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Air Pollution and Plant Health: Exploring the Link Between Ozone Levels and Vegetation in Bangladesh

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Abstract

Ground-level ozone, a known carcinogen, threatens public health and regional food security by disrupting plant biological functions. Bangladesh, one of the least developed countries with 180 million people, ranks 8th globally in population density. Agriculture, contributing 41% to the labor force and 15% to GDP, faces chronic challenges from annual flooding, affecting 20-65% of the land. Additionally, worsening air pollution, especially ground-level ozone in western Bangladesh, further reduces crop yields, making the country the 3rd largest global food importer. This study aims to assess the relationship between the Normalized Difference Vegetation Index (NDVI) and tropospheric ozone concentrations to understand the impact of air pollution on vegetation health across five districts in Bangladesh. This study uses the NDVI, a remote sensing index for measuring vegetation health, and ground-level ozone, a pollutant that affects plant health and ecosystems. The relationship between the spatial distribution of NDVI and ground-level ozone was analyzed both qualitatively and quantitatively across five western districts of Bangladesh, where ground-level ozone shows the most significant interannual variability. Preliminary results show that areas with high ozone concentrations consistently align with low NDVI values, suggesting ozone damage to vegetation. A statistically significant negative correlation was found between NDVI and ground-level ozone across five districts in Bangladesh. Regions with the highest ozone levels had the lowest NDVI, and different crops exhibited varying sensitivities to ozone. The findings indicate that rising ozone levels negatively impact vegetation health and density. This study is significant for understanding how air pollution, specifically ground-level ozone, impacts ecosystems and agricultural productivity. Examining the relationship between ozone levels and vegetation health provides insights into the broader effects of air quality on food security and environmental sustainability in Bangladesh.

Background

Tropospheric ozone (O_3), specially ground-level ozone, a phytotoxic air pollutant, poses a significant threat to public health and regional food security by disrupting plant biological functions[1]. Ground-level ozone adversely affect plant health (NDVI) and reduces crop yields and exacerbates global food insecurity.
Western parts of Bangladesh and eastern part of the Indian state of West Bengal show highest concentration of ground-level Ozone during summer months. Earlier studies show excessive amount of ground-level Ozone negatively affected health of colver[2], Maize, Rice, Wheat.

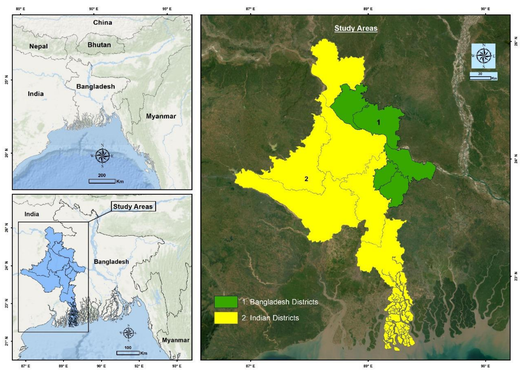


Figure 1: Study areas map showing different districts of Bangladesh (green color) and West Bengal state of India (yellow color).

Research Objectives

- To analyze the amount of O_3 and NDVI in specific areas.
- To show the spatiotemporal distribution of O_3 and NDVI in Study Areas.
- Demonstrate a spatial correlation between O_3 and NDVI in the country's border districts of Bangladesh and the state of West Bengal in India.

Data Sources

In this research, we comprehensively analyzed two factors: O_3 and NDVI. The data were taken from 2019 to 2024 (November). Table 1 lists the data source and different characteristics of the data.

Table 1: Data source and characteristics

Satellite	Band	Pixel Size	Unit	Dataset Availability	Sources
Sentinel-2	B4 & B8	10 m		03/28/2017	GEE
Sentinel-5P	O3_column_number_density		mol/m²	09/08/2018	GEE

Research Design

We collected Normalized Difference Vegetation Index (NDVI) and O_3 data from Google Earth Engine using JavaScript algorithms. A flow chart represents the total procedure required to complete the data collection process from top to bottom.

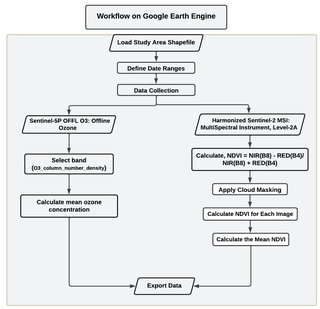


Figure 2: Flow chart of the data collection

For NDVI data, we took Harmonized Sentinel-2 MSI: MultiSpectral Instrument, Level-2A which Provides surface reflectance data from Sentinel-2 satellites.
Total Bands: 13 spectral bands
Bands Used for NDVI:
- Band 4 (B4): Red (Spatial Resolution 10 m) &
- Band 8 (B8): Near Infrared (NIR) (Spatial Resolution 10 m)

Besides, For O_3 data, we used Sentinel-5P OFFL O_3 : Offline Ozone which measures atmospheric ozone concentration.
- Spatial Resolution: 7 km × 3.5 km (approximately)
- Monitoring air quality and ozone-related phenomena

Correlation Coefficient in Each District

Districts	Correlation Coefficient
Barddhaman	-0.04
Birbhum	-0.14
Chapainababganj	-0.01
Chuadanga	-0.18
Kushtia	-0.11
Maldah	-0.03
Meherpur	-0.30
Murshidabad	-0.14
Nadia	-0.13
North 24 Parganas	-0.49
Rajshahi	-0.18

Figure 3: Correlation Coefficient Values

Among the five districts of Bangladesh, the highest value of correlation coefficient (r) values in Meherpur District is -0.30 and the lowest value of correlation coefficient (r) values in Chapainababganj District is -0.01.
On the other hand, in the eastern region of the Indian state of West Bengal, the district of North 24 Parganas has the greatest value of r (-0.49), while the district of Maldah has the lowest value (-0.03).

Spatio-Temporal Distribution of NDVI in Meherpur District

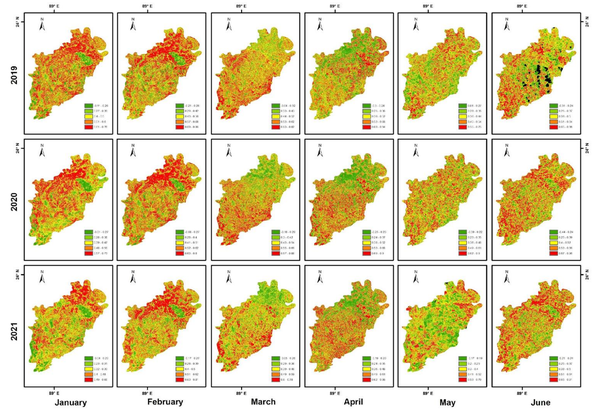


Figure 4: NDVI classified images from 2019 to 2021(January-June) in Meherpur District

Spatio-Temporal Distribution of O_3 in Meherpur District

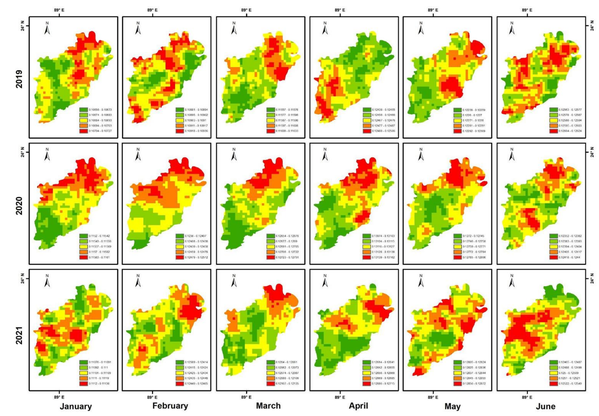


Figure 5: O_3 classified images from 2019 to 2021(January-June) in Meherpur District

Monthly Average O_3 and NDVI Trends in Meherpur District

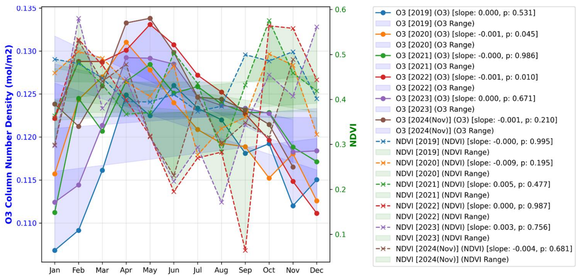


Figure 6: Monthly Average O_3 and NDVI Trends in Meherpur District

Choropleth Map of Study Areas

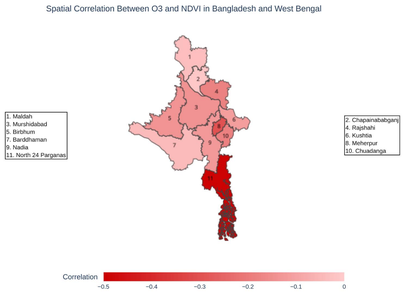


Figure 7: Spatial Correlation Between O_3 and NDVI in the selected Bangladesh and West Bengal districts.

Heatmap

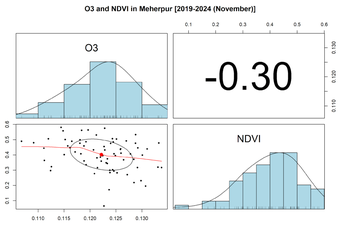


Figure 8: Heatmap of O_3 and NDVI in Meherpur District

Conclusion

Our study finds a statistically significant negative correlation between Ozone concentration and NDVI (plant health).
Ozone is uptake by plant leave > leave burn-out due to toxicity> crop yield decrease > food insecurity.

References

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