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Monitoring and Analysis of Air Quality in Zonguldak Province by Remote Sensing

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Keywords
Sentinel-5P TROPOMI
Nitrogen Dioxide
Sulphur Dioxide
Ozone
Carbon Monoxide

ABSTRACT

While air pollution poses a major threat to environmental health, monitoring and understanding this problem is extremely important. Especially in industrial areas, it is a vital requirement to monitor the levels of pollutants such as Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Ozone (O_3), Formaldehyde (HCHO) and Carbon Monoxide (CO) in the atmosphere. This situation becomes even more critical in areas such as Zonguldak where industrial activities are intense. In this study, the Sentinel-5P TROPOMI satellite and Google Earth Engine (GEE) platform were used to determine the air quality values in Zonguldak province. The study extracted data using coding method to determine the values of pollutants such as NO_2, SO_2, O_3, HCHO and CO in the atmosphere between 2020 and-2022. Coding was performed using satellite data on the GEE platform and thematic maps and graphs were created with the data obtained. According to the results obtained, it was observed that air pollution is intense especially in Ereğli district and Filyos town. Such analyses are extremely important in terms of understanding the pollution levels in certain regions and evaluating their possible environmental impacts. These findings can provide important clues for taking protective measures for environmental health and reducing the effects of industrial activities on the environment.

Uzaktan Algılama ile Zonguldak İlinde Hava Kalitesinin İzlenmesi ve Analizi

Anahtar Kelimeler:
Sentinel-5P TROPOMI
Azot Dioksit
Kükürt Dioksit
Ozon
Karbon Monoksit

ÖZ

Hava kirliliği, çevre sağlığı için büyük bir tehdit oluştururken, bu sorunun izlenmesi ve anlaşılması son derece önemlidir. Özellikle endüstriyel bölgelerde, Azot Dioksit (NO_2), Kükürt Dioksit (SO_2), Ozon (O_3), Formaldehit (HCHO) ve Karbon Monoksit (CO) gibi kirleticilerin atmosferdeki seviyelerini izlemek hayati bir gerekliliktir. Bu durum Zonguldak gibi endüstriyel faaliyetlerin yoğun olduğu bölgelerde daha da kritik bir hal alır. Bu çalışmada, Zonguldak ilindeki hava kalitesi değerlerini belirlemek amacıyla Sentinel-5P TROPOMI uydusu ve Google Earth Engine (GEE) platformunu kullanmıştır. Çalışma, 2020-2022 yılları arasında NO_2, SO_2, O_3, HCHO ve CO gibi kirleticilerin atmosferdeki değerlerini belirlemek üzere kodlama yöntemiyle veri çıkartmıştır. GEE platformunda uydu verileri kullanılarak kodlama yapılmış ve elde edilen verilerle tematik haritalar ve grafikler oluşturulmuştur. Elde edilen sonuçlarına göre özellikle Ereğli ilçesi ve Filyos beldesinde hava kirliliğinin yoğun olduğu gözlemlenmiştir. Bu tür analizler, belirli bölgelerdeki kirlilik seviyelerini anlamak ve olası çevresel etkilerini değerlendirmek açısından son derece önemlidir. Bu tespitler, çevre sağlığı için koruyucu tedbirler alınması ve endüstriyel faaliyetlerin çevreye olan etkilerinin azaltılması açısından önemli ipuçları sunabilir.

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1. INTRODUCTION

Air pollution is the presence of high levels of harmful substances in the atmosphere. These harmful substances are usually caused by human activities such as industrial activities, vehicle emissions, agricultural processes, and energy production. Pollutants such as ozone, particulate matter, carbon monoxide, sulfur dioxide and, nitrogen dioxide can cause air pollution. Air pollution carries serious risks to the environment and human health. It can cause health problems such as respiratory system diseases, heart disease, lung damage, and even cancer. Air pollution also damages ecosystems and can have negative impacts on vegetation, water resources and biodiversity.

Air is a vital component for the survival of living organisms and its cleanliness is extremely important. However, human activities are the main source of environmental air pollution, which poses significant risks to public health. These activities contribute significantly to the emissions of various harmful pollutants (Gautam & Hens, 2020; Ghorani-Azam et al., 2016). Factors such as economic development, energy consumption, urbanization, motor vehicle use, transportation and rapid population growth are known to contribute significantly to air pollution (Kaplan et al., 2019). Particulate matter (PM), SO_2, O_3, NO_2 and CO are the main air pollutants we encounter in our daily lives (Chen et al., 2007). NO_2 plays a critical role in urban air pollution and PM acts as a precursor to acid rain and ground-level ozone (Bechle et al., 2013). Fossil fuel combustion, such as oil, coal, and gas, is the main source of NO_2 in the atmosphere. This highly reactive pollutant is emitted during fossil fuel combustion and is a primary contributor to transport emissions (Muhammad et al., 2020).

Increasing greenhouse gas emissions are a global concern of harmful consequences leading to climate change (Jain, 1993). Components such as sulfur dioxide and nitrogen oxides react with other chemicals in the atmosphere, leading directly to the production of greenhouse gases and indirectly affecting global warming. In addition, SO_2 emissions are known to reduce the atmosphere's oxidation capacity. Therefore, increased emissions accelerate the accumulation of greenhouse gases and other pollutants in the atmosphere (Ward, 2009).

O_3 is formed by the oxidation of CO, CH_4 (methane), non-methane hydrocarbons and other volatile organic compounds under the influence of sunlight in the troposphere (Badarinath et al., 2012). Assessing the level of ozone is quite complex because it depends on the presence of nitrogen oxides, cloud cover, level of exposure to sunlight and population density in each area. Furthermore, the effect of aerosols on the surface ozone is uncertain; this effect may vary depending on the optical properties, chemical composition, and loss of regional aerosols (Li et al., 2011).

HCHO (formaldehyde) is a carcinogenic trace gas and a toxic pollutant in the atmosphere (Tesfaye et al., 2020). The US Environmental Protection Agency (EPA) considers it one of the most important outdoor carcinogens among 187 harmful air pollutants (Scheffe et al., 2016; Blair et al., 1990). HCHO, the most common aldehyde in the atmosphere, is one of the main volatile organic compounds and pollutants in the troposphere (Jin et al., 2020).

About 40 percent of carbon monoxide (CO) in the atmosphere originates from natural sources, especially factors such as volcanic eruptions, natural gas emissions, degradation of vegetation and animals, and forest fires (Varma et al., 2009). The remaining 60 percent comes from anthropogenic factors such as fossil fuel consumption, garbage disposal, tobacco smoke and charcoal fires (Vreman et al., 2000).

Carbon monoxide in the troposphere is generally not perceived as a serious health problem outdoors. However, recent research suggests that exposure to high concentrations of carbon monoxide, especially in urban areas, may have a possible association with heart problems (Andre et al., 2010). This suggests that CO should be considered not only in terms of its environment but also in terms of its possible effects on human health.

The economy of the Zonguldak is mainly based on coal mining. Therefore, Zonguldak is one of the most problematic provinces in Türkiye in terms of air pollution. The main source of air pollution in Zonguldak is coal-fired thermal power plants. These power plants generate electricity by burning coal. During the coal burning process, harmful particles, gases and fumes are released into the air. These pollutants can cause respiratory diseases, heart diseases and cancer.

This study investigated the air quality in Zonguldak province, especially the changes in NO_2, SO_2, O_3, HCHO, and CO concentrations. Zonguldak, a region with intensive coal industrial activities, is particularly important to air quality problems.

In the data processing and analysis phase, the increase in large geographic data, cloud computing technologies and big data processing services are important factors shaping future Remote Sensing applications. Without the challenges of traditional data analysis methods, Google Earth Engine enables scientists, experts, and to extract meaningful information from large remote sensing datasets quickly (Amani et al., 2020). In this study, we investigated the changes in air quality and pollution in Zonguldak province using Sentinel-5P/TROPOMI satellite data on the GEE platform.

2. MATERIAL and METHOD

Zonguldak is an important industrial city located on the Black Sea coast of Türkiye. Figure 1 shows the location of Zonguldak province on the Google Earth platform. With the increase in industrial activities, the problem of air pollution is also increasing. Many satellite data contain information from advanced sensors used to detect different pollutants in the atmosphere. These data can be used to determine the air pollution in Zonguldak and the sources of pollutants. In this way, authorities can better understand environmental risks and take preventive measures.

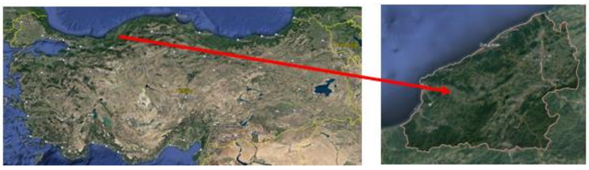


Figure 1. Location of Zonguldak province on the Google Earth platform.

Sentinel-5P, a satellite operated by the European Space Agency (ESA), is designed to measure air pollution parameters. Sentinel-5P is equipped with a sensor called TROPOMI (Tropospheric Monitoring Instrument). TROPOMI is a spectrometer operating in the UV-Vis (Ultraviolet-Visible) spectrum. This spectrometer measures the emission of pollutant molecules in the air and determines the concentration of these pollutants.

Launched on 13 October 2017, Sentinel-5 Precursor (Sentinel-5 P) is the first Copernicus mission satellite dedicated to monitoring the atmosphere. Sentinel 5P is equipped with a spectrometer called TROPOMI, which measures high spectral irradiances of ultraviolet earthlight. TROPOMI maps the global atmosphere daily with a resolution of 7 km × 3.5 km (Theys et al., 2019).

In this article, NO_2, SO_2, O_3, HCHO and CO parameters were analysed on the Google Earth Engine platform using Sentinel-5P, TROPOMI satellite.

NO_2, SO_2, O_3, HCHO and CO pose a serious threat to human health and the environment. These pollutants can cause respiratory diseases, heart diseases, cancer, and adverse effects on vegetation and the environment. The Sentinel-5P TROPOMI satellite is designed to monitor pollutant gases in the atmosphere with high resolution. Sentinel 5 data is readily available on the GEE platform, and data can be processed, analyzed, and visualized.

While air pollution is a major environmental health threat, it is extremely important to monitor and understand the problem. Figure 2 shows the workflow diagram. In this study, the Sentinel-5P TROPOMI satellite and the Google Earth Engine (GEE) platform were used to determine air quality levels in Zonguldak province. As a first step of the research, the relationship between air pollution and environmental health was focused and Zonguldak province was selected as the study area. As part of this study, the necessary tools such as satellite data and GIS software were identified and NO_2, SO_2, O_3, HCHO and CO were selected as the pollutants to be monitored in the atmosphere. Satellite data were collected by coding on the GEE platform and pollutant levels between 2020-2022 were extracted. The collected data were transferred to GIS software, spatial analysis was performed, and thematic maps and graphs were created. Air pollution risk map created based on satellite data. It was found that air pollution is intense in Ereğli and Filyos district pollution levels in specific regions were evaluated. Such analyses are extremely important in terms of understanding environmental impacts and taking protective measures. These findings, supported by GIS-based maps and graphics, can provide strategic guidance that is critical to environmental health.

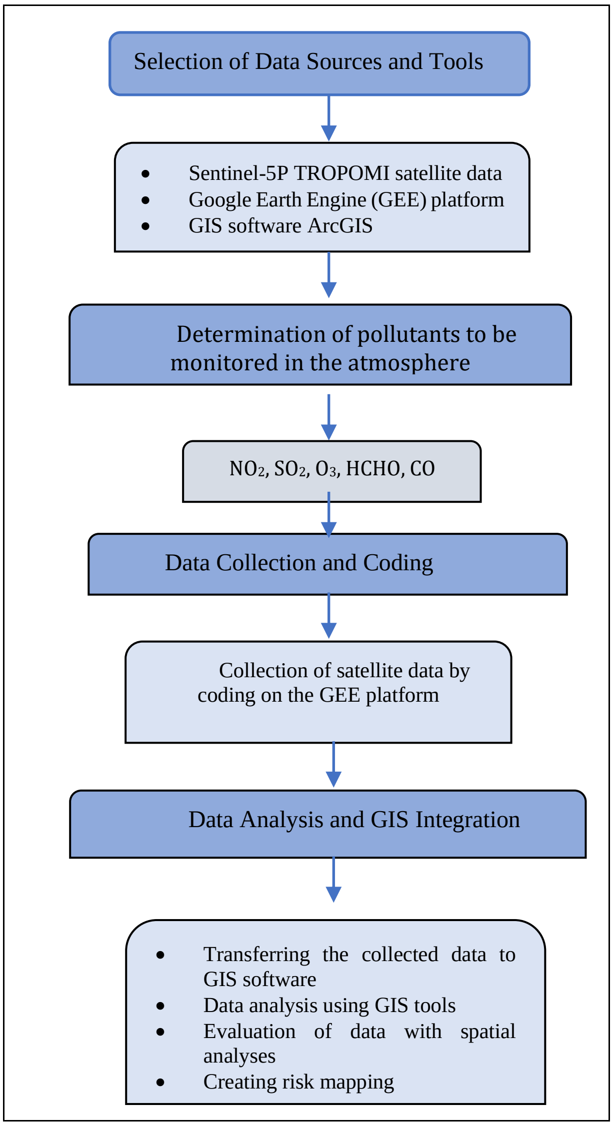
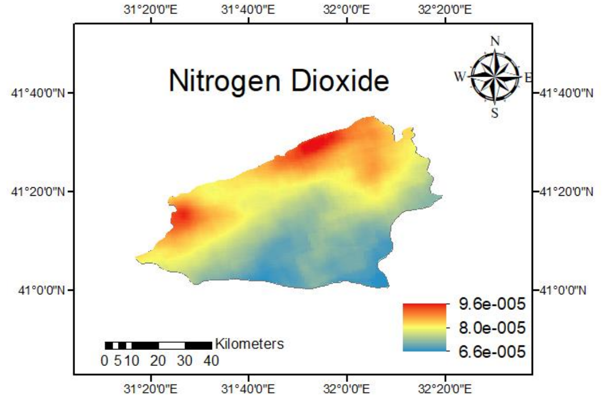


Figure 2. Work flow chart

3. RESULTS

In the study, Sentinel-5P satellite data designed to measure air pollution parameters (NO_2, SO_2, O_3, HCHO and CO) were used Google Earth Engine platform was used to extract these parameters from Sentinel-5P satellite data. In this platform, by writing coding; maps were created, and graphics were obtained to analyze the data.



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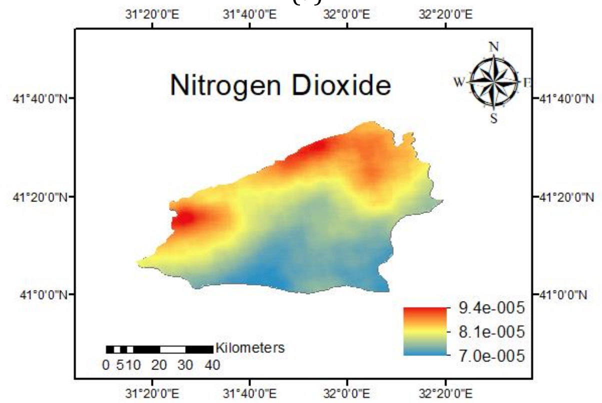

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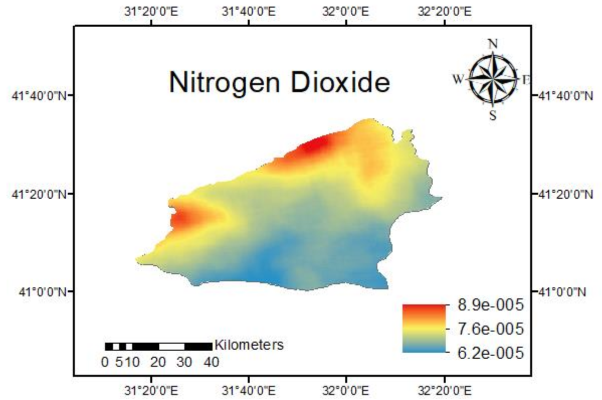

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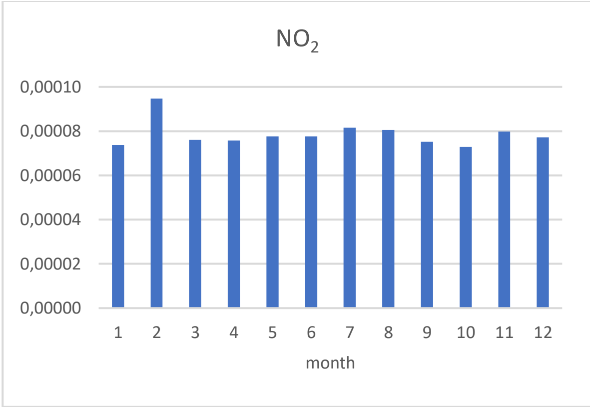
Figure 3. Thematic maps of NO_2 value for (a) 2022 (b) 2021 (c) 2020.

Figure 3 shows the thematic maps of the NO_2 parameter in 2020-2022. Values range from 9.6e-005 to 6.2e-005. For the year 2020, NO_2 values were observed to reach high values. For the year 2022, it was observed that NO_2 reached the lowest values. Especially in coastal areas, Alaplı, Ereğli, Zonguldak Centre, Kilimli districts and Filyos town, NO_2 parameter is observed to be intense.



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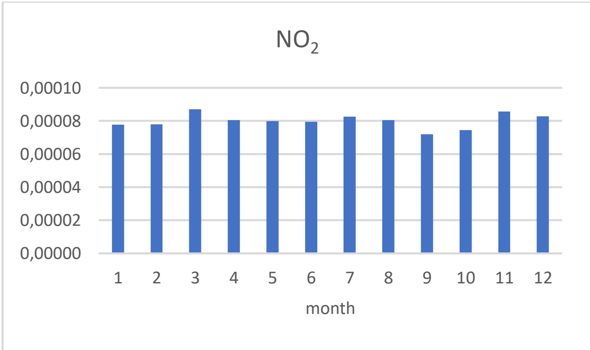

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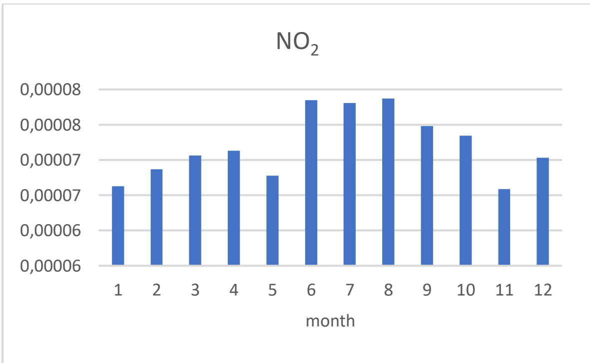

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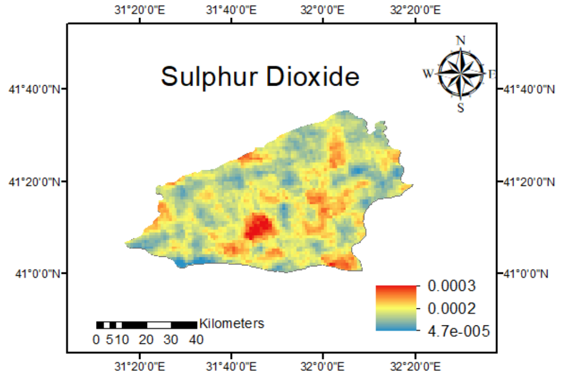
Figure 4. Charts of average values of NO_2 value for (a) 2022, (b) 2021, (c) 2020.

Figure 4 shows the maximum, minimum and average values of the NO_2 parameter in 2020-2022. For 2022, NO_2 values reached the highest values in February, while the lowest values were observed in May and July. For 2021, NO_2 values reached high values in November, December, and February, while the lowest values were observed in July and August. For 2020, it was observed that NO_2 reached the highest values in August and July, while it reached the lowest values in January and November.



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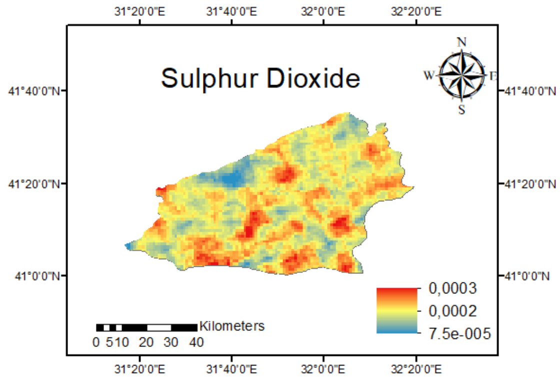

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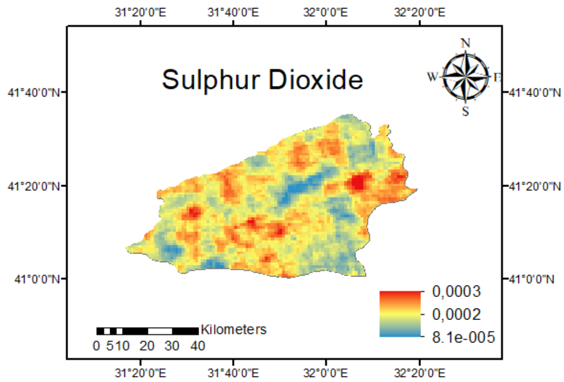

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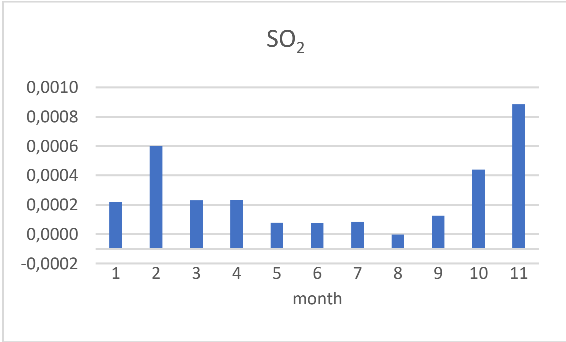
Figure 5. Thematic maps of SO_2 value for (a) 2022 (b) 2021 (c) 2020.

Figure 5 shows the thematic maps of the SO_2 parameter in 2020-2022. Values range from 0.0003 to 8.1e-005. For 2021, SO_2 values are observed to reach high values. For 2022, it was observed that the SO_2 value reached the lowest values. In 2020 and 2021, it was observed that the SO_2 value of the years 2020 and 2021 was widely observed in the districts of Zonguldak province.



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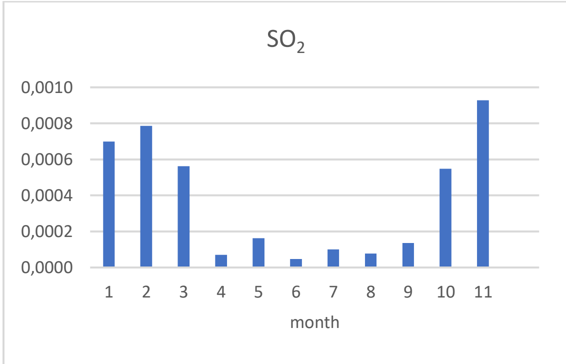

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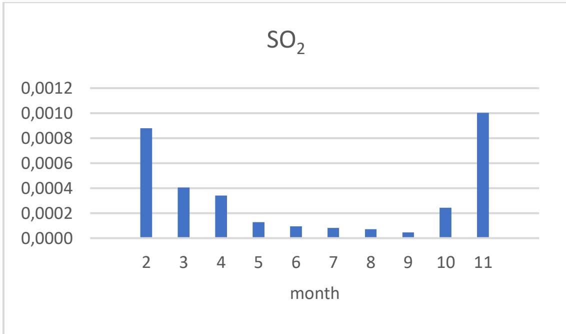

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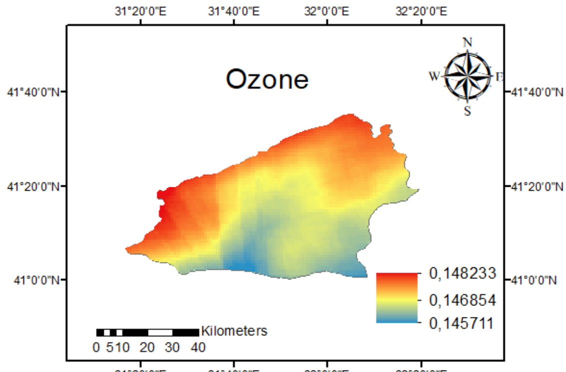
Figure 6. Charts of average values of SO_2 for (a) 2022, (b) 2021, (c) 2020.

Figure 6 shows the maximum, minimum and average values of SO_2 parameter in 2020-2022. For 2022, SO_2 values are observed to reach high values in November, while reaching the lowest values in August. For 2021, SO_2 values: It is observed that it reaches high values in November, while it reaches the lowest values in August. SO_2 values for 2020: It was observed that it reached high values in November, while it reached the lowest values in August.



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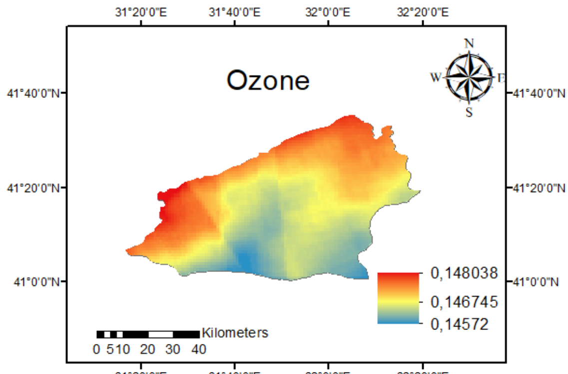

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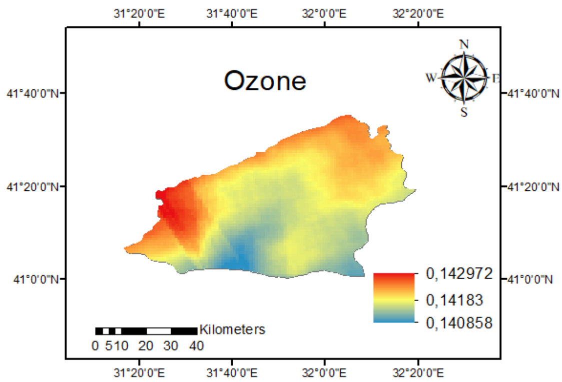

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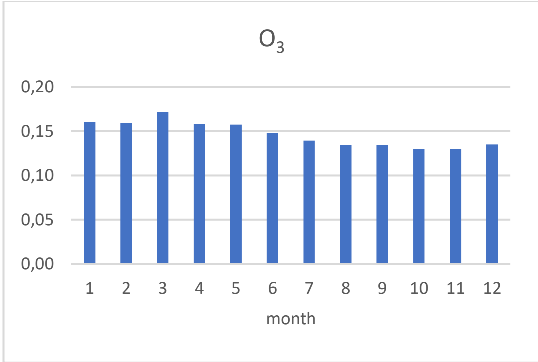
Figure 7. Thematic maps of O_3 value in (a) 2022 (b) 2021 (c) 2020

Figure 7 shows the thematic maps of the O_3 parameter in 2020-2022. Values range from 0.178 to 0.140. For 2021, O_3 values were observed to reach high values. For 2020, it was observed that O_3 reached the lowest values. The O_3 parameter is intense in the coastal areas of Alaplı, Ereğli, Zonguldak Centre, Kilimli and Çaycuma districts.



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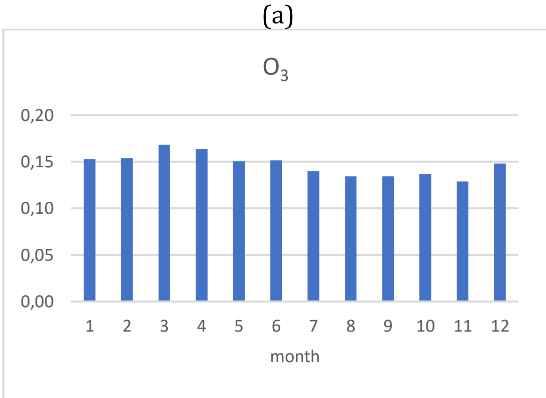

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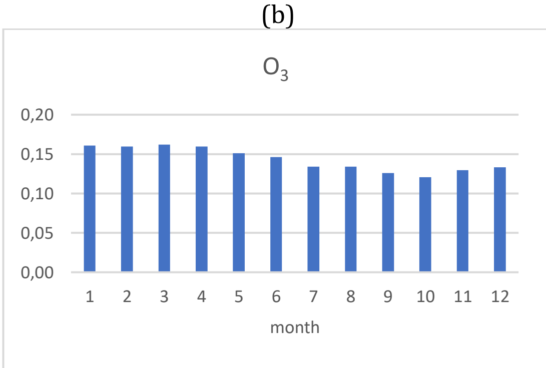

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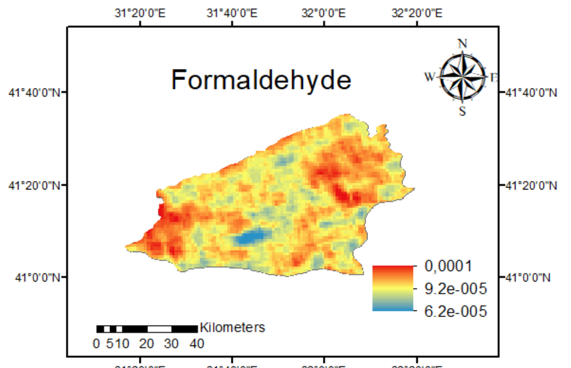
Figure 8. Schedules of the average values of O_3 in (a) 2022, (b) 2021 (c) 2020

Figure 8 shows the maximum, minimum and average values of the O_3 parameter in 2020-2022. For the year 2022, O_3 values reached high values in March, while they reached the lowest values in November. For the year 2021, O_3 values reached the highest values in March, and the lowest values in November. For 2020, O_3 values reached high values in March, and the lowest values in October.



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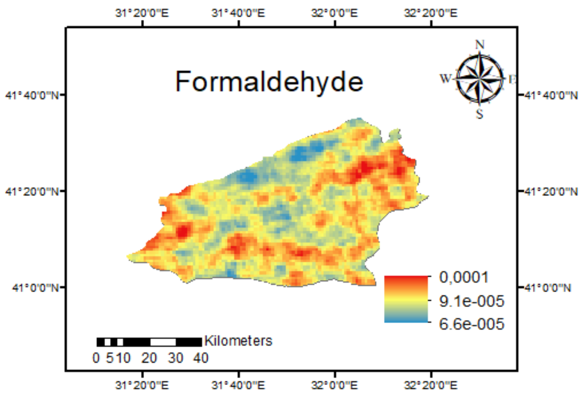

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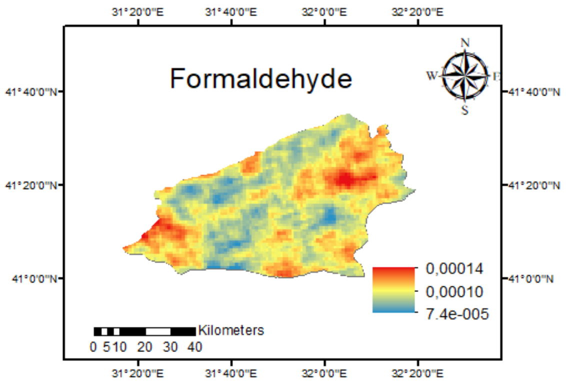

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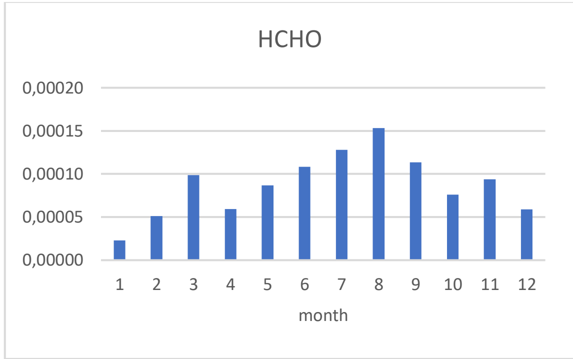
Figure 9. Thematic maps of HCHO value in (a) 2022 (b) 2021 (c) 2020

Figure 9 shows the thematic maps of the HCHO parameter in 2020-2022. Values range from 0.0001 to 7.4e-005. For 2022, it was observed that HCHO values reached high values. For 2021, HCHO reached the lowest values. Especially in Ereğli district and Filyos town, HCHO parameter was observed to be intense.



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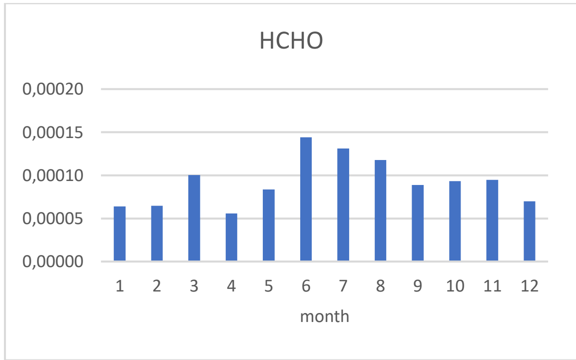

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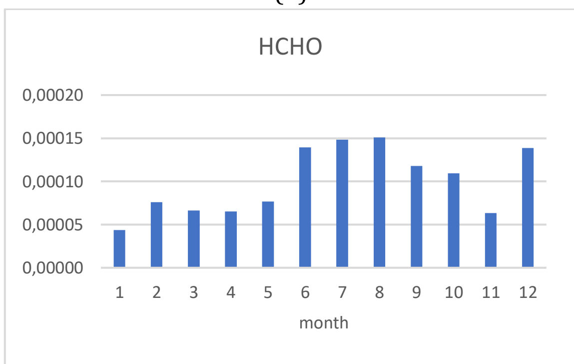

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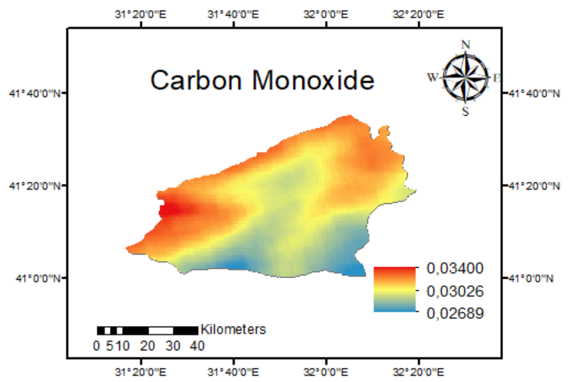
Figure 10. Plots of the average values of HCHO in (a) 2022, (b) 2021, (c) 2020

Figure 10 shows the maximum, minimum and average values of the HCHO parameter in 2020-2022. For 2022, HCHO values are observed to reach the highest values in August, and the lowest values in January. It was observed that HCHO values for 2021 reached the highest values in June and the lowest values in January. For 2020, it was observed that HCHO values reached the highest values in August, and the lowest values in January.



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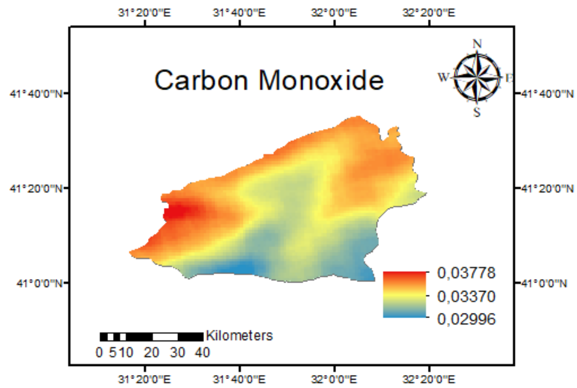

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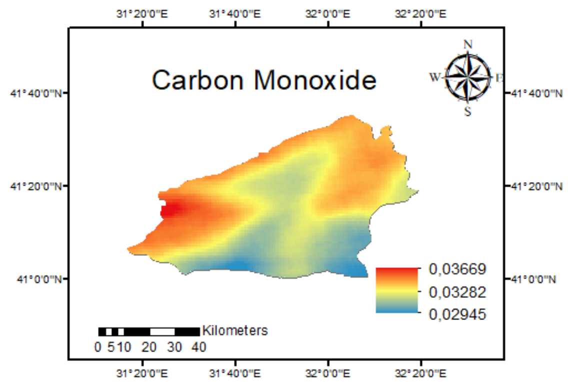

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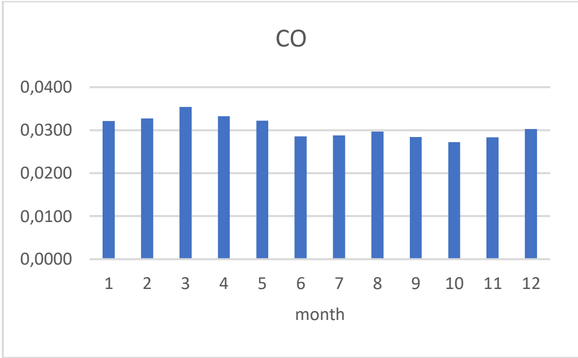
Figure 11. Thematic maps of CO value in (a) 2022 (b) 2021 (c) 2020

Figure 11 shows the thematic maps of the CO parameter in 2020-2022. Values range from 0.037 to 0.026. For 2021, it was observed that CO values reached high values. For 2022, it was observed that CO values reached the lowest values. It was determined that CO levels were high in Alaplı, Ereğli, Zonguldak Centre, Kilimli and Çaycuma districts, especially in coastal areas.



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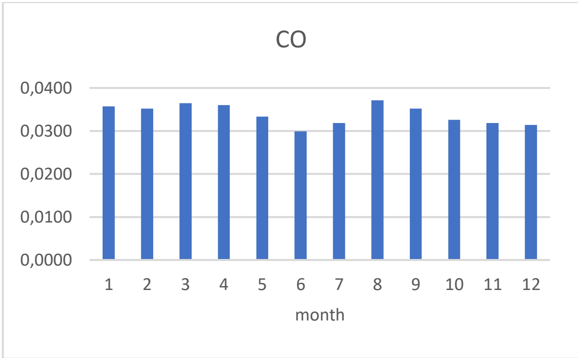

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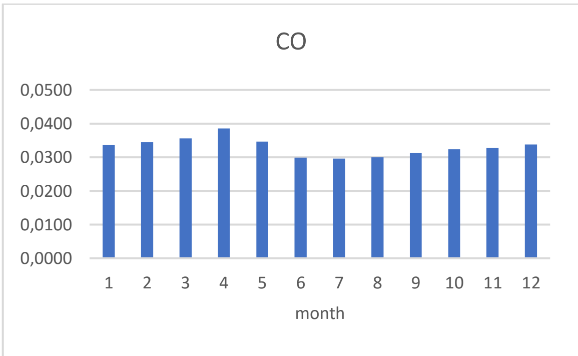

(c)

Figure 12. Charts of the average values of CO in (a) 2022, (b) 2021 (c) 2020

Figure 12 shows the maximum, minimum and average values of the CO parameter in 2020-2022. For 2022, CO values are observed to reach the highest values in March, and the lowest values in October. For the year 2021, CO values are observed to be highest in August, and lowest in June. For 2020, it was observed that CO values reached the highest values in April, and the lowest values in July.

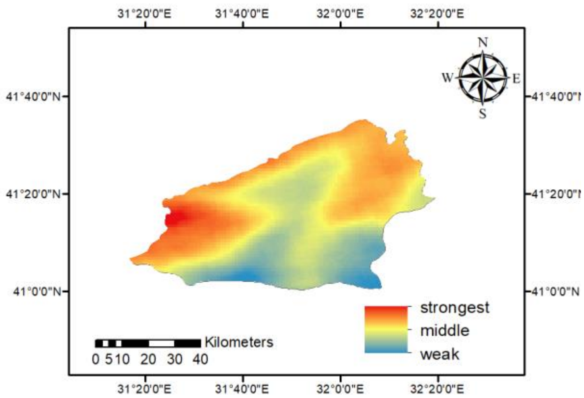

Figure 13. Air pollution risk map created based on satellite data.

Figure 13 shows an air pollution risk map based on satellite data. Air pollution risk map generation process based on satellite data was carried out using Multi-Criteria Decision Analysis (MCDA) model. In this process, the concentration data of NO_2, SO_2, O_3, HCHO, CO pollutants were collected and uploaded to ArcGIS software. Equal weights were assigned to each pollutant in line with their health and environmental impacts. This map helps environmental assessment and decision-making processes by visualizing air pollution risk levels in specific regions. It is critical for understanding the potential impacts of air pollution on human health and the environment, especially in areas with intensive industrial activities. The map consists of color-coded regions according to the concentrations of various pollutants (NO_2, SO_2, O_3, HCHO, CO) in the atmosphere. Red colors indicate areas with higher air pollution risk, while green color represents lower risk levels. According to the results obtained, it is observed that the risk of air pollution is high especially in Ereğli district and Filyos town of Zonguldak province. The intensity of industrial activities in these regions is one of the main factors that negatively affect air quality. The high-risk areas identified on the map emphasize the need for urgent intervention and continuous monitoring for environmental health.

4. CONCLUSION

Air pollution is a factor that seriously affects environmental quality and human health. In recent years, the use of satellite data has gained great momentum in air pollution detection and monitoring efforts. Satellite data have become an important tool for determining air pollution levels over a wide geographical scale, monitoring trends, and identifying pollution sources. These data have the potential to understand air quality in urban areas and support decision makers in environmental planning processes.

Many techniques are employed for space-based air quality and pollutant measurement, with Sentinel-5P being one of the most widely used satellites for this purpose. Sentinel-5P provides detailed data on various atmospheric pollutants, aiding in the comprehensive analysis and investigation of air quality on a global scale (Zheng et al., 1939; Hashim et al., 2021; Vîrghileanu et al., 2020).

The results of the analyses show the distribution of air quality values in Zonguldak province and change over time. This information is important for environmental management and health organisations to monitor air quality and take necessary measures. The Sentinel-5P TROPOMI satellite and the GEE platform are a powerful tool for monitoring and understanding the effects of air pollution. Determining air quality values in Zonguldak province using the Sentinel-5P TROPOMI satellite and GEE platform is important in protecting environmental health and combating air pollution. This method can be similarly applied in other regions and can be a useful resource for monitoring air quality. The results obtained with Sentinel-5P/TROPOMI data can make an important contribution to monitoring the air quality of Zonguldak province, identifying pollution sources and understanding environmental impacts.

Ereğli district and Filyos town stand out among the regions where air pollution is intense. Especially in these areas where industrial activities are intense, it can be associated with the activities of industrial facilities as well as environmental factors. Air pollutants such as NO_2, SO_2, O_3, HCHO and CO were detected at particularly significant levels in these regions.

This study shows that air pollution can be reduced by implementing systematic pollution source control measures within a given time interval. Furthermore, satellite remote sensing-based air pollution observations can provide complete measurements, considering the spatial extent and distribution of the study area. The pollution control decision maker can easily identify regions with high pollution levels and address regional control measures for these areas.

Furthermore, improving long-term data collection and analysis capabilities can be a critical step to identify and combat the impacts of air pollution. In this process, large-scale and remote sensing systems, such as satellite data, can provide a broad perspective on air pollution and, accordingly, can be used in environmental planning and policy-making processes. The use of satellite data for the detection and management of air pollution offers significant benefits to decision-makers in preserving the health and quality of the environment. Therefore, given the high resolution and extensive coverage of satellite imagery, it is critical that future research focuses on developing more efficient and predictive systems.

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Author contributions

The study was conducted by a single author.

Conflicts of Interest

The author declares no conflict of interest.

Research and publication ethics statement

In the study, the author declares that there is no violation of research and publication ethics and that the study does not require ethics committee approval.

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