1. **Which geographic area of interest (AOI) are you focusing on?**

The Atlantic Forest (*Mata Atlântica*; *Bosque Atlántico*) is the second largest rainforest in South America. It is located in the Atlantic coast of Brazil (92 percent of its total area), northern Argentina (2 percent of its total area), and southern Paraguay (6 percent of its total area). The forest is the third most extensive biome in Brazil after the Amazon and the Cerrado and is considered one of the most threatened forests in the world, with only about 12 percent of its original area remaining (de Lima Palidon and dos Santos Guapyassu, 2005).

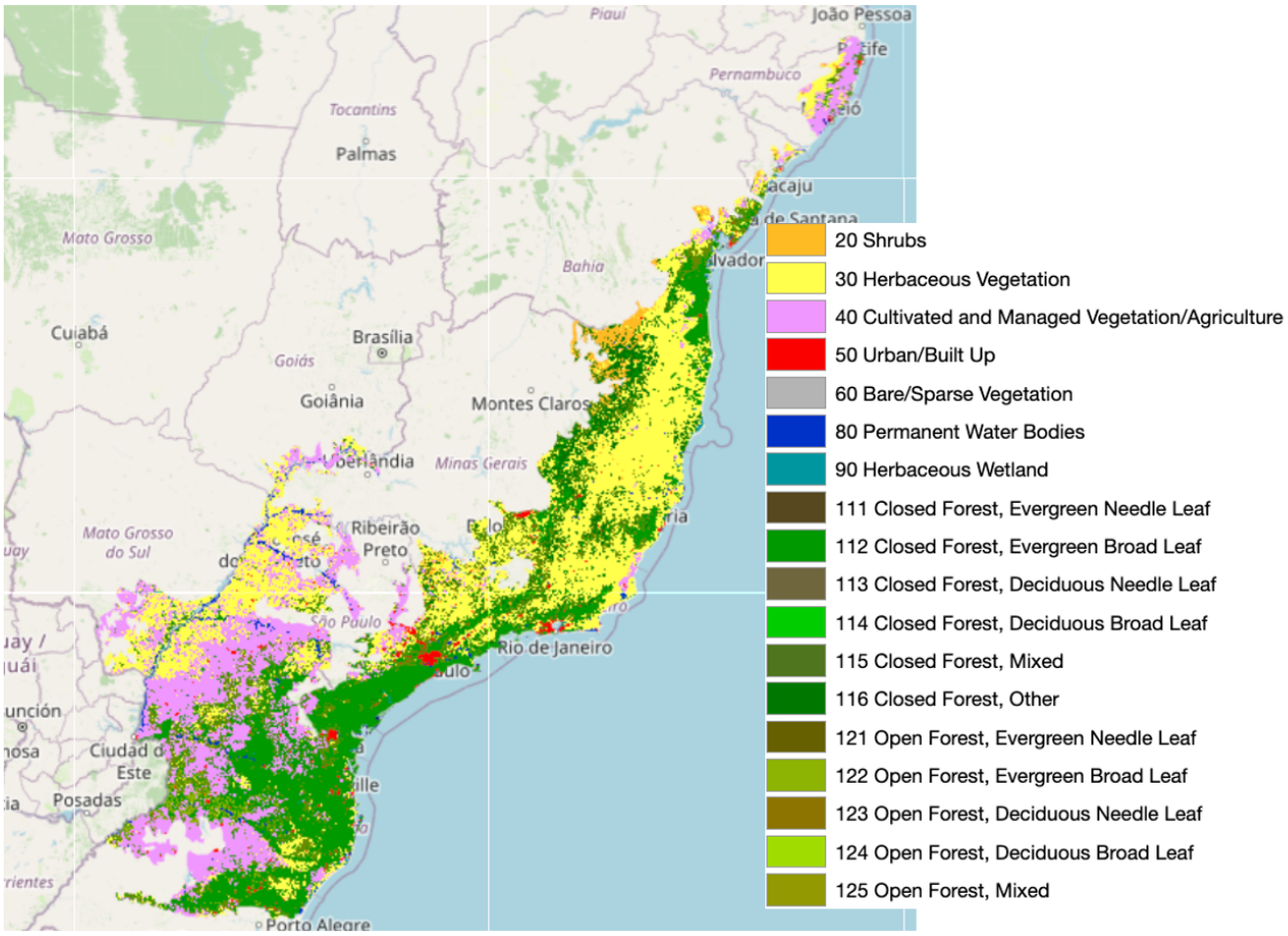
The Atlantic Forest is highly fragmented and is pressured by urbanization, deforestation, and agricultural plantations (Singh and Huang, 2022). The original area of the forest covered 15 percent of the land area of Brazil. Now, it is estimated that only about 8.5 percent of its area surpasses 100 hectares in size (Burak et al., 2023). The Atlantic Forest's ecoregion composes some of Brazil's largest cities, including Rio de Janeiro and São Paulo. This region produces an estimated 70 percent of the country's gross domestic product (World Wildlife Fund n.d). About 35 percent of the remaining area is a protected area with 14 national parks, 14 biological reserves, and 6 ecological stations (de Lima Palidon and dos Santos Guapyassu, 2005).

The area has high levels of biodiversity. An estimated 2,200 species of birds, mammals, reptiles and amphibians can be found in the Atlantic Forest (The Nature Conservancy n.d.). About 40 percent of its vascular plants and about 60 percent of its vertebrate species are endemic species that cannot be found anywhere else in the world. In Brazil, there are an estimated 20,000 species of plants in the Atlantic Forest (about 8 percent of the Earth's total)(The Nature Conservancy n.d).

2. **Which broad forest type(s) does your AOI fall under? Can your forest be classified into more specific categories?**

The Copernicus Land Cover layer categorizes the Atlantic Forest as an evergreen broad leaf forest. The literature classifies different areas of the forest into coastal, deciduous and semideciduous inland forests, low montane forests, as well as ecosystems including mangrove swamps, and high-altitude swamps (de Lima Palidon and dos Santos Guapyassu, 2005). The coastal forest has been the most disturbed, with only about 3 percent of its original area remaining.

Figure 1. Land Cover Type in the Atlantic Forest (Data Source: Copernicus Global Land Cover Layers)



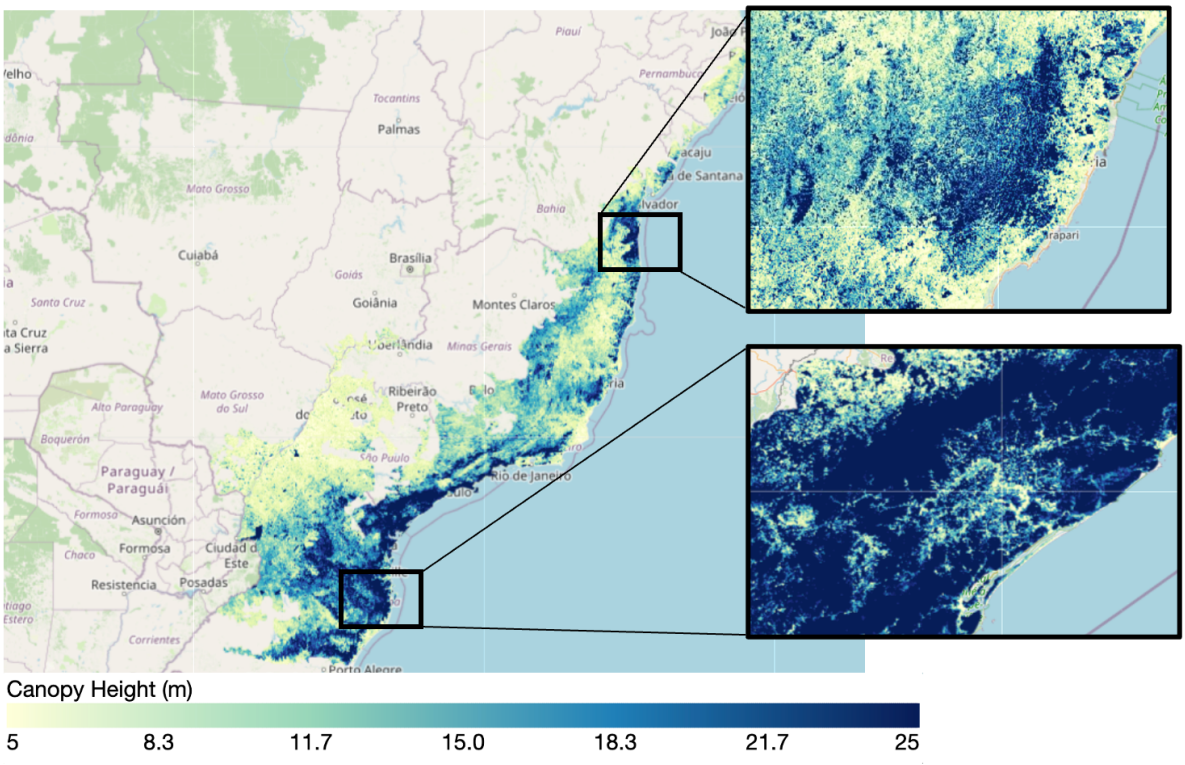
3. **How carbon dense do you *expect* these forests to be (low, medium or high) relative to other forest types? And in which pools is that carbon mostly stored? (There is no need for actual carbon estimates at this point, just describe your own expectations).**

The literature shows a diverse range in carbon density throughout the Atlantic Forest. Due to it fragmented location in high elevation areas, I expect carbon density to be lower in the Atlantic Forest compared to biomes like the Amazon. I also expect above ground biomass (AGB) to be higher than below ground biomass (BGB) throughout the forest.

I expect there to be some variation in ABG throughout the forest. AGB is likely higher in the inland forest section compared to the coastal forest. Soil in the coastal forest has been described as sandy, infertile soil, which likely affects the composition of trees due to poor soil quality (de Lima Palidon and dos Santos Guapyassu, 2005).

The figure below shows AGB carbon estimates from the Global Land Analysis and Disccovery at the University of Maryland using Global Ecosystem Dynamics Investigation (GEDI) lidar data and Landsat time series data. Estimates are provided for 2019 at a 30-meter spatial resolution (Potapov et al., 2020). The maximum canopy height estimated in the Atlantic Forest is about 30 meters.

Figure 2. Canopy Height (2019) (Data Source: GLAD)



4. **Choose two elements of within-type variability and briefly explain how they each might be impacting the carbon density of your forest. Example elements include species composition, elevation, soils, temperature, or age composition.**

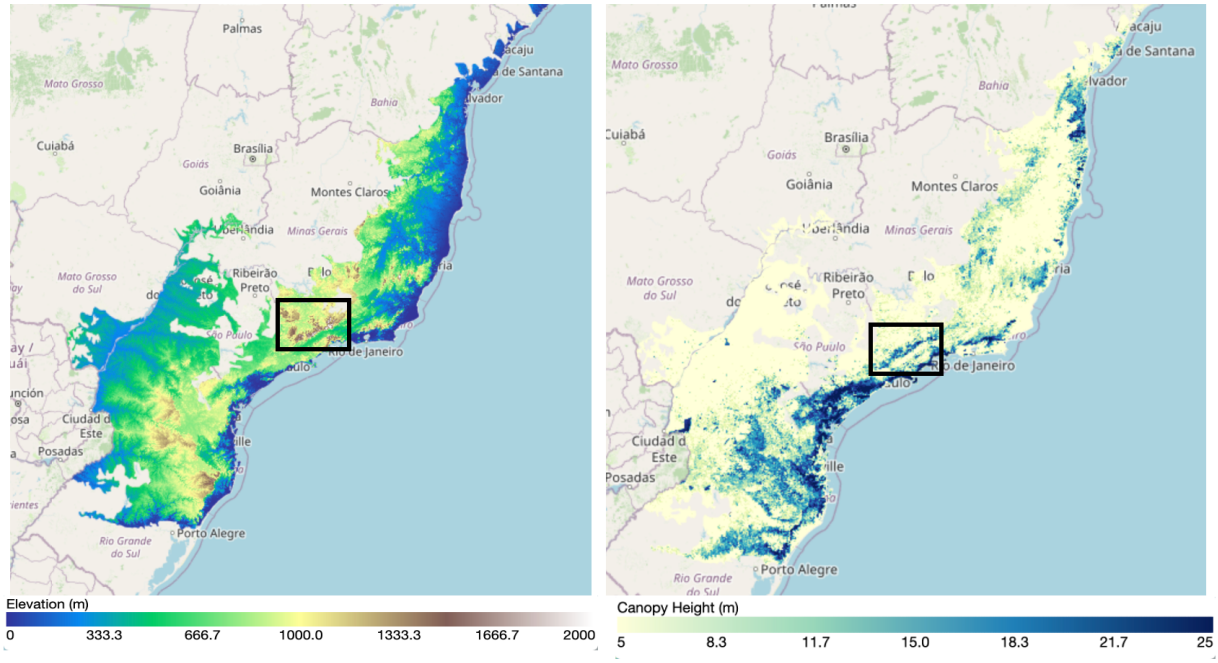
Elevation

There is a diversity in elevation and topographies in the Atlantic Forest. Elevation ranges from around -100 to 2800 meters in altitude, with distinct microclimates observed with differences in slope of about 100 meters (Burak et al., 2023). Although typically carbon density decreases with elevation, I believe carbon density likely *increases* with elevation in sections of the Atlantic Forest due to the historic role that elevation has played in which areas get deforested or degraded. For example, Hengl et al. (2015) found that both above and below ground biomass *increased* with elevation. A confounding element in this study is that remaining sections of the forest are largely inaccessible and cannot be cost-effectively cleared

due to high elevations. This gives the impression that AGB increases with elevation, ignoring that forests in a lower elevation have already been converted to other land uses but might have a higher AGB in a counterfactual scenario.

The figure below shows a comparison of elevation and canopy height estimates. The box shows a peak in elevation near the metropolitan city of Rio de Janeiro accompanied by high canopy heights.

Figure 3. Elevation and Canopy Height in the Atlantic Forest (Data Sources: Copernicus and DEM and GLAD GEDI)



Species Composition

Species composition in the Atlantic Forest varies widely by latitude and forest type. Previous studies have mapped the genus Pleroma in about 10.8 percent of the Atlantic Forest, particularly in areas with higher elevation, slope, tree cover, and precipitation (Wagner, 2021). Klipel et al. (2022) analyzed the species distribution of 1,138 trees in the Atlantic Forest to investigate their range. Their findings showed that warm and wet-affiliated species had narrower ranges along their optimal temperature and water requirements, while species with a niche in colder and drier temperatures had a wider geographic range.

5. **What are the typical natural disturbances in your AOI? And over what spatial and temporal scales do these occur? When was the last time one of**

these natural disturbances impacted your AOI? What were the consequences?

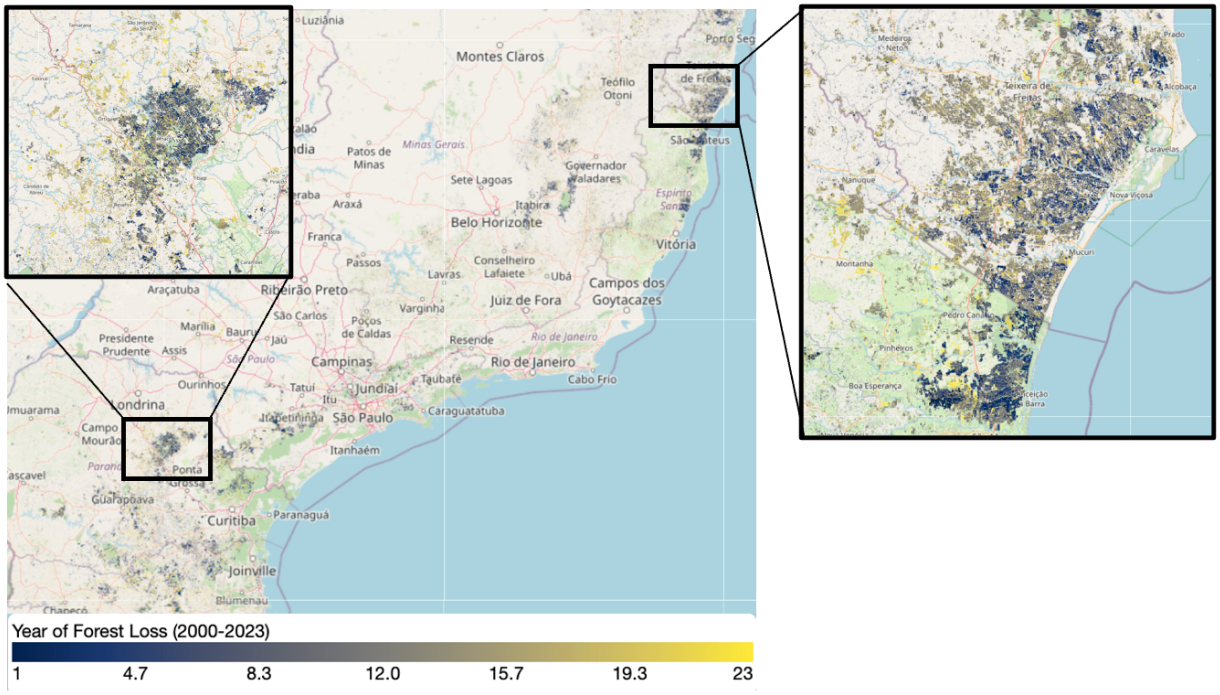
Fires are the most typical disturbance in the Atlantic Forest, which are both natural and human caused. These occur on a yearly basis at localized temporal scales that do not affect the entire forest. The susceptibility of the Atlantic Forest to fire has increased over the past two decades due to climate change, land cover change, and forest fragmentation (Singh and Huang, 2022). Fragmentation facilitates the spread of one disturbance to the surrounding landscape, increasing tree mortality and increasing fire frequency (Singh and Huang, 2022). The Atlantic Forest is not fire adapted and does not include fire as in influence in its evolutionary history. In 2020, the National Institute for Space Research (INPE) reported over 250,000 fire foci in the Atlantic Forest. In 2024, about 615,000 hectares of fire damage were reported in the Atlantic Forest (Mapbiomas Fire Monitor) .The fires had an uneven distribution and were focused on the Rio Grando do Sul state in southern Brazil.

In a spatial modeling study of fire in the Atlantic Forest, Boelter Herrmann et al. (2023) found that the most predictive variable in fire modeling was the maximum temperature during the warm season and having livestock as the most influential economic activity. Singh and Huang (2022) found that the Normalized Difference Vegetation Index (NDVI) value, temperature, and solar radiation were significant drivers of fire occurrence risk in the Atlantic Forest.

6. How are humans impacting the forests in your AOI? Is there deforestation and degradation occurring? Overall, do you expect your forest is typically a carbon source or a sink? Why? Actual data is not required for this question, just use your intuition.

The forest has been disturbed for over 500 years due to logging and clearing for the cultivation of sugarcane, coffee, and cacao plantations that drove exports in Brazil from early colonial times to early in the 20th century (de Lima Palidon and dos Santos Guapyassu, 2005). In recent history, forest disturbances have been driven by expanding human populations and land conversion to urban areas. Figure 4 shows the year of forest loss in the Atlantic Forest from 2001 to 2023. Coastal areas saw deforestation in the early 2000s, while inland and outer forest sections have seen deforestation in the 2010s and 2020s.

Figure 4. Year of Forest Loss (2001-2023) (Data Source: GLAD)



7. What were your primary sources of information for answering these questions? Which of these questions (if any) were the most difficult to answer and why?

My primary sources for answering these questions were academic articles (listed in the references section) and Google Earth Engine datasets from sources like Copernicus, the University of Maryland, and Sentinel. The most difficult to answer were related to soil and species composition, particularly since these require field samples that are difficult to capture over an area as wide as the Atlantic Forest.

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