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AIR QUALITY IN THE COLOMBIAN ANDEAN REGION: BEHAVIOR OF TROPOSPHERIC NO2 FROM SATELLITE DATA

C. H. Oviedo Sanabria[1,✉], J.P. Rojas Suárez[2] and M. Vergel Ortega[3]
[1]Department of Environmental Sciences, Francisco de Paula Santander University,
Cúcuta - 540003, Colombia.
[2]Department of Infrastructure, Roads, Transportation, Hydraulics and Fluids, Francisco de Paula
Santander University, Cúcuta - 540003, Colombia.
[3]Department of Mathematics and Statistics/ Francisco de Paula Santander University,
Cúcuta - 540003, Colombia
✉Corresponding Author: carloshumbertoovsa@ufps.edu.co

ABSTRACT

This study focuses on the analysis of air quality behavior, with a specific focus on tropospheric nitrogen dioxide as a parameter of interest in the Andean region of Colombia. To achieve this analysis, 12 cities in the country were taken as reference points. By processing more than 250,000 images, crucial data were extracted to evaluate the behavior of air quality during the period between 2019 and 2022. The results reveal a counterintuitive behavior, as the city with the most inhabitants is not the one with the highest pollution levels.

Keywords: Air Pollution, Nitrogen Dioxide, Pollution Levels, Sentinel-5P, Tropomi, Colombia and Andean Region.
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INTRODUCTION

Nitrogen dioxide (NO_2) air pollution is a problem that impacts both public health and the environment at a global level, which is why it has been studied in different parts of the world.[1] NO_2 is an air pollutant that can cause skin and eye irritation and have negative effects on respiratory and cardiovascular health.[2] In high concentrations, NO2 can be toxic to the lungs, increasing the risk of heart disease and stroke.[3] For this reason, it is important to take measures to reduce NO2 exposure and protect air quality.[4] Remote sensing and remote sensing are essential tools for understanding air quality around the world.[5] One such example is Sentinel 5P, a European Space Agency (ESA) satellite that measures and monitors air quality around the world.[6] Sentinel 5P is equipped with a high-resolution TROPOMI sensor, which measures the concentration of pollutants in the atmosphere and provides information on air quality.[7] This work aims to analyze the behavior of tropospheric NO2 in the Colombian Andean Region from Sentinel 5P data processed in GEE, addressing the problem of atmospheric pollution.[8] We will use this information to better understand how NO2 air pollution affects the region, and then institutions can take measures to protect health and the environment.[9]

EXPERIMENTAL

Material and Methods

For this study, the behavior of tropospheric NO_2 was evaluated over 4 years in 12 Colombian cities in the Andean region, as shown in Table-1, using the limits of their urban areas as a spatial delimitation, since some municipalities in Colombia have rural territories where industrial and transportation activities are not significant[10], which could influence the final average concentration of the contaminant for each one.

Table-1: Major Cities in the Andean Region and Their Population

	Population			
City	2018	2020	2022	Growth Rate
Armenia	268,445	304,764	345,997	14%
Bogotá	7,166,249	7,743,955	8,368,233	8%

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Bucaramanga	519,111	607,428	710,770	17%
Cali	1,781,388	2,252,616	2,848,497	26%
Cúcuta	607,236	777,106	994,496	28%
Ibagué	469,251	541,101	623,952	15%
Manizales	375,432	446,160	530,213	19%
Medellín	2,332,487	2,533,424	2,751,671	9%
Neiva	294,905	364,408	450,291	24%
Pasto	274,200	392,589	562,094	43%
Pereira	337,149	477,027	674,938	41%
Popayán	230,298	325,477	459,992	41%

Data Source

Daily NO_2 concentration values were captured using Google Earth Engine (GEE) tools using the Sentinel-5P OFFL NO_2[11]: Offline Nitrogen Dioxide dataset. This was carried out to evaluate the Total NO_2 parameter, which is related to the NO_2 slant column density and the total air mass factor. On the other hand, population data and political-spatial boundaries were acquired from the National Administrative Department of Statistics (DANE).

Data Processing

These data were processed to calculate its arithmetic mean, using the Microsoft PowerBi data analysis service. The QGIS tools were used for the spatial representation, which allowed for generating concentration maps for each of the study periods. The data were classified into averages for the cities on a daily, monthly, and yearly basis, which allows for visualization of the times in time when the behavior of the NO2 concentration has undergone significant variations.

RESULTS AND DISCUSSION

Tracking of NO_2 Concentration

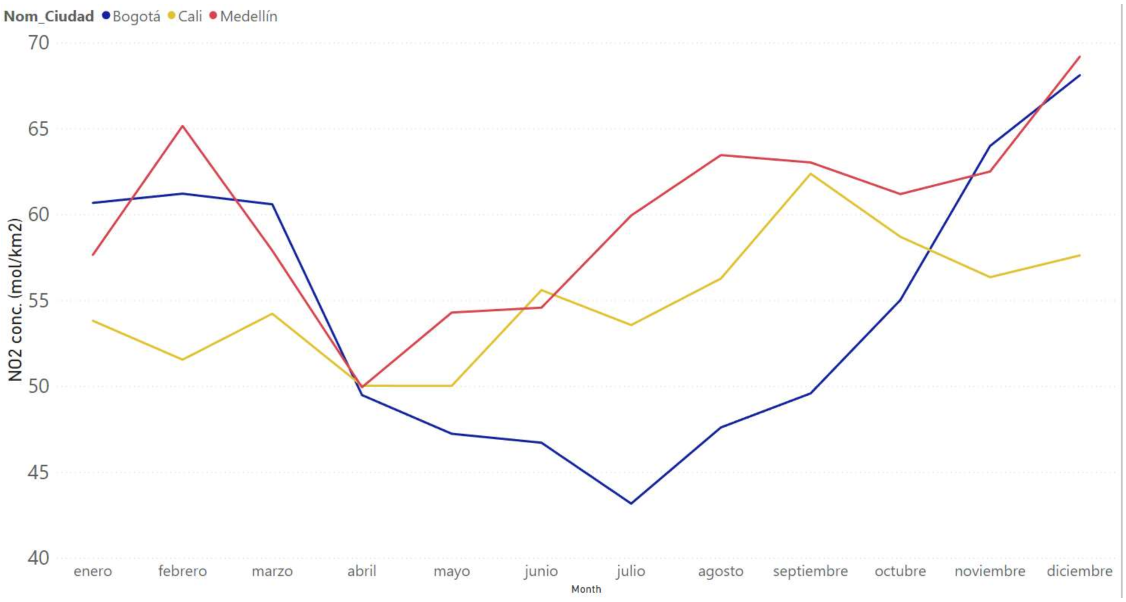
Using the data collected by Sentinel-5p for the study period, we proceeded to calculate and consolidate the arithmetic averages[12] for each of the main cities in the Andean region during the years of interest, as detailed in Table-2. In 75% of the cities, the behavior of NO2 concentration is similar, showing a reduction in 2020 with respect to 2019 and an increase in 2021 compared to 2020. For 100% of the cities, the year 2022 is the one with the highest levels of NO2 concentration, and in 70% of them, the increase in 2022 is greater than 10% with respect to 2019.

Table-2: NO_2 Concentration per City in Four Periods

	Mean NO2 conc. (mol/Km2)			
City	2019	2020	2021	2022
Armenia	42.04	42.30	46.05	46.05
Bogotá	52.69	51.00	52.52	61.58
Bucaramanga	39.91	40.62	43.99	44.29
Cali	53.84	50.04	55.52	60.49
Cúcuta	43.83	43.19	43.68	47.75
Ibagué	39.35	39.03	42.14	44.16
Manizales	42.65	41.47	43.12	44.50
Medellín	60.47	56.07	59.63	63.33
Neiva	35.31	37.22	39.43	41.01
Pasto	31.40	32.33	34.43	35.73
Pereira	42.72	40.93	43.81	45.76
Popayán	32.04	31.75	34.29	37.38

Comparison of the 3 Cities with the Largest Population

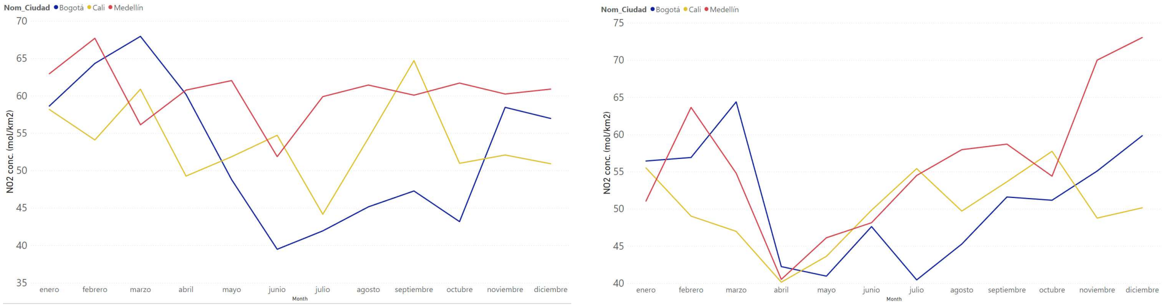
Bogotá as the capital of Colombia is home to a population of about 8 million people, an amount that exceeds the approximately three million inhabitants in the cities of Medellín and Santiago de Cali, respectively. However, as shown in Fig.-1, these cities show a counterintuitive behavior in the periods between April and November, where a marked decrease in NO2 concentration in Bogotá is evident. Only from the year 2022 does Bogotá begin to exceed Medellín concentration levels in a trending manner. This shows that tropospheric NO_2 levels are not only correlated with the number of inhabitants of an urban center but also with the number of people living in the city.



Observation window average behavior

Annual Behavior in 2019

Annual Behavior in 2020



Annual Behavior in 2021

Annual Behavior in 2022

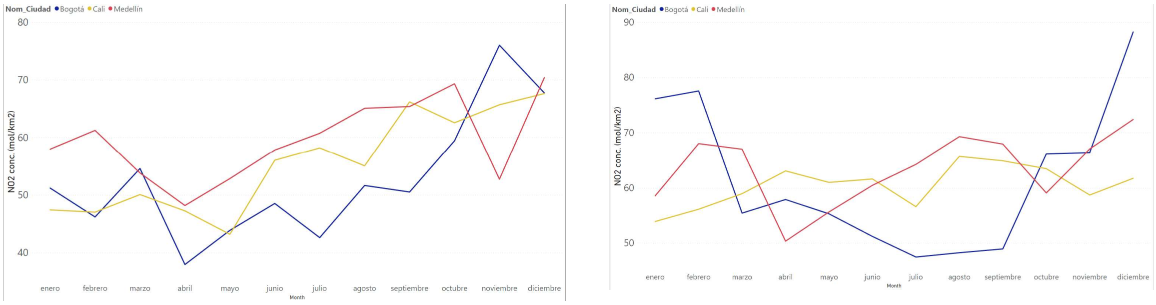


Fig.-1: Monthly Average Concentration of Tropospheric NO_2

Spatial Behavior of the Tropospheric NO_2 Concentration

Spatializing the levels of concentration of a pollutant enables a better understanding of its behavior, especially the places of origin and destination.[13] In the case of Medellín, an intuitive behavior is evident in Fig.-2, which reflects a decrease in NO2 concentration levels in the urban center and a progressive increase following the 2020 lockdowns. Bogotá, on the other hand, shows in Fig.-3 a progressive increase throughout the observation window, and a marked shift from the central zone to the eastern zone, which is related to the main sources of urban emissions and the average behavior of the wind direction.[14]

CONCLUSION

On average, the NO_2 concentration level showed a decrease in 2020, possibly as a result of the confinements caused by the COVID-19 pandemic. However, with the economic reactivation, the region has been registering higher NO_2 levels, even higher than those recorded prior to the pandemic, which highlights the need to increase regulation and control activities for the protection of human health and the environment, especially in cities with important industrial activity, such as Medellín and its metropolitan area. Data captured by Sentinel-5p allows the identification of pollution hotspots and the visualization of contaminant dispersal in the atmosphere, aligned with the average wind regimes in the area of interest.

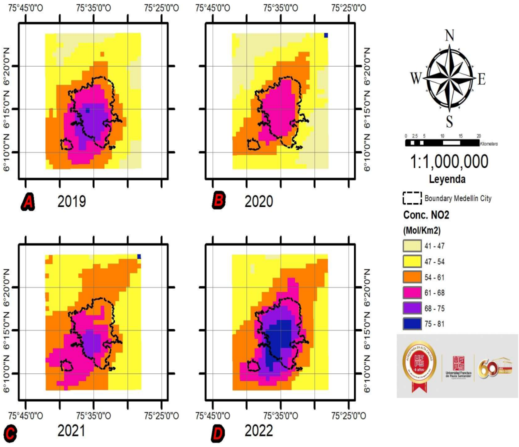


Fig.-2: Spatial Behavior of Tropospheric NO2 in the City of Medellín

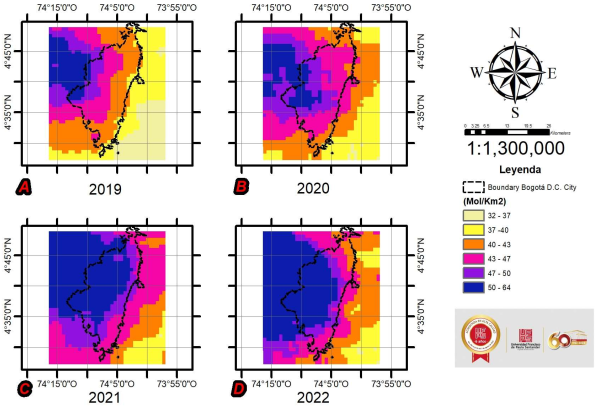


Fig.-3: Spatial Behavior of Tropospheric NO2 in the City of Bogotá de Bogotá

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CONFLICT OF INTERESTS

In the interest of transparency, we affirm that there are no conflicts of interest that could influence the impartiality of this manuscript's publication.

AUTHOR CONTRIBUTIONS

Every author has made substantial contributions to the creation of this manuscript. They have been actively involved in the review and editing processes, ensuring the final version meets the highest standards. The expertise of each author can be ascertained through the ORCID IDs provided below:

C. H. Oviedo Sanabria https://orcid.org/0000-0003-4109-3701
J.P. Rojas Suárez https://orcid.org/0000-0003-2682-9880
M. Vergel Ortega https://orcid.org/0000-0001-8285-2968

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