and shifting moisture regimes that drove reproductive isolation and adaptive divergence.

| Biogeographical Driver | | Environmental Mechanism | | Evolutionary Outcome |

| Andean Mountain Uplift | | Creates steep elevation, temperature, & cloud-forest gradients | | Prompts colonization & speciation in montane niches |

| Soil Composition Shifts | | Alters nutrient & mineral availability across Amazonian basins | | Drives edaphic specialization between adjacent habitats |

| Coastal & Regional Drying | | Fragments continuous humid forest corridors | | Isolates peripheral populations and accelerates divergence |

| "Out of Amazonia" Dispersal | | Exports lowland lineages into neighboring biomes |

| Combines ancient museum persistence with recent cradle bursts |

How Geological Upheavals Act as Speciation Engines

Three interconnected physical drivers stand out in the Neotropical fern radiation. First, the progressive uplift of the Andes Mountains transformed western South America's topography, carving out cool, wet montane slopes and cloud forests adjacent to the warm Amazonian lowlands. Lineages dispersing upward out of Amazonia encountered unoccupied ecological space along sharp elevational gradients.

Second, Amazonia itself is not a uniform green carpet of identical soil. Tectonic shifts, river-system reorganization, and erosion created a mosaic of distinct soil compositions across Amazonian basins. Because terrestrial ferns are tightly sensitive to soil chemistry and drainage, adapting to distinct soil types fostered ecological speciation even within lowland rainforests. Third, episodes of coastal drying and habitat fragmentation isolated peripheral populations, accelerating genetic divergence.

Rethinking Tropical Conservation in Dynamic Landscapes

Recognizing that tropical biodiversity depends on both ancient lowland reservoirs and geologically driven speciation zones reframes conservation priorities across the Neotropics. Protecting intact Amazonian core forests safeguards the deep evolutionary lineages that serve as the source pool for future diversification, while conserving heterogeneous Andean foothills, transitional soil mosaics, and peripheral coastal corridors preserves the active ecological frontiers where young species continue to emerge and adapt.

References & Primary Sources

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