FIRE IN BRAZILIAN BIOMES IN THE FACE OF EMISSIONS AND INTERNATIONAL AGREEMENT

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ABSTRACT

Brazil is one biggest emitters of greenhouse gases (GHGs). Fire foci across the country compromises emission reduction targets pledged under the Paris Agreement. In this paper, we quantify fire foci, and carbon emissions in all Brazilian biomes. We analyzed these variables using cluster analysis and non-parametric statistics to predict carbon and CO_2 emissions for the next decade. Our results showed the highest emissions occur and will persist in the Amazon and Cerrado biomes. The other biomes have low emissions in relation to these. Based on 2030 projections, the sum of emissions from fire foci in the six Brazilian biomes will exceed 5.7 Gt CO_2, compromising the national GHG reduction targets. To reduce emissions, Brazil will need control deforestation induced by the expansion of the agricultural frontier in the Amazon and Cerrado biomes. This can only be achieved through signifcant political efort involving the government, entrepreneurs and society as a collective.

Key words *— Paris Agreement, fire, trend, deforestation, agricultural frontier.*

1. INTRODUCTION

The 2015 Paris Agreement was the result of a worldwide efort to combat global warming. It came into effect in 2016 and Brazil committed to a target of reducing its greenhouse gas (GHG) emissions to 43% of its 2005 level by 2030 [1]. At the time, Brazil presented promising results in terms of reducing deforestation in the legal Amazon area by 67.35% (from 19,014 km^2 in 2005 to 6207 km^2 in 2015). However, since this time, the situation has rapidly evolved; from 2018 to 2019, deforestation in this region has increased by 30% (from 7536 to 9762 km^2) [2]. As such, Brazil still remains the seventh biggest emitter of GHGs in the world with 1939 billion gross tons of GHGs emitted in 2018 [3]. Of these emissions, 69% were due to land use changes, particularly relating to agriculture and deforestation [3]; the Amazon and Cerrado biomes experienced the highest rates of deforestation. With deforestation comes the occurrence of fires, considered the cheapest and most effective way to clean up deforested areas or to clean up degraded areas, and are widely practiced throughout the country. Fires in Brazil are mostly of anthropogenic origin and affect the distribution of ecosystems, compromising the reproduction and survivability of plant and animal species [4], in addition to its impacts on the carbon cycle and global climate [5].

Brazil has already shown that it is possible to reduce deforestation and its GHG emissions [6]. However, the synergies between new environmental policies [7] and the return of deforestation, numerous fires and the extreme climate-related events that may occur, threaten to compromise the country's GHG emission reduction commitments under the Paris Agreement. In this paper, we quantify fire foci and their emissions in all Brazilian biomes between 1999 and 2018, and present future emissions projections for 2030. This study aims to address some key questions: (i) do fire foci have a direct relationship with CO_2 emissions observed in recent years? (ii) what is the contribution of each biome to the total Brazilian GHG emissions? (iii) what is the projected GHG emissions in 2030 with the implementation of current environmental policies? (iv) what are the key biomes in Brazil that need to reduce their emissions in order to achieve the emission reduction targets as per the 2015 Paris Agreement?

2. MATERIAL AND METHODS

The monthly data on fire foci and carbon emissions was acquired between 1999 and 2018. Fire foci data were calculated using the MODIS sensor product MCD14DL (TERRA/AQUA). Data were downloaded directly from

FIRMS (https://frms.modaps.eosdis.nasa.gov/) and arranged in the shapefle format (https://earthdata.nasa.gov/active-fre-data). The FIRMS fire map enables interactive browsing of the full archive of global active fire detections from MODIS and Visible Infrared Imaging Radiometer Suite (VIIRS). Near real-time fire data was available within approximately 3 h of the satellite overpass and imagery was available within 4–5 h. The same data generated from Terra/Aqua for fire foci was used from the Brazilian fires database [8].

This product provides carbon emissions at a 0.25° spatial resolution and categorizes emissions by the types of fire to calculate gas traces using emission factors (https://www.globalfredata.org/). All of these datasets are based on burned areas driven by a small burned area. Emissions were computed at a monthly temporal resolution and released at this time, as well as a day cycle based on Mu et al.[9].

The ARIMA model was used to predict expected probable carbon emissions and the number of fire foci for 2019–2030 was based on a number of changes from the 1999–2018 data time series, representing carbon emissions and fire foci (number). ARIMA modeling has been considered a robust model used in numerous scientific fields, in an attempt to predict the future of numerous input variables [10].

Boxplot graphics were constructed for the fire foci and carbon emissions data associated with biomes on a monthly scale. Statistical analysis was based on the Mann–Kendall test (MK) [[11],[12]] in order to identify significant trends in annual fire foci and carbon emissions.

Cluster analysis (CA) was applied to identify biomes with homogeneous distribution of fire foci and carbon emissions overtime [13].

All analyses in this study were carried out using R version 3.4.3 sofware [14], utilizing the following packages; ggplot2, trend, Kendall and factoExtra.

3. RESULTS

Between 1999 and 2018, 16,141,383 fire foci were detected across Brazil; the most affected biomes were the Cerrado and Amazon which constituted 41.56% and 38.34% of total fire foci, respectively. In addition, both biomes consisted of similar seasonal patterns with fire peaks from June to September. Approximately 9.89% of fires occurred in the Atlantic Forest, largely between January and April. Of the total fire foci, 5.94% were located in the Caatinga biome, especially in November and December. The biomes with the least number of fire foci were the Pantanal and Pampa biomes accounting for 3.83% and 0.44% of the total, respectively. Regardless of the month and biome, outliers were also present in the time series.

Fires in all Brazilian biomes produced of 8089.17 Tg of carbon emissions between 1999 and 2018. Most emissions originated from the Amazon (60.71%) and Cerrado biomes (32.04%), whilst the contribution from other biomes was less than 3% each. The highest monthly carbon emissions were measured in the Amazon, although the Cerrado also had significant emissions between April and October.

Until 2009, the annual evolution of fire foci occurred most frequently in the Amazon (Fig. 1). However, from 2010 onwards, the situation evolved as a significant number of fires were located in the Cerrado. Regardless, the Amazon continued to be the main source of carbon emissions.

The Man-Kendall test highlighted a significant upward trend in fire foci for the Atlantic Forest, Cerrado, Pantanal and Pampa biomes. The Pettitt test identified turning points in the fire foci patterns for the Atlantic Forest, Cerrado and Pampa biomes in 2009, 2009 and 2011, respectively.

The cluster analysis in Fig. 2, shows the formation of two homogeneous groups; the first containing the Amazon and Cerrado biomes, and the second containing the Atlantic Forest, Caatinga, Pantanal and Pampa.

Despite these poor correlations for some biomes, regression analysis showed the positive linear correlation of an increase in fire foci and carbon emissions across all biomes.

The largest and most significant error was associated with the Amazon with carbon emissions of 8.04 Tg. The predictions indicate that carbon emissions will increase in the Amazon and Cerrado. From 2019 to 2030, the highest emissions for the Amazon and Cerrado are projected to occur in September, with values exceeding 33 and 21 Tg, respectively (Fig. 3, 4). The lowest emissions are predicted to occur in Caatinga, Pampa and Pantanal.

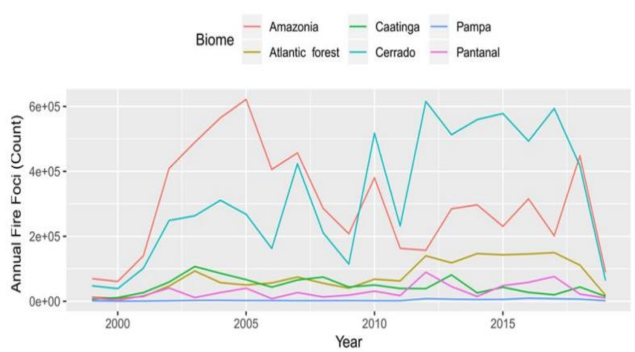

Figure 1. Annual evoluation of fire foci in differents biomes.

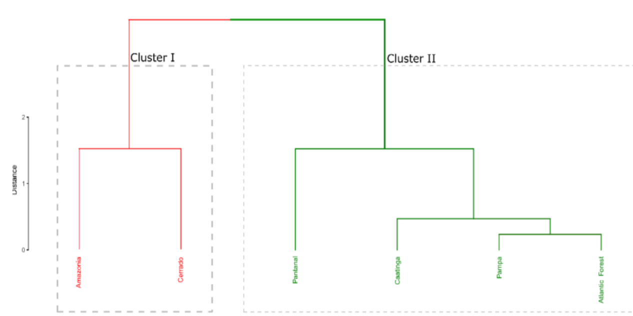

Figure 2. Cluster analysis applied to Brazilian biomes using annual carbon emission and fire foci.

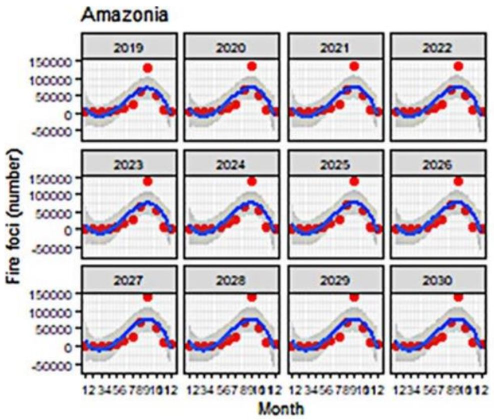

Figure 3. ARIMA modeling and validation for fire foci in the Amazon biome.

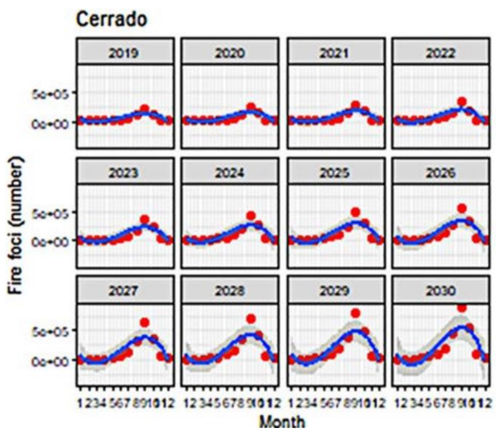

Figure 4. ARIMA modeling and validation for fire foci in the Cerrado biome.

4. DISCUSSION

Only 7.6% of Brazil's total land mass (approximately 8,511,000 km2) is utilized for agriculture to cultivate major crops such as soybean, corn, cotton, sugarcane and irrigated rice [15], as well as agriculture for extensive cattle ranching [16]. Brazil benefits from diverse soil and climatic conditions that are distributed among the six biomes. These biomes are prone to accidental fires and those that may occur as a result of inappropriate management practices [16].

In this study, fires and carbon emissions (atmospheric CO_2) measured between 1999 and 2018 predominately originate from the Amazon.

It is also important to consider the size of the affected area where an increase in fires is associated with coverage and a portion of the Amazon in Brazilian territory (greater than 49%). In a study on fires in Brazil, Caúla et al.[17] analyzed the relationship between the number of fires and the burned area. They concluded that the burned area does not always reflect the concentration of fires when area density and fire foci are used. Researchers have also observed an increase in the number of fires during winter and spring, consistent with the findings from this study.

The acceleration of deforestation in the Amazon is associated with human activities and agricultural expansion in this region. Deforestation due to human activities highlights the concern for future generations regarding atmospheric carbon emissions [18]. As the Amazon possesses the largest national-territorial portion, there were higher carbon emissions throughout the time series this is a major concern for high atmospheric carbon concentrations. In this study, 2007 had the highest carbon emissions, whilst Aragão et al. [18] found that the highest emissions occurred during the 2015 dry season. This difference may be associated with the territorial portion that was used.

Studies in the Amazon, such as Fonseca et al. [15], where future scenarios Representative Concentration Pathway (RCPs) were used, found a significant increase in the probability of fire in the Amazon, occurring mainly in October.

The anthropogenic causes of fires in Cerrado may be attributed to cattle raising, where burning is a practice to restore pastures. In a study aiming to estimate GHG emissions from cattle raising in Brazil, Bustamante et al. [19] reported that 36.8% of Brazil's pastures are located in Cerrado (546,250.9 km2). They also verified that approximately 50% (1.69 Mt CO_2 eq) of total CO_2 emissions for pasture management in Brazil occurred in this biome.

5. CONCLUSION

In the Paris Agreement, Brazil committed to reducing its emissions from 2.1 Gt CO_2 eq in 2005 to 1.2 Gt CO_2 eq by 2030. To achieve this goal, the country has established a series of targets, including zero illegal deforestation in the Amazon by 2030 [1]. When it signed the agreement, Brazil was in a place of confidently being able to achieve these targets, demonstrating a 67.35% reduction in the deforestation rates for the legal Amazon (from 19,014 km^2 in 2005 to 6207 km^2 in 2015).

However, in 2019 there was a 30% increase in deforestation compared to 2018 (7536 to 9762 km^2) [2]. This recent increase in deforestation may be attributed to the environmental policies adopted by the new Brazilian government; these policies have promoted a dismantling of the inspection agencies which ultimately enables the occupation and exploitation of the Amazon [7].

The modeling projects that the total gross emissions from all Brazilian biomes will be 5.7 Gt CO_2 in 2030 and, more importantly, it shows no signs of decrease throughout the decade. A decrease is required for Brazil to at least approach the emission reduction commitments under the Paris Agreement

All these factors relating to climate phenomena are counterproductive to Brazil's success in reaching its emissions reduction commitments. When we analyze the percentage of emissions attributable to "Land and Forest Use Change" in relation to total Brazilian emissions, we observed that between 2005 and 2018, this component was responsible for 50.15% of emissions [3]. As such, land use changes would be the most promising sector for the Brazilian government to invest in order to reduce its emissions to meet the Paris Agreement commitments.

Mitigating the impact of these new policies will depend on a new approach by the Brazilian government to address deforestation in agricultural frontier areas. Politicians, entrepreneurs and society as a collective need to engage in a major debate on the directions the country needs to take in order to address the existing issue of Brazil being one of the greatest global GHG emitters.

6. REFERENCES

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