

SOIL CARBON IN THE COLOMBIAN ANDES

Andean soil carbon: the deep pool, still uncredited

High-Andean forests store six times more soil carbon than lowland forests, in a durable pool that carbon markets do not see.

Photo: Ted Feldpausch

Across the Colombian Andes, soil carbon stocks rise six-fold from lowland to high-elevation forests. A fire-derived (pyrogenic) fraction, nine times the Amazon-wide average, makes this pool exceptionally persistent, even where land has been cleared and farmed. Yet no carbon-credit standard currently rewards its protection.

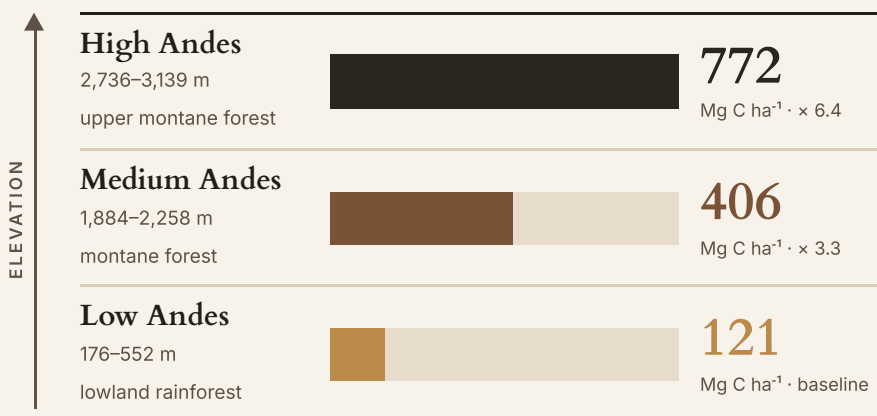
The evidence comes from 36 plots in five nature reserves, from 176 m to 3,139 m above sea level, with soils sampled to 1 m depth. Plots spanned old-growth forest to farmland with trees (agro-silvopasture).

KEY MESSAGES

- Soil carbon rises **six-fold** from lowland to high-Andean forest.
- Andean soils hold **nine times** the Amazon-wide average of pyrogenic carbon.
- This carbon **survives land-use change**, from old-growth forest to farmland with trees.
- Local clay and rainfall data predict it, so **baselines are cheap to set**.
- Carbon standards treat soil as optional, so **most of the climate benefit goes unmeasured**.

01 · THE ELEVATION GRADIENT: SOIL CARBON TO 1 M DEPTH

The higher the forest, the more carbon its soil holds



≈ 1,000 flights

One hectare of high-Andean forest soil holds about **2,830 tonnes of CO₂**, roughly 1,000 return flights between Bogotá and London, and about five times the aboveground carbon of an average intact Amazonian forest.

Mean soil organic carbon to 1 m depth (soil only; carbon in trees is not included). In montane forests the soil, not the trees, holds most of the carbon, and High-Andean soils hold ten times the pyrogenic carbon of the Low Andes.

02 · THE DISTURBANCE GRADIENT

Fire-derived carbon survives land-use change

34 Mg C ha⁻¹

average pyrogenic carbon in Andean soils, nine times the Amazon-wide average

~8%

of total soil carbon is pyrogenic, against 2–5% in lowland tropical soils

3% → 13%

pyrogenic share from the surface to 30–50 cm, where it is best protected

p = 0.77

no change in pyrogenic share from old-growth forest to farmland with trees

Old-growth,
selectively logged
Low disturbanceFarmed until
10–15 years ago
Medium disturbanceCleared 16–20 years ago
High disturbanceActive agro-silvopasture
Very high disturbance ·
farming with trees

The pyrogenic share did not differ across the four classes (Kruskal–Wallis $\chi^2 = 1.12$, $p = 0.77$): it reflects past fires, not recent land use, giving soil carbon the durable core that permanence claims require. Total soil carbon, by contrast, falls when lowland Amazon forest is farmed (Naval et al. 2025).

03 · FROM MEASUREMENT TO MAPS

Clay content and annual rainfall, together with soil pH, calcium and satellite greenness (NDVI), explained **56% of the variation** in pyrogenic carbon across the region. One field campaign plus free satellite data can deliver credible, locally calibrated baselines at project scale.

Global soil maps miss this variation; local calibration corrects them conservatively, as carbon standards require.

The policy gap. Under Verra's VCS and similar programmes, soil carbon is an optional pool that projects routinely leave out. In Andean projects, where most carbon sits below ground, this leaves most of the climate benefit unmeasured, unpriced and unprotected.

KEY TERMS

Mg C ha⁻¹. Megagrams of carbon per hectare; one megagram is one tonne.

Pyrogenic carbon (PyC).

Charcoal-like carbon left by incomplete burning. It resists decay for centuries to millennia.

Verra and the VCS. The most widely used voluntary carbon-credit programme.

04 · RECOMMENDATIONS: BRING ANDEAN SOIL CARBON INTO CONSERVATION FINANCE

1

PROJECT DEVELOPERS

Measure soil carbon to 1 m, not just the top 30 cm

Use locally calibrated baselines: the deepest carbon is the largest, most persistent share.

2

CARBON STANDARD BODIES

Recognise pyrogenic carbon as evidence of permanence

Measure carbon fractions, not just bulk totals, when crediting soil carbon.

3

GOVERNMENTS AND CONSERVATION FUNDERS

Prioritise high-elevation Andean forests

They hold the largest soil carbon stocks, under pressure from burning, grazing and farming.

Reference. Montes-Pulido, C.R., Bird, M.I., da Silva Carvalho, L.C., Serrano, J., Quesada, C.A. & Feldpausch, T.R. (2025) Climatic and edaphic drivers of soil organic carbon and pyrogenic carbon stocks across elevation and disturbance gradients in Colombian Andean forests. *Global Change Biology* 31: e70135. doi.org/10.1111/gcb.70135

Notes on the numbers. CO₂ = carbon × 44/12; ~2.8 t CO₂ per passenger for a return Bogotá–London flight. Amazonian aboveground carbon (~150 Mg C ha⁻¹) from Malhi et al. (2006) *Global Change Biology* 12: 1107–1138. doi.org/10.1111/j.1365-2486.2006.01120.x

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