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Air pollution analysis in Istanbul between January 2019 and April 2022 through remote sensing technology

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Abstract

The need to study air pollution and its connection to human health is no longer a strange idea. Despite the fatalities and illnesses caused by COVID-19, the quarantines significantly decreased air pollution and deaths during this period. Today, satellites can monitor air pollution with great precision, and the research process has quickened, providing professionals with helpful information. This research analyzed six air contaminants using the Sentinel 5P satellite and the Google Earth Engine platform in Istanbul, Turkiye. January 2019 to January 2020, as before COVID—the pandemic period, and January 2020 to April 2022, during and somehow after the pandemic period. The data revealed a notable upward trend in air pollution and pinpointed hot spots. It should be mentioned that the whole city is now affected by different types of air pollution. The issue has been exacerbated in districts like Fatih, bey, and Bayrampasa, where air pollution decreased during COVID's quarantine. Meanwhile, Asian neighborhoods of Istanbul, such as Kadikoy and Uskudar, have been identified as new hotspots where air pollution has also reached severe levels recently.

1. Introduction

Due to industrialization and globalization over the last several decades, air pollution has become one of the world's most significant challenges, threatening many elements of human existence, such as health, and directly influencing and triggering illnesses such as cancer. According to the World Health Organization (WHO), 90% of the world population lives in areas where air pollution exceeds the guideline and 4.2 million people die as a consequence. Air pollution consists of a spectrum of hazardous gases with varying concentrations, reflecting the extent of exposure to these pollutants (Moghimi et al., 2020). The deterioration of public health produces several challenges for communities, including economic concerns and problems with the healthcare system, such as inadequate medical facilities (Kermani et al., 2017).

COVID-19 is a sort of respiratory illness that might not be an exception to the impact of air pollution on diseases. COVID-19 pandemic resulted in extensive quarantines across the globe and also Turkiye, particularly in Istanbul which plays a vital role in the country, from the perspective of tourism attraction to industry and education. The first case of COVID patient was recorded in Turkiye on March 10, 2020, and it reached its first peak in April 2020 with more than 37000 daily new cases. As a result of the infection peak, the government enacted several quarantines to combat the rising mortality. Turkiye's president officially announced the first public closure from 26 April to 17 May 2020.

Many forms of air pollution might be specified. The first kind consists of exhaust fume pollutants such as Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Carbon monoxide (CO), and Carbon dioxide (CO_2). The second category of pollutants is those produced by the interaction of water, temperature, and sunlight with the first type, which includes ozone (O_3) (Moghimi et al., 2020). In addition, the relationship between COVID-19 and CO_2 concentration in an area's environment has been established, and CO_2 concentration has a protracted effect on humans' health (Mehta et al., 2020). These air pollutants cause cardiovascular disorders, high blood pressure, and diabetes, which are underlying conditions for respiratory diseases such as influenza and COVID-19. NO_2, a pollutant of the first kind that leads to respiratory

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illnesses, generates second-type pollutants such as ozone and nitric acid (Huang et al., 2018; Shin et al., 2020). It was demonstrated by (Li et al., 2021) that significantly decreasing the number of cars leads to NO_x reduction. However, (Wang et al. 2020) note that considerable reductions in emissions would not prevent severe air pollution in China when meteorological conditions are adverse. Formaldehyde (HCHO) may also be formed from automobile gasoline; however, the use of tobacco in homes, the combustion of wood, and the use of natural gas in industrial areas are its principal sources. If this material is in the air, a person will have a cough, runny nose, or watery eyes. Since June 2011, formaldehyde also has become a compound known to cause human cancer (US Department of Health and Human Service).

Remote sensing using satellite data and images appears to be a viable tool for monitoring air pollution. Additionally, they are free and straightforward for people to use and process. Satellites such as Sentinel-5P with the TROPOMI onboard sensor presented vast data by viewing the whole planet multiple times. Google Earth began storing Landsat satellite data in 2008 and built an open-source cloud or internet platform (Shami et al., 2021). The Google Earth Engine (GEE) platform has collected data from satellites such as Landsat and Sentinel to benefit users. This platform can effectively handle metadata, eliminating the requirement for a powerful processor when dealing with vast amounts of data. Environmental research necessitates acquiring brand-new technology and techniques for data processing that can combine many disciplines, such as location or remote sensing data, on a worldwide scale. The GEE benefits in this sector give a mix of images that can be quickly arranged and filtered to make them user-friendly (Ghasempour et al., 2021). (Vafa et al., 2021) studied air pollution in the Khuzestan province of Iran during the COVID-19 pandemic and revealed how partial quarantine led to a decreasing pattern of various types of air pollution.

This study aims to explore the effects of COVID-19 quarantines on air pollution in Istanbul, particularly nitrogen dioxide, using remote sensing technology. This paper represents the first step of a bigger environmental investigation of Istanbul's air pollution. NO_2, SO_2, CO, HCHO, O_3 percentage, and Aerosol Indexes, referred to as particulate matter ($PM_{2.5}$), were retrieved from Sentinel-5P data packages using Java scripts written in the GEE IDE environment. The observation period extends **from January 1, 2019, to April 30, 2022**, corresponding to the time before and following the epidemic.

2. Materials and method

This research focuses on Istanbul, located at 41° 0' 49.82" N, 28° 56' 58.78" E. (Figure 1). Istanbul, one of the most important cities in Turkiye's northwestern region, has an estimated 5,343 km^2 with more than 15 million people population and plays a critical role in Turkiye. Its climate may be described as the transitional Mediterranean; in reality, it has cold winters, but otherwise, it has Mediterranean characteristics: autumn and winter are the wettest seasons, while summer is bright and sunny. GEE is the fundamental technology used to implement remote sensing technologies. The Code Editor, a web-based Integrated Development Environment (IDE) for creating and executing detailed data using Python or JavaScript, was utilized to perform the technique. The GEE data catalog has been updated with Copernicus Data, allowing users to access random data using its explorer. Table 1 summarizes this research's data-related information (GEE Catalogue).

Figure 1. Study Area, Istanbul, Turkiye

Figure 2 depicts the main phases of the employed approach. The picture also depicts the temporal and geographical distribution of air pollution in Istanbul from 2019 to 2022, before, during, and after the COVID-19 epidemic, using data taken from the Sentinel-5P satellite on Google Earth Engine.

Table 1. Tropomi Data Information

Data	Unit	Lowest	Highest	Accuracy
Absorbing_aerosol_index		-21	39	0.01 arc degree
CO_column_number_density	(mol / m²)	-34.43	5.71	0.01 arc degree
NO2_column_number_density	(mol / m²)	-0.00051	0.0192	0.01 arc degree
O3_column_number_density	(mol / m²)	0.025	0.3048	0.01 arc degree
SO2_column_number_density	(mol / m²)	-0.4051	0.2079	0.01 arc degree
Tropospheric_HCHO_column_number_density	(mol / m²)	-0.0172	0.0074	0.01 arc degree

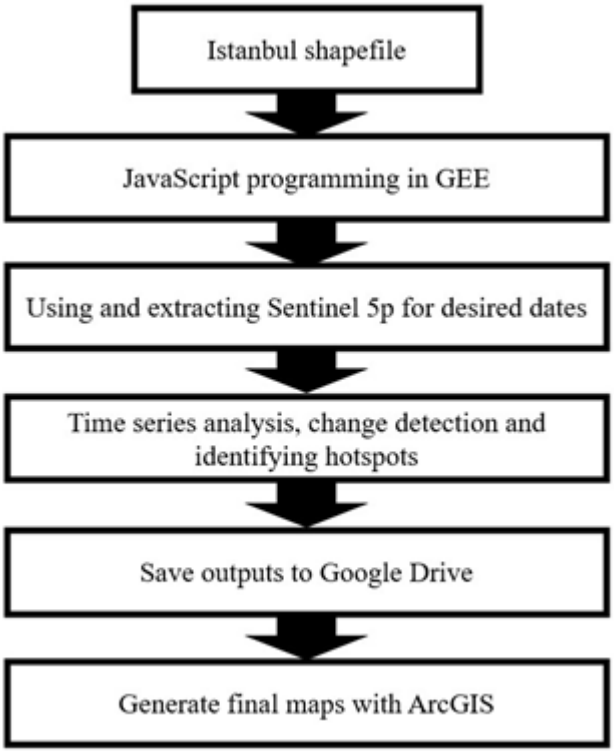
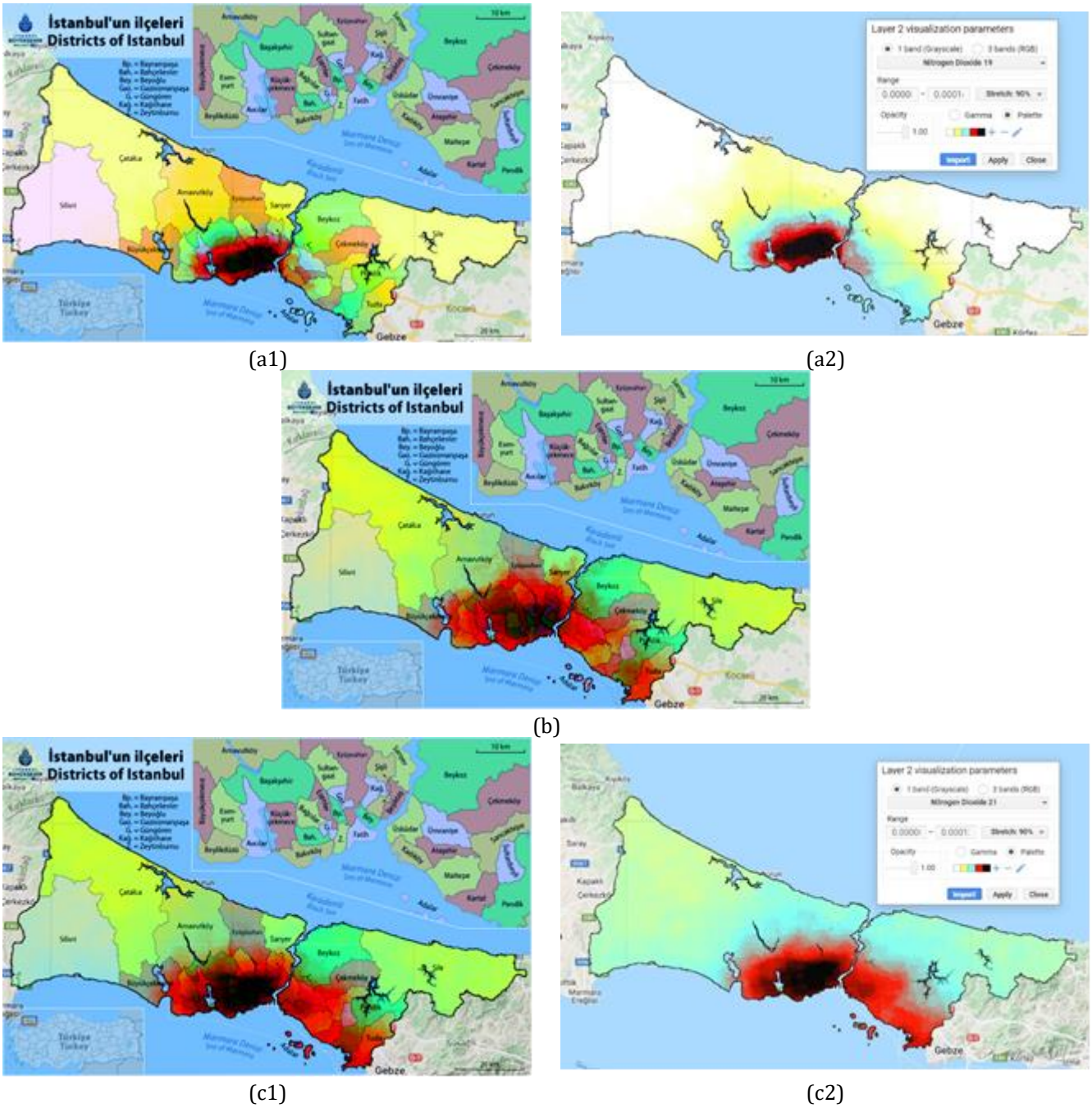


Figure 2. Project process flowchart

3. Results and discussion

Significant results of the study are presented for each parameter. Besides thematic maps and charts that show the daily changes in Nitrogen Dioxide are presented in Figure 3 and Figure 4 respectively. Figure 3 depicts the average levels of Nitrogen Dioxide in 2019, 2020, and 2021, from low (white) to very high (black), using themed maps. According to the thematic maps given in Figure 3 and the diagrams in Figure 4, it is evident that, despite a declining trend in 2020, the NO_2 concentration in Istanbul will increase in 2021. The dark patches are recognized as hotspots.

As shown in Figure 3, a2, and c2, the amount of nitrogen dioxide pollution in hotspots fell in 2020, increased in 2021, and surpassed its former levels in 2019. Despite this, the rise in air pollution is visible in all parts of Istanbul, necessitating immediate preventative action.



(a1) (a2)

(b)

(c1) (c2)

Figure 3. Comparative Average Nitrogen Dioxide in Istanbul for the years 2019, 2020, and 2021.

4. Conclusion

In this study, with the aid of Sentinel 5P satellite imagery and Java programming in the IDE of the GEE platform, six types of pollution in the Istanbul of Turkiye from 2019 to 2022 were studied. Summarizing all cases can be concluded that most parts of Istanbul are affected by NO_2. Fatih, bey, Bayrampasa, and neighbor districts have been identified as hotspots. It can be logically understood that all the hotspots are affected by different types of pollution due to the number of cars and industries in the region. Similar to previous studies, this study could point out that the emergence of the COVID-19 could reduce air pollution mortality. It can be noted

that satellite studies can be done faster, and it is better to repeat the air pollution at regular intervals for all regions of the country. In the continuation of this study, data retrieved from the ground bases of air pollution purification, wind velocity, air temperature, and the number of patients in various Istanbul neighborhoods could be analyzed. Using the AHP method and co-kriging interpolation, and despite comparing Google Earth engine results with ground bases, there is a significant relationship between wind intensity, air temperature, increasing pollution, and the number of patients with respiratory diseases such as Covid 19 could be defined.

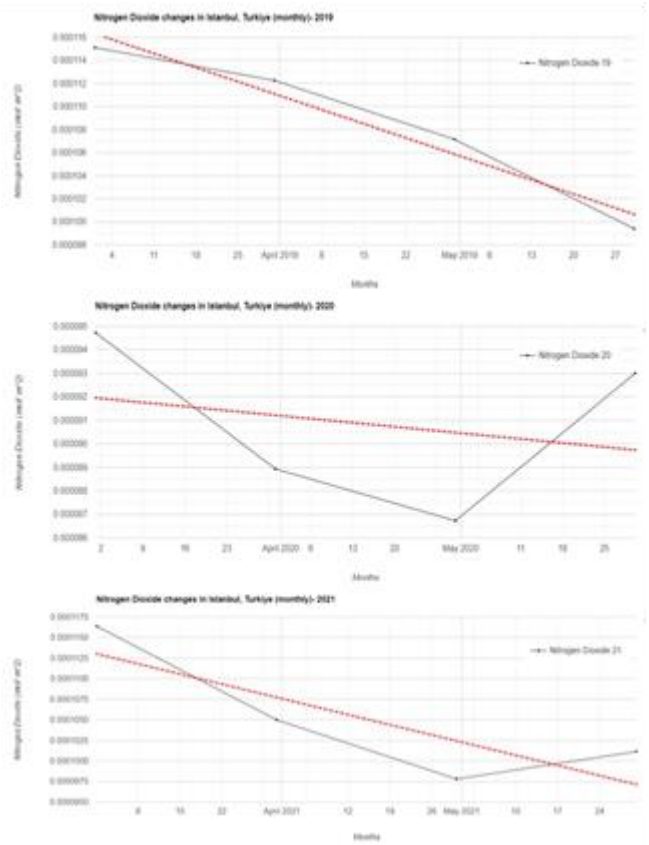


Figure 4. Comparative dynamics of monthly Nitrogen Dioxide values from a) 1 January 2019 to 1 January 2020, b) 1 January 2020 to 1 January 2021 c) 1 January 2021 to 1 January 2022

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