Amazon Deforestation: A Spatial Analysis of Its Impact on Carbon Sequestration and Global CO_2 Emissions

Abstract

The Amazon rainforest is one of the largest carbon sinks in the world, playing a critical role in regulating global carbon dioxide levels. However, deforestation has significantly reduced its ability to sequester carbon, contributing to rising CO_2 emissions (NOAA, 2021). We will analyze deforestation trends in the amazon over the last three decades by integrating satellite imagery, historical land cover data, and carbon flux models. Using remote sensing data from Nasa and Brazil's National Institute for Space Research (INPE), we will generate temporal GIS layers to map forest loss and quantify the impact on carbon sequestration. Through identifying key deforestation hotspots, this project aims to provide important insights into the relationship between land-use changes and atmospheric carbon levels, supporting future conservation strategies and policy recommendations.

Background

The amazon rainforest, often referred to as the 'lungs of the Earth,' plays a vital role in global climate regulation due to its vast capacity to absorb and store carbon dioxide. As one of the planet's largest terrestrial carbon sinks, it stabilizes atmospheric CO_2 levels and helps mitigate climate change (NOAA, 2021). However, widespread deforestation—driven by logging, agriculture, cattle ranching, and mining—has severely compromised this function. Over recent decades, the Amazon has faced escalating forest loss, not only reducing its biomass but also releasing stored carbon into the atmosphere (WWF, 2019). The increasing frequency and intensity of forest fires, many caused by human activity, further exacerbate this degradation (Alencar, 2015). Understanding how these land-use changes affect carbon sequestration is essential for developing data-driven conservation policies and climate strategies.

Objectives

This project aims to:

1. Analyze spatial and temporal deforestation trends in the Amazon between 2003 and 2023.
2. Quantify the impact of forest loss on carbon sequestration capacity.
3. Identify deforestation hotspots and areas most affected by anthropogenic forest fires.
4. Provide data-informed insights to support conservation planning and carbon mitigation efforts.

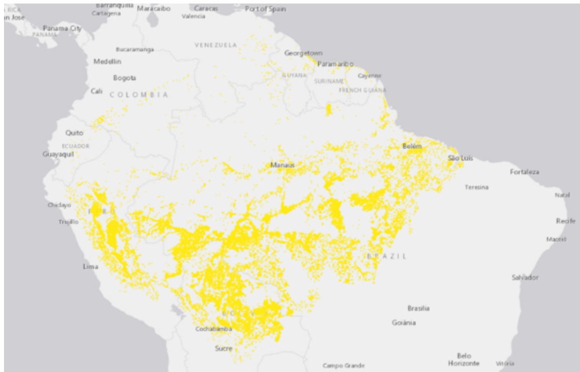

Figure 1 | Map of Forest Fires since 2019 in the Amazon

Methods

Data collection

- Raster datasets showing Amazon land cover for the years 2003, 2013, and 2023 were extracted from Google Earth Engine.
- Additional spatial data includes:
  - An ArcGIS layer mapping human-induced forest fires since 2019 (Figure 1).

Remote Sensing and GIS Analysis

- Temporal land cover data were processed to generate change detection layers showing forest loss and degradation over the 20-year span.
- Deforestation hotspots were identified using spatial analysis tools (e.g., NDVI trends, forest cover classification).
- Forest fire data were overlaid with land cover maps to assess fire-driven deforestation impacts.
- Carbon flux models were used to correlate forest loss areas with carbon loss data.

Visualization

- Temporal GIS layers were created to map forest loss and carbon flux trends over time.
- Symbology was applied to differentiate zones of high carbon loss from areas of gain or stability.

Results

Between 2003 and 2023, the Amazon experienced significant deforestation, particularly in the southeastern and central regions of Brazil. Land cover analysis shows a marked decline in dense forest areas, with notable forest fragmentation and conversion to pasture or cropland. Areas with the greatest forest loss correspond with zones of high carbon loss, supporting direct relationship between deforestation and diminished carbon sequestration. Human-induced forest fires, especially after 2019, align closely with areas of forest degradation, suggesting fire as a major driver of carbon release. The temporal maps illustrate how deforestation has accelerated in the past decade, reducing the Amazon's ability to function as a carbon sink. Using ArcGIS, it was calculated that forest cover decreased from 6048829834 units of forest in 2003 to 5705181912 units of forest in 2023 (Figure 2). This means that there was a loss of 5.86% of forest cover in that 20 year period.

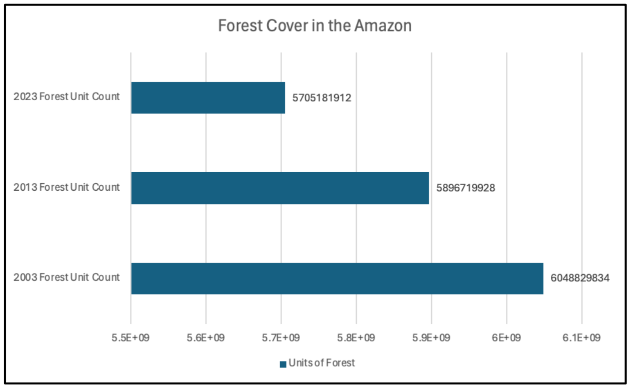

Figure 2 | Bar graph of forest cover in the Amazon by units of forest (pixels)

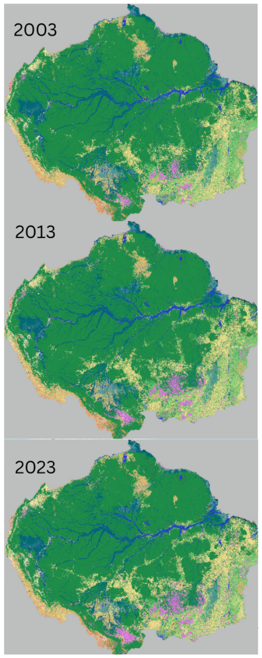

Figure 3 | Forest Cover in the amazon (forest cover in green)

Discussion

The findings confirm that deforestation in the Amazon has substantially weakened its carbon sequestration potential. Between 2003 and 2023, the region lost approximately 5.68% of its forest cover, a reduction clearly visible in remote sensing imagery (Figures 2 & 3). This decline is closely tied to a measurable decrease in the rainforest's ability to absorb atmospheric CO_2. Spatial overlays reveal that many of the deforested areas align with regions affected by human-caused forest fires, underscoring the direct role of anthropogenic activities in accelerating carbon release (Figures 1 &3).. These forest fires, usually started to clear large land areas for agricultural or livestock activities, not only result in a large carbon release but also remove that area's ability to sequester carbon in the future (Zemp, 2017). These patterns highlight the urgent need for policies that both protect the remaining forest and prioritize the restoration of degraded areas. The environmental consequences of continued deforestation extend beyond local biodiversity loss, contributing significantly to global climate instability. Effective mitigation will require a combination of stricter land-use enforcement, large-scale reforestation programs, and sustainable development alternatives that support the livelihoods of forest-dependent communities.