Degradation of Amazon Rainforests

Spatial Informatics Course Project

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Monsoon'24

Introduction

The Amazon rainforest, stretching across nine South American countries and primarily located in Brazil, spans approximately 5.5 million square kilometers, making it one of the largest and most biodiverse rainforests on Earth. This vast ecosystem is home to over 10% of the world's known species, from unique plant varieties to diverse wildlife. Beyond its role as a biodiversity hotspot, the Amazon is essential for global climate regulation, as it absorbs significant amounts of carbon dioxide, helping to moderate global temperatures. Additionally, it plays a critical part in the water cycle, generating substantial rainfall that influences weather patterns both within South America and internationally.

Aim

The project aims to investigate the complex factors driving deforestation in the Amazon rainforest, with a particular focus on nine Brazilian states over a 15-year period (2004-2024). By analyzing trends in deforestation rates alongside occurrences of climate phenomena—such as El Niño, La Niña, and forest fire outbreaks—the study seeks to uncover patterns and potential causes of forest loss. Additionally, it examines both the spatial distribution and temporal variation in deforestation across the Amazon. Through this approach, the project aspires to provide a deeper understanding of the environmental drivers and risks contributing to deforestation, offering insights that could inform conservation strategies and policies for the Amazon region.

Assumptions & Criteria

- **Climate Impact**: El Niño and La Niña events are assumed to have a measurable effect on deforestation in the Brazilian Amazon.
- **Policy Stability**: No major policy changes significantly influenced deforestation patterns during 2004-2019.
- **Uniform Effects:** The impact of climate phenomena (El Niño, La Niña) & forest fires is treated as uniform across the nine Brazilian states, although regional variations may exist.
- **Data Selection**: The time period (2004-2024) and geographic scope (nine states) were chosen due to data availability, covering key deforestation trends and climate events.
- **State Selection**: The nine states—Acre, Amazonas, Amapá, Maranhão, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins—were selected for their relevance to Amazonian deforestation trends.

Data Sources

Datasets Used:

1. **Deforestation Data (2004-2019):**
   - Sourced from INPE, monitored using the PRODES program.
   - Provides annual records of primary forest loss in nine Brazilian states.
   - Uses satellite imagery with 20-30m resolution and a 16-day revisit rate for high precision.

2. **Climate Data (1999-2019):**
   - Sourced from Golden Gate Weather Services.
   - Includes onset, duration, and severity of El Niño and La Niña events.
   - Helps compare climate events' timing and intensity with deforestation trends.

3. **Treecover Loss by Region(1999-present):**
   - sourced from Global Forest Watch.
   - Tracks changes in forest cover over time.

4. **VIIRS Fire Alerts Data(1999- present):**
   - sourced from Global Forest Watch.
   - contains fire alert data from the Visible Infrared Imaging Radiometer Suite (VIIRS)
   - provides a count of fire alerts, giving insight into the frequency and intensity of fire events

Data Characteristics

The datasets are provided in CSV format, suitable for time-series and spatial-temporal analysis.

Deforestation Dataset:

- Year: The year when deforestation was recorded.
- Deforested Area (km^2): The total deforested area in square kilometers across the nine states.
- State: The Brazilian state where deforestation occurred.

Climate Dataset:

- Phenomenon: Identifies whether the event was El Niño or La Niña.
- Start Year: The year when the climate event began.
- End Year: The year when the climate event ended.
- Severity: The severity level of the event (Weak, Moderate, Strong, Very Strong).

Data Characteristics

Treecover Loss by Region (treecover_loss_by_region__ha.csv):

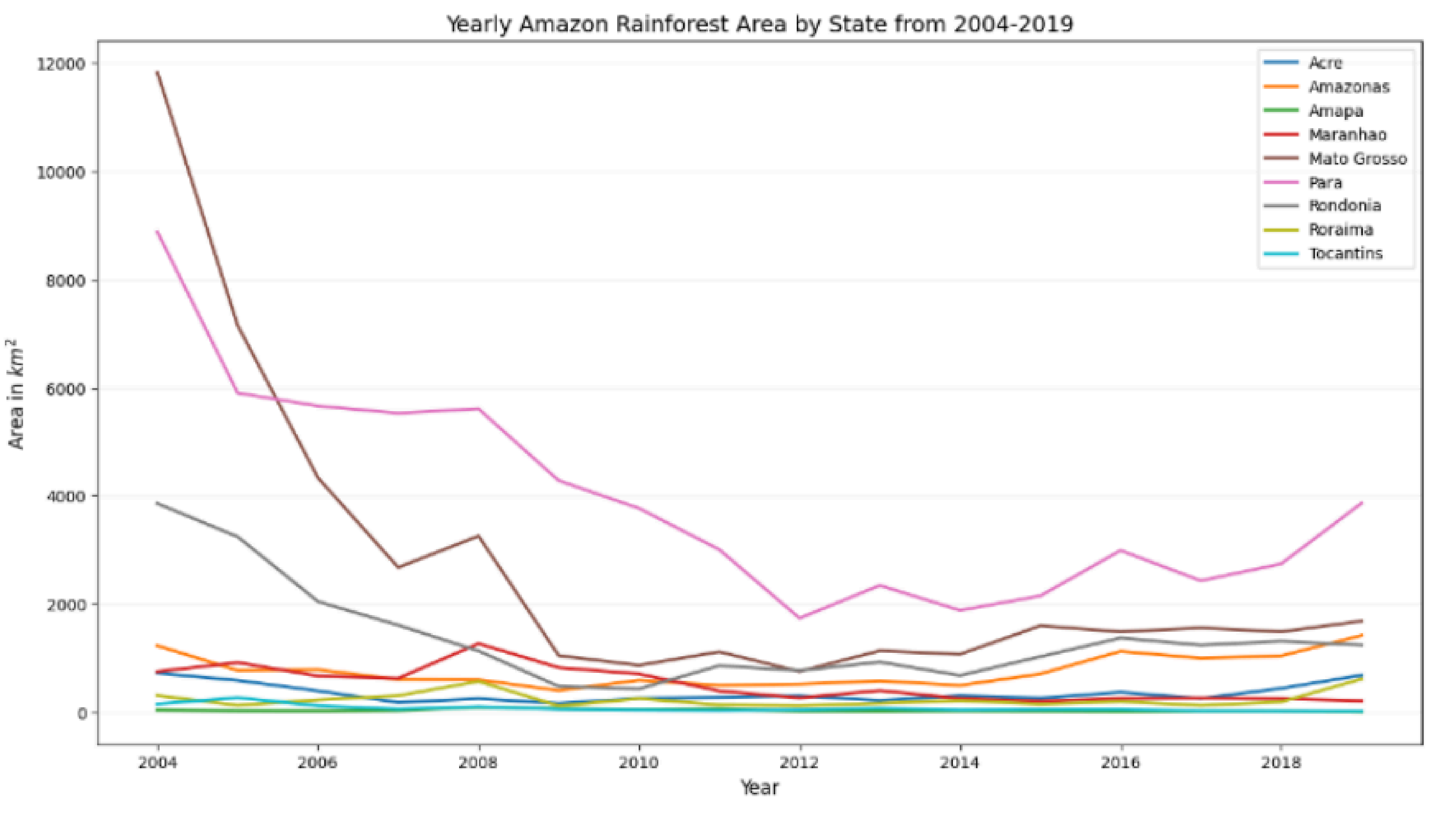
- iso: Country code (Brazil for all entries).
- adm1: An identifier assigned to each state in Brazil (numeric ID for each state).
- umd_tree_cover_loss__year: The year of tree cover loss.
- umd_tree_cover_loss__ha: The amount of tree cover loss in hectares for each year and state.
- gfw_gross_emissions_co2e_all_gases__Mg: The gross emissions of CO2 equivalent (all gases) in megagrams (Mg), associated with tree cover loss.

VIIRS Fire Alerts (viirs_fire_alerts__count.csv):

- iso: Country code (Brazil for all entries).
- alert__year: The year the fire alerts were recorded.
- adm1: An identifier assigned to each state in Brazil (numeric ID for each state).
- alert__count: The total number of fire alerts detected in that state for the given year.
- confidence__cat: The confidence category of the fire alerts (e.g., Low, Moderate, High), indicating the reliability of the fire detection.

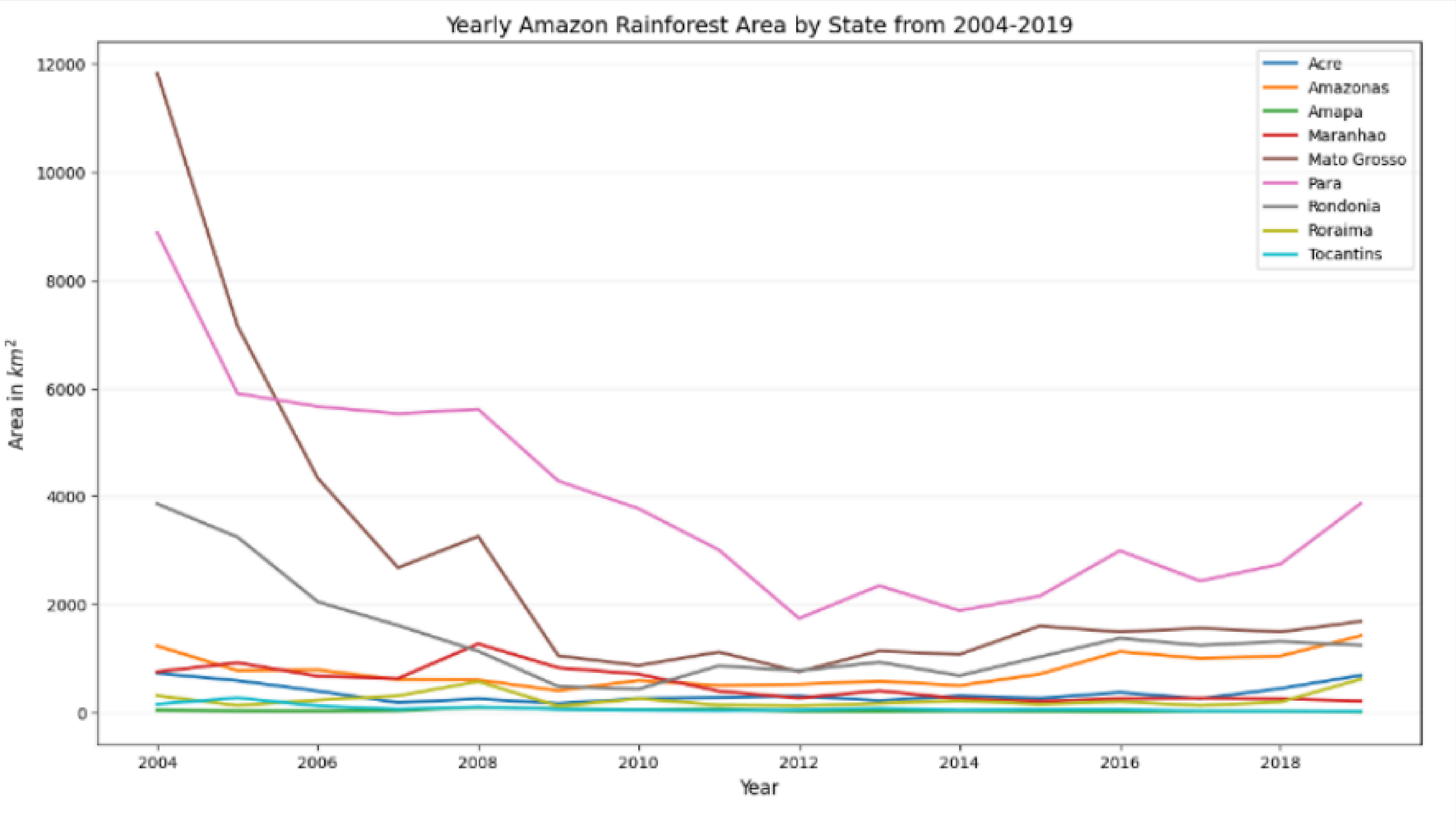
Visualisations & Analysis

- **Deforestation Trends (2004-2019):**
    - 2004 Peak: A significant surge in deforestation was observed, marking the highest point across the Amazon states.
    - Decline until 2012: After the peak, a downward trend in deforestation was noted, showing short-term improvements.
    - Post-2012 Increase: Deforestation started rising again, especially in certain states, indicating fluctuating long-term trends.



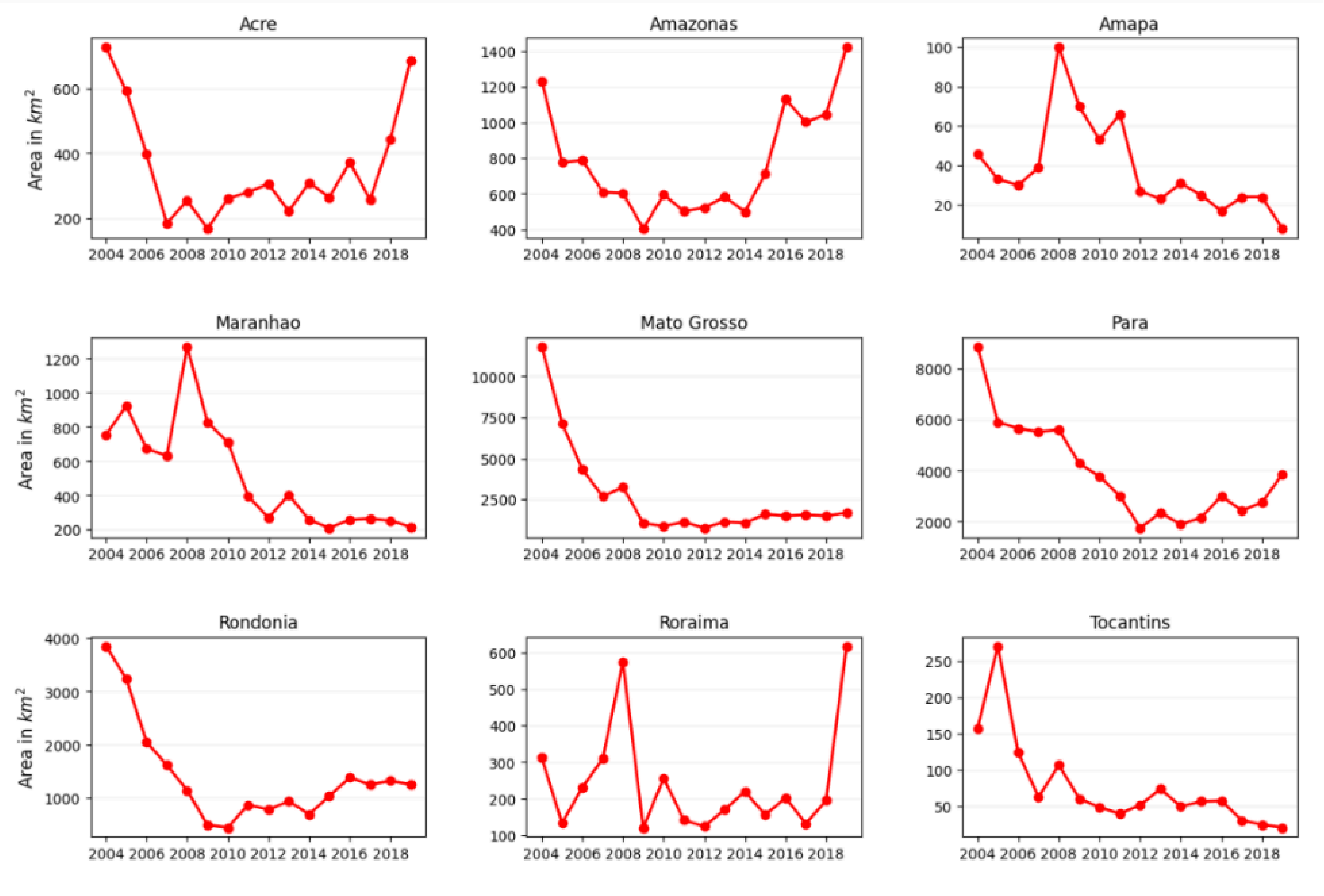
Visualisations & Analysis

- **State-wise Analysis:**
  - Mato Grosso: Experienced the most significant decline in deforestation from 2004 onwards, showing a dramatic reduction over time.
  - Pará and Rondônia: Saw substantial declines in deforestation, ranking third in total area affected.
  - Tocantins and Amapá: Showed relatively insignificant changes due to lower initial forest cover, leading to less noticeable impacts after deforestation.



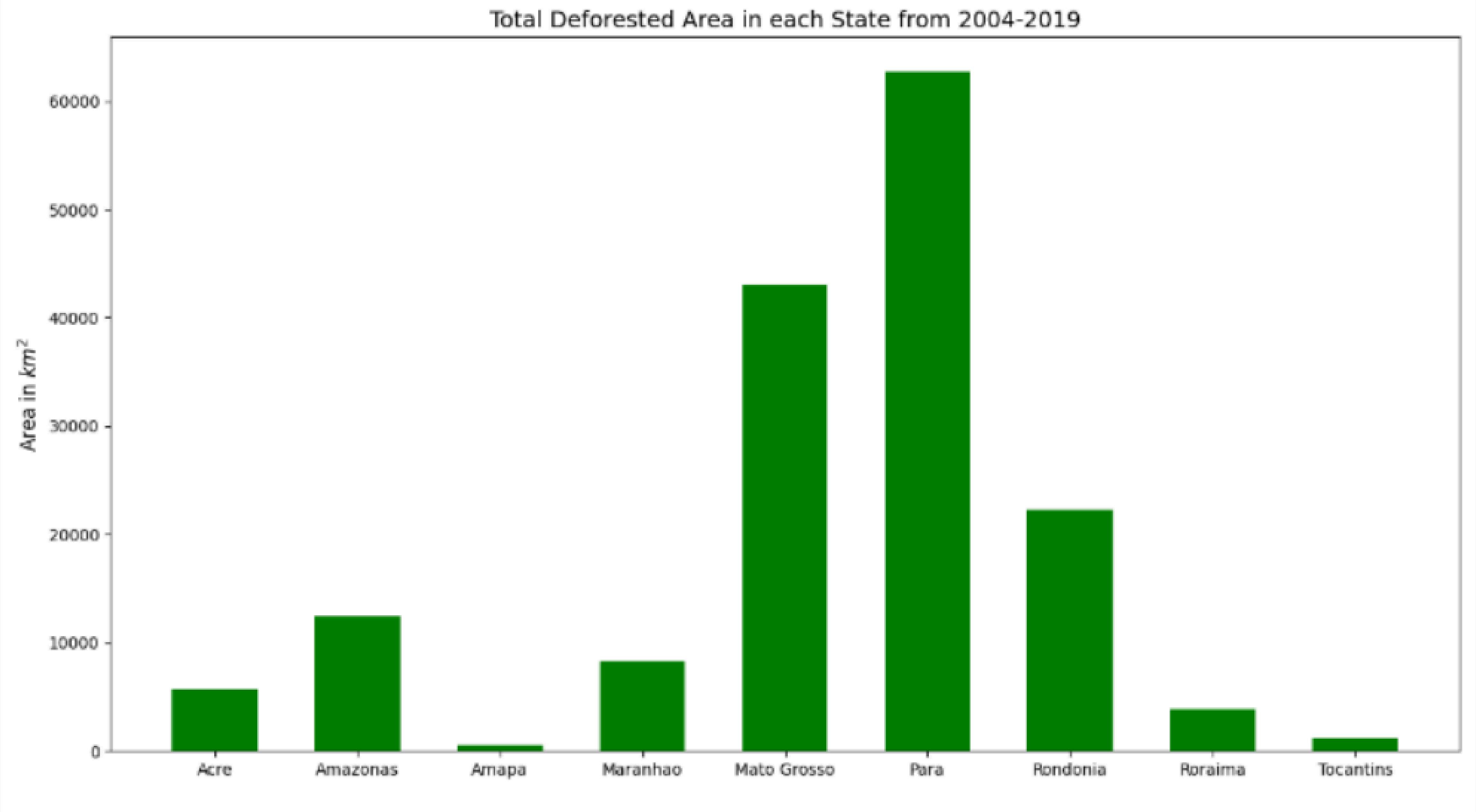
Visualisations & Analysis

- The deforested area for each state was plotted separately to visually compare deforestation trends across regions.
- From 2004 to 2012, many states showed a decline in deforestation, but **Amapá, Maranhão, and Roraima saw an increase** during this period.
- The rise in deforestation in these states suggests the influence of local factors such as land-use practices, economic pressures, or policy enforcement.
- The data highlights a **divergence in deforestation trends**, with some states not following the broader decline observed in other areas of the Amazon.



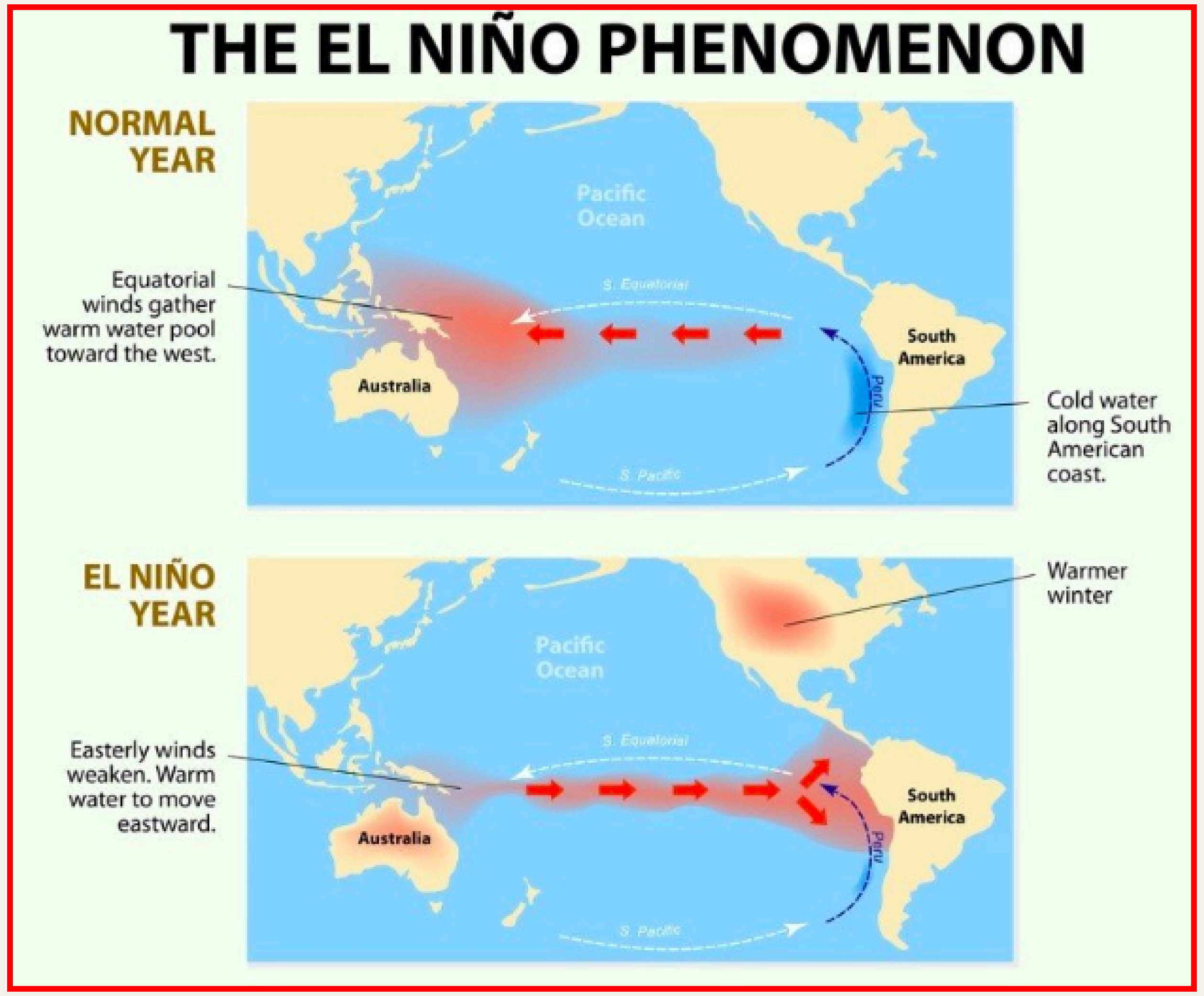
Visualisations & Analysis

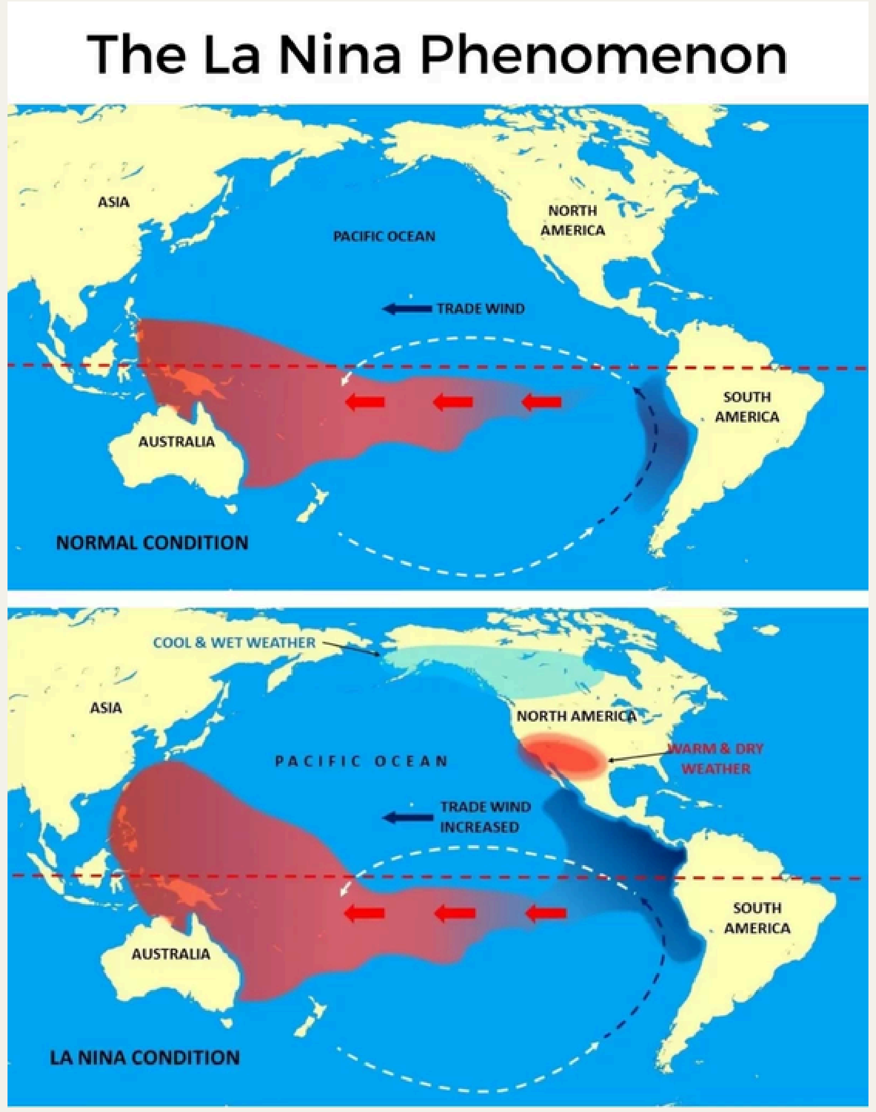
- **Pará** had the **highest total deforestation** from 2004 to 2019, indicating significant environmental pressures and forest loss.
- **Amapá** had the **least deforestation**, suggesting lower deforestation activities or stronger conservation efforts.
- The total deforested area in states like Mato Grosso and Rondônia also showed substantial forest loss, ranking high in deforestation over the years.
- Further investigation will explore the role of fires in deforestation, especially in Pará, to determine if fire events contributed to the high deforestation rates.



El Nino and La Nina

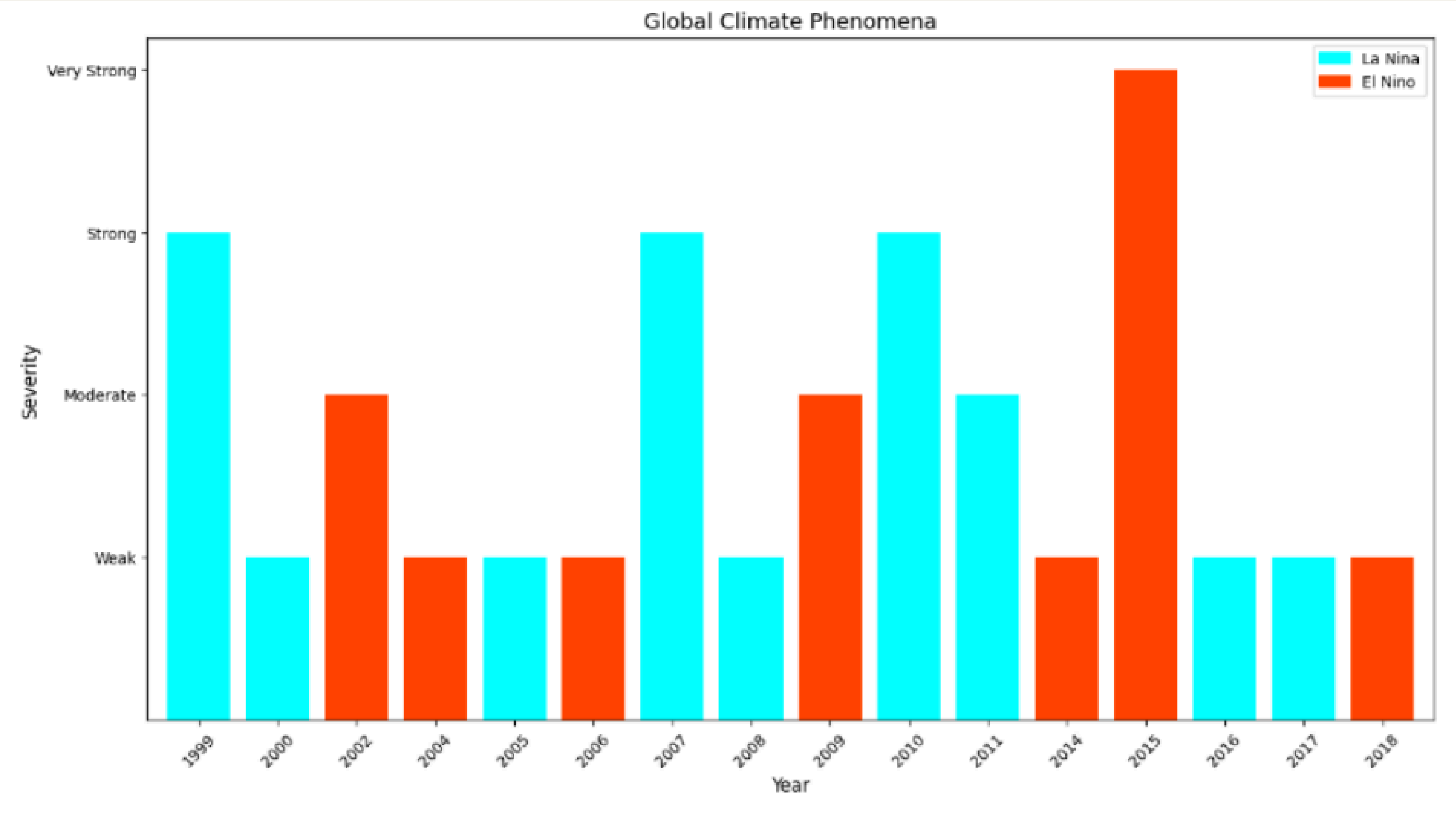
- El Niño is associated with warmer-than-average sea surface temperatures, leading to dry conditions in the Amazon, increasing the likelihood of forest fires, and worsening deforestation.
- The dry conditions during El Niño years allow both natural and human-induced fires to spread more easily, causing significant environmental damage, especially in regions with poor fire management.
- La Niña is linked to cooler-than-usual sea surface temperatures, bringing wetter conditions to the Amazon, which reduces the frequency and intensity of forest fires.
- The wetter conditions during La Niña years help preserve the rainforest by preventing fires and supporting forest health.





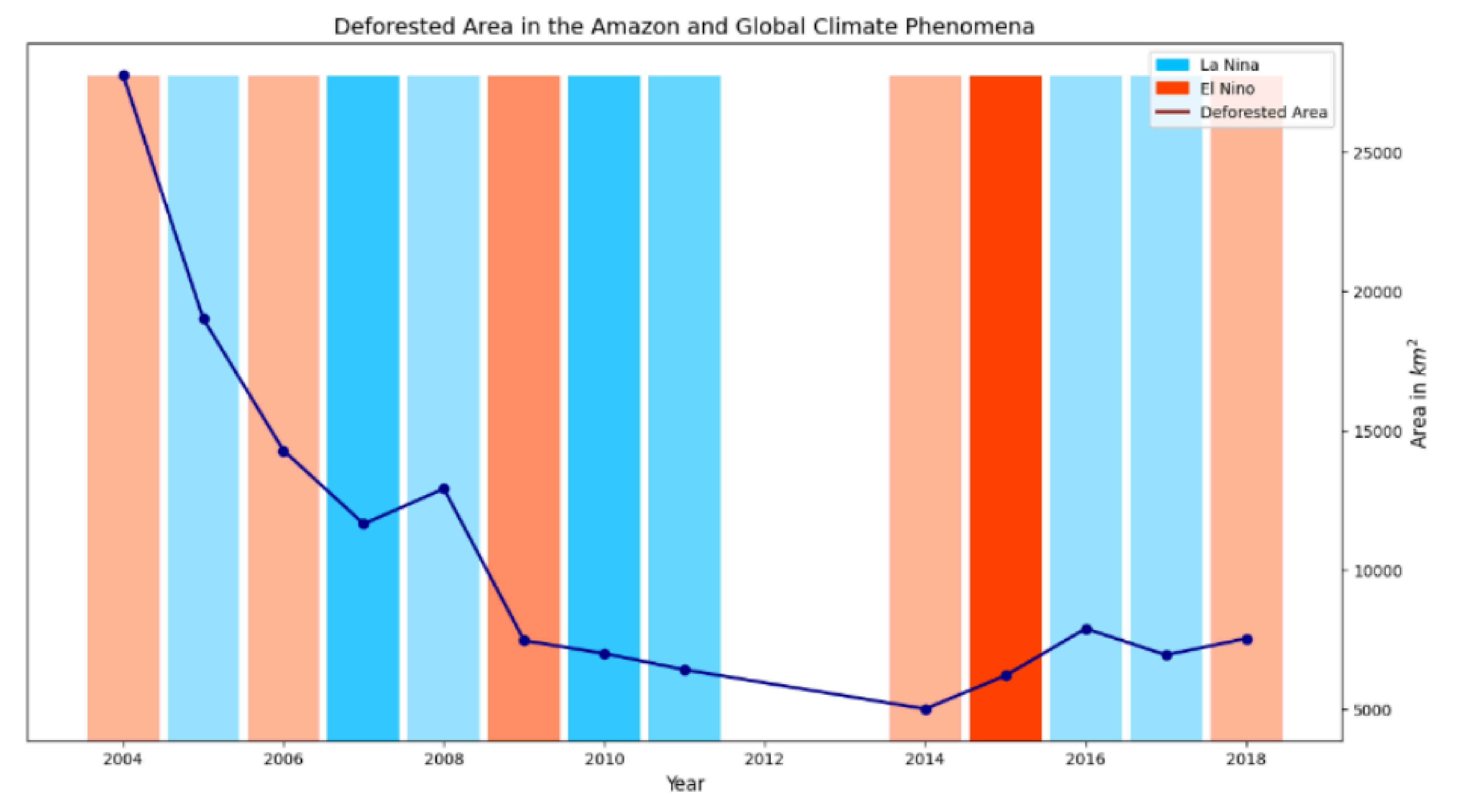
Visualisations & Analysis

- The analysis will examine the years and severity of El Niño and La Niña events to identify potential correlations with deforestation rates in the Brazilian Amazon.
- The chart displays the occurrence and intensity of these climate events, helping to understand their relationship with observed deforestation patterns over time.



Visualisations & Analysis

- When overlaying the deforestation trend with the severity of El Niño and La Niña, using bar transparency to indicate the intensity of each event, **no clear correlation was observed between the two factors.**
- Despite expectations that El Niño's dry conditions would increase deforestation due to more frequent fires and La Niña's wet conditions would reduce deforestation by limiting fire risks, the data showed no consistent pattern.



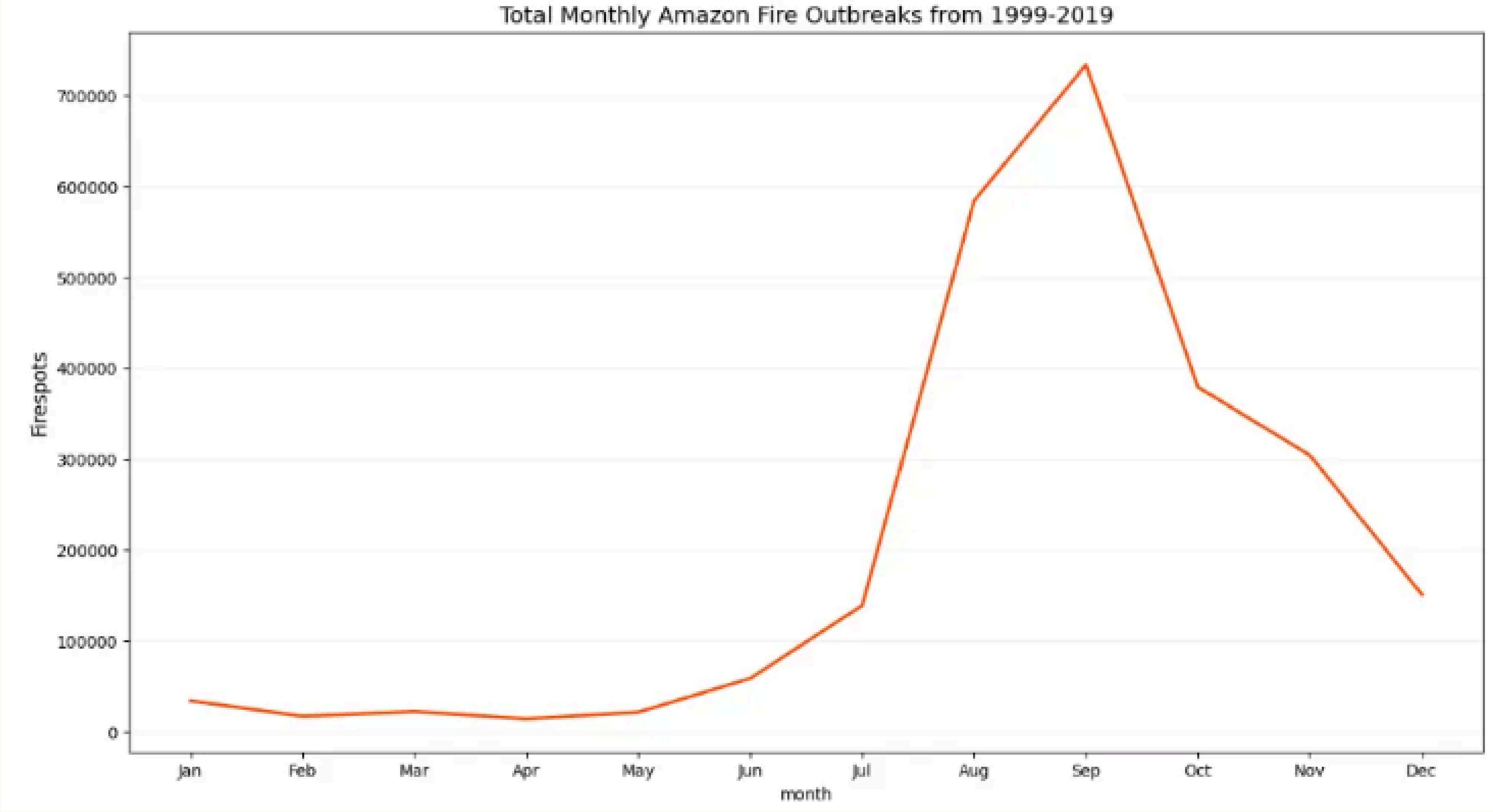
- The **lack of a strong link between climate phenomena and deforestation** suggests that other factors, such as land-use policies, illegal logging, agricultural expansion, and socio-economic influences, may play a more significant role in driving deforestation in the Amazon.

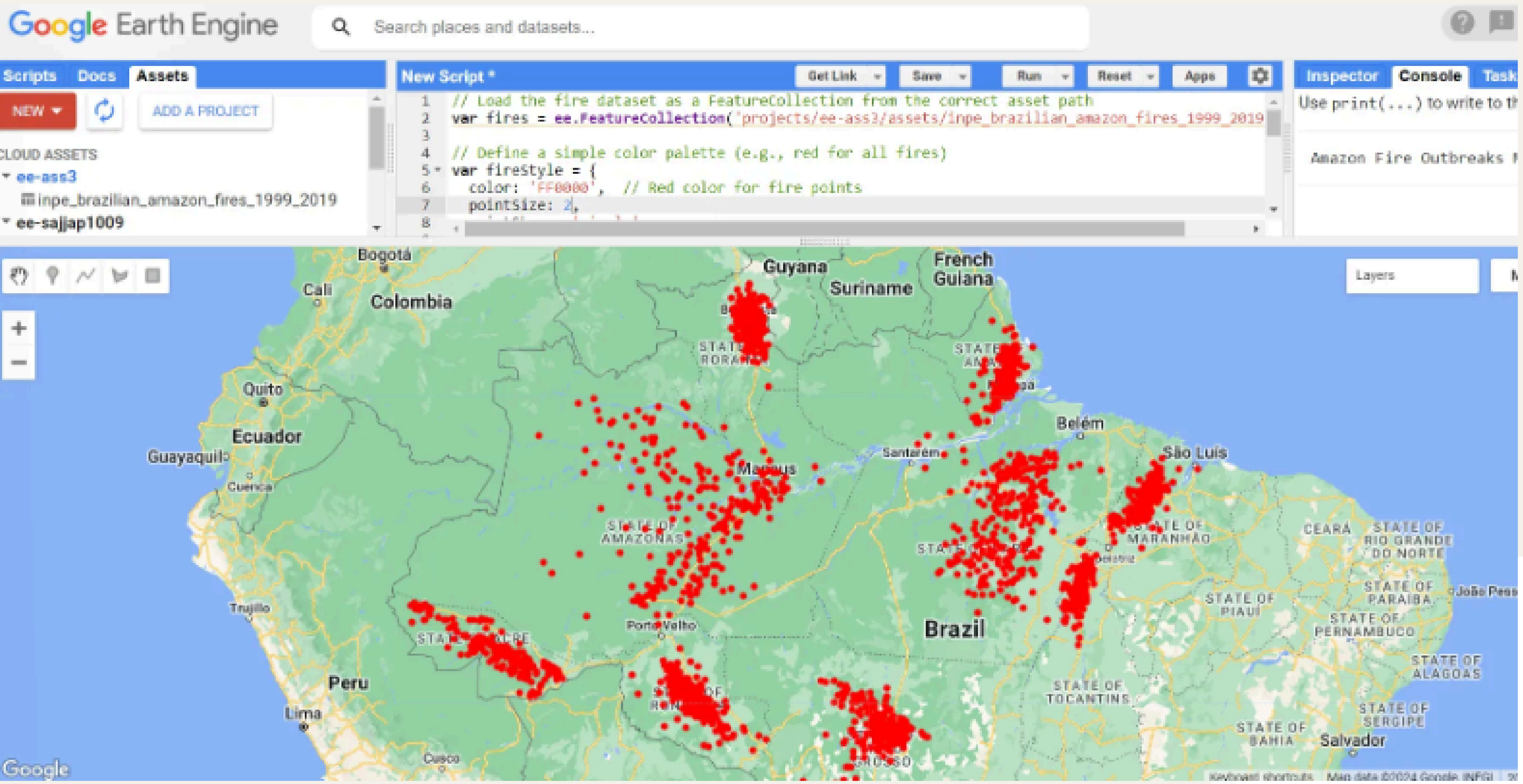
Forest Fires

Forest fires are a significant driver of degradation in the Amazon rainforest, causing widespread destruction of vegetation, loss of biodiversity, and disruption of vital ecosystem functions. These fires, often exacerbated by dry conditions, lead to the release of large amounts of carbon into the atmosphere, contributing to climate change. Additionally, they degrade the soil, hinder the forest’s ability to regenerate, and disrupt the region's water cycle, further threatening its ecological balance. As a result, the Amazon's capacity to store carbon and regulate global climate is diminished, making it increasingly vulnerable to environmental collapse.

CHOICE OF PLATFORM, SATELLITE, DURATION

- **Landsat 8** satellite imagery was used for the analysis.
- **Google Earth Engine (GEE)** was the platform for processing and visualization.
- Pre-fire analysis used images from **January to June** (wet season with minimal fire activity).
- Post-fire analysis focused on **July to November** (dry season and peak forest fire period).
- Temporal distinction between pre-fire and post-fire periods was crucial for evaluating fire effects.




Google Earth Engine
Search places and datasets...
Scripts
Docs
Assets
NEW
ADD A PROJECT
CLOUD ASSETS
ee-ass3
inpe_brazilian_amazon_fires_1999_2019
ee-sajjap1009
New Script *
Get Link
Save
Run
Reset
Apps
// Load the fire dataset as a FeatureCollection from the correct asset path
var fires = ee.FeatureCollection('projects/ee-ass3/assets/inpe_brazilian_amazon_fires_1999_2019
// Define a simple color palette (e.g., red for all fires)
var fireStyle = {
color: 'FF0000', // Red color for fire points
pointSize: 2,
Inspector
Console
Use print(...) to write to th
Amazon Fire Outbreaks
Layers
Bogotá
Cali
Colombia
Guyana
Suriname
French Guiana
Quito
Ecuador
Guayaquil
Cuenca
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Santarém
São Luís
Manaus
STATE OF AMAZONAS
Porto Velho
Brazil
CEARÁ
STATE OF RIO GRANDE DO NORTE
STATE OF PARAÍBA
STATE OF PIAUÍ
STATE OF PERNAMBUCO
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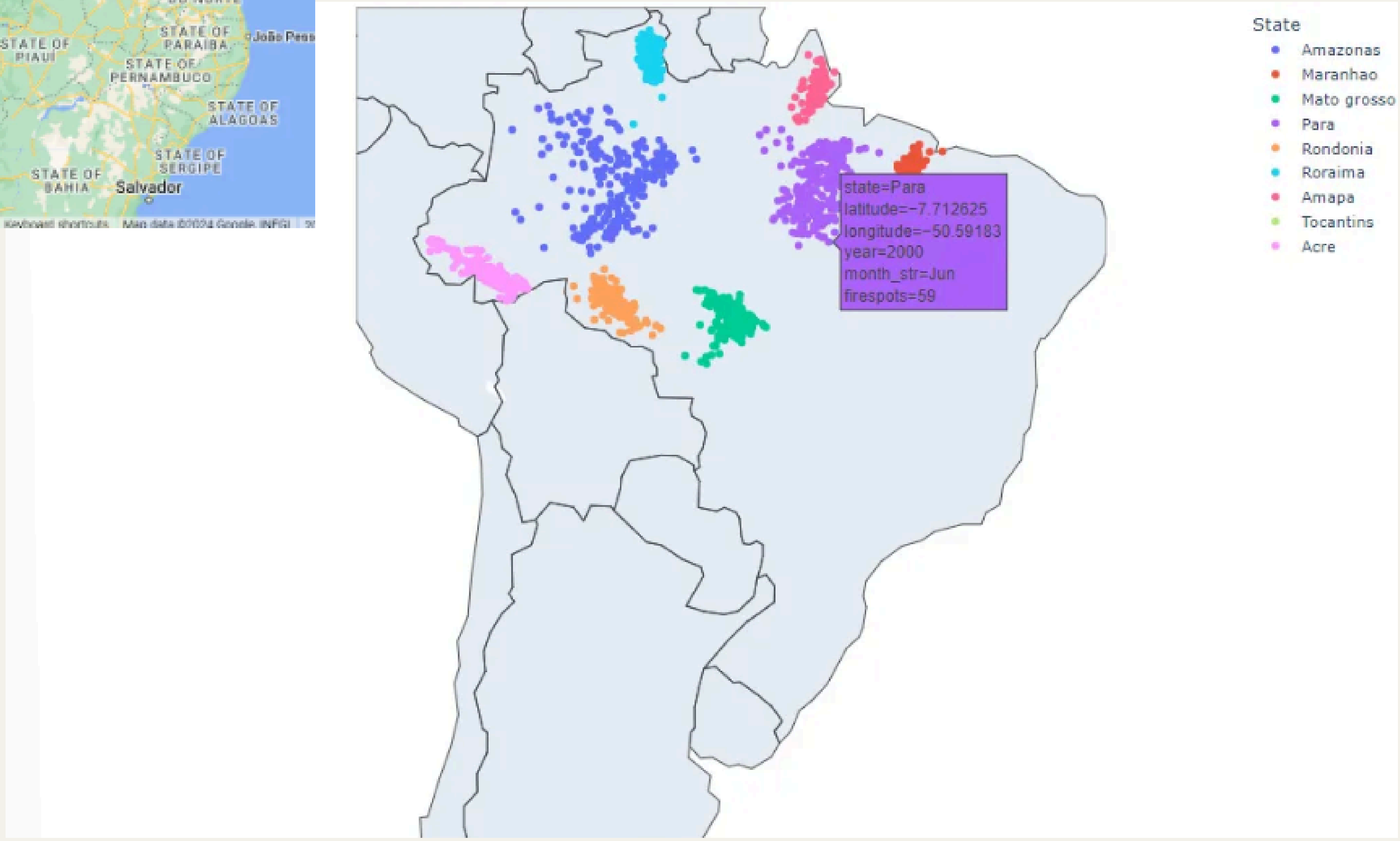
State
Amazonas
Maranhao
Mato grosso
Para
Rondonia
Roraima
Amapa
Tocantins
Acre
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longitude=-50.59183
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month_str=Jun
firespots=59

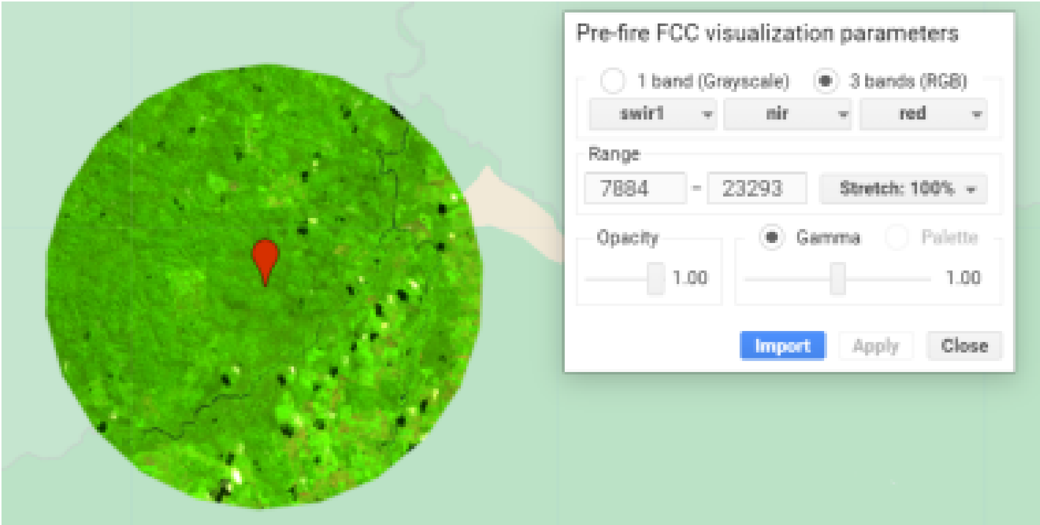
Indices Chosen for Analysis

1. **False Color Composite (FCC):** is a combination of multiple bands, often involving NIR, red, and SWIR bands, to enhance the visibility of fire-impacted areas. By comparing pre- and post-fire FCCs, changes in vegetation health, structure can be easily visualized.
2. **Normalized Difference Vegetation Index (NDVI):** is widely used to assess vegetation health by comparing the difference between NIR and red bands. It uses red and near-infrared bands to measure vegetation density and health which helps us in understanding how the fire affected vegetation cover. A significant drop in NDVI values post-fire indicates a loss of vegetation and damage to the landscape.
3. **Burn Area Index (BAI):** is used to detect fire-impacted areas based on spectral reflectance differences in the red and SWIR bands. It is particularly useful in identifying the extent of burned areas and is sensitive to both vegetation and soil changes following a fire.

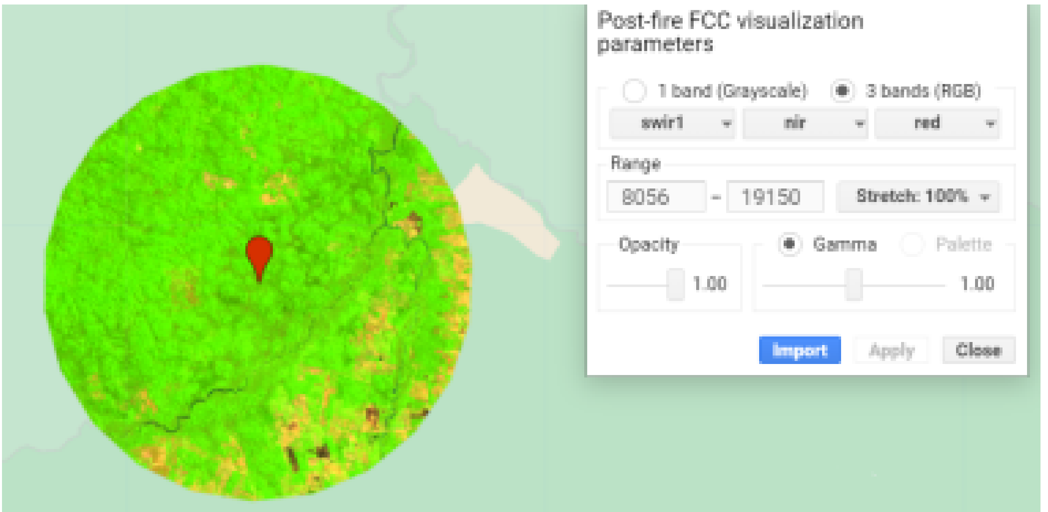
Para, Brazil

FALSE COLOUR COMPOSITE :

- In the Pre-Fire FCC, the dominant green color around the area of interest indicates healthy, intact vegetation.
- In contrast, the Post-Fire FCC shows a noticeable shift towards a yellowish tone, highlighting significant vegetation loss following the forest fire.
- Over the past 10 years, a clear decline in overall vegetation is evident in the Pre-Fire FCC (left column). Meanwhile, the Post-Fire FCC (right column) reveals an increase in vegetation loss due to forest fires, demonstrating a growing impact over time.

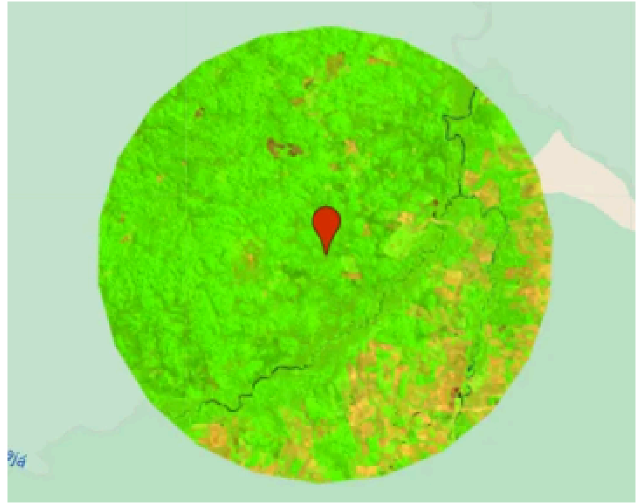


Pre Fire FCC 2014

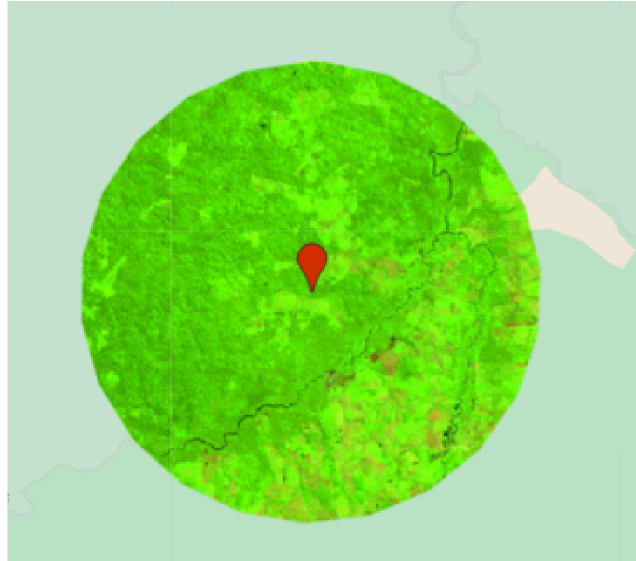


Post Fire FCC 2014

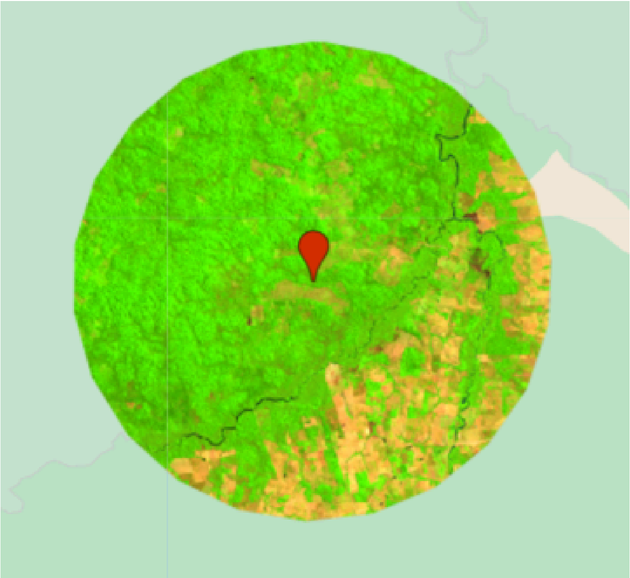
Pre fire FCC 2019



Post fire FCC 2019



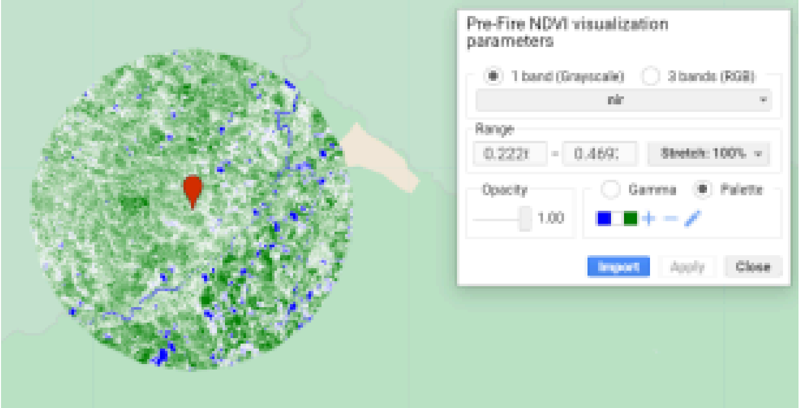
Pre Fire FCC 2024



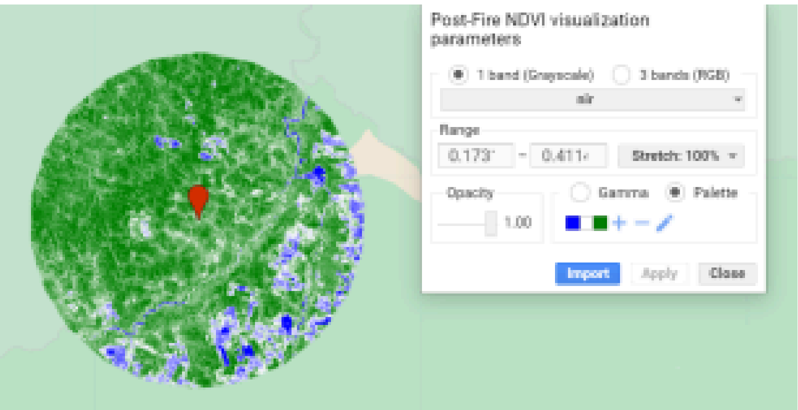
Post Fire FCC 2024

<u>Normalised Difference Vegetation Index :</u>

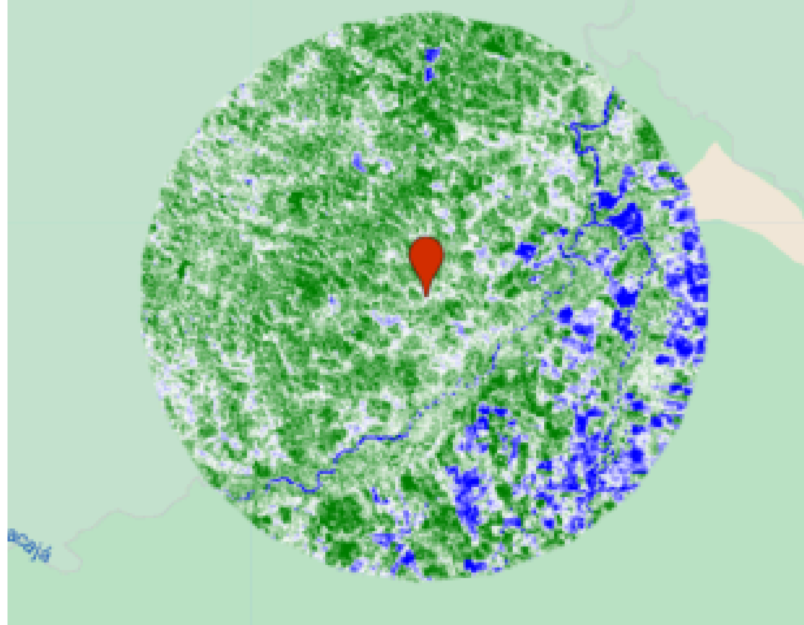
- In the figures below, the highest NDVI values are shown in Green, the lowest in Blue, and White represents moderate NDVI. The color gradient for increasing NDVI is <u>Blue < White < Green.</u>
- In the pre-fire NDVI images for all three years, <u>vegetation appears moderate.</u>
- In the post-fire NDVI images, we observe a higher intensity of Blue areas, indicating significant <u>vegetation loss due to fire.</u> Additionally, a darker shade of Green is visible compared to pre-fire images, likely due to <u>regeneration</u> from high rainfall in the Amazon.
- This supports our assumption that forest fires contribute to the degradation of rainforests in Brazil.

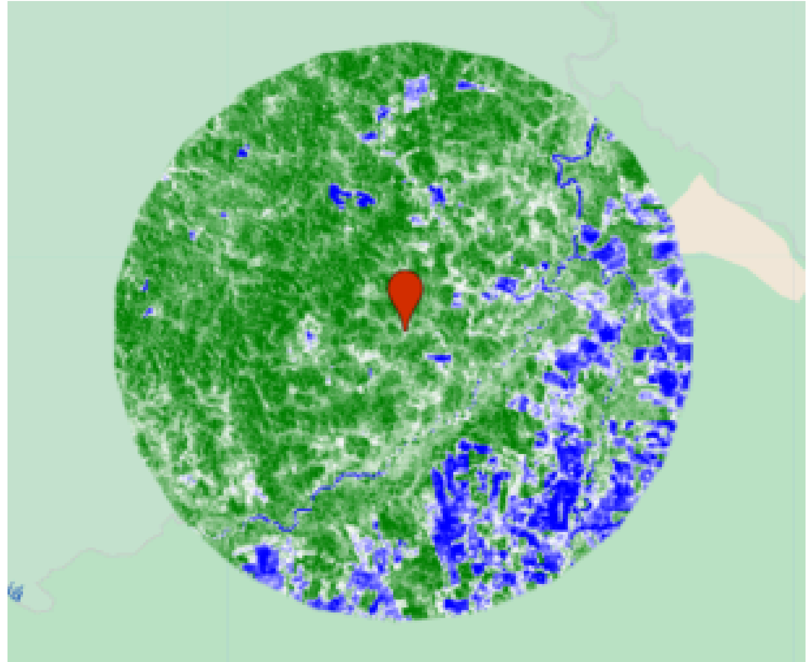


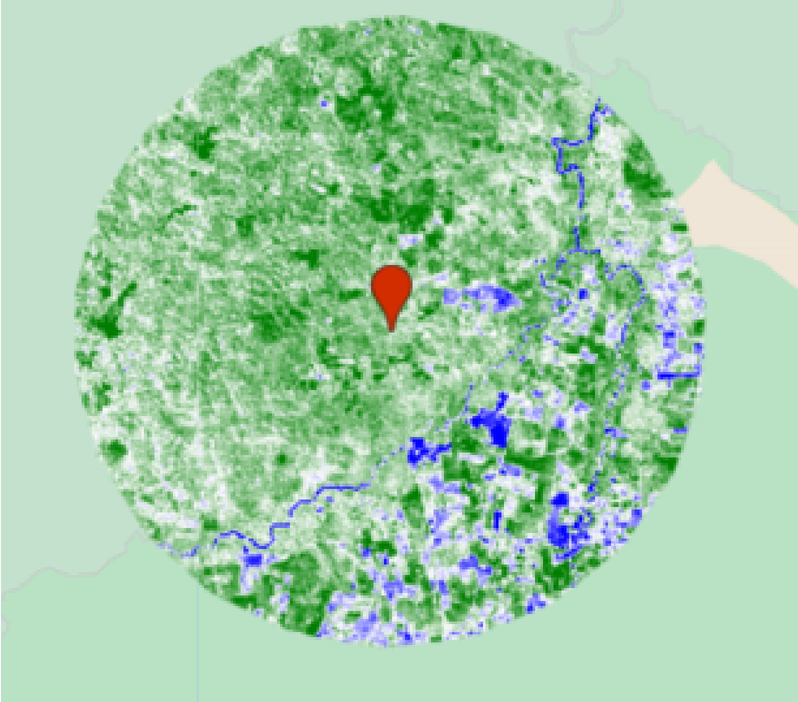
Pre fire NDVI 2014

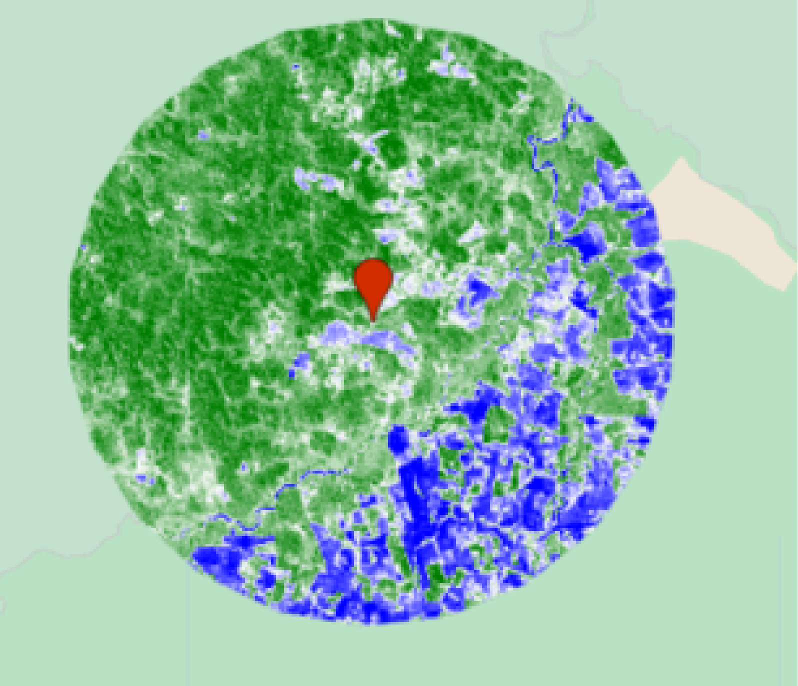


Post fire NDVI 2014


Pre fire NDVI 2019

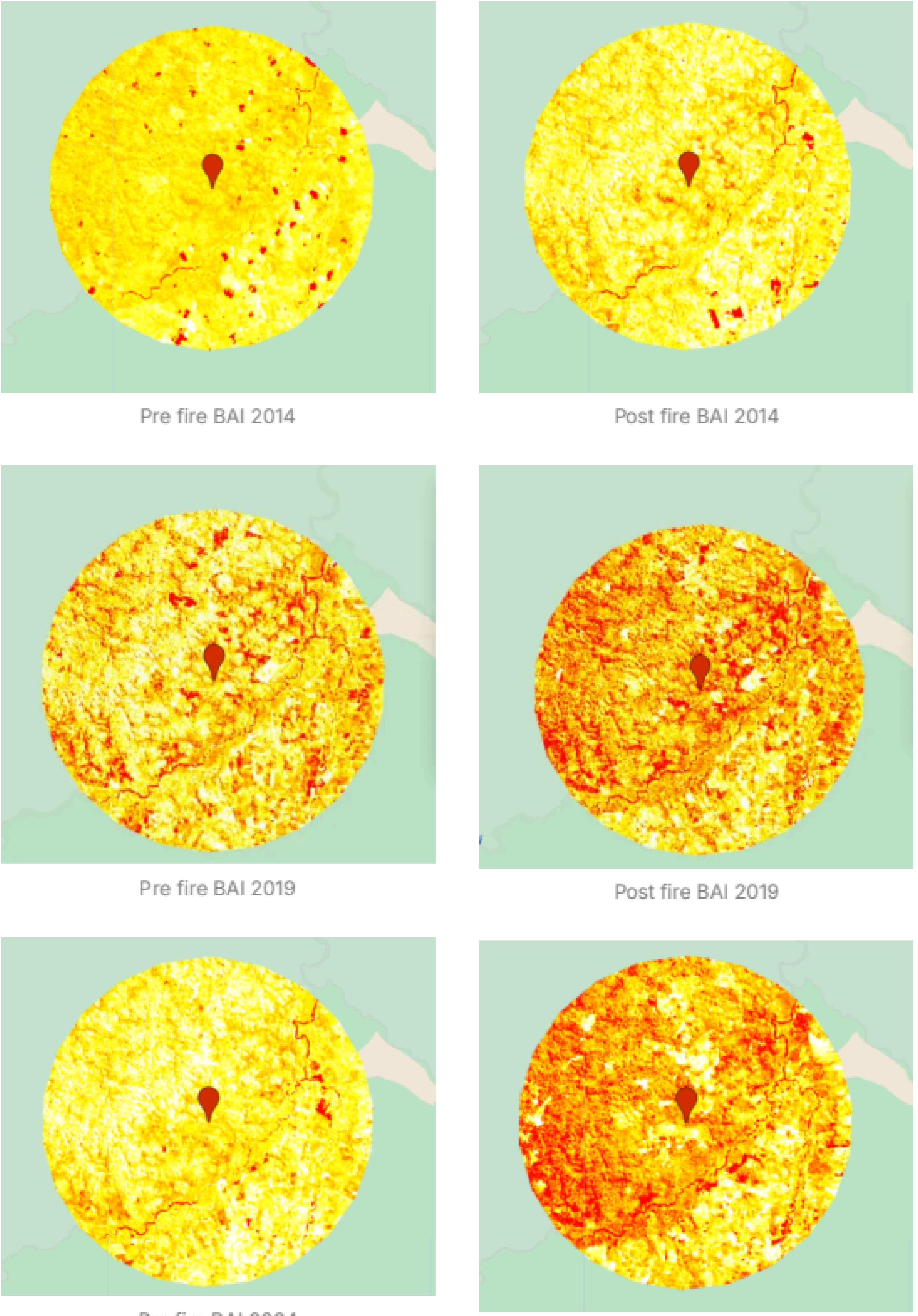

Post fire NDVI 2019


Pre fire NDVI 2024


Post fire NDVI 2024

BURNED AREA INDEX (BAI) :

- In the analysis, White, Yellow, Orange, and Red represent the increasing order of BAI values, helping detect burned areas and track early regrowth, important for high-rainfall regions like the Amazon.
- In 2014, the post-fire BAI snippet shows lighter yellow shades, indicating regrowth, likely due to the high rainfall in the Amazon.
- In 2019 and 2024, the post-fire BAI snippets show moderate to high-intensity burns (dark orange-red tones), indicating significant damage from forest fires.



Pre fire BAI 2014

Post fire BAI 2014

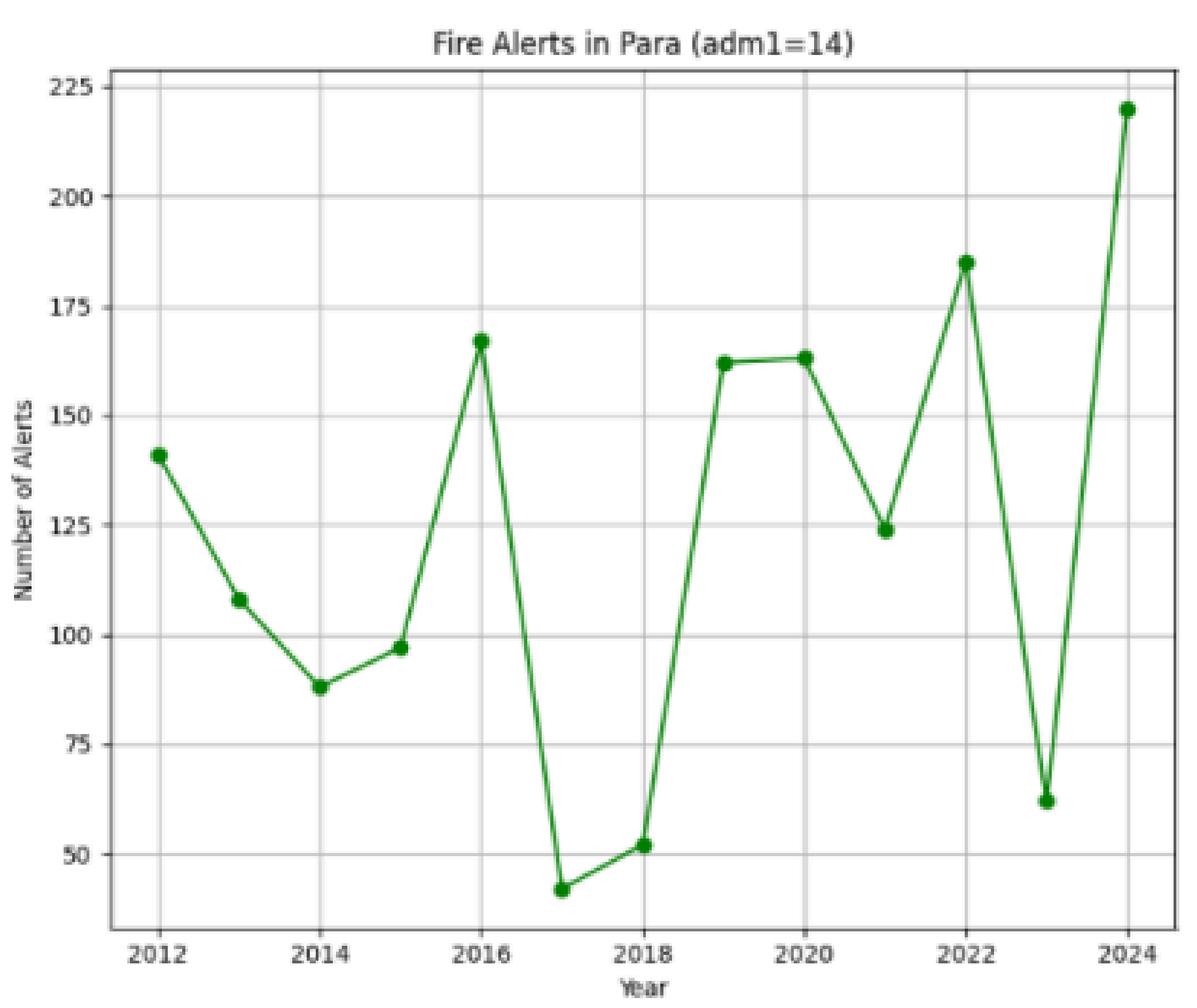
Pre fire BAI 2019

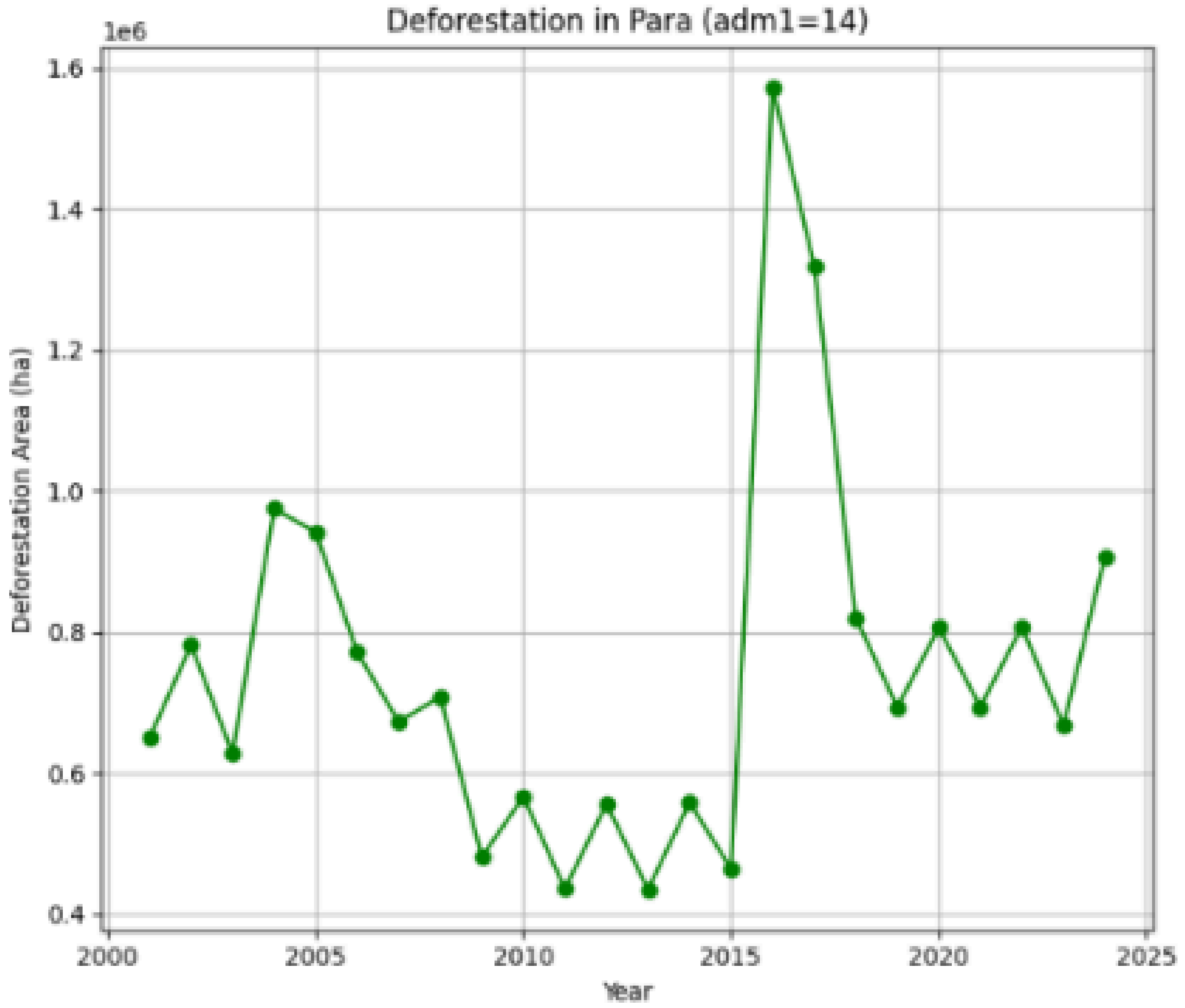
Post fire BAI 2019

Pre fire BAI 2024

Post fire BAI 2024

Validating our GEE analysis with numerical data



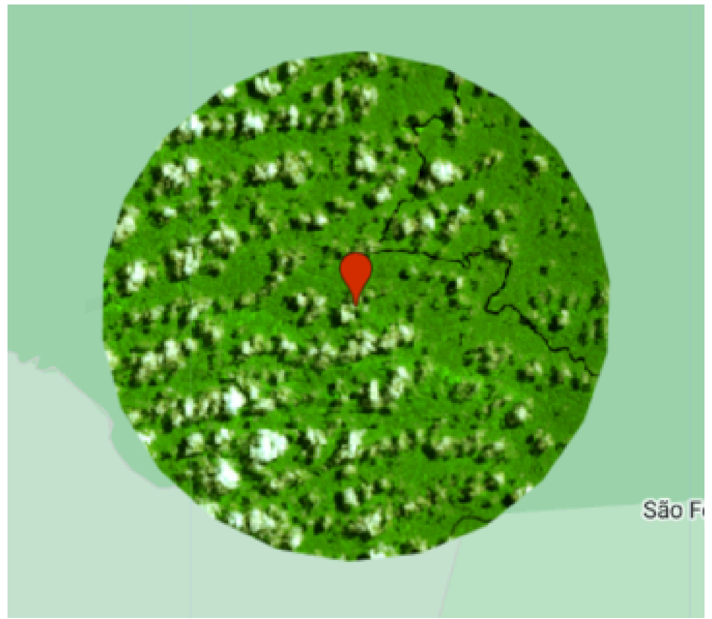


It is clearly illustrating that forest fires and deforestation in the Amazon are directly proportional. The intertwined relationship shows that as the number of fires increases, so does the extent of forest degradation, underlining the compounding threats to the Amazon rainforest ecosystem

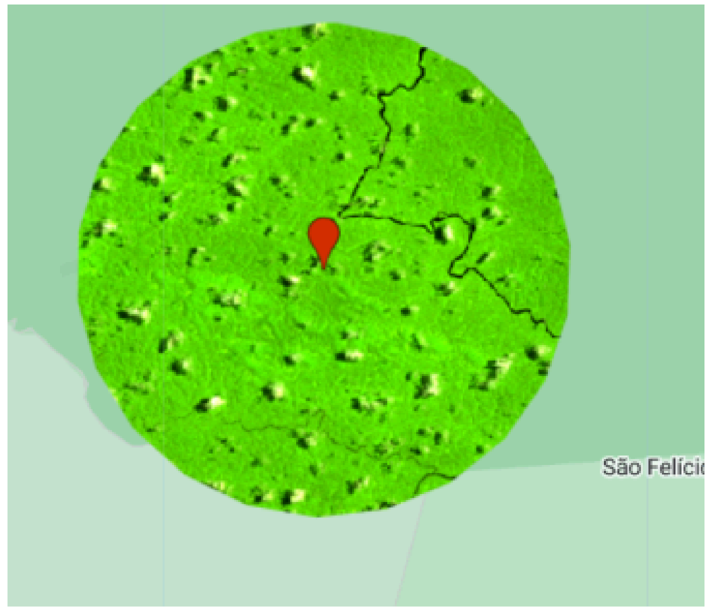
Amapa, Brazil

FALSE COLOUR COMPOSITE :

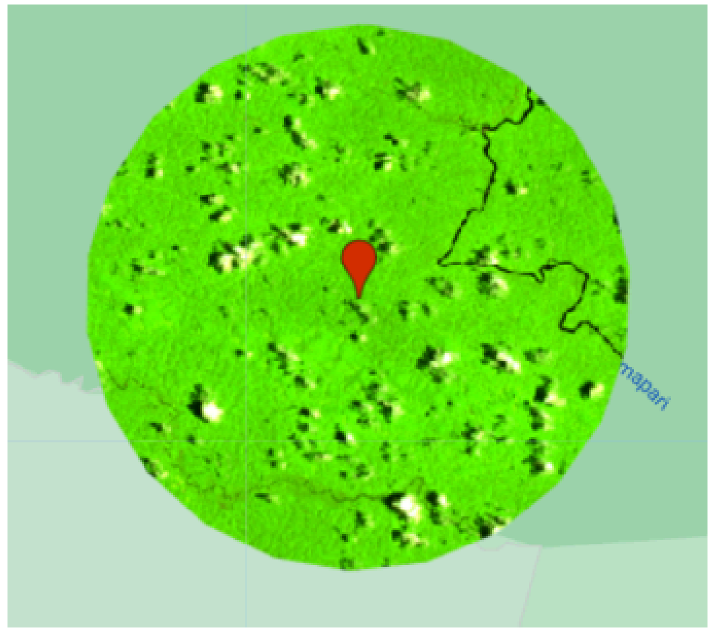
- Observing all three years, there is minimal change in the FCC, indicating that the impact on vegetation post-fire has been relatively small. This suggests that the fire may have been minor or that the vegetation experienced rapid regrowth, which will be further confirmed using the BAI.
- Another key observation is that the intensity of the green color in both pre- and post-fire images may vary due to reflectance on specific days. When the images are clouded, the shade tends to appear darker, while on sunny days, the reflectance changes and the green intensity may differ.



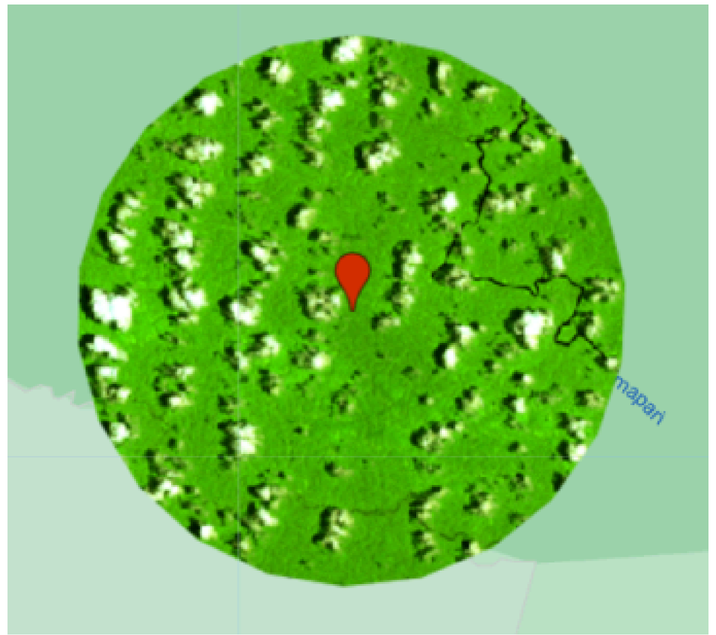
Pre fire FCC 2014



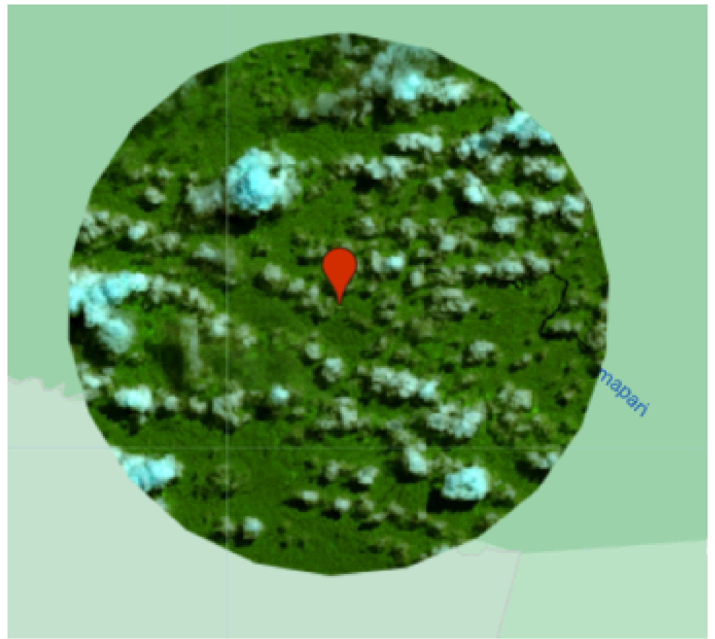
Post fire FCC 2014



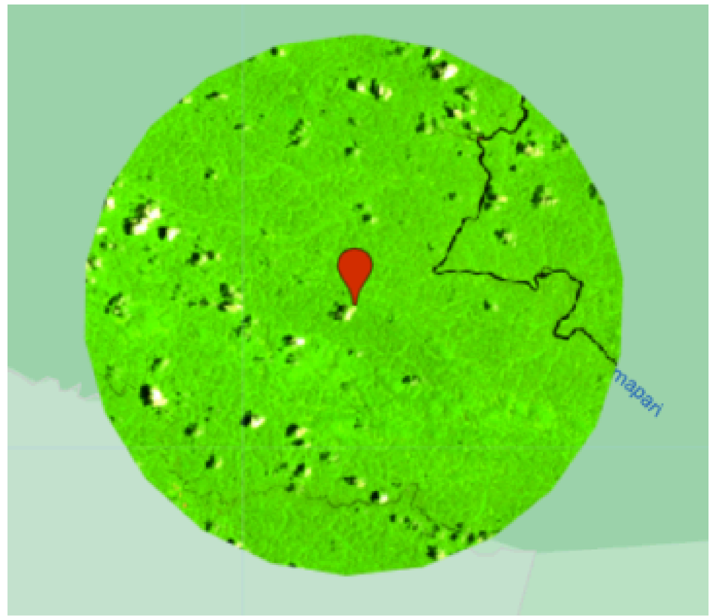
Pre fire FCC 2019



Post fire FCC 2019



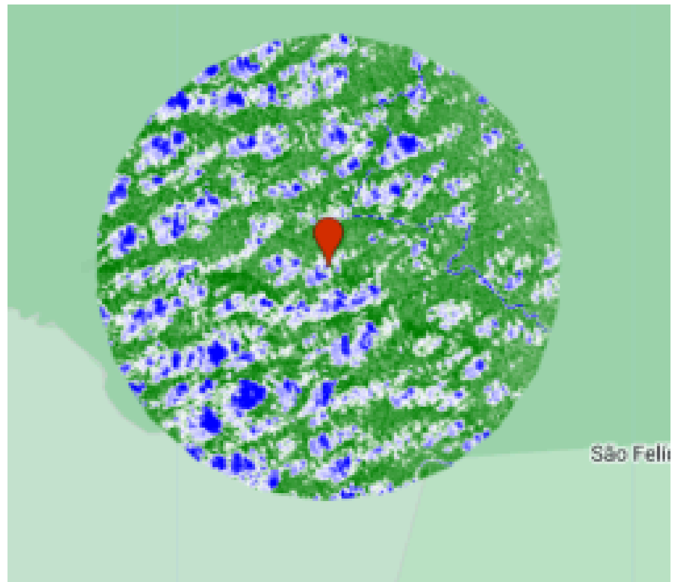
Pre fire FCC 2024



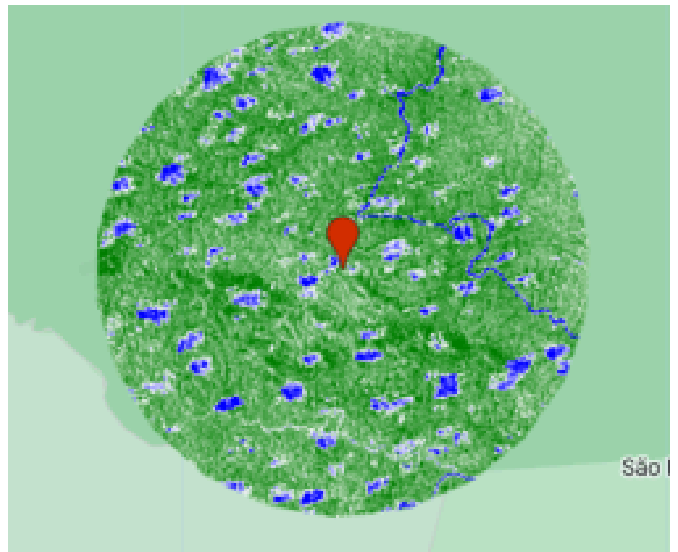
Post fire FCC 2024

Normalised Difference Vegetation Index :

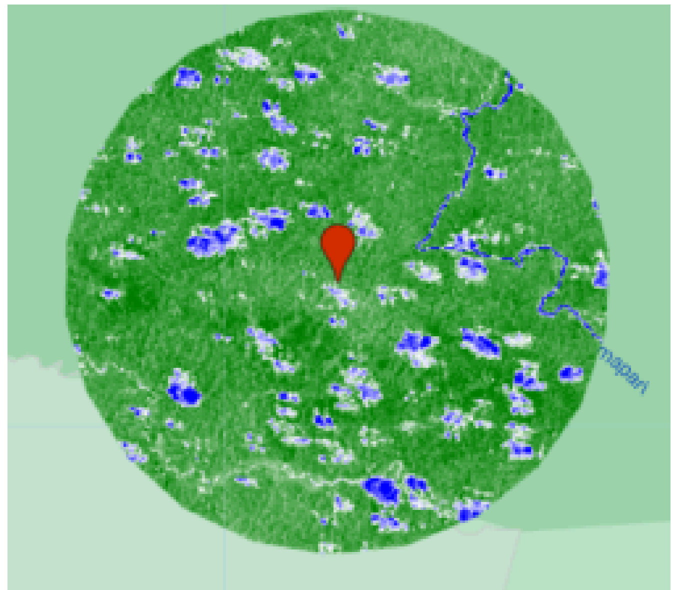
- In the Pre-Fire NDVI image (2014/24), the area appears white, indicating low vegetation health, possibly due to environmental stress or prior fire impacts, with cloud cover affecting accuracy.
- In the Post-Fire NDVI image (2014/24), the area turns green, showing regrowth or recovery, likely due to favorable climatic conditions like high rainfall.
- In 2019, the post-fire image shows blue spots, indicating significant vegetation loss following the fire.



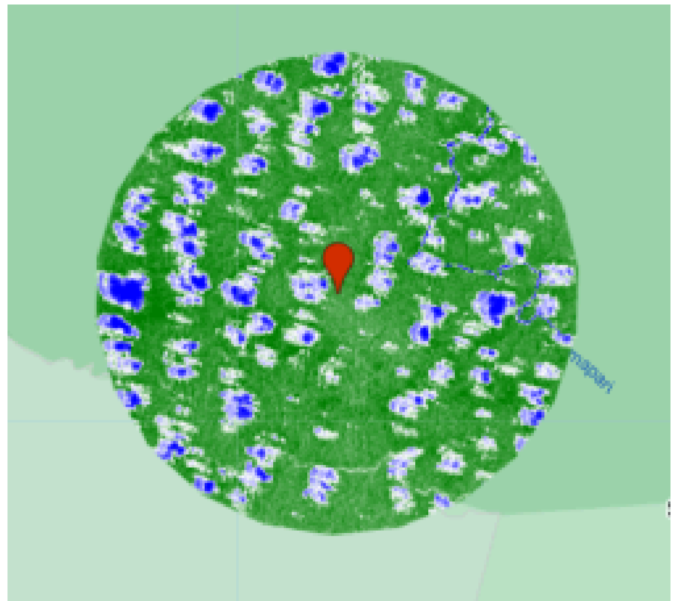
Pre fire NDVI 2014



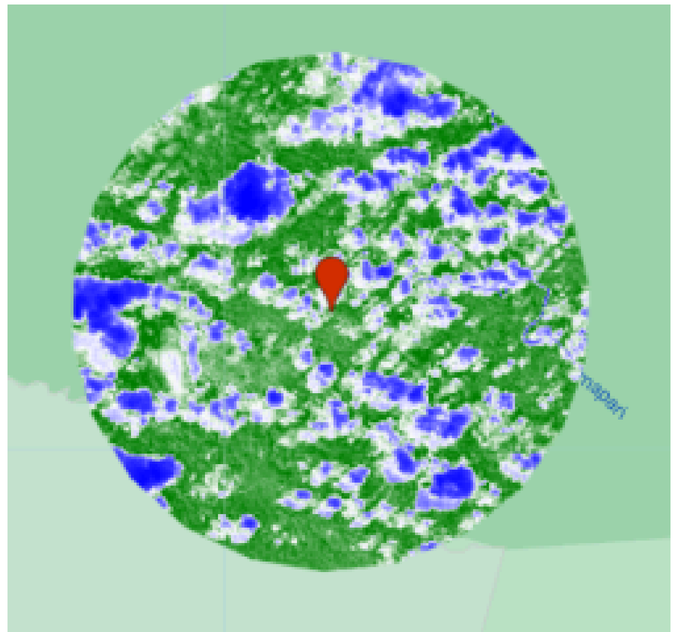
Post fire NDVI 2014



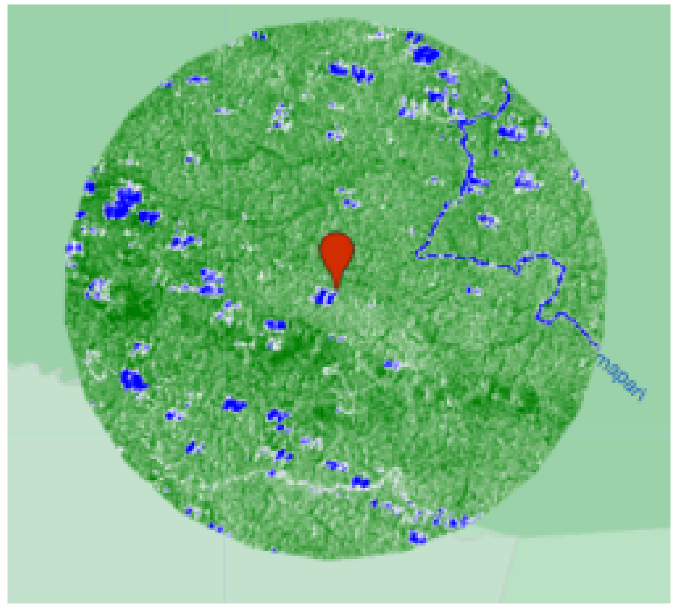
Pre fire NDVI 2019



Post fire NDVI 2019



Pre fire NDVI 2024

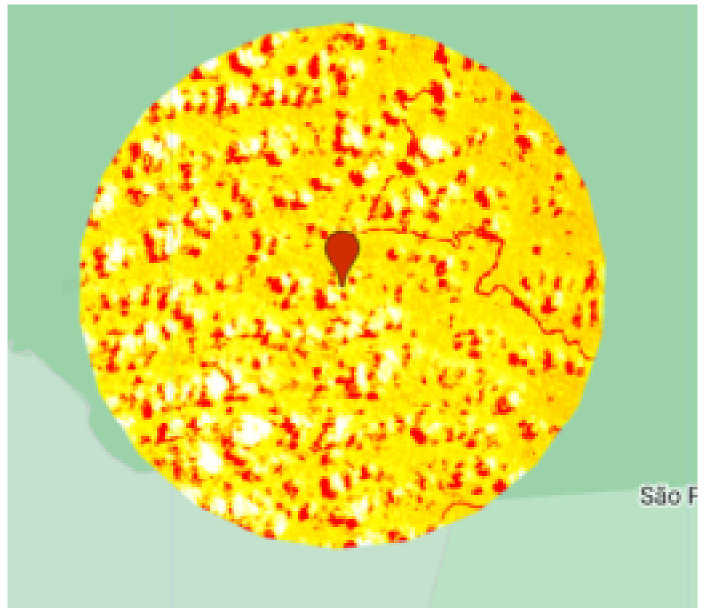


Post fire NDVI 2024

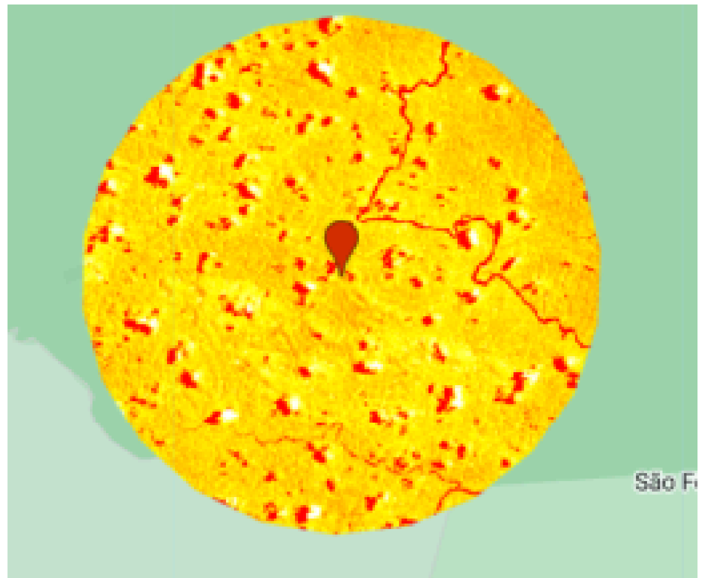
BURNED AREA INDEX (BAI) :

- The pre- and post-fire BAI snippets indicate that there were few fires, and those that occurred were of low severity, which aligns with our FCC results.
- The yellow in the post-fire BAI suggests signs of regrowth following the fire events.

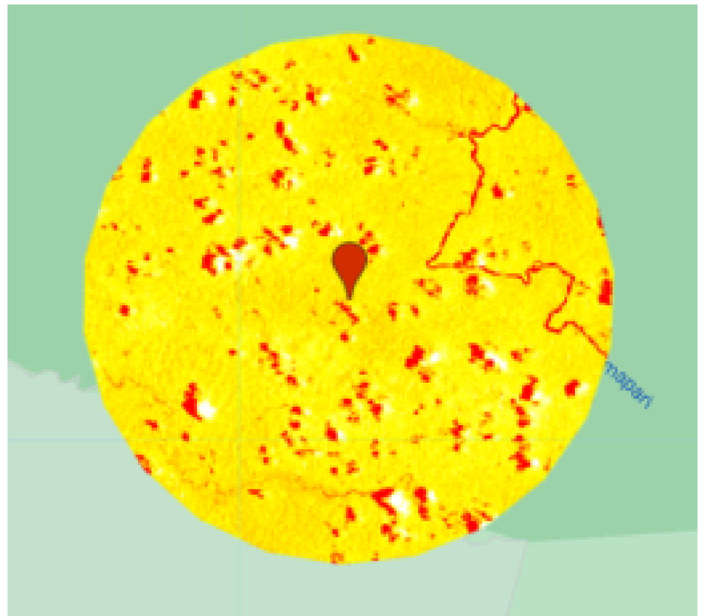
We can conclude that forest fires in Amapá have been significantly fewer compared to Pará, with minimal destruction observed. The wet climate of Amapá has also facilitated rapid regrowth, as evident from the patterns observed in the BAI analysis. In 2014, 2019, and 2024, Amapá experienced significantly fewer fire alerts compared to Pará, where an average of 160 alerts were recorded each month. This highlights the contrasting fire activity between the two regions.



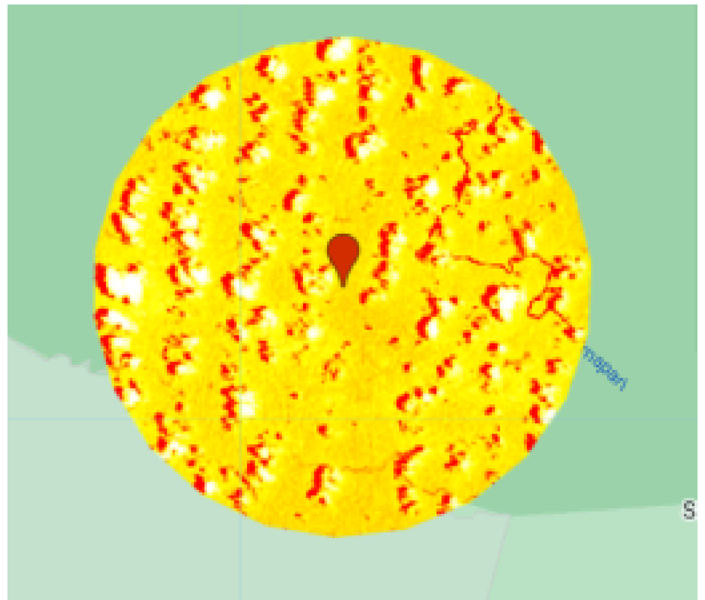
Pre fire BAI 2014



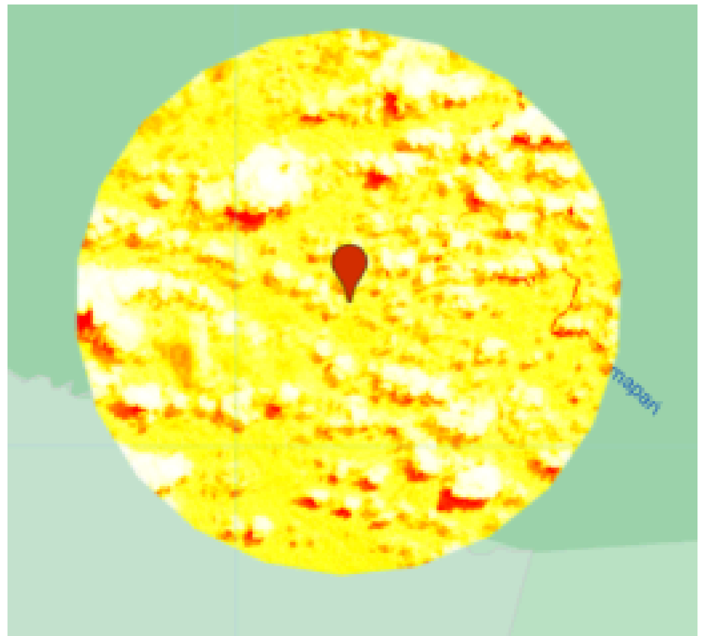
Post fire BAI 2014



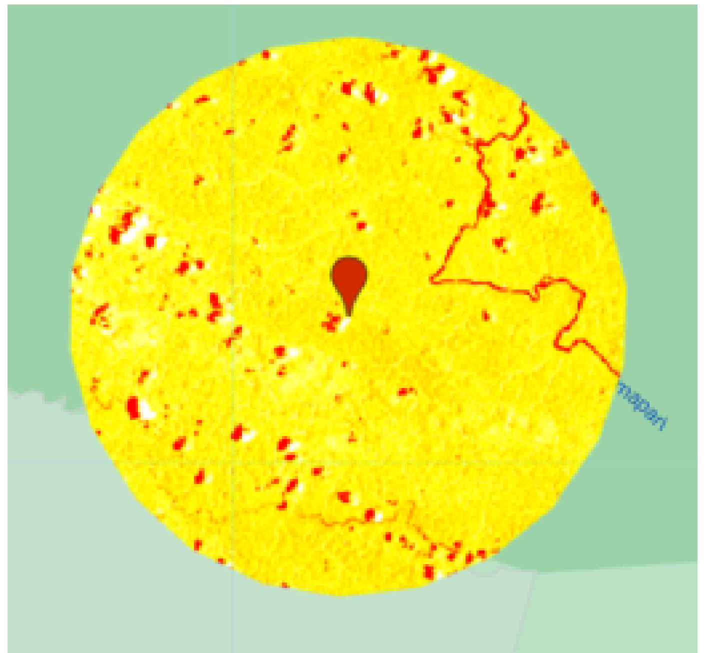
Pre fire BAI 2019



Post fire BAI 2019

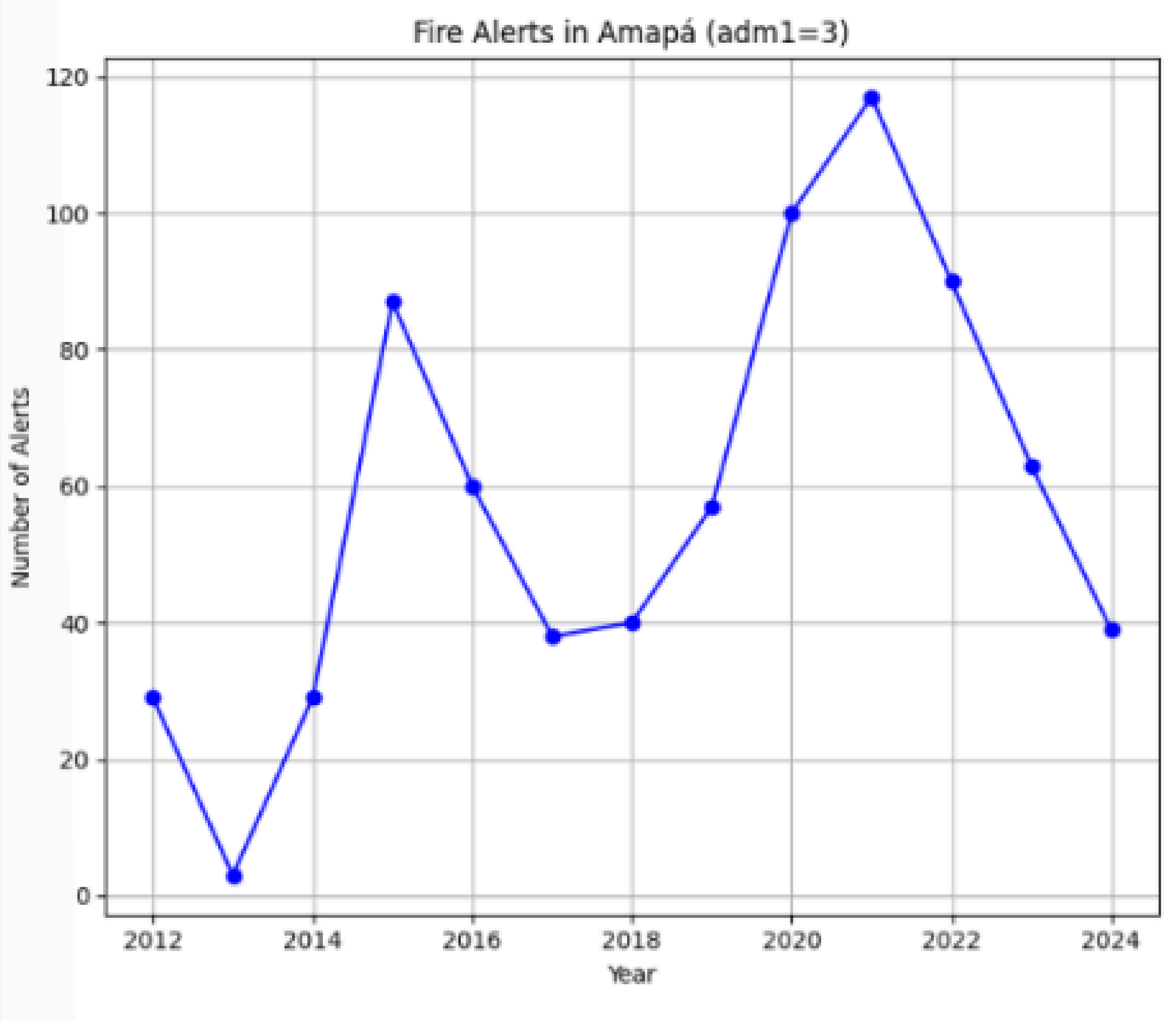


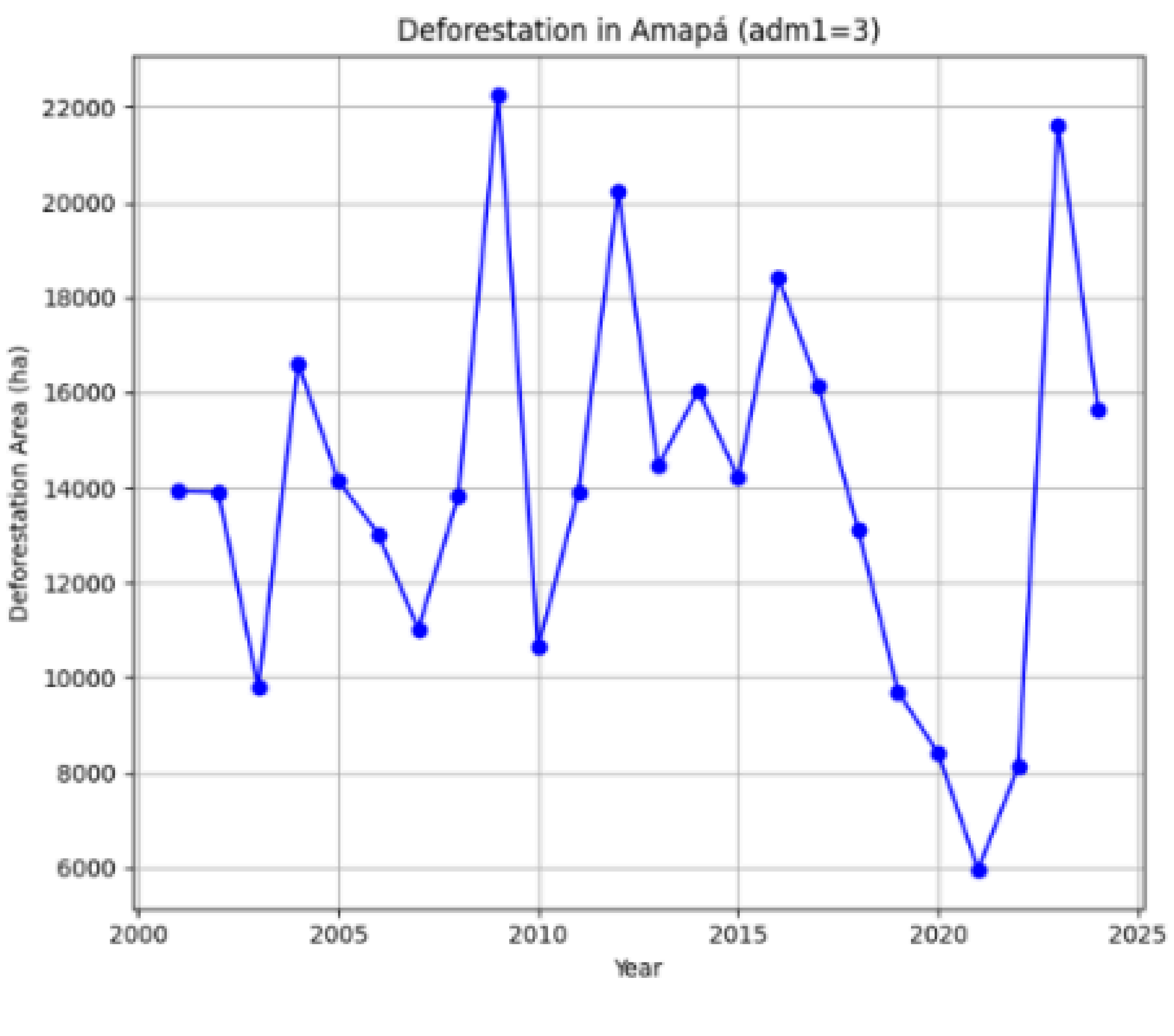
Pre fire BAI 2024



Post fire BAI 2024

Validating our GEE analysis with numerical data



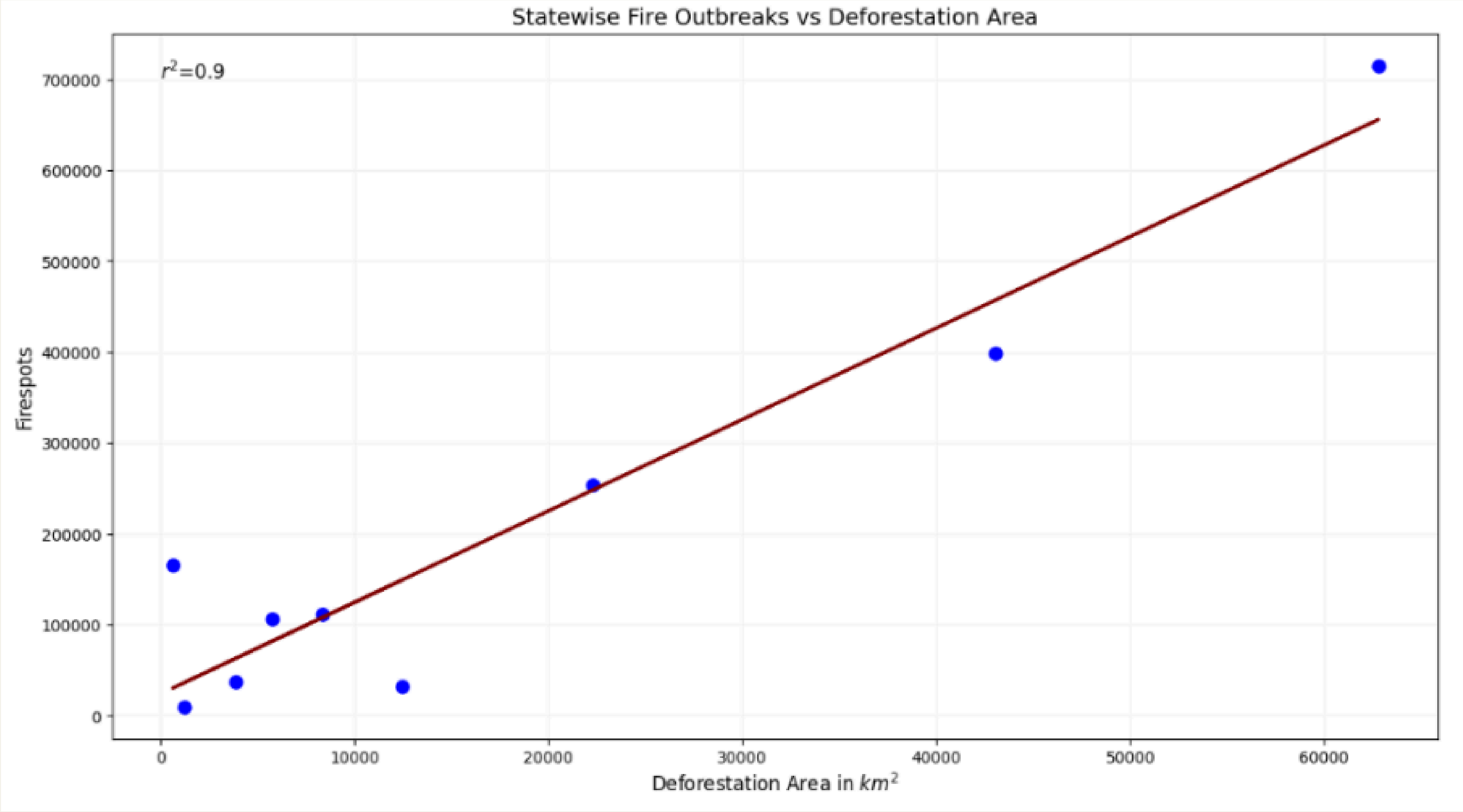


Challenges faced

- Amapá experiences high cloud cover throughout the year, especially during the wet season, while Pará is less clouded.
- Sorting by CLOUD_COVER metadata does not guarantee cloud-free images, as low values can still include localized clouds.
- The QA_PIXEL band failed for cloud masking, as some pixels flagged as "clear" still contained haze or thin clouds.
- Cloud-free image selection failed due to high cloud cover in the region and no available cloud-free images in the specified date ranges.
- As a result, images with residual clouds had to be used for Amapá.

Conclusion

- We analyzed **Pará (highest deforestation) and Amapá (least deforestation)** to explore trends between forest fires and deforestation.
- A scatter plot for all nine Amazon states was created to examine the relationship between the number of forest fires and the deforested area.
- The analysis showed a **high correlation** with an R^2 value of 0.9, indicating a strong linear relationship between forest fires and deforestation.
- This high correlation suggests that forest fires significantly contribute to deforestation, highlighting the need for strategies to mitigate fire impacts in the Amazon.



Thank you!