

FIRE, FARMING AND SOIL CARBON · MATO GROSSO, BRAZIL

# Amazon soil carbon: the missing credit

*Burned Amazonian forests still hold large soil carbon stocks, yet no carbon-credit programme recognises them.*

Photo: Ted Feldpausch

Forest fires and conversion to agriculture are depleting soil carbon across Amazonia. New experimental evidence from Mato Grosso in southern Amazonia shows that even repeatedly burned forests retain substantially more soil carbon than land converted to agriculture. Yet this carbon pool has no financial protection under existing standards such as Verra's Verified Carbon Standard (VCS).

The evidence comes from a long-term fire experiment. Forest plots were burned every year or every three years from 2004 to 2010, and their soils were sampled in 2019, nine years after the last fire. They were compared with intact forest kept as a legal reserve and with soybean fields farmed on former forest land, measuring carbon in the top 30 cm of soil.

## KEY MESSAGES

- Repeatedly burned forests still hold about **36% more soil carbon** than farmland.
- Fire damage to the soil **lasted at least nine years** after the last burn.
- Converting forest to farmland destroys carbon equal to about **1.2 times** the forest's aboveground stock.
- No carbon-credit standard rewards protecting **burned but carbon-rich forest**.

## AT A GLANCE · SOIL CARBON LOST AS FOREST BECOMES FARMLAND



Photo: Ted Feldpausch

### Intact forest

Undisturbed legal reserve

**50.5** Mg C ha<sup>-1</sup>

Baseline



Photo: Paulo Brando

### Burned forest

Burned repeatedly, 2004–2010

**~42** Mg C ha<sup>-1</sup>

–16% to –19%

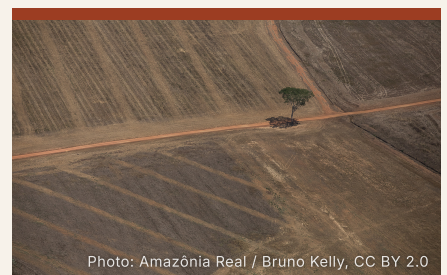


Photo: Amazônia Real / Bruno Kelly, CC BY 2.0

### Cropland

Soybean rotation, no-till since 2008

**31.4** Mg C ha<sup>-1</sup>

–38%

Soil carbon in the top 30 cm, in megagrams (tonnes) of carbon per hectare. Burned forest still holds about 36% more soil carbon than cropland.

## 01 · SOIL CARBON STOCKS, 0–30 CM

## Agriculture removes twice as much soil carbon as repeated fire

**-16 to -19%**

soil carbon in burned forest, compared with intact forest

**-38%**

soil carbon in cropland, compared with intact forest

**+36%**

more soil carbon in burned forest than in cropland

**9+ years**

that fire damage to the soil persisted after the last burn

| LAND USE                                                             | SOIL CARBON STOCK, RELATIVE TO INTACT FOREST                                       | CHANGE                                        |
|----------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------|
| <b>Intact forest</b><br>Undisturbed legal reserve                    |   | <b>Baseline</b><br>50.5 Mg C ha <sup>-1</sup> |
| <b>Burned every year</b><br>Forest, 2004–2010                        |   | <b>-16%</b><br>-8.0 Mg C ha <sup>-1</sup>     |
| <b>Burned every three years</b><br>Forest, 2004, 2007, 2010          |   | <b>-19%</b><br>-9.7 Mg C ha <sup>-1</sup>     |
| <b>Long-term agriculture</b><br>Soybean rotation, no-till since 2008 |  | <b>-38%</b><br>-19.1 Mg C ha <sup>-1</sup>    |

Carbon stocks corrected by the equivalent soil mass method, with intact forest as the reference. Sampling: 11 points per forest site; 6 for agriculture.

## KEY FINDINGS

- How often a forest burned made little difference to soil carbon loss (-16% for yearly fires, -19% for fires every three years; not statistically different). Over the same fires, aboveground losses rose from 40% to 60% (Brando et al. 2019).
- Soil and tree carbon respond differently to fire. Soil can record degradation that biomass monitoring alone misses, and the reverse.

## 02 · THE DEFORESTATION MULTIPLIER

## Clearing forest for farming destroys carbon equal to 1.2 times the original aboveground stock

Deforestation removes all of the aboveground carbon held in trees. It then triggers a further 38% loss of soil carbon. In total, the ecosystem loses carbon equal to about 1.2 times the original forest's aboveground pool.

| INTACT FOREST        |                                   | AFTER CLEARING AND AGRICULTURE  |                                    |
|----------------------|-----------------------------------|---------------------------------|------------------------------------|
| Aboveground carbon   | ~125                              | Aboveground carbon lost (-100%) | -125                               |
| Soil carbon, 0–30 cm | 50.5                              | Soil carbon lost (-38%)         | -19.1                              |
|                      |                                   | Soil carbon remaining           | 31.4                               |
| <b>Total</b>         | <b>175.5 Mg C ha<sup>-1</sup></b> | <b>Total lost</b>               | <b>-144.1 Mg C ha<sup>-1</sup></b> |

**≈ 190 flights**

Clearing **one hectare** of forest for agriculture releases about **528 tonnes of CO<sub>2</sub>**, the same as roughly 190 return flights between São Paulo and London. The soil carbon alone accounts for about 25 of those flights.

## 03 · THE POLICY GAP

## Burned forests protect more carbon than agriculture, but receive no credit

Repeatedly burned Amazonian forests store about 36% more soil carbon than land converted to agriculture, and this pool persists for at least nine years after the last fire. Yet no existing soil carbon credit standard rewards landowners for protecting degraded but carbon-rich forests, whether in their legal reserves (*reservas legais*) or elsewhere on private land. This includes Verra's Verified Carbon Standard and the sustainability certification schemes used by agribusiness.

The gap matters most where degradation leaves little sign above ground. In selectively logged or repeatedly burned forests, soil carbon can make the material difference to a project's carbon balance, and measured soil baselines give it a conservative, verifiable foundation. Without a financial incentive, burned forests face continued pressure to be converted to farmland.

A soil carbon credit standard built on this gradient could cover all three land uses: it would reward protection of intact forest most, but also recognise burned forest as a large intermediate stock, worth far more in carbon than farmland.

## KEY TERMS

**Mg C ha<sup>-1</sup>.** Megagrams of carbon per hectare; one megagram is one tonne.

**Verra and the VCS.** Verra is the non-profit that runs the Verified Carbon Standard (VCS), the world's most widely used voluntary carbon-credit programme.

**Legal reserves (*reservas legais*).** The share of native forest that Brazilian law requires every rural property in the Amazon to keep standing.

**IFM.** Improved forest management, a VCS category for projects that store more carbon in managed forests.

## 04 · RECOMMENDATIONS

## Develop a soil carbon credit standard for the Amazon that recognises burned forests

Amazonian soils store about 70 Pg C (billion tonnes of carbon) in the upper metre. Financial protection for burned forests under a tiered soil carbon credit scheme would slow deforestation at the agricultural frontier, limit greenhouse gas emissions, and support landowners who keep degraded but carbon-rich forest standing.

1

## CARBON STANDARD BODIES

### Create tiered soil carbon credits

Cover intact, burned and agricultural land, and bring soil carbon into the avoided-deforestation and improved forest management (IFM) accounting of Verra's VCS for the Amazon.

2

## FEDERAL AND STATE GOVERNMENTS

### Invest in fire prediction, detection and suppression

Soil carbon lost to fire was still missing nine years after the last burn. Preventing fires protects a stock that is slow to return.

3

## REGULATORS AND CERTIFICATION SCHEMES

### Halt agricultural expansion into burned legal reserves

Burned *reservas legais* still hold 36% more soil carbon than converted land. Clearing them releases it.



### ABOUT THIS BRIEF

This brief summarises new research for policymakers, carbon standard bodies and agricultural certification schemes. It is based on Naval, Feldpausch et al. (2025), a study of how repeated forest fires and agriculture change soil organic matter in southern Amazonia.

### THE STUDY

Soils were sampled in 2019 at an experimental site in Mato Grosso, Brazil. Forest plots had been burned every year (2004–2010) or every three years (2004, 2007, 2010) and were compared with intact forest in a legal reserve and with soybean fields under no-till since 2008. Carbon stocks to 30 cm depth were corrected by the equivalent soil mass method, with 11 sampling points per forest site and 6 for agriculture.

### THE AMAZON PYROCARBON PROJECT

Amazon PyroCarbon is a NERC–FAPESP project making the first pan-Amazonian measurement of what fire does to soil carbon, and of the pyrogenic carbon (charcoal) that burning leaves in forest soils.

### NOTES ON THE NUMBERS

CO<sub>2</sub> is calculated as carbon × 44/12. A return economy flight between São Paulo and London (about 18,900 km) emits about 2.8 t CO<sub>2</sub> per passenger.

### REFERENCE

Naval, M.L.M., Bieluczyk, W., Alvarez, F., ... Camargo, P.B. & Feldpausch, T.R. (2025) Impacts of repeated forest fires and agriculture on soil organic matter and health in southern Amazonia. *Catena* 254: 108924.

[doi.org/10.1016/j.catena.2025.108924](https://doi.org/10.1016/j.catena.2025.108924)

Brando, P.M. et al. (2019) Prolonged tropical forest degradation due to compounding disturbances: implications for CO<sub>2</sub> and H<sub>2</sub>O fluxes. *Global Change Biology* 25: 2855–2868.

[doi.org/10.1111/gcb.14659](https://doi.org/10.1111/gcb.14659)

### HOW TO CITE THIS BRIEF

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### PHOTO CREDITS

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