Deforestation and Health in Brazil

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1 Introduction

The Amazon rainforest, the largest forest in the world, provides a great amount of carbon sequestration, an ecosystem service that benefits the entire globe by offsetting carbon emissions. It is also a biodiversity reservoir, containing many species found nowhere else on earth. These services are not sold in markets and basic economic theory says that given that conservation will be inefficiently underprovided, in lieu of increased logging and agricultural land use. This fact is especially true post 2019 as Brazil, the country to which most of the Amazon belongs, has elected a right-wing populist President, Jair Bolsonaro. This political ideology actively eschews collective action to solve global environmental problems. Bolsonaro has strenuously exerted that Brazil is the exclusive decision maker regarding deforestation of its Amazon, as a matter of its national sovereignty. The rate of deforestation in the Amazon reached a record in April 2021. As this rate continues to accelerate, the full weight of damage must be examined. This knowledge can also serve to demonstrate that there are major costs to deforestation that are borne by Brazil's (most vulnerable) citizens themselves in the hopes of affecting policy change. A major ecosystem service that the Amazon might provide is to mitigate mosquito populations and mitigating the spread of infectious disease. Our paper seeks to add to the existing literature by looking at the effects of deforestation on a more expansive set of health outcomes, using rich health data from Datasus [1].

2 Literature Review

While many prior studies have shown that deforestation has deleterious effects on infectious disease, some have shown positive effects. In particular, Macdonald and Mordecai, 2020 found that deforestation is causally linked to malaria in the Brazilian Amazon. Berazneva and Byker, 2017 found that forest loss significantly increases the incidence of malaria in Nigeria, though it does not affect the incidence of diarrhea and respiratory diseases.[2] Carrillo et al.,2019 found that the conservation policy launched in 2004 had positive effects on infant health in Brazil but do not explain the mechanism. On the other hand, Yasuoka and Levins, 2007 showed that deforestation reduced malaria in Thailand. Overall, negative effects of deforestation in terms of disease prevalence can outweigh positive effects (Canyon, 2001). In contrast to the aforementioned studies, Bauhoff and Busch, 2020 found no relationship between deforestation and malaria in African countries, suggesting that the socioeconomic of deforestation may differ in Latin American, African and Asian contexts.

Because there are discrepancies in different contexts and studies, it is important to understand the specific processes or mechanisms that are generating these different data sets. The canopy cover provided by forest land has ambiguous effects on the reproduction of mosquitoes. Petney, Trevor et al., 2009 found that in Thailand the canopy lowers the temperature of water on the ground below to a more ideal temperature for reproduction. In contrast, the Amazon rain-forest has milder temperatures than Thailand and the canopy keeps water on the ground below under that ideal temperature. Mordecai et al., 2017 found that there is a bell-shaped relationship between temperature and both mosquito reproduction and disease transmission that is sharply peaked at 29 degrees Celsius (84 degrees Fahrenheit). Weather (temperature and climate) is just one confounding when looking across different

[1] http://datasus1.saude.gov.br/
[2] Garg, 2019 also found similar results in Indonesia.

regions, necessitating our studies narrow geographic focus on Brazil.

We are highly focused on internal validity, not external validity because of the observed ambiguity of the effect across different regions and the Brazilian case being of significance importance in and of itself.

3 Methods

3.1 Data

3.1.1 Deforestation

We extract deforestation data in the Legal Amazon from TerraBrasilis web portal[3], a web platform built by the National Institute of Space Research (INPE). This platform provides publicly available spatial data of environment monitoring projects such as PRODES and DETER by Brazil government to establish public policies. In addition, the PRODES[4] project carries out satellite monitoring of clear-cut deforestation since 1988 and has relatively higher data precision than DETER. Therefore, we decide to construct our deforestation data set using meta-data representing annual rates and deforestation increments in the Legal Amazon from the PRODES project rather than directly processing satellite images.

The Legal Amazon covers an area of more than five million square kilometers comprising nine Brazilian states of Acre (AC), Amapá(AP), Amazonas(AM), Maranhão (MA), Mato Grosso (MT), Pará (PA), Rondôni(RO), Roraima (RR) s(TO). We compiled state-year deforestation data set with aggregation of nonsuccessive daily data of these nine states from 2008 to 2019[5].

[3]see details on the official website: http://terrabrasilis.dpi.inpe.br/

[4]PRODES is operated by the National Institute of Space Research (INPE) in collaboration with the Ministry of the Environment (MMA) and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA).

[5]In the PRODES project, data for annual increments prior to 2008 are aggregated in a single set, from 1988 to 2007, so data before 2018 is not available

3.1.2 Health

We used health data from Datasus, the information data bank from the Sistema Unico de Saude, Brazil's integrated health reporting system. Health data is comprised of several reporting subsystems, and we used data from the compulsory case reporting system, which contains information of reported cases for several infectious diseases. The system reports the date of diagnosis (month, day and year since 2001), city of residence of diagnosed individual, age, gender, race, schooling and a list of disease-specific symptoms. In addition, we restricted our attention to Malaria, Tuberculosis and Chagas Disease.

3.2 Empirical Strategy

At the moment, we are able to provide basic descriptive statistics as our initial analysis results.

4 Results

4.1 Descriptive Statistics

For the deforestation data, figure 1-3 provide summary statistics of spatial and temporal variations of deforestation in the Legal Amazon. In figure 1, Pará (PA) has the largest deforestation area (35,338 km^2) in total over the past 12 years, which is more than twice than Mato Grosso (MT) (16,746 km^2) among the nine Brazilian states. Furthermore, there is a sharp decrease in deforestation area from 2008 to 2012 for some states as shown in 2. One potential reason for the observations is that Brazil enacted a series of anti-deforestation policies in 2005-2006 to combat the destruction of the Amazon. However, there is a reverse trend after 2012, which means deforestation remains a problem for this country.

For the health data, first we plot the total number of cases for Malaria (Figure 4), Tuberculosis (Figure 5) and Chagas Disease (Figure 6). None of the plots show a clear increasing or decreasing trend across the time span, however it must be noted that malaria cases exhibit seasonality as the number of cases increase significantly during summer months, probably because it is a mosquito-borne disease that is more likely to spread after the rainy season. Second, we have that tuberculosis cases plummeted during 2020, this is likely a consequence of the protective measures taken due to the COVID pandemic (social distancing, face masks, and regional lock-downs), because tuberculosis is transmitted by aerosol droplets from infected persons. Finally, there is a strange pattern in Chagas Disease case numbers, since they exhibit a significant increase after 2012 for no apparent reason, thus implying a change in reporting, but further research is needed to elicit the actual motive.

Figures 7, 8, 9 and 10 depict the geographical distribution of tuberculosis cases for selected years, there is no clear pattern either, since cases are strongly correlated with population size of each state, a further analysis should be performed at a more disaggregate level and also include a per capita incidence measure.

Chagas disease case counts are heavily concentrated in rural areas on the northeastern states of Brazil, this pattern is also stable across time. malaria cases also behave similarly, but problems with georeferencing prevent us from providing a comprehensive plot.

4.2 Correlations

Furthermore, we look at the simple correlations between cases and deforestation using the Pearson linear correlation coefficient. Tuberculosis cases and deforested area (in squared kilometers) have a positive correlation of 0.393, the respective correlation for Chagas Disease cases is also positive and equal to 0.498. Finally, the correlation for Malaria cases is surprisingly negative and equal to -0.495.

Without a more detailed model we cannot make any causal statements beyond the fact that we need to ascertain a clear causal mechanism that drives the number of cases and can be linked to the degree of deforestation in specific states.

5 Conclusion

To sum up, we have shown that the degree of deforestation and the number of reported cases of infectious diseases are correlated, but their sign depends on the transmission mechanism of the specific disease.

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Yasuoka, J. and R. Levins. "Impact of deforestation and agricultural development on anopheline ecology and malaria epidemiology." The American journal of tropical medicine and hygiene 76 3 (2007): 450-60 .

A Figures and Tables

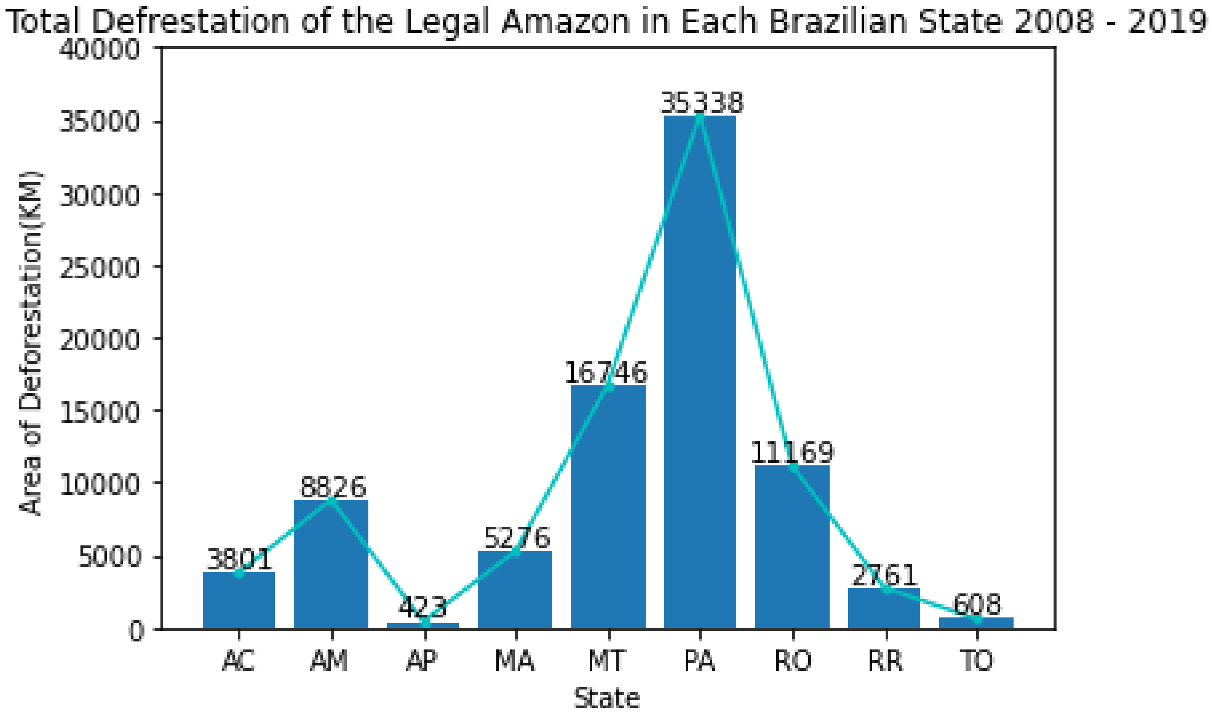

Figure 1: Total Deforestation of the Legal Amazon by Brazilian States in 2008-2019

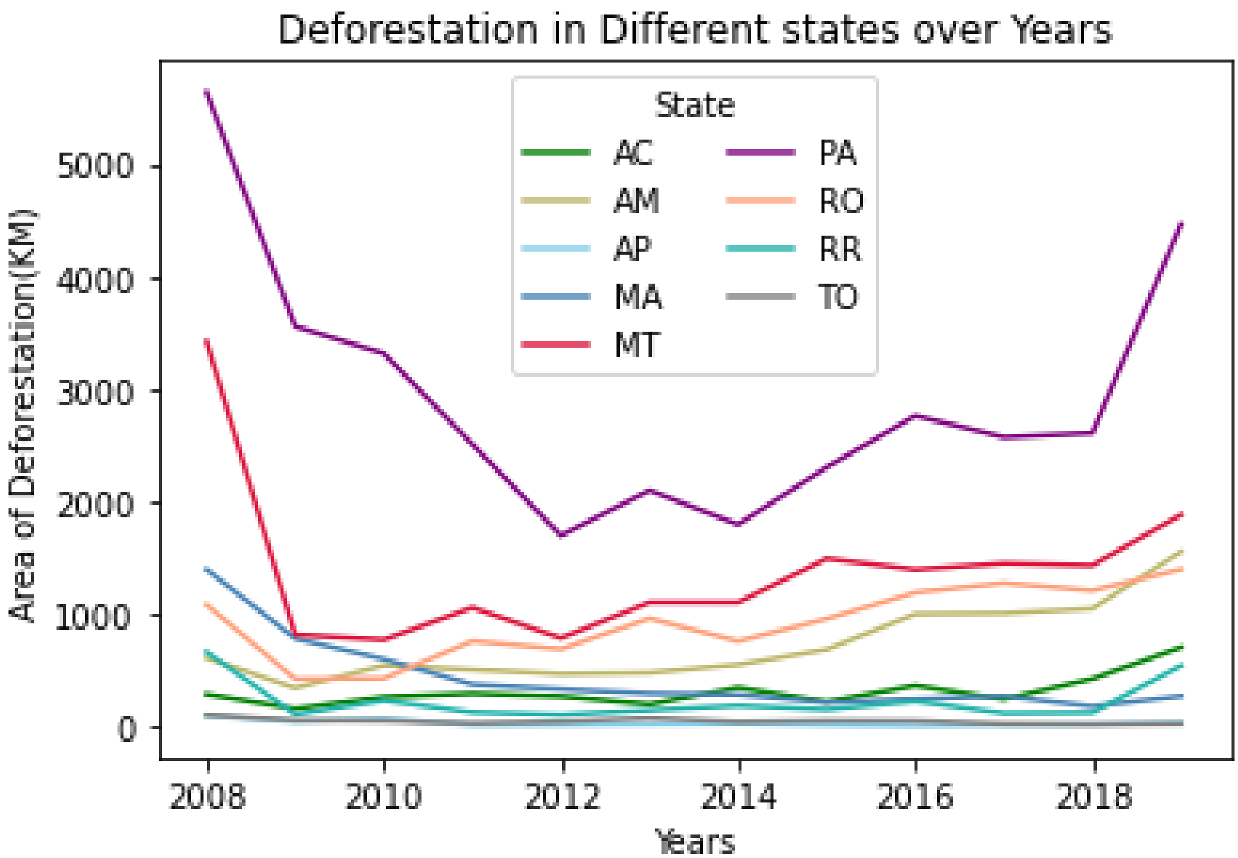

Figure 2: State-level Deforestation of the Legal Amazon over Years 2008-2019

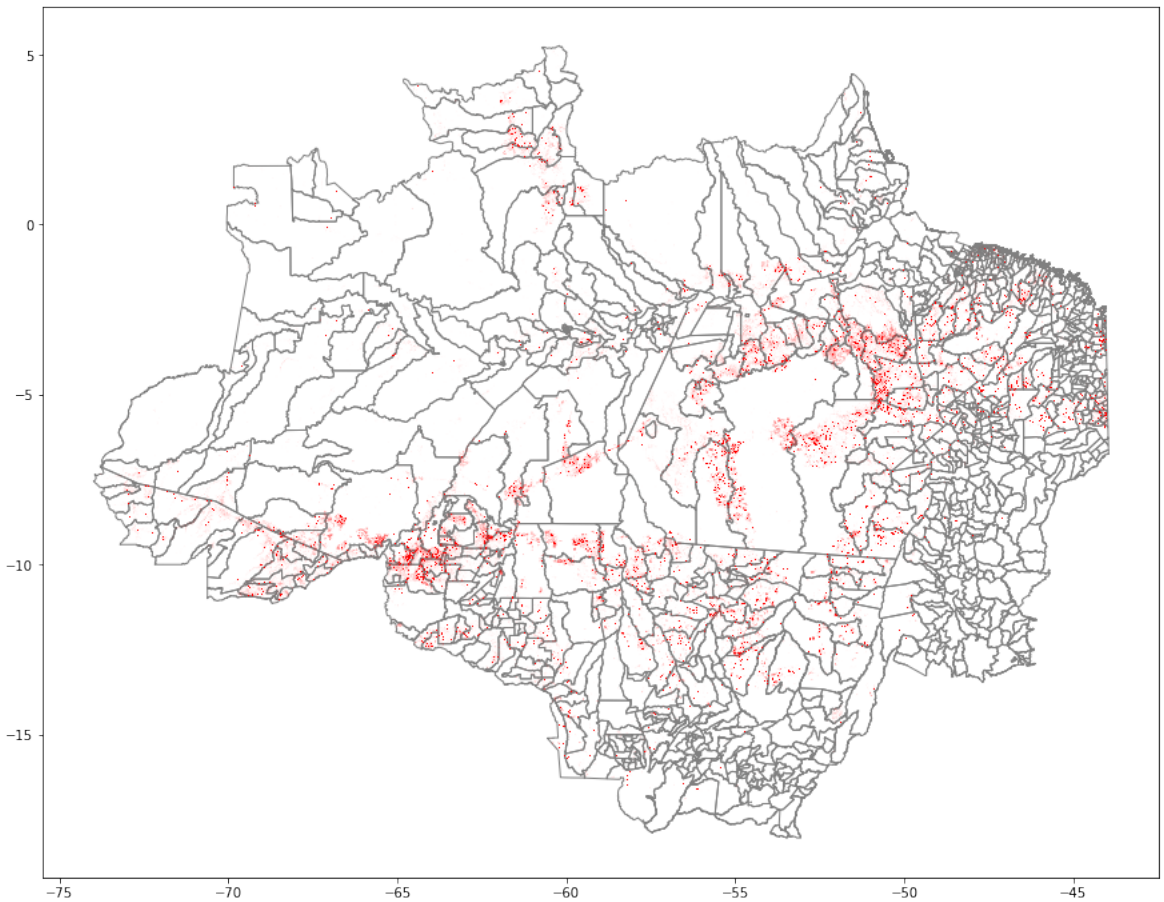

Figure 3: Total Deforestation (area km) of the Legal Amazon in 2009-2009

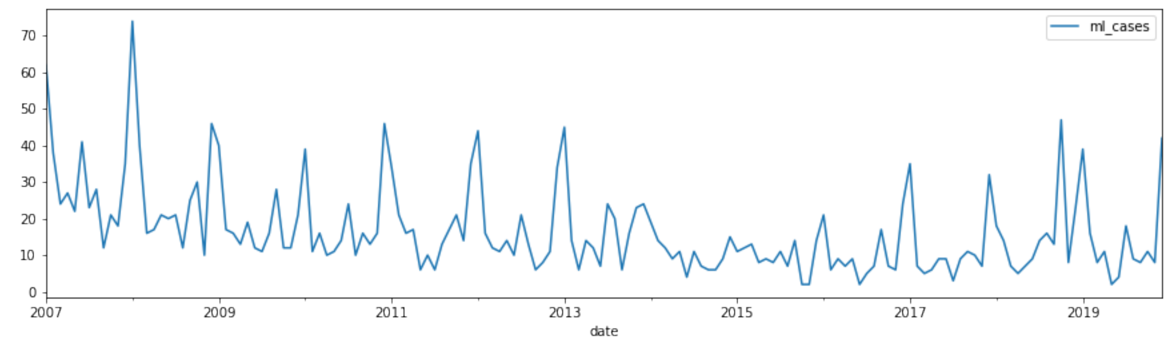

Figure 4: Malaria cases by date

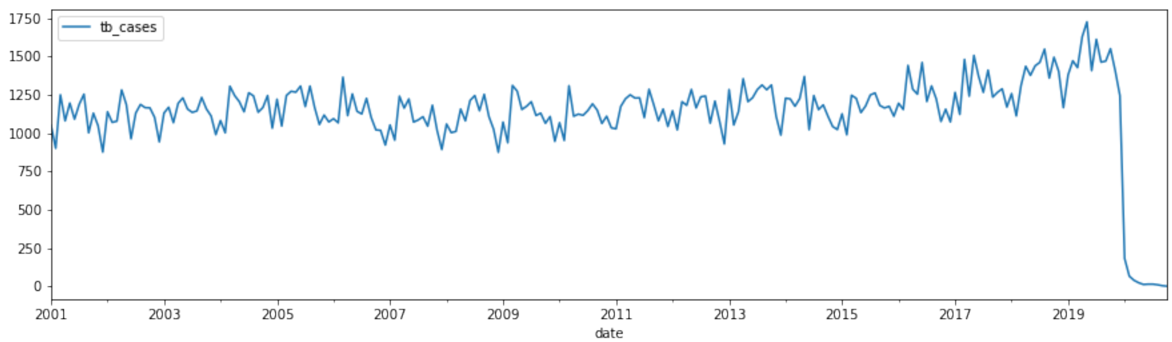

Figure 5: Tuberculosis cases by date

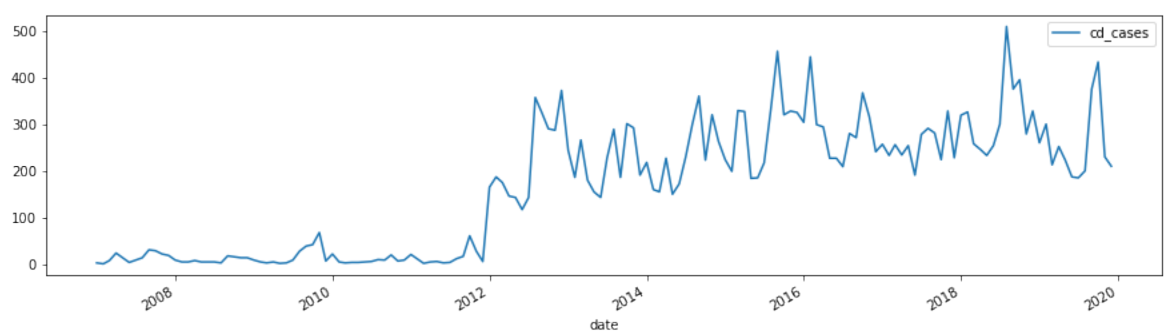

Figure 6: Chagas Disease cases by date

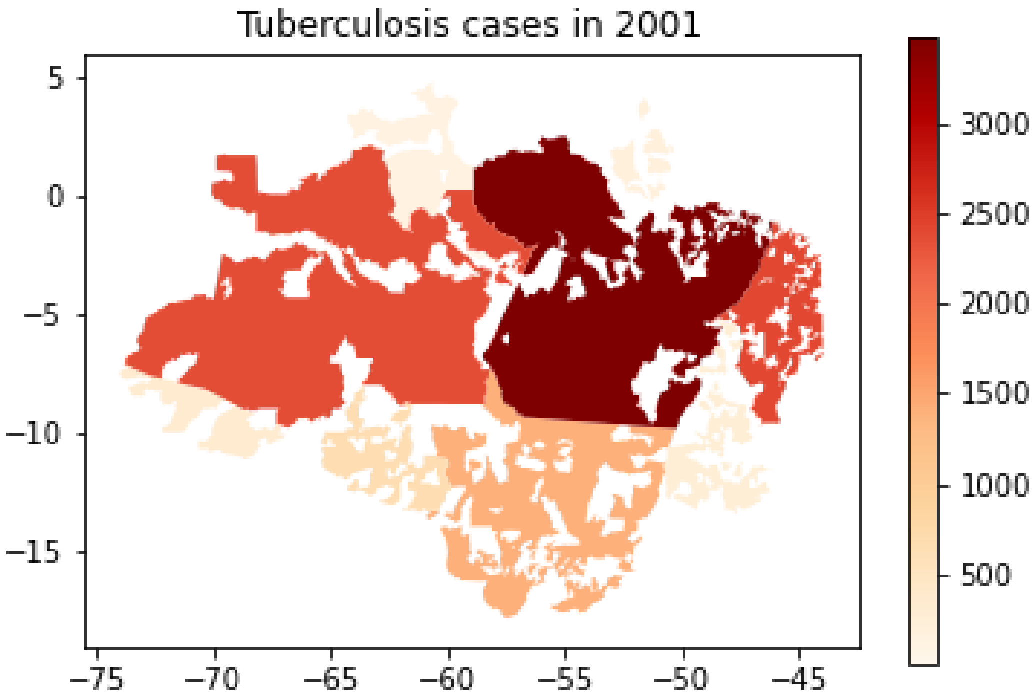

Figure 7: Tuberculosis cases - 2001

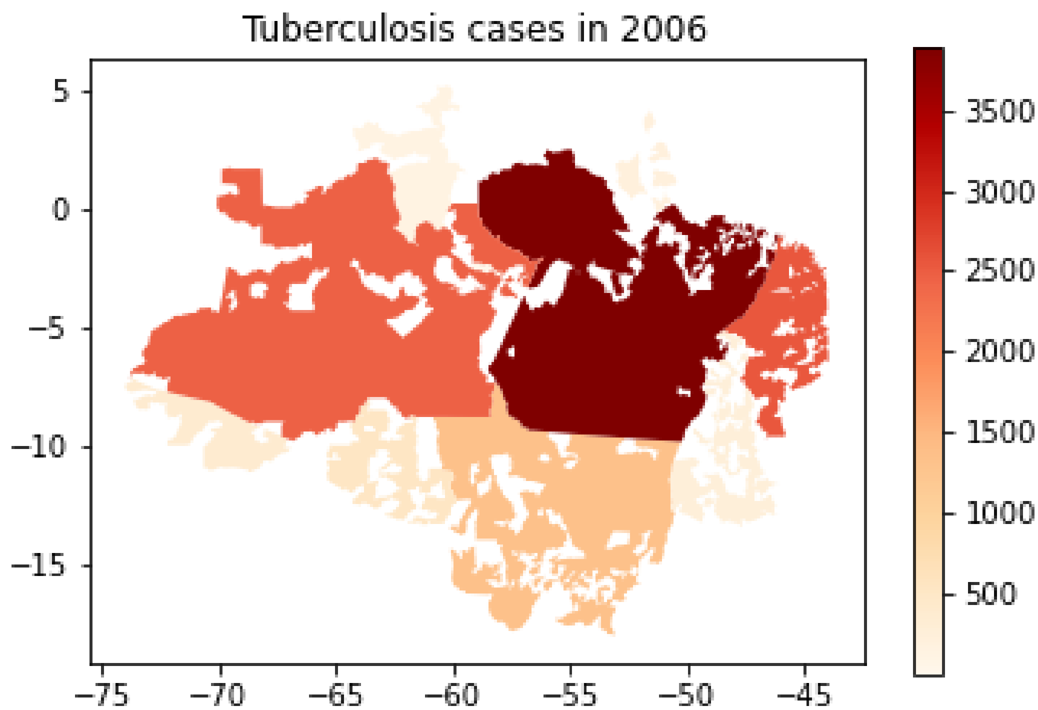

Figure 8: Tuberculosis cases - 2006

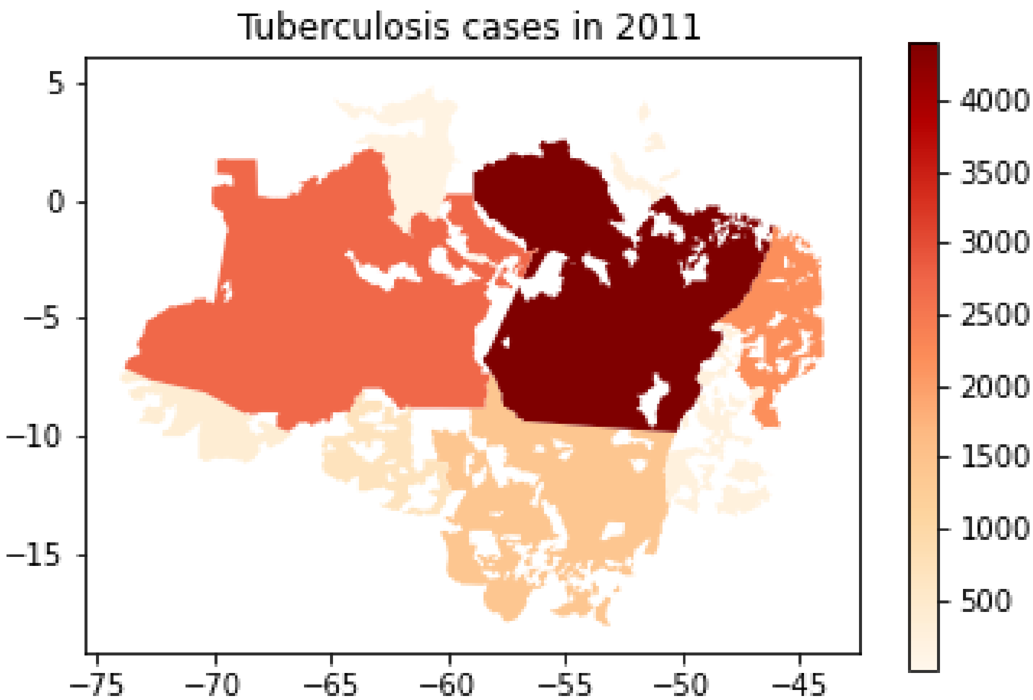

Figure 9: Tuberculosis cases - 2011

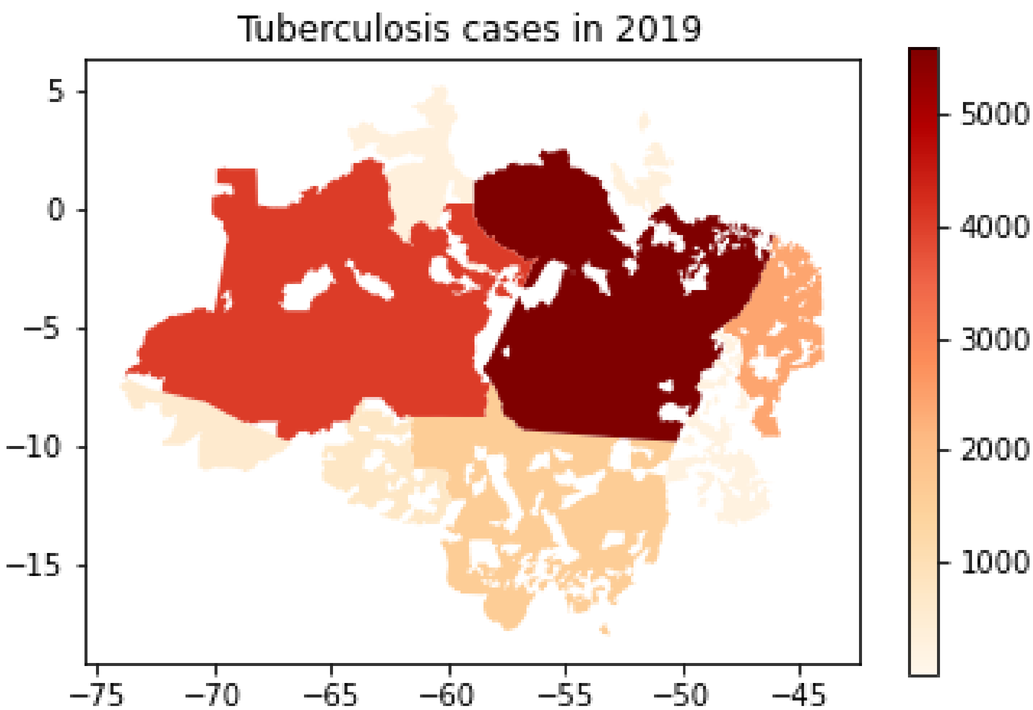

Figure 10: Tuberculosis cases - 2019

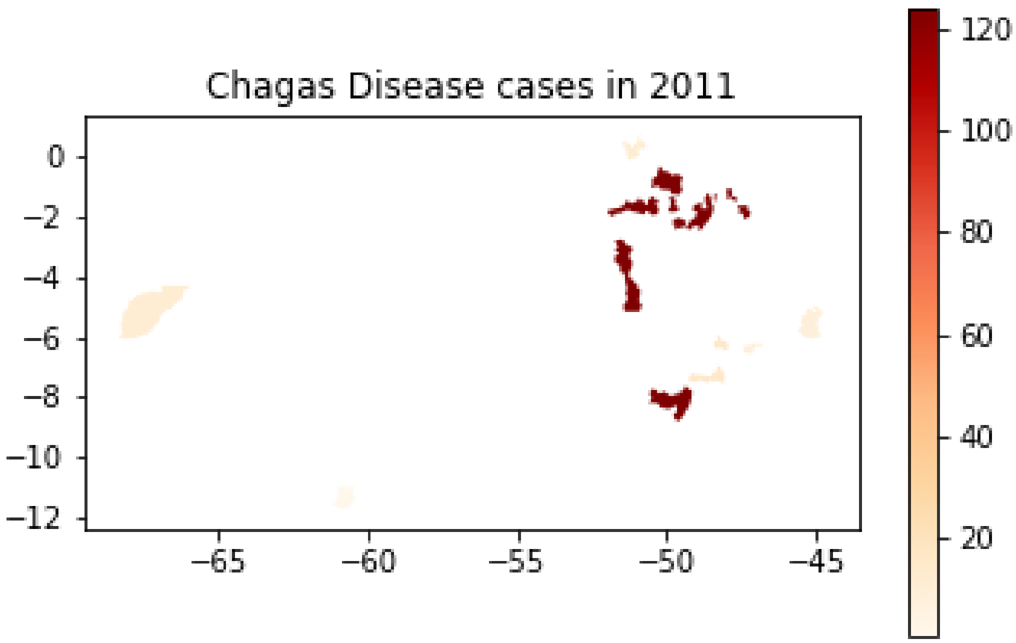

Figure 11: Chagas Disease cases - 2011

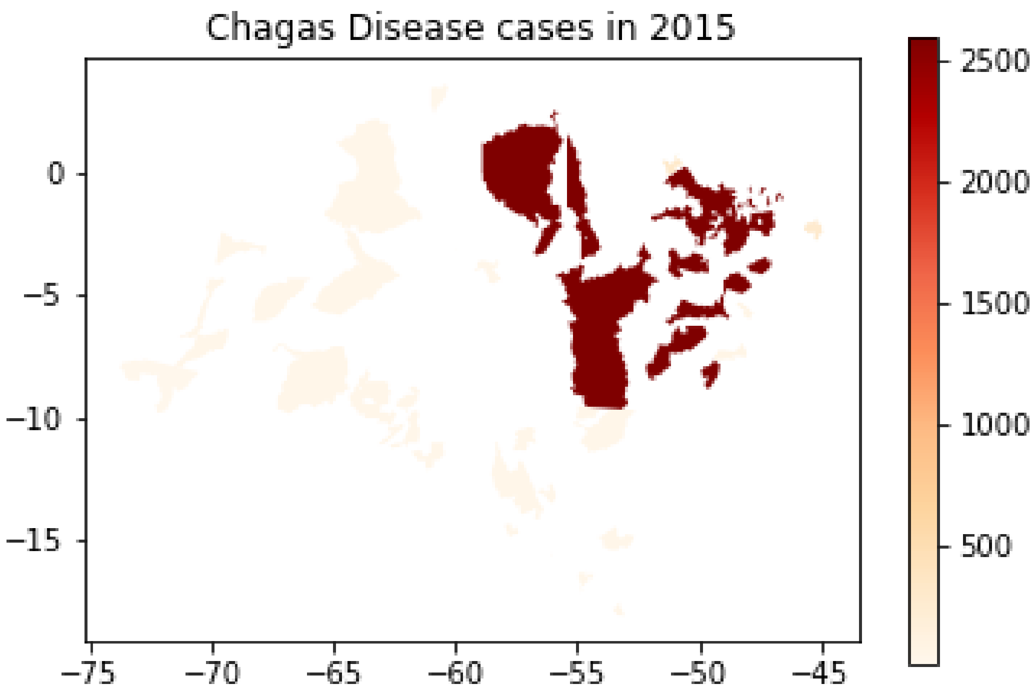

Figure 12: Chagas Disease cases - 2015

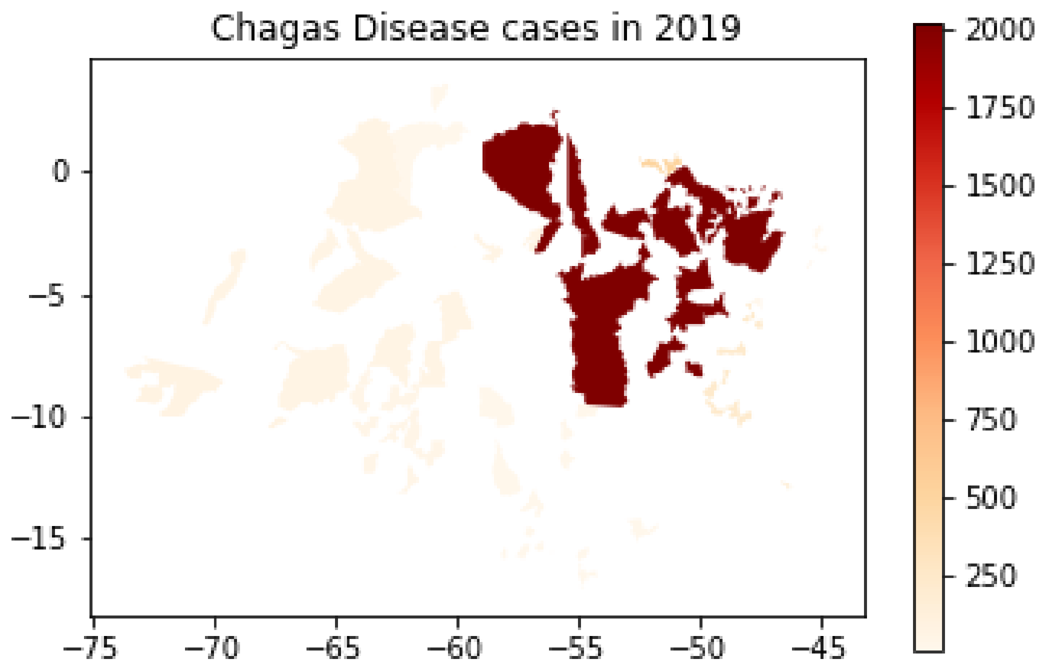

Figure 13: Chagas Disease cases - 2019

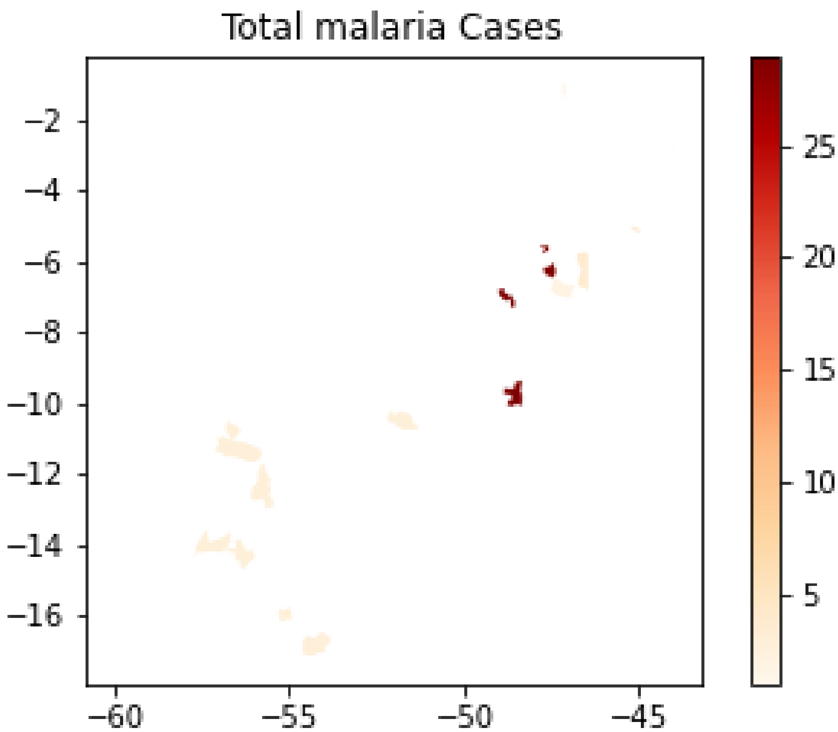

Figure 14: Total Malaria Cases