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Influence of the COVID-19 pandemic on the concentration of aerosols observed over the Brazilian territory

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ABSTRACT
Due to the emergence of a new variant of viruses belonging to the family of coronaviruses, SARS-CoV-2, or COVID-19, still unknown to the scientific community and with great power of contagion and dissemination, several countries around the world have been forced to adopt measures of social restrictions, such as lockdown. As a result of the reduction in the circulation of people and transport, as well as in industrial activities, improvements in air quality were observed in several countries. Thus, with the objective of verifying the influence of the pandemic on the concentration of aerosols in the Brazilian atmosphere, this study carried out a bibliographic survey on the subject, and generated monthly maps of aerosol concentration in Brazil, in the years 2019 and 2020, for comparative purposes. As a result, it was observed that the restriction measures adopted had a positive effect on air quality, mainly in the South and Southeast regions of the country, where the largest population concentrations, vehicle fleets and industrial groups are located. In contrast, higher rates of aerosols were observed in the Brazilian Amazon, coinciding with the period of and occurrence of fires in this region related to slash-and-burn agriculture, which may explain the fact. Air pollution, as well as the accumulation of particles resulting from forest fires, aggravates the occurrence of respiratory problems, which can lead to more people being hospitalized, compromising the capacity of health systems.

KEYWORDS: Air pollution. Concentration of atmospheric aerosols. Forest fires.

1 INTRODUCTION

In December 2019, in the city of Wuhan (China), the emergence of a new virus belonging to the family of coronaviruses was detected, a family that includes other respiratory syndromes, such as the Severe Acute Respiratory Syndrome (SARS-CoV) and the Middle East Respiratory Syndrome (MERS-CoV). This new variant of the disease became known as Coronavirus Disease 2019 (SARS-CoV-2), or COVID-19. Since then, numerous cases have emerged in several other countries on the Asian continent, such as Thailand, Japan, South Korea and Singapore. In a short time, new cases were reported on the European continent, which became the new epicenter of the disease, and on the other continents, leading the World Health Organization to declare, on March 11th, 2020, a COVID-19 pandemic (AQUINO *et al*., 2020; LONE & AHMAD, 2020).

Due to the speed with which it spread, the little knowledge about this new variant and the inexistence of vaccines or scientifically proven treatments to fight the new virus, several countries chose to adopt measures of social distancing in order to slow down the spread of the disease. In more serious cases, some of them have adopted the lockdown regime, a restriction policy directed towards the community, in which the authorities of a particular city, region or country establish stricter measures of restrictions, such as the prohibition of events that may generate agglomeration of people, restrictions on the movement of people and on the use of public transport, as well as the reduction or interruption of commercial and industrial activities, keeping open only those considered essential (KUPFERSCHMIDT & COHEN, 2020; WILDER-SMITH & FREEDMAN, 2020).

Thus, a drop of up to 90% in the mobility of people in all parts of the world was observed, with the “Home Office”, or remote work, being increasingly encouraged (MUHAMMAD; LONG; SALMAN, 2020). Table 1 is the product of a survey on population displacement rates in different parts of the world, between the months of February and April 2020, when most countries implemented the lockdown.

Table 1 – Mobility index in several countries around the world, resulting from the COVID-19 pandemic

Country	Transports	Markets and Pharmacies	Leisure and Miscellaneous	Work	Parks and Walks	Residential
United States	-54%	-20%	-49%	-40%	-20%	+13%
Spain	-89%	-77%	-94%	-68%	-90%	+23%
Italy	-86%	-82%	-95%	-62%	-90%	+24%
France	-82%	-62%	-85%	-53%	-73%	+17%
Germany	-47%	-13%	-58%	-30%	-61%	+8%
United Kingdom	-70%	-41%	-82%	-54%	-29%	+15%

Source: Adapted from Muhammad; Long; Salman (2020).

Table 1 clearly shows the effects of the pandemic in these countries. Transport, in general, has dropped considerably, especially in European countries such as Spain, Italy and France, where the effects of the pandemic were felt quickly and took on catastrophic proportions. On the other hand, while mobility indices were negative for all countries surveyed, the residential index was the only one to show a positive balance, indicating that, during the period studied, more people remained at home.

As a result, a considerable drop in the concentrations of some air pollutants have been observed in different parts of the world. In Europe, NO_2 concentrations in 2020 have fallen by about 50% when compared to the same period in 2019 (ESA, 2020). In Wuhan, where the pandemic erupted, reductions of up to 30% have been observed in atmospheric CO_2 concentration (NASA, 2020). In the United States, research pointed to significant reductions in CO, NO_2, SO_2 and particulate matter ($MP_{2,5}$ and MP_{10}) during the lockdown period, when compared to the same period in 2019 (ESPEJO *et al*., 2020; SHAKOOR *et al*., 2020). In Africa, some countries have also reported improvements in air quality during this period (KHOMSI *et al*., 2020).

In Brazil, discussions took place about the best strategy to face the pandemic: vertical isolation, applied to the sick or people who presented characteristics of the disease; or horizontal isolation (lockdown), which makes no distinction between citizens and, therefore, restrictive measures are applied to everyone, with a halt in displacement flows and non-essential activities. Meanwhile, the number of confirmed cases and the number of deaths grew exponentially, pushing the country into the biggest health crisis in recent times (RIBEIRO; CUSTÓDIO; PRAÇA, 2020; WERNECK & CARVALHO, 2020).

Given this scenario, the Federal District was the first unit of the Brazilian federation to adopt effective measures to control the spread of the virus, on March 11th, 2020, followed by the states of Rio de Janeiro and São Paulo, whose capitals were among the most affected in the country. On March 23rd, 2020, the most restrictive measures were applied in most Brazilian states, reaching 25 of the 27 federative units (SILVA *et al*., 2020). As in other countries, in Brazil, the effects of the reduction in activities that emit air pollutants were also reflected in improvements in air quality.

According to the Environmental Company of the State of São Paulo (CETESB), a significant drop was registered in the concentrations of several atmospheric pollutants during the lockdown period, with emphasis on the drop in the CO indices, which went from 9 ppm to just 1 ppm (CETESB, 2020). In Rio de Janeiro, the State Institute for the Environment (INEA)

assessed the impacts of contingency measures on air quality in the Metropolitan Region of Rio de Janeiro and noted that, during the quarantine period, NO_2 concentrations fell by 80% in some monitoring stations, when compared to the period before the adoption of restrictive measures (INEA, 2020).

As can be seen, many studies have been carried out in Brazil and in the world, relating the effects of the pandemic and the consequent restrictions imposed with the effects on the concentrations of different pollutants, such as NO_2, CO_2, CO, SO_2, particulate material ($MP_{2,5}$ and MP_{10}), among others. On the other hand, another important way to assess the pollution resulting from industrialization processes, especially in the automobile and construction industries, which considerably increase the particles in the air, is by measuring the concentration of aerosols present in the atmosphere (DE SOUZA; DA SILVA SANTOS; CALDIN, 2017).

Aerosols are solid particles in suspension or droplets dispersed in a gas with dimensions less than 100 µm. They can originate from natural sources such as desert dust, sea salt and volcano ash; or from anthropogenic sources, such as burning fossil fuels (coal and oil) vehicular emissions, energy production or even through the burning of vegetation (biomass). Aerosols contribute to the cooling of the Earth's surface by causing the scattering and reflection of sunlight (ALVES, 2005).

2 OBJECTIVE

The present study aims to evaluate the effects of the COVID-19 pandemic on the concentration of aerosols present in the Brazilian atmosphere.

3 METHODOLOGY / METHOD OF ANALYSIS

The methodology applied in this study can be divided into three stages: qualitative analysis of information; generation of contamination maps, containing information on the concentration of aerosols; analysis and interpretation of data.

At first, in the qualitative analysis, information was collected about the COVID-19 pandemic, its causes and main effects on air quality, in different parts of the world. For this purpose, several scientific articles published in the last year were used, as well as data provided by important organizations, international agencies or reputable research institutes. In a second moment, maps of the concentration of aerosols for the years 2019 and 2020 were generated, which served as material for this research.

The aerosol concentration maps were generated with images from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor coupled to the Terra satellite, originally known as EOA AM-1, from NASA. This sensor is the one that provides the best estimates regarding the concentrations of aerosols and gases released into the atmosphere (NASA, 2020a). The Terra satellite is programmed to pass the equator to the south in the morning, around 10:30 (NASA, 2020b).

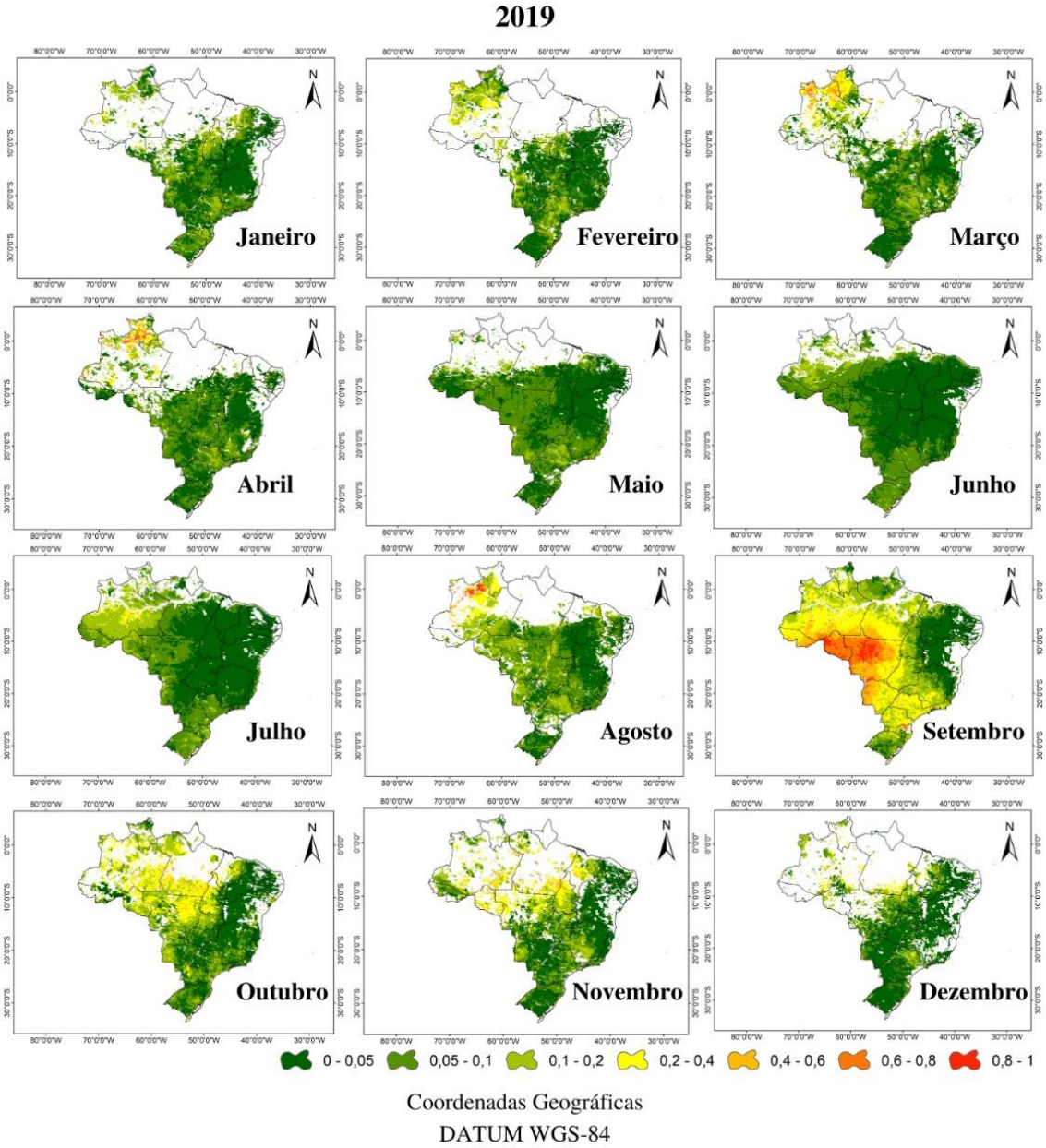
The MODIS algorithm uses spectral reflectance to calculate the concentration of aerosols on the planet (NASA, 2020c). For this analysis, monthly images of the aerosol optical thickness for the years 2019 and 2020 were obtained, which were treated with the aid of the QGis 3.16 software.

Finally, the maps were interpreted and critically analyzed, comparing the results with information present in the literature, historical data and main recent events, in order to seek possible explanations for such results.

4 RESULTS

Figures 1 and 2 show the monthly variation in the concentration of aerosols in Brazil for the years 2019 and 2020, respectively.

Figure 1 – Maps of the monthly variation of aerosol concentration in Brazil, in the year 2019.



Source: The authors (Generated from NASA, 2020a).

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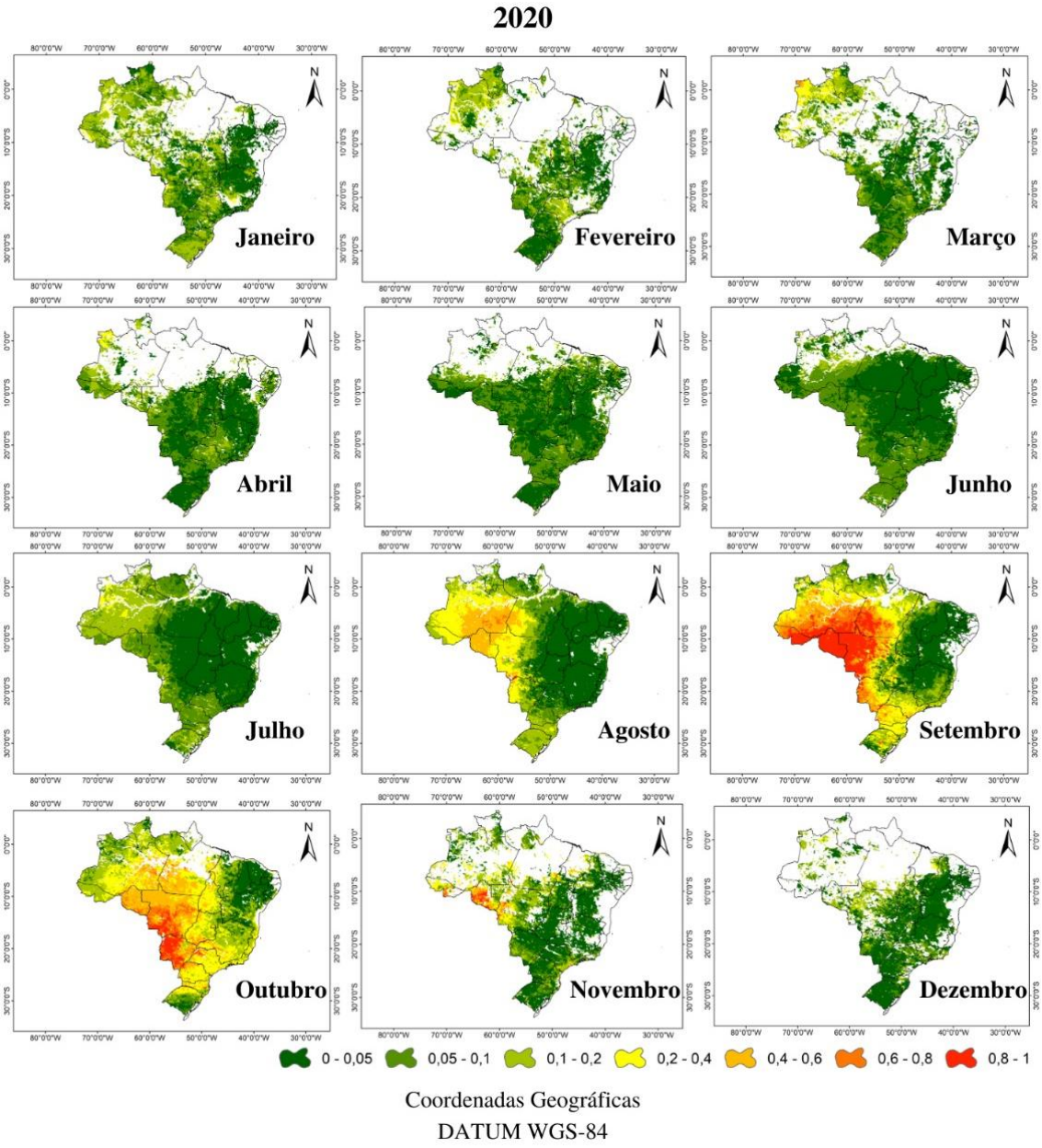
Figure 2 – Maps of the monthly variation of aerosol concentration in Brazil, in the year 2020.



Source: The authors (Generated from NASA, 2020a).

From the images in Figures 1 and 2, it is possible to see that some regions of the map are blank. These regions represent data failures, or data unavailable, due to the sensor not being able to perform the measurements. The colored parts, which include dark green (0 – 0.05), medium green (0.05 – 0.1), light green (0.1 – 0.2), yellow (0.2 – 0.4), medium orange (0.4 – 0.6), orange (0.6 – 0.8) and red (0.8 – 1), represent aerosol concentrations in the Brazilian atmosphere, in a range from 0 to 100%.

As the process of industrial concentration in Brazil allowed 77.3% of industries to establish in the Southeast and South regions of the country (SILVA; FILHO, 2017), according to official data from the latest survey by the National Confederation of Industries, these regions are responsible for contributing approximately 70% of the Brazilian GDP and 74% of the industrial fraction of the indicator (CNI, 2018). Thus, the high industrial activity in both regions

has impacts on air quality, since, in most cases, effective measures aimed at controlling air pollution are not adopted. However, with the restrictions imposed by the COVID-19 pandemic, many activities were reduced or even suspended. In addition, companies have had difficulty in acquiring inputs and raw materials, a factor that also contributes to the weakening of production and hinders the fulfillment of market demands (CNI, 2021).

Industrial Productivity is the index obtained through the ratio between the volume produced and the number of hours worked. Due to the COVID-19 pandemic, the year 2020 was marked by a drop in Industrial Productivity, specifically by 0.6% (CNI, 2020). The first half of 2020 saw a decrease of 7.1% in terms of Industrial Productivity, which then recovered, reaching the average level for the year (CNI, 2020). This drop in productivity may be a determining factor with regard to the reduction in the concentration of aerosols in the Southeast and South Regions of Brazil in August 2020, when compared to the same period in 2019 (Figures 1 and 2). This information may also be evidence of the direct relationship existing between the weakening of industrial activities during the pandemic and the improvement in air quality (CNI, 2021).

Vehicular traffic is a factor that also contributes to the increase in the concentration of pollutants in the atmosphere. With the decrees establishing a quarantine enacted by the states during the pandemic, the circulation of vehicles had a significant drop. The state of São Paulo showed a decrease of up to 40% in the mobility rate in the period between the end of March and April 2020 (FREITAS et al., 2020a). Thus, most monitoring stations in the state recorded a decrease in the concentration of air pollutants (for example, NO_2) compared to the same period in 2019.

FREITAS *et al*. (2020b) also evaluated the concentrations of CO, NO_x, PM_{10} and $PM_{2,5}$ during the quarantine period between March and April 2020, in the Metropolitan Region of São Paulo. The authors found reductions of 25% to 75% in the concentration of pollutants in the first week of confinement. These characteristics may be related to the appearance of lower concentrations of aerosols in the month of April 2020, when compared to April of the previous year, as shown in Figure 3. Through this figure, it is possible to see that the dark green spot is more expressive than that observed in 2019.

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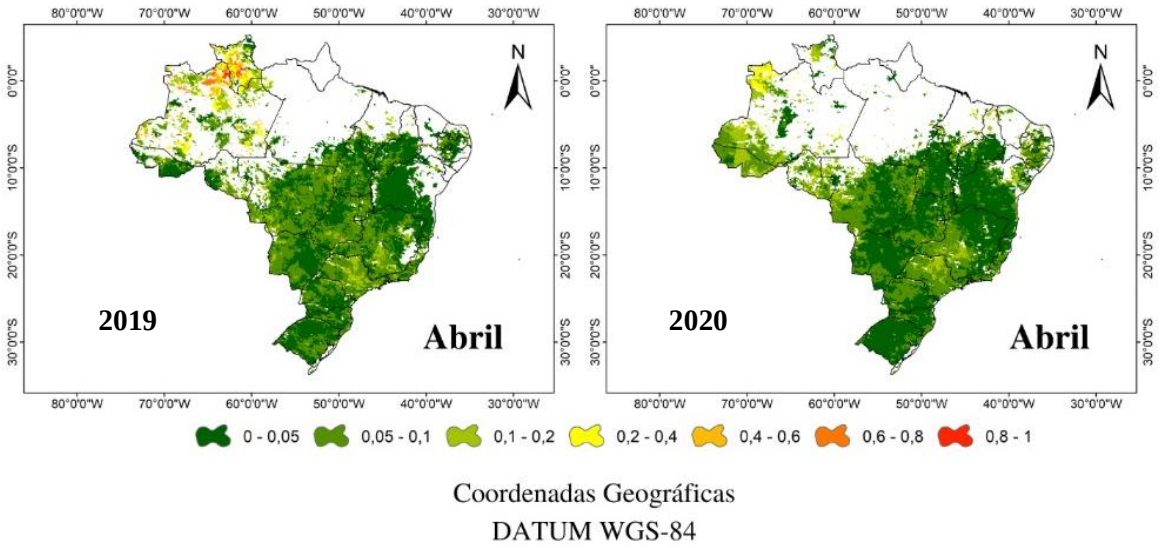
Figure 3 – Comparison between aerosol concentrations in Brazil in the months of April 2019 and April 2020, respectively.



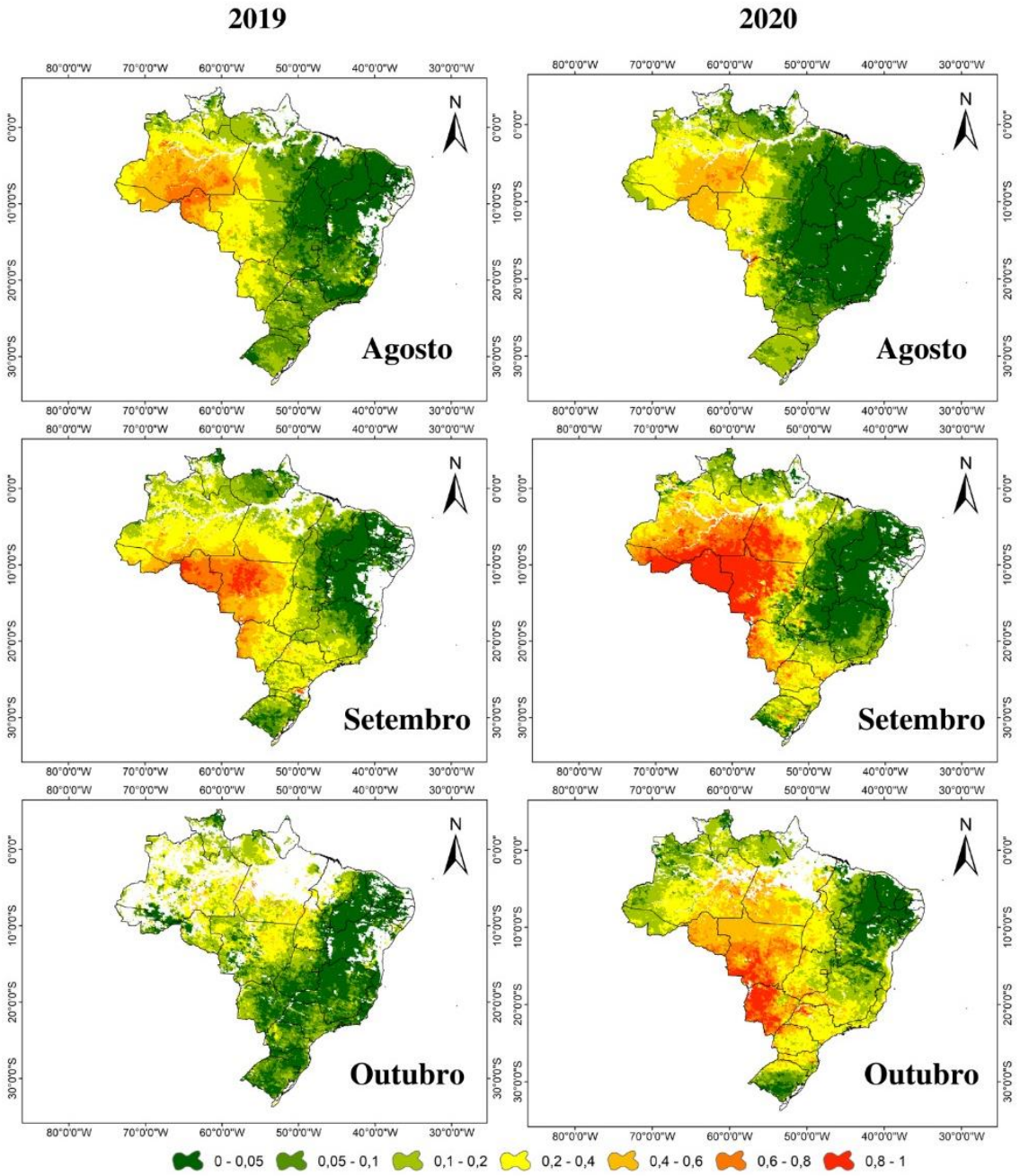
Source: The authors (Generated from NASA, 2020a).

Similar results were found in a study conducted in 367 cities in China during the period of confinement established by the local government (Chen *et al*., 2020). The purpose of the study was to evaluate the impact that the reduction of vehicular traffic had on the improvement of air quality. The pollutants NO_2 and $PM_{2,5}$ were chosen for the analysis because they are directly related to emission from mobile sources. The results found show that, with the practice of isolation measures, the concentrations of NO_2 and $PM_{2.5}$ decreased in all regions evaluated, even in large cities.

The deceleration of activities due to the COVID-19 pandemic contributed to the reduction in the concentration of air pollutants, mainly in large urban centers. According to the WHO, air pollution is responsible for about 4.6 million deaths a year, resulting from complications caused by cardiorespiratory diseases (DUTHEIL; BAKER; NAVEL, 2020). Therefore, with the reduction in pollutant emissions due to confinement, not only deaths caused by the COVID-19 pandemic are being avoided, but also those caused by other illnesses resulting from exposure to poor quality air.

Another fact that stands out in the maps generated is the intense yellow-orange and red spots in the Brazilian Amazon region, especially in the States of Rondônia and part of Amazonas, Pará and Mato Grosso, in the months of August, September and October. As can be seen in Figure 4, there was a considerable increase in the concentration of aerosols in the driest period, especially when comparing the peak, observed in September 2020, with the same period of the previous year. This phenomenon coincides precisely with the period characterized by a greater occurrence of fires in the Brazilian Amazon. According to Aragão *et al*. (2020), more than 80% of fires in the region are the result of deforestation processes, in order to create agricultural areas for planting and raising cattle. These areas normally use fire as a management and cleaning tool for newly deforested spaces.

Figure 4 - Comparison between aerosol concentrations in Brazil in the months of August, September and October 2019 and 2020, respectively.



Source: The authors (Generated from NASA, 2020a).

As can be seen in Figure 4, the concentration of aerosols moves, over the months, to the southernmost part of the map. This phenomenon can be explained through the processes of atmospheric circulation. The dispersion of pollutants is greatly influenced by meteorological conditions, especially the atmospheric circulation. The Earth's atmosphere is dynamic and, as a result, the air can be displaced, both vertically and horizontally, according to physical principles and mechanisms. These mass movement processes, associated with centers of pressure, carry atmospheric pollution over continents and oceans (GONZAGA & FREITAS, 2020). In high

pressure centers, or anticyclones, the atmosphere has great stability and little vertical mixing, therefore, it does not help with dispersion and allows the accumulation of pollutants in that location. Low pressure systems, or cyclonic systems, on the other hand, promote instability of air masses and large turbulence, facilitating the dispersion of pollutants (DAMILANO & JORGE, 2006). According to the National Institute for Space Research (INPE), in October 2020, the continent remained under low pressure, with mass instability, facilitating atmospheric dispersion (INPE, 2020), which may explain the lightening of the pollution spot from September to October 2020.

Therefore, the area affected by this "aerosol particles curtain" may suffer from changes in the rainfall regime, as these particles are capable of influencing the processes of cloud formation (GABARDO; SARZEDAS; SILVA, 2020). In addition, the increase in fires increases air pollution and, statistically, the number of hospitalizations in the health system (SUS) of people with respiratory problems. According to Santiago and Lopes (2021), among the main impacts related to human health resulting from slash-and-burn agriculture processes are the emergence or worsening of respiratory and cardiovascular diseases, in addition to mortality in elderly people, aged over 65 years of age. This scenario becomes even more worrying, since these groups of people are considered at risk for COVID-19, that is, they are more susceptible to suffer the most serious consequences if they contract the virus.

As a result, the concern with fires, especially in this health crisis brought about by the new coronavirus pandemic, should be even greater than that observed in previous years. More stringent measures of restriction should be taken in order to avoid the occurrence of these cases, enabling the health systems to apply greater efforts in the treatment of patients with the new coronavirus. In the United States, for example, where fire is traditionally used to manage pine forests, many fire programs have been interrupted, as public health measures, to control the spread of the virus and in order to minimize the population's exposure to smoke (NASA, 2020d).

5 CONCLUSION

Restriction policies applied to the Brazilian population, as measures to contain the spread of the new coronavirus, positively influenced the air quality, mainly in the South and Southeast regions of the country, where higher population concentrations are observed, as well as more intense traffic of vehicles and a larger grouping of industries. On the other hand, in 2020, more cases of fire were observed in the Brazilian Amazon region, which caused the levels of atmospheric aerosol particles to be the highest observed in recent years, especially when compared to the same period of the year 2019.

Atmospheric pollution, as well as the fires related to the slash-and-burn agriculture in the Amazon region, should receive special attention from government officials, as they aggravate the occurrence of cases of respiratory and cardiac diseases, especially in people who belong to the COVID-19 risk group. The control of these occurrences, through efficient environmental public policies, contributes to the reduction of cases of hospitalization for these diseases, making the Brazilian health system able to receive and treat the most serious cases of patients with the new coronavirus.

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