

Amazon deforestation

Spatio-temporal analysis of land cover between 2001 and 2012

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The Amazon

- Located in the north of South America, the Amazon covers much of Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, and French Guyana.
- It is the **largest tropical rainforest on Earth**, covering an area of over 6.5 million square kilometers, and it houses **ten percent of the world's known species**, including endemic and endangered flora and fauna.
- It holds a crucial ecological and environmental value, influencing Earth's climatic balance: its trees absorb heat and carbon dioxide (CO₂), thus creating a "**cooling effect**" on the planet.
- However, when trees are cut down and burned, the stored CO₂ is released back into the atmosphere, contributing to global warming.

The Amazon rainforest



Figure: Map of the Amazon rainforest

Amazon deforestation

- Over the last fifty years, the **deforestation of the Amazon** has turned this carbon sink (the so-called "green lung" of our planet) into a source of carbon emissions.
- Mining, logging, farming, agriculture, and oil and gas extraction have put **unsustainable pressure** on this fragile forest.
- According to several studies, the Amazon has lost one-fifth of its forest cover, its connectivity has been increasingly disrupted and many endemic species have been subjected to uncontrolled exploitation.

Study aim

- The objective of this study was to assess the level of **deforestation of Rondônia**, a state located in the western part of Brazil.
- Recently, Rondônia - once home to 208,000 square kilometers of forest - has become **one of the most deforested parts of the Amazon**.
- Clearing and degradation of Rondônia's forest have been rapid: 4,200 square kilometers cleared by 1978; 30,000 by 1988; and 53,300 by 1998. By 2003, an estimated 67,764 square kilometers of rainforest had been cleared.

State of Rondônia



Figure: Location of the state of Rondônia in Brazil

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Dataset

- The images used in this project belong to a satellite time series collected from 2000 to 2012 by MODIS on **NASA's Terra satellite** (<https://earthobservatory.nasa.gov/world-of-change/Deforestation>).
- The Moderate-Resolution Imaging Spectroradiometer (**MODIS**) is an instrument designed for satellite observation of the Earth with a spatial resolution ranging from 250 to 1000 m.

Images

- The satellite images under study date back to **2001** and **2012**, respectively, and have a spatial resolution of 500 m.
- Healthy forest areas are dark green, while deforested areas are brown (bare ground) or light green (cropland, pastureland, or occasionally second-growth forest).
- As my study attempts to show, over 11 years, **deforested areas have increased significantly**, and are still increasing, due to anthropogenic impact.

Raster images

```
par(mfrow=c(2, 1))  
plotRGB(amazon2001, r=1, g=2, b=3)  
plotRGB(amazon2012, r=1, g=2, b=3)
```



Amazon rainforest - 2001



Amazon rainforest - 2012

DVI

- The **Difference Vegetation Index** (DVI) is defined as the difference between the reflectance value in two bands of the electromagnetic spectrum - typically, near-infrared (NIR) and red bands.
- DVI can be useful for detecting the presence and density of vegetation. It is calculated using remote sensing data, typically obtained from satellites.

$$DVI = NIR - red \quad (1)$$

NDVI

- The **Normalized Difference Vegetation Index** (NDVI) provides standardized values that can be more easily interpreted and compared with other raster images.
- NDVI quantifies vegetation by evaluating the presence of **photosynthetic activity** and measuring the difference between NIR (which vegetation strongly reflects) and red bands (which vegetation absorbs).
- NDVI values range from -1 to +1, with higher values indicating a higher density of green vegetation.

$$NDVI = \frac{NIR - red}{NIR + red} \quad (2)$$

Spatio-temporal change detection

- The **spatio-temporal variation in vegetation cover** between 2001 and 2012 was then detected.
- It involves the analysis of raster images acquired at different time periods to identify and quantify changes in land use, vegetation cover, or other environmental phenomena over time.

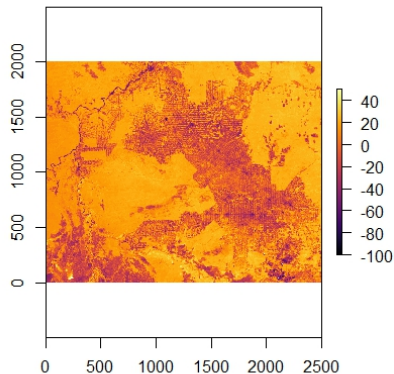
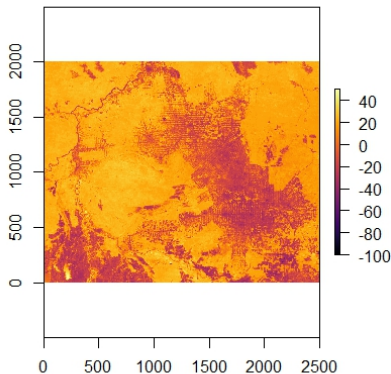
Unsupervised classification

- Finally, the unsupervised classification of the raster images into two classes (forest and human components) was detected.
- **Raster images classification** can be used to monitor changes in land use, land cover, or the natural environment over time. For example, it can be used to assess deforestation, urbanization, or other environmental changes.

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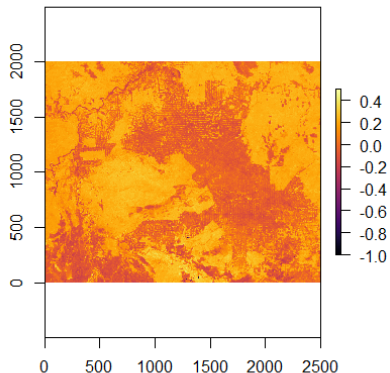
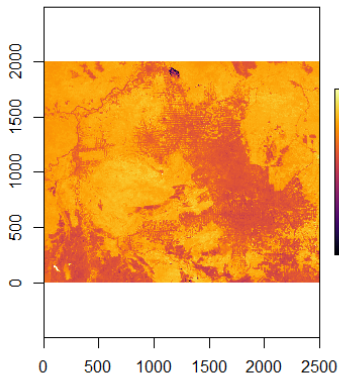
DVI

```
par (mfrow=c(1, 2))  
viridis <- colorRampPalette(viridis(7))(255)  
plot (dvi2001, col=viridis(255, option="inferno"), zlim=c(-100, 50))  
plot (dvi2012, col=viridis(255, option="inferno"), zlim=c(-100, 50))
```



NDVI

```
par(mfrow=c(1, 2))  
plot(ndvi2001, col=viridis(255, option="inferno"), zlim=c(-1, 0.5))  
plot(ndvi2012, col=viridis(255, option="inferno"), zlim=c(-1, 0.5))
```

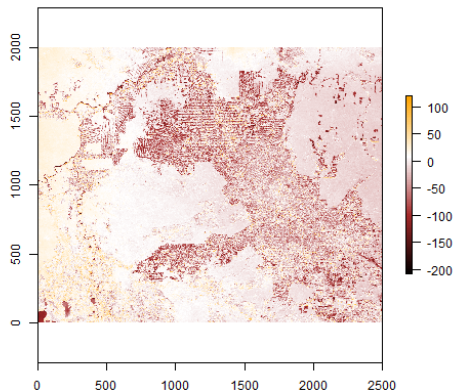


Vegetation indices

- Higher values (lighter areas) represent a higher density of green vegetation, while lower values (darker areas) correspond to the loss of forest cover caused by human activities.
- The two vegetation indices used (DVI and NDVI) show a **decrease in the presence and density of vegetation** between 2001 and 2012.

Spatio-temporal change detection

```
amazondif = amazon2001[[1]] - amazon2012[[1]]  
cl2 <- colorRampPalette(c("black", "brown", "white", "orange"))(100)  
plot (amazondif, col=cl2)
```

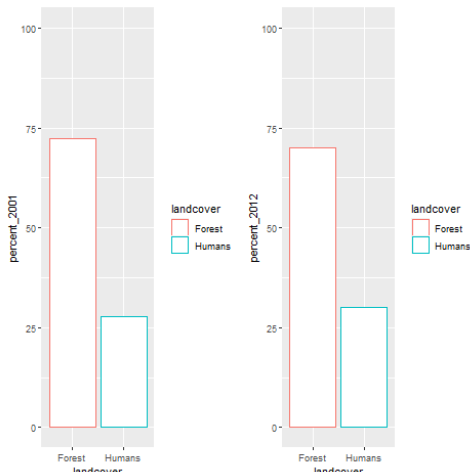


Spatio-temporal change detection

Darker areas indicate the biggest vegetation losses, usually the complete clearing of the original rainforest, while lighter areas showed little or no change.

Unsupervised classification

```
p1 <- ggplot(percentage, aes(x=landcover, y=percent_2001, color=landcover))  
+ geom_bar(stat="identity", fill="white") + ylim(c(0, 100))  
p2 <- ggplot(percentage, aes(x=landcover, y=percent_2012, color=landcover))  
+ geom_bar(stat="identity", fill="white") + ylim(c(0, 100))  
p1 + p2
```



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Discussion

- The study shows a **decrease in the Amazon's forest cover** from 72.5 to 70 percent and an **increase in the human component** from 27.5 to 30 percent.
- The results obtained are in line with what has been reported in the scientific literature so far.

Discussion

- Recently, an international study led by the Federal University of Santa Catarina in Brazil, published in the journal Nature (<https://www.nature.com/articles/s41586-023-06970-0>), estimated that 10 to 47 percent of the **Amazon rainforest is at risk of collapse by 2050**.
- The Amazon forest system may soon reach a **tipping point** due to warming temperatures, extreme drought, deforestation, and wildfires, with unpredictable and far-reaching consequences for the Amazon itself, but also the entire planet.
- The study emphasizes the urgency of taking action to reverse this trend, for example by restoring the areas most at risk, curbing deforestation, and focusing on renewable energy sources.

Conclusion

- **All major tropical forests** - including those in the Americas, Africa, Southeast Asia, and Indonesia - **are disappearing**, mostly to make way for human food production, including livestock and crops.
- Although tropical deforestation meets some human needs, it also has profound, sometimes devastating, consequences, including social conflict and human rights abuses, extinction of plants and animals, and climate change - challenges that affect the whole world.

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Script

Here you can find my script on GitHub:

https://github.com/irenecassinellii/Spatial_ecology_in_R/blob/main/R_code_exam.R