SPATIOTEMPORAL ANALYSIS OF AIR POLLUTANTS BASED ON GOOGLE EARTH ENGINE (GEE) DURING AND POST-COVID-19 IN DHAKA, BANGLADESH

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ABSTRACT

Air pollution is the urgent environmental issues for the survival of cities and the health of their residents. The Covid-19 epidemic became a natural assessment ground exemplifying the challenges associated with anthropogenic and industrial activities of pollution in air. In this research, the spatiotemporal pattern of TROPOMI based (Sentinel-5P) nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon mono-oxide (CO) products and MODIS emanated AOD (i,e) aerosol optical depth was investigated in three periods of time from March to June of 2020, 2021, and 2022 (including the first wave.of Covid-19 and shutdown) in Dhaka division by proper utilizing of Google Earth Engine (GEE). The research figure out a remarkable increase in NO_2, SO_2 and CO concentrations over Dhaka Division in 2021 and 2022 compared to 2020. The CO density was to be 6.08% higher in 2021 and 5.52% higher in 2022 respectively, while the NO_2 was increased 37.3% in 2021 and 20.6% in 2022 compared to 2020. Moreover, SO_2 density rose by 52% in 2021 and 297% in 2022 compared to 2020. However, it was noted that air pollution was highly related to meteorological parameters like temperature and precipitation. Overall, the satellite-based spatiotemporal insights garnered from GEE empower policymakers, environmental agencies, and researchers with valuable information for evidence-based decision-making. Consequently, this research could suggest to the stakeholders adopting viable measures in order to enhance the quality of air and thereby residents health in the study area.

Keywords: *GEE, air pollutants, COVID-19, Dhaka*

1. INTRODUCTION

The basic element of the environment is the air, in recent decades the degradation of this element has become a major concern on a national, continental and international scale *(Eckhoff, 2009)*. Air quality in developing countries is a serious issue, largely caused by the growth of manufacturing, rapid urbanization and the burning of fossil fuels for both home and industrial use *(Angelevska et al., 2021; Ghasempour et al., 2021)*. Air pollution occurs when harmful stuff like particulate matter, gases and biotic molecules are released into the atmosphere in a large quantities. These substances could have a negative impact on human health, the environment and climate change *(Arya, 1999)*. The effect pollution of air on public health is major concern especially in densely populated urban areas. As cities grow in size and population is the sources of air pollution. Industrial emissions, energy consumption and automobile traffic all contribute to poor air quality which can have a number of negative health consequences *(Kahyaoğlu-Koračin et al., 2009)*. Air pollution is a major health concern that can exacerbate existing conditions like asthma, bronchitis as well as contribute to development of new diseases. It can also lead to breathing problem, heart attacks and different respiratory allergies *(Eckhoff, 2009)*. Rooting out to various air pollutants such NO_2, CO, SO_2, O_3 and particulate matter (PM) including Optical Aerosol Depth (AOD) originating from natural and human sources has a significant impact on individual health and well-being *(Gopalakrishnan et al., 2018)* .The primary air pollutants in urban areas worldwide are CO, O_3, SO_2, NO_2 and particulate matter (PM2.5 as well as PM10) *(Zhang et al., 2020)*.

Air pollution is a major environmental concern that is caused by both firm and moving sources. Firm sources are stationary sources of pollutions as like factories, power plants and homes. Moving sources like as cars, trucks as well as airplanes etc *(Islam & Chowdhury, 2021)*. Air pollution has long been a critical concern in Dhaka, stemming from rapid urbanization, industrial growth and vehicular emissions. The lockdowns and restrictions imposed during the pandemic led to a temporary reduction in anthropogenic activities, offering a remarkable opportunity to evaluate the air quality in Dhaka to overlook the comparison scenario between during to post Covid 19. Hence lockdown started in Bangladesh from March-2020 *(Shammi et al., 2021)*. Geo-information systems (GIS) and remote-sensing (RS) technologies offer a powerful approach to gather information about the Earth particularly in remote or inaccessible regions. These tools provide valuable data on various aspects including land and sea surface temperature, vegetation cover, air quality and even enabling the prediction and assessment of natural disasters *(Matci et al., 2022)*.

This research endeavors to comprehensively analyze spatiotemporal variations in air pollutants such optical aerosol depth (AOD) and key gases as like NO_2, CO and SO_2 during to post COVID-19 in the month of March, April, May, June of 2020, 2021 and 2022 in Dhaka, Bangladesh. Google Earth Engine (GEE) is a revolutionary cloud-based platform that empower the scientists, the researchers and the developers to conduct planetary-scale geospatial analysis. It provides seamless access to a vast petabyte-scale catalog of satellite imagery and geospatial datasets as well as coupled with robust analysis capabilities. Leveraging GEE's cutting-edge technology that users can effectively detect changes, map trends and quantify differences on Earth's surface and enabling groundbreaking insights into our planet's dynamics *(Zhao et al., 2021)*. The proper utilization of GEE cloud based platform for geospatial data analysis that offers a powerful tool for processing and visualizing vast datasets enabling the creation of accurate and up-to-date air quality assessments. The study aims to shed light on several key aspects. First, it seeks to explore how the restrictions imposed during the pandemic influenced air quality in different parts of Dhaka. By examining during-pandemic and post-pandemic periods, researchers can identify both short-term and long-term effects.

2. RESEARCH METHODS

2.1 Study Area

Dhaka divison is the mostly populated place in Bangladesh. Risiding almost in the middle of the country. Capital and world's fourth dense city situated in this area even importants industrial and economical cluster cities such Gazipur, Narayangonj, Norsigndi, Manikganj and Tangail. The research area Dhaka Figure (1) were selected to assesment of air quality of four month (March, April, May and June) of years 2020, 2021

and 2022. Electric utilities particularly those burn coal as the primary sources of SO_2 emissions released into the environment. Additionally cement manufacturing, petroleum refineries, paper pulp manufacturing and metal smelting as well as processing facilities contribute to SO_2 emissions (Sulfur Dioxide | Wisconsin Department of Health Service*s, 2018)*. Hundreds of cements, brick kilns, electronics, paper pulp, petrolium refineries industries situated in Dhaka Division. The brick kiln industry in Bangladesh predominantly relies on coal as its primary fuel source while wood is employed as a secondary fuel to supplement the combustion process *(Rahman et al., 2019)*. Brick kilns are the largest seasonal industry in Greater Dhaka contributing significantly to air pollution. Heavy-duty vehicles primarily powered by high-sulfur diesel fuel are prevalent on Dhaka's roads. A substantial portion of vehicles operating in Dhaka utilize high-sulfur diesel while gasoline and natural gas are also used as fuel sources. Motor vehicles and brick kilns are the major contributors to particulate air pollution including black carbon emissions in Dhaka *(Rahman et al., 2019)*. Mobile sources are the primary contributors to release the carbon monoxide (CO) in Greater Dhaka specifically accounting for 40.5% of the total CO emissions. Fossil fuel combustion contributes 27.1% followed by industrial emissions including brick kilns at 16.4% *(Randall et al., 2015)* .

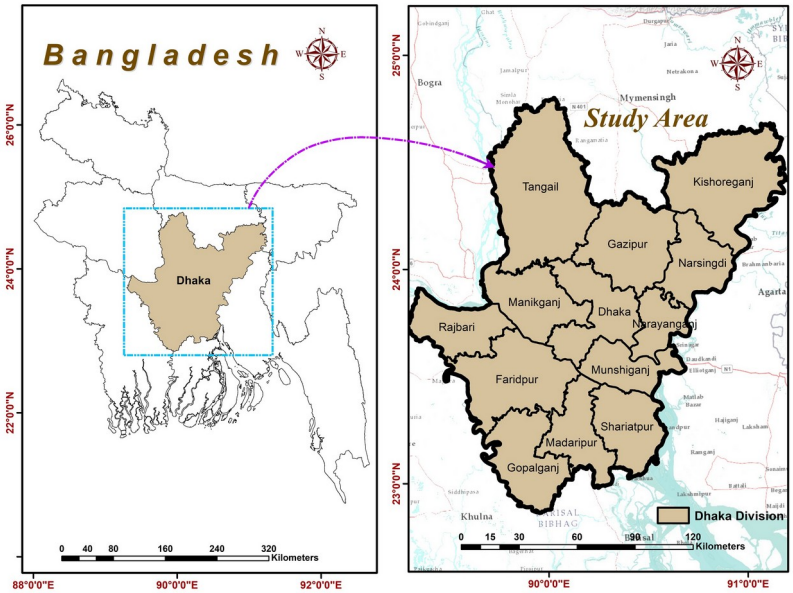

Figure 1**:** Study Area

The primary source of nitrogen dioxide (NO_2) emissions arising from human activities is the combustion of fossil fuels particularly gasoline used in vehicles. Also NO_2 is generated during the production of nitric acid, welding and the use of explosives as well as in the refining of petroleum, metals, commercial manufacturing and food manufacturing (Nitrogen Dioxi*de, 2021)*. The transportation sector encompassing automobiles, trucks, motorcycles and other vehicles is the predominant source of nitrogen dioxide (NO_2) emissions in Greater Dhaka.

2.2 DATA COLLECTION

In this study we properly utilized Sentinel-5 satellite data with Google Earth Engine to analyze Dhaka's air pollutants of different periods of time of 2020 (during COVID-19), 2021 and 2022 (post Covid-19). Launched by the European Space Agency (ESA) on October 13, 2017 the Sentinel-5P satellite conducts daily environmental monitoring and analysis of air pollutants across the globe. Equipped with the TROPOMI sensor Sentinel-5P's mission includes tracking atmospheric gases such as NO_2, CO, SO_2, O_3, formaldehyde (CH_2O), methane (CH_4) and aerosols *(Morozova et al., 2022)* . Specifically in this study has been considered SO_2, NO_2 and CO following March to June of 2020, 2021 and 2022. Majority of the data was collected from from Google Earth Engine plateform using their own algorithm JavaSrcipt API. By eliminating the limitations of traditional data analysis techniques. Google Earth Engine (GEE) is

revolutionizing the way the researchers, the experts and the programmers eventually they can rapidly extract valuable insights from large remote sensing (RS) datasets *(Amani et al., 2020)*. The numerous advantages of Google Earth Engine (GEE) that makes an indispensable tool as wide range of applications including land use and land cover (LULC) analysis, agricultural monitoring, hydrological modeling, environmental disaster assessment and various other geospatial tasks *(Amani et al., 2020)* . Time series of each product were helped to get appropiate data to anylyze the air quality condition during study period. Below table-01 is presentated all data collection's list. In table has been represented breif details of data source including name of data provider institute . Gases product's (NO_2, SO_2, CO) units were calculated as mol/m^2 including minimum and maximum limit thereafter brand names were presesnted column number density and AOD units as microgram.

2.2.1 Dataset of Air Pollutants

Table:01

Air Pollutant	Image Name	Brand Name	Description	Dataset providers
SO_2 Sulfur dioxide	Sentinel-5P OFFL:SO_2	SO_2 column number density	SO_2 column density at ground level	European Union/ESA/Copernicus
NO_2 Nitrogen dioxide	Sentinel-5P OFFL:NO_2	NO_2 column number density	NO_2 column density at ground level	European Union/ESA/Copernicus
CO Carbon mono-oxide	Sentinel-5P OFFL:CO	CO column number density	Vertical integrated column density of CO	European Union/ESA/Copernicus
AOD Optical Aerosol depth	MCD19A2.061: Terra & Aqua MAIAC Land Aerosol Optical Depth Daily 1km	Optical Depth 047	Aerosol optical depth in the MODIS blue brand (0.47 μm)	NASALP DAAC at the USGSEROS Center

2.2.2. Temperature and rainfall data

The MOD11A2 version 6.2 datasets provide temperature data for the Greater Dhaka region. These datasets offer 8-day average (LST&E) land surface temperature and emissivity measurements for each pixel with 1 kilometer's spatial resolution. Generally MOD11A2 represent temparature in Kalvin here minimum scale is 7500 and maximum 65535. We converted it to centigrade in this study. The CHIRPS Pentad dataset which combines satellite-based precipitation estimates of station data was employed to obtain average precipitation information for any region in millimeters. Both rainfall and temperature have been shown to correlate with density of air pollutants.

2.3 OVERVIEW OF METHODS

In order to analysis the air quality over greater Dhaka division here several data has been selected. Data processing, data etraction, visualization were done by Google Earth Engine. Open-source image data serves as a valuable resource for the researchers and individuals interested in maps and geographic information.This freely accessible data is becoming increasingly extensive and high-resolution that providing a vast and largely untapped source for scientific research. Due to its popularity among users seeking as open-source image or ground records data fosters a thriving community of the map enthusiasts and the group of researchers (Ragheb & Ragab, 2015). For data spanning we have analyzed SO_2, NO_2, CO and AOD satellite data of the month of March, April, May and June epoch the years of 2020, 2021 and 2022. MODIS land cover data were employed to assess the spatial resolution of air parameter data (Sentinel-5P, TROPOMI). Programming language was implemented in the GEE code editor as built in Java

Script API. JavaScript (JS) along with HTML and CSS stands as a cornerstone programming language that forms the bedrock of the World Wide Web. In the context of SI connection and country table's link, filter arrays are utilized to selectively display and manage the data. Utilizing the JavaScript filter array function an image can be filtered based on pre-defined criteria. The filter method in JavaScript systematically examines each element in the array and selects those that comply with the specified requirements. Code editors are embellished with three distinct features: Scripts, Docs and Assets. The Assets feature enables users for importing shapefiles, excel spreadsheets and more documents. Bangladesh's vector data downloaded from DIVA GIS was imported for analysis.. Then extracted Dhaka divison's data in GEE by JAVA API. The entire coding process was carried out within the scripts feature. Code editor scripts can be shared using an encoded URL. To generate a script URL a variable function 'var' was employed. Following the importation of the shapefile into the assets section the code writing was initiated in the scripts feature (Amani et al., 2020). LST and AOD time series has been evaluated and analyzed from MODIS. By filtering region of interest and study period CSV file has been exported. CHIRPS Pentad provided rainfall CSV here built in JAVA API implemented to get rainfall CSV. The breif fowchart of the implemented methodology is given in Fig. 2.

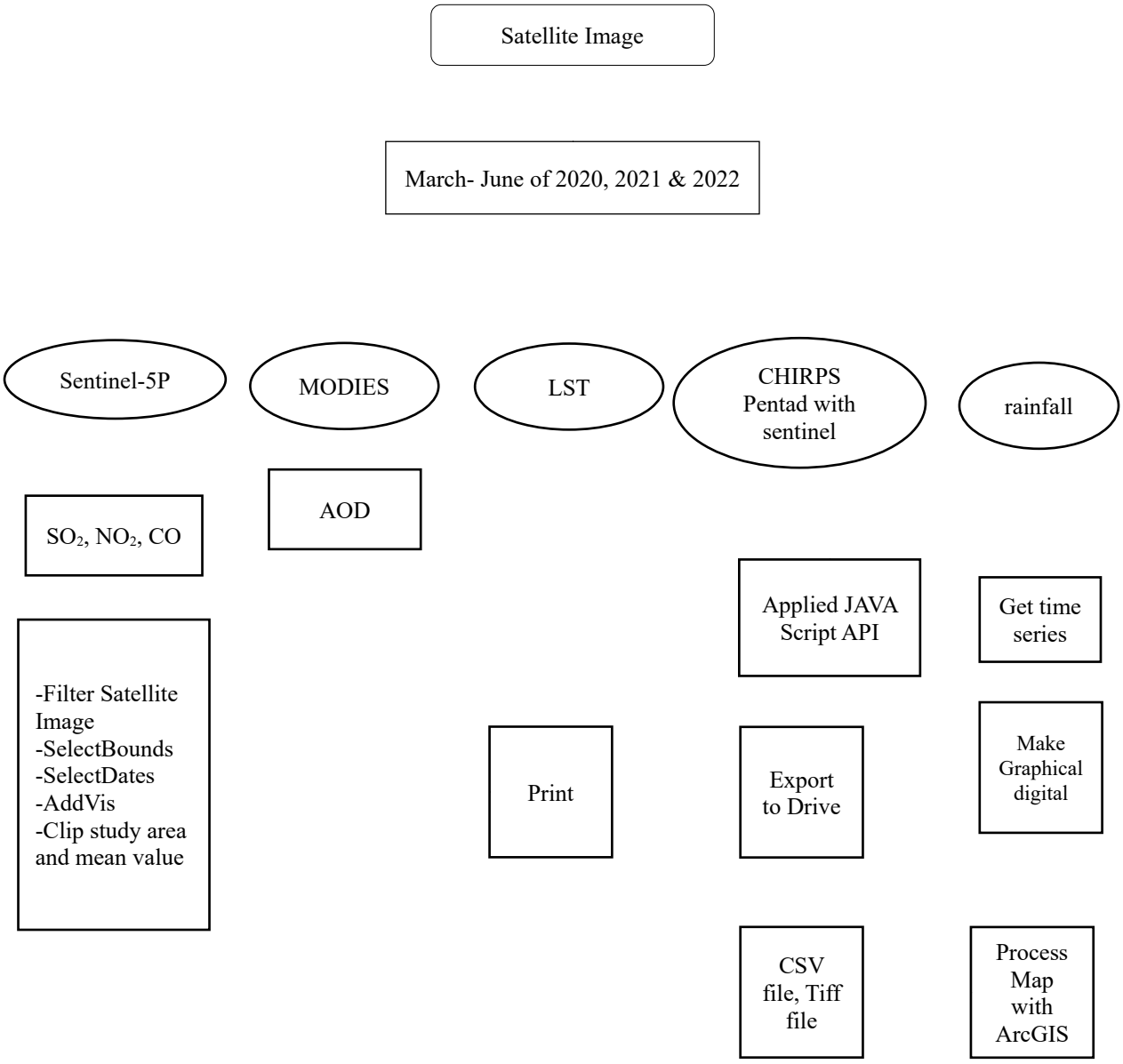

Figure 2: Methodological flowchart

3. RESULTS AND ANALYSIS

3.1. Assessment of NO_2 column number density during to post COVID-19 over greater Dhaka

One of the highly reactive gases in the air pollutants is Nitrogen Dioxide (NO_2). Its variation can be determined by numerous factors such as vehicular emissions, industrial processes, and weather conditions. The impact of NO_2 (Nitrogen Dioxide), a harmful air pollutant has been significantly reduced during lockdown periods globally due to the decreased human activity. With less cars on the road, factories running, or businesses operating, the emissions of NO_2 have dropped, leading to cleaner air quality. Bangladesh enacted a lockdown on March 24, 2020, which included a ban on all domestic sea, rail, and air travel (Haque et al., 2022). The density of NO_2 gas dropped accross the country after imposing the lockdown but in post-lockdown period NO_2 concentration again significanly increased . Specifically differences has visualized in greater Dhaka (Figs. 3 and 4). Comparing to full lockdown period of 2020, NO_2 was increased 37.3% in 2021 and 20.6% in 2022. In Figs. 3 has been represented four months mean NO_2 concentreation (mol/m^2) of each year of 2020, 2021 and 2022. Here monthly mean NO_2 concentration (mol/m^2) of indivisual years has decreased due to temperature drop and precipitation, it's presented in Fig.10 and Fig.12.

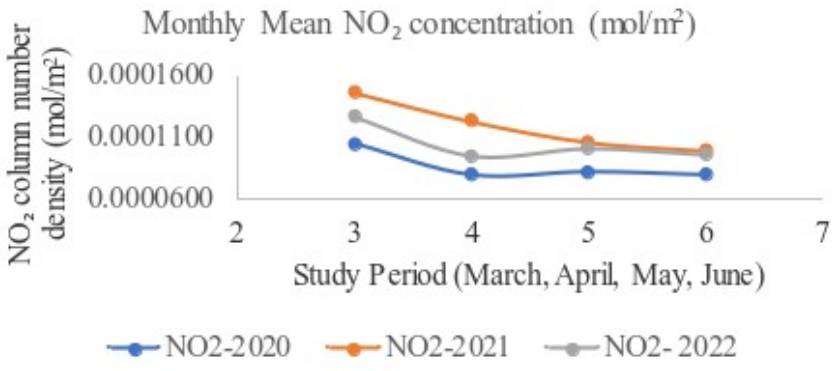

Figure 3: NO_2 monthly mean density (mol/m^2) of Dhaka division from March to July (2020, 2021, 2022)

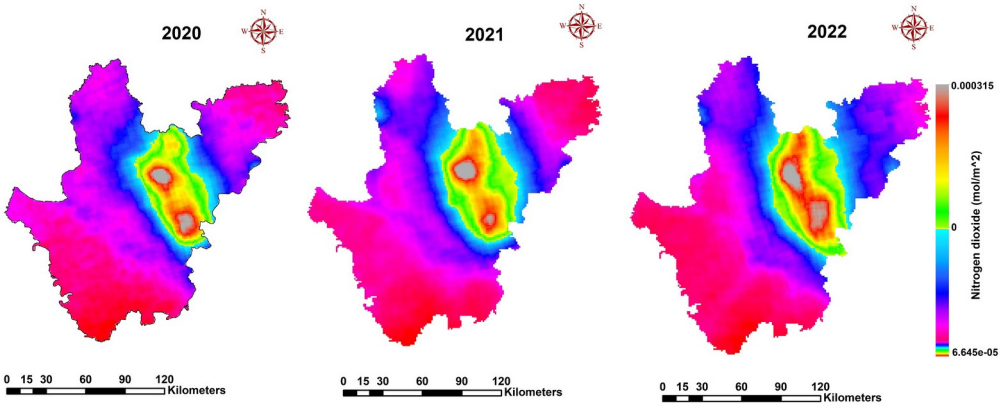

Figure 4. NO_2 yearly mean density (mol/m^2) map of Dhaka division from March to July (2020, 2021, 2022)

3.2. Assessment of SO_2 column number density during to post COVID-19 over greater Dhaka

Sulfur dioxide (SO_2), it's released naturally by volcanic activity but it's also an important pollutant, produced by various industrial processes such coal which contain sulfur compounds and combustion of fossil fuels (Ghasempour et al., 2021). Exposure to high concentrations can cause numerous health problems, including respiratory issues and lung damage. The monthly mean SO_2 concentration (mol/m^2) spatio-temporal flctuations accrose greater Dhaka has been assessed details in (Fig.5). SO_2 density rose by 52% in 2021 and 297% in 2022 compared to 2020. In the Fig. 6 has visualized yearly mapping of mean SO_2 column density (mol/m^2). SO_2 gradually increased each year.

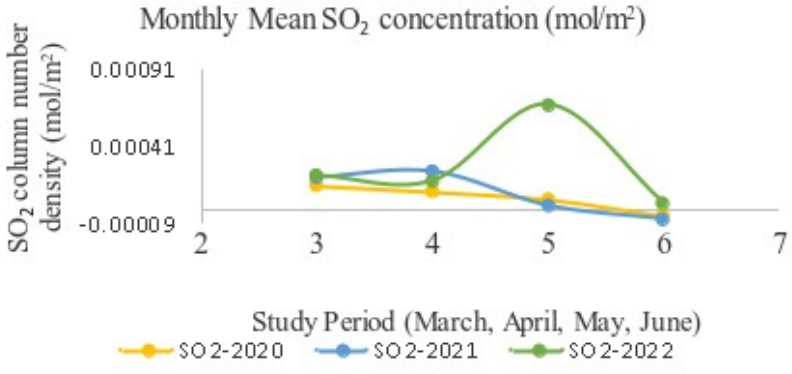

Figure 5: SO_2 monthly mean density (mol/m^2) of Dhaka division from March to July (2020, 2021, 2022)

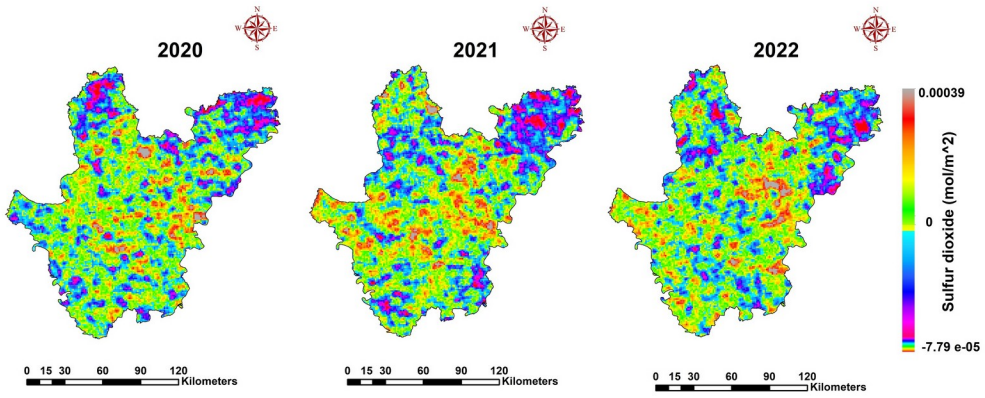

Figure 6: SO_2 yearly mean density (mol/m^2) map of Dhaka division from March to July (2020, 2021, 2022)

In March, the during covid SO_2 concentration was less than the post Covid-19 SO_2 mean concentration value. In 2022 SO_2 column number density (mol/m^2) has been alarmingly increased.

3.3. Assessment of CO column density during to post COVID-19 over greater Dhaka

Major sources of CO gas emission are vehicles, industries, brick kilns, biomass burning, and power plants, which are quite prevalent in Bangladesh. Vehicle exhaust is a major contributor to CO emissions in the air. As vehicles were not being used during the initial surge of COVID-19 in Bangladesh, a reduction in CO emissions was projected (Haque et al., 2022). In (Figs. 7 and 8) it is diagonised the concentration of CO (mol/m^2) month of March, April, May and June of 2020, 2021 and 2022. Result showing CO density was to be 6.08% higher in 2021 and 5.52% higher in 2022, respectively. Highest CO density was 0.056 mol/m2 on March 2021 (post COVID-19) and lowest density was 0.038 mol/m^2 on June 2020 (Figs. 07 and 08).

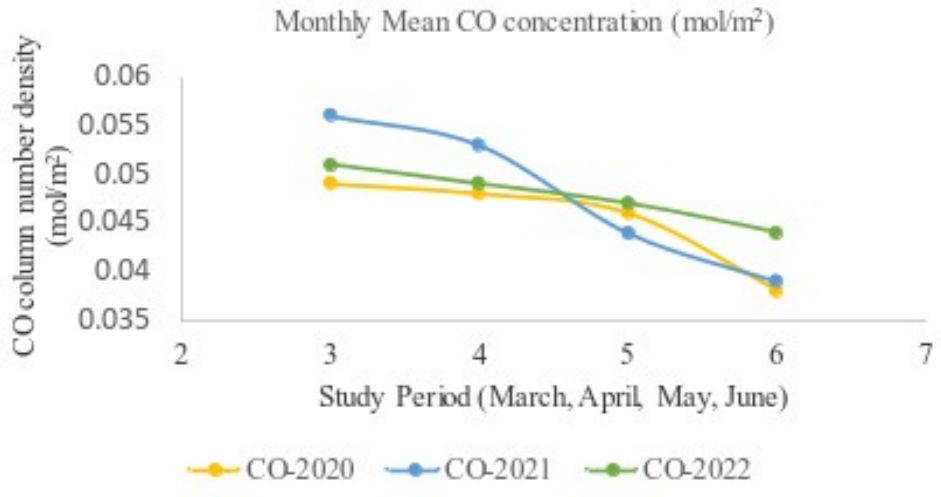

Figure 7: CO monthly mean density (mol/m^2) of Dhaka division from March to July (2020, 2021, 2022)

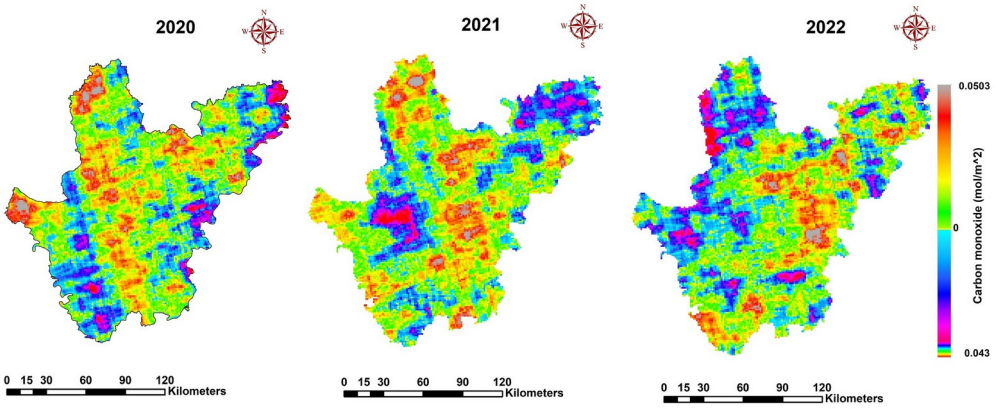

Figure 8: CO yearly mean density (mol/m^2) map of Dhaka division from March to July (2020, 2021, 2022)

3.4. Assessment of Aerosol Optical Depth (AOD) over greater Dhaka

The telemetry parameter were employed in this research to obtain the atmosphere's optical depth. Aerosols, which are suspensions of liquid or solid particles in a gas such as dust, ash, mist or fog are widely dispersed. Anthropogenic aerosols are prevalent in densely populated areas. AOD index which gauges an aerosol's ability to measure the portion of solar radiation scattered and absorbed by aerosols over a specified wavelength and distanc (Ghasempour et al., 2021). A standardized system called the Air Quality Index (AQI) quantifies and interprets air cleanliness by considering various airborne contaminants including fine particulate matter (PM2.5 as well as PM10), NO_2, SO_2, CO and (O_3). The AQI provides a numerical value that reflects the total air quality with higher values indicating worse air quality. In the AOD's geographic distribution (Fig.09) in March, April, May and June of year 2020, 2021 and 2022 here AOD concentration was very high in 2021. Maximum AOD was 850.507 μg in March 2021 and minimum AOD was 392.309 in March 2022 (Fig. 09). AOD was higher in post-COVID-19 comparing to during lockdown. Due to temperature fall in 2022 AOD was significantly down . AOD is commonly correlated to temperature and precipitation.

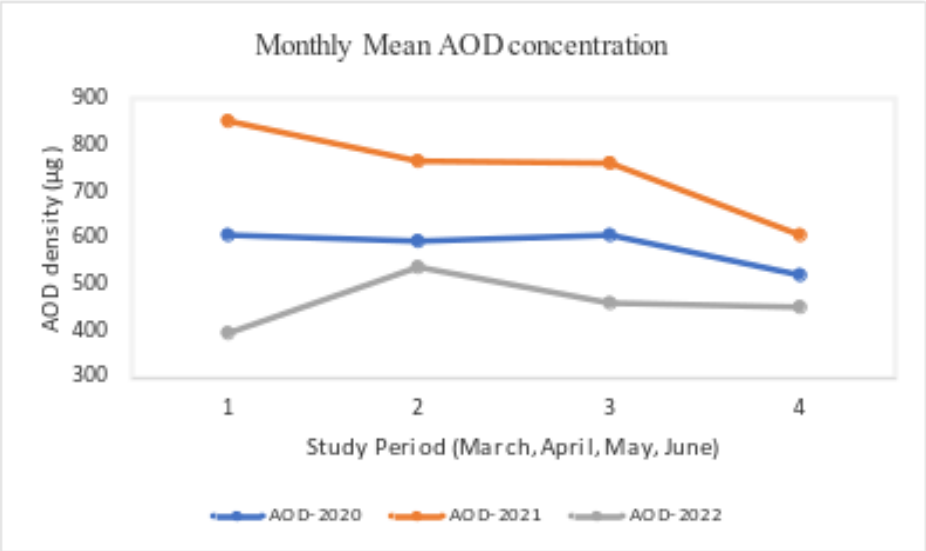

Figure 9: Monthly mean AOD density of Dhaka division from March to July (2020, 2021, 2022)

3.5. Assessement of temperature (°C) in greater Dhaka

Rainfall and temperature impose the huge impact on the airborne pollutant's dynamics (Oji & Adamu, 2020). In the study, the average monthly temperature had been calculated as degrees Celsius Fig. 10. Minimum monthly mean tempature was 25.49 degree celsius in June, 2022 and maximum monlth mean temperature was 31.54 degree Celsius in April, 2021 (Fig. 10).

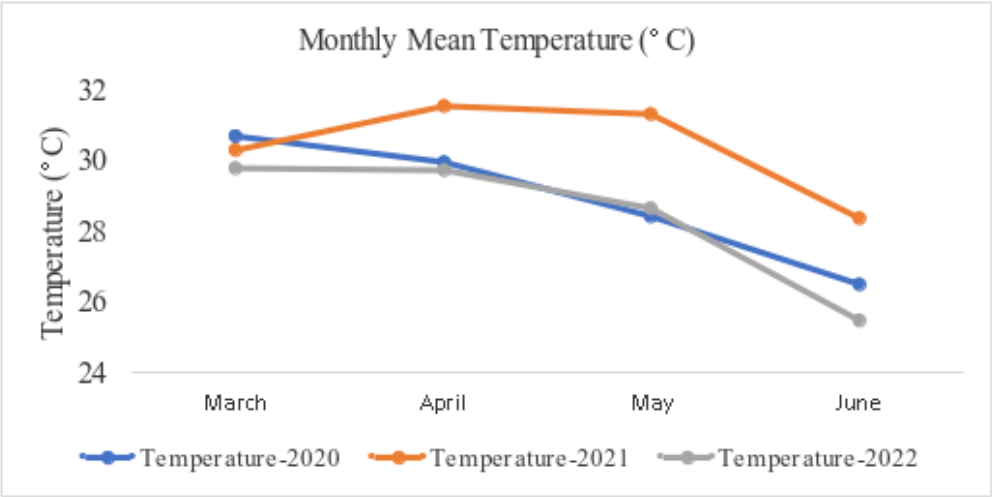

Figure 10: Monthly mean temperature (° C) of Dhaka division from March to July (2020, 2021, 2022)
Overall temperature is very high in 2021 then 2020. Temperature was very low in 2022. There were a strong connection between temperature and various types of air pollutants with the density of these pollutants increasing or decreasing as temperature rises or falls. This indicates that temperature plays a crucial role in air quality.

3.6. Assessement of rainfall (mm) in greater Dhaka

Emerging research suggests that particulate air pollution may be the driving force behind the recently observed decrease of 10% to 25% in the ratio of precipitation between hilly and upwind lowland areas particularly in regions located downwind of urban and industrial zones (Rosenfeld et al., 2007). Rainfall can help improve air quality by acting as a natural "cleaner" for the atmosphere. Monthly mean rainfall (mm) data were analyzed Fig.12 of year 2020, 2021 and 2022. Total rainfall was high in 2020 of study period then 2021. Rainfall was very low in march of earch study period. An increase in atmospheric water could

potentially contribute to a reduction in pollution concentrations. This cleansing effect is primarily due to two mechanisms: disintegration and dispersion dilution. (Haque et. al,. 2022) (Haque et al., 2022).

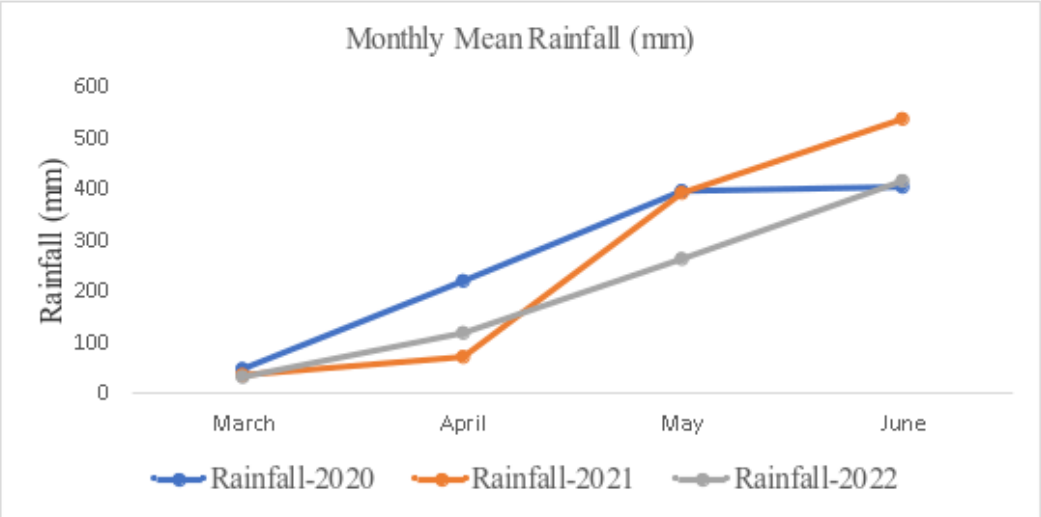

Fig. 12. Monthly mean rainfall (mm) of Dhaka division from March to July (2020, 2021, 2022)

4. DISCUSSION

In this study huge sattelite data have been performed to measure of air quality condition in Dhaka division during to post Covid 19 pandemic including lockdown in 2020. In March 2020 was fully lockdown in Bangladesh. The lockdowns brought about a welcome respite for the environment, as reduced industrial and vehicular activity led to lower greenhouse gas emissions, cleaner waterways, and significantly quieter environments (Haque et al., 2022). Adverse consequences included a surge in medical waste and household plastics/waste along with negligent and excessive utilization of masks, gloves and disinfectants (Ghasempour et al., 2021). In this research, TROPOMI based sentinel-5P sattelite data has been analyzed to get time series of NO_2, SO_2 and CO column number concentration (mol/m^2). MODIS-derived AOD are tracked to get overall particle concentration in study period March, April, May and June on years 2020, 2021 and 2022.Correlation between air contaminant (NO_2, SO_2 and CO) concentrations and temperature in greater Dhaka has evaluated as well as Rainfall in Dhaka. The research employed Google Earth Engine (GEE) to gather, analyze, and process satellite data, capturing satellite imagery throughout the months of March, April and May, which represent summer season in Bangladesh. The wet season in Bangladesh typically commences in June and our observation extended over both summer and rainy seasons. The result shown the carbon mono-oxide (CO) density was 6.08% higher in 2021 and 5.52% higher in 2022, respectively, while the NO_2 was increased 37.3% in 2021 and 20.6% in 2022 compared to 2020. Moreover, SO_2 density rose by 52% in 2021 and 297% in 2022 compared to 2020. AOD concentration was very high in 2021 but 2022 respectively lower than 2020. Meteorological factors were found to have a remarkable influence on air quality during COVID-19 including lockdown and the subsequent period as demonstrated by the experimental findings. A key limitation of this research was the absence of lab-based verification. Due to the necessity of satellites scanning the entire air column beneath can be difficult to quantify pollution levels in the lowest few areas where we breathe. In this study therefore highlights the potential of combining Google Earth Engine, RS and ArcGIS to address these limitations.

5. CONCLUSIONS

In conclusion, the spatiotemporal analysis of air pollutants based on Google Earth Engine (GEE) during and post-COVID-19 in Dhaka, Bangladesh provides valuable insights into the dynamic nature of air quality in

this densely populated urban area. The study revealed important findings about how the pandemic influenced air pollution levels and how subsequent changes in human activity affected the environment. In fully lockdown period (March to April-2020) had have very less concentration of CO, NO_2 and SO_2 and here concentration was very high in 2021 of each pollutants but only SO_2 was high in 2022. Eventually GEE with its powerful geospatial analysis capabilities proved to be an invaluable tool for monitoring and understanding these changes. During the COVID-19 lockdowns reduced industrial and vehicular emissions led to temporary improvements in air quality and underscoring the potential benefits of environmental regulations as well as reduced human activities.The findings also highlighted the importance of continued monitoring and data-driven policy decisions to address air quality issues. This study can serve as a blueprint for future research and policy initiatives aimed at mitigating air pollution in Dhaka and other rapidly growing urban areas. The integration of remote sensing and geospatial technologies, like GEE, provides a powerful means to assess, monitor, and manage air quality in a rapidly changing world where understanding and addressing environmental challenges are more critical than ever.

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