Investigating the Relationship Between Seismic Events and Air Quality: A Case Study of The Türkiye Earthquake 2023

Abdullah Sukkar[1]*, Sara Essoussi[2], Ugur Alganci[3], Dursun Zafer Seker[3]

[1] ITU, Istanbul Technical University, Graduate School, Geomatics Engineering Program, Türkiye

[2]Laboratory of Geo-Bio-Environment Engineering and Innovation (2GBEI), Polydisciplinary Faculty of Taroudant, Ibnou Zohr University, Morocco

[3]ITU, Istanbul Technical University, Department of Geomatics Engineering, Türkiye

*sukkar20@itu.edu.tr

Abstract *On February 6th, 2023, Türkiye experienced the devastating impact of two powerful earthquakes measuring 7.5 and 7.8 on the Richter scale, resulting in widespread chaos and tragedy. This study was designed to investigate the relationship between earthquakes and remotely sensed atmospheric parameters obtained by the Sentinel 5P TROPOMI instrument. This comprehensive analysis compared the monthly measurements from February to June of certain air pollutants such as the UV Aerosol Index, SO2, NO2, O3, CO, HCHO, and CH4 in 2023 and the average monthly measurements of the previous year. The Sentinel 5P satellite data was obtained through the Google Earth Engine platform and analyzed by GIS software. The results indicate that the earthquake triggered significant aerosol emissions into the atmosphere; this increase is attributed to the collapse of numerous buildings caused by the earthquake and the subsequent rubble removal efforts, which lasted several months. In addition, CO, SO2, and NO2 levels decreased, especially in February and March, which may be linked to a downturn in human and industrial activities in the region. However, the levels of CH4 have significantly increased in the entire earthquake area since February. While earthquakes can lead to the release of methane, the substantial mortality rate may also play a key role in contributing to this rise. Moreover, the air and soil temperatures of the ERA5-Land data from the Copernicus Data Store were utilized to assess the variations in monthly temperatures throughout the last years to check whether there is any potential relationship between the increasing air quality levels and temperature.*

Keywords: Google Earth Engine, TROPOMI, Remote Sensing, Air Pollution, Earthquake

Introduction

On 6 February 2023, Türkiye experienced two seismic events of 7.5 and 7.8 magnitudes, followed by several aftershocks (Zilio & Ampuero, 2023). These earthquakes were recorded as the most severe in Türkiye since 1939 (Bayram et al., 2023). According to the Disaster and Emergency Management Presidency (AFAD), the number of fatalities exceeded 50 thousand, and the number of injuries exceeded 100 thousand. (AFAD, 2023). The earthquakes significantly impacted the lives of approximately 9 million people and destroyed more than 270,000 buildings (Şahin & Kaynak, 2024).

Several studies and research indicate that the increase in global greenhouse gases (GHG) in the atmosphere is the main reason for extreme weather events, which is reflected in creating suitable conditions for the occurrence of natural disasters (Prohaska & Peters, 2019). Disasters, such as wildfires and volcanic eruptions, exacerbate air pollution directly by releasing extensive quantities of gases and particles into the atmosphere. However, there is limited information regarding the relationships between air pollution and natural disasters like earthquakes, and more researches are required to understand these correlations (Zanoletti & Bontempi, 2024). The relationship between seismic activities and air quality is complicated and impacted by various elements. Earthquakes have both direct physical impacts and broader consequences, such as ecosystem disturbances and the pollution of air, water, and soil (Vural, 2024).

Earthquakes can impact pollution levels as a result of the dispersion of dust from collapsed structures, debris removal, construction activities, and damaged industries, where a variety of hazardous substances including volatile organic compounds (VOC_s), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter ($PM_{2.5}$ and PM_{10}) can be released (Somervell & Aberkane, 2014; Zanoletti & Bontempi, 2024). These pollutants presented acute health hazards, worsening respiratory and cardiovascular diseases, and had lasting impacts on air quality and regional climate trends. For this reason, earthquakes, in addition to being a direct cause of mortality, can be considered a direct cause of significant risks to human health at regional and local scales (Vural, 2024).

In this context, the relationship between the air quality and the earthquake that hit Türkiye in February 2023 was examined in this study depending on remotely sensed data. Air pollutants such as UV aerosol index, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), Ozone (O_3), formaldehyde (HCHO), and methane (CH_4) were analyzed on a monthly scale between February and May 2023, and the results were compared with the average measurements of previous years from 2019 to 2022. In addition, the air temperature and soil temperature parameters of the ERA5-Land dataset were utilized to understand the impact of these air pollutants on climate patterns.

Study Area

The two earthquakes affected eleven provinces (Kahramanmaras, Gaziantep, Sanliurfa, Diyarbakir, Adana, Adiyaman, Osmaniye, Hatay, Elazığ, Kilis, and Malatya). Over 14 million people live in the affected cities, accounting for 16.4% of the national population of Turkey. Moreover, the region hosts 1,738,035 Syrians under Temporary Protection in

Türkiye (SBO, 2023). Figure 1 represents the study area in the south of Turkey. Hatay, Kahramanmaras, and Gaziantep were the most affected provinces, where districts like Antakya, Dulkadiroğlu, and Nurdagi were destroyed completely.

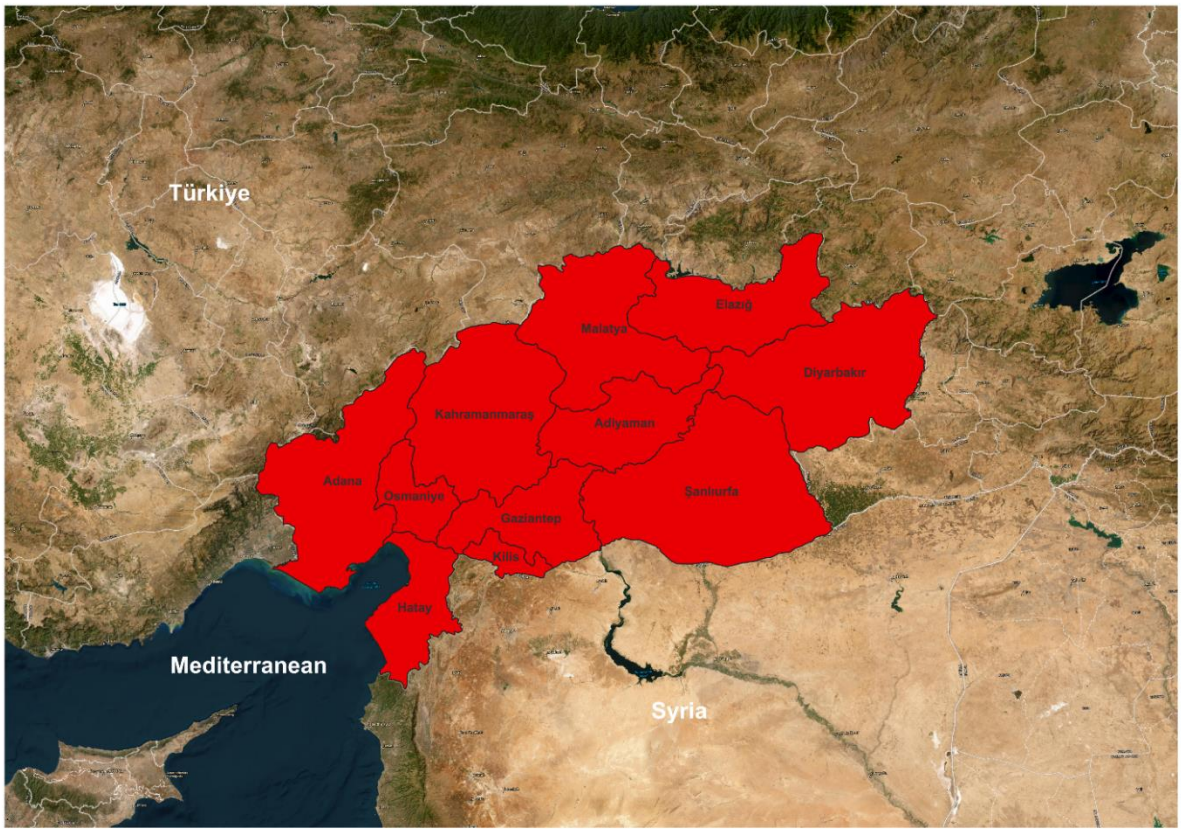

Figure 1. Geographical location of the study area.

Materials and Methodology

The Sentinel-5P TROPOMI satellite sensor is an essential instrument for diverse environmental monitoring applications. TROPOMI was launched in 2017 as part of the Copernicus Sentinel 5 Precursor (S-5P) satellite, delivers high-resolution data on atmospheric composition, encompassing trace gases such as SO_2, CO, NO_2, O_3, HCHO, and CH_4 as well as the UV Aerosol Index (Cho et al, 2021; Levelt et al, 2022).

Monthly air and soil temperatures from ERA5-Land were utilized to compare the monthly temperatures of 2022 and 2023, then the monthly measurements of these two years were compared with the monthly average from 2013 to 2022. The ERA5-Land dataset is a high-resolution 0.1° at hourly and monthly scales and provides meteorological observations for various variables from 1950 to the present (Muñoz-Sabater et al., 2021).

Both datasets, air quality and meteorological, were acquired via the Google Earth Engine (GEE) platform for the designated study area. GEE signifies a substantial progression in

remote sensing and environmental monitoring, offering researchers a robust cloud-based platform for accessing and analyzing extensive remote sensing and geospatial datasets (Zhao et al., 2021; Mutanga & Kumar, 2019; Amani et al., 2020).

The measurements of air pollutants of 2023 (the year of the earthquake) were averaged on a monthly scale from February to June, then compared with the measurements of from February and June of 2019 to 2022. In addition, the monthly air and soil temperatures of 2022 and 2023 were also compared. The ESRI ArcMap product was used to map and visualize all the datasets.

Results and Discussion

Aerosols are diminutive liquid or solid particulates dispersed in the atmosphere. They directly influence climate by absorbing and scattering solar and terrestrial radiation (Boucher, 2015). Aerosols can be classified based on their radiative properties into two categories based on their radiative properties: absorbing aerosols and scattering aerosols. Aerosols that absorb radiation, including smoke, desert dust, volcanic ash, and soot produced by human activities. This type of aerosol contributes to climate warming. Meanwhile, scattering aerosols, such as sulfate particles and clouds, disperse solar radiation and typically exert a cooling influence on the climate. The Ultraviolet (UV) Absorbing Aerosol Index (AAI) refers to the atmospheric absorption caused by aerosols. It distinguishes the spectral contrast at two ultraviolet (UV) wavelengths resulting from aerosol absorption from that of molecular Rayleigh scattering, surface reflection, and trace gas absorption (de Graaf et al., 2005). The AAI is 0 without absorbing or scattering aerosols in the scene (Kooreman et al., 2020). The AAI findings demonstrate that the earthquake caused substantial aerosol emissions into the atmosphere (Figure 2a). Comparing the average monthly measurements from 2019 to 2022 with those of the corresponding months in 2023 reveals a marked increase in aerosol levels starting in February 2023, coinciding with the earthquake. The levels increased further in March, had a minor reduction in April, surged dramatically in May, and subsequently began to reduce in June. This trend is attributed to the destruction of many structures resulting from the earthquake and the ensuing debris removal operations that persisted for several months.

Sulfur dioxide (SO_2) is a significant air pollutant with numerous sources and impacts. anthropogenic activities are responsible for emitting about 64.2 Tg per year of SO_2 (Gac & Petelczyc, 2019). This emission comes mostly from industrial operations and electricity generation. Exposure to sulfur dioxide has serious health effects. SO_2 can lead to respiratory difficulties, including bronchitis and emphysema, and worsen existing health concerns like

asthma (Chang et al., 2019). In addition, SO_2 contributes to acid rain generation, resulting in considerable ecological damage, including soil deterioration and destruction of aquatic systems (Kane, 2024). The results indicate that in Kahramanmaraş province, the SO_2 levels noticeably dropped relative to the averages of previous years (Figure 2b). Nonetheless, across the entire affected area, SO_2 levels increased in March but then slightly decreased.

Nitrogen dioxide (NO_2) is a significant air pollutant primarily produced from vehicular emissions and industrial processes. Its health implications have been extensively studied, revealing associations with various respiratory and cardiovascular diseases, as well as potential neurodevelopmental impacts. Studies demonstrate that exposure to NO_2 correlates with heightened risks of respiratory ailments, including asthma and other pulmonary disorders (Dijkema et al., 2016). NO_2 exposure has been linked to cardiovascular disorders, in addition to its effects on respiratory health. Performed a pooled analysis of multiple European cohorts, demonstrating correlations between prolonged exposure to low levels of NO_2 and elevated mortality rates, even at concentrations beneath the World Health Organization's recommended limits (Strak et al., 2021). This indicates that the health hazards linked to NO_2 are not solely acute but can also develop over extended durations, leading to chronic health issues. The findings indicate that the NO_2 levels fell post-earthquake until May before beginning to rise (Figure 2c). This reduction may be linked to a downturn in human and industrial activities in the earthquake region.

Carbon monoxide (CO) is a colorless, odorless, and extremely poisonous gas that presents considerable health hazards, especially via inhalation. It is generated mostly by the partial combustion of carbonaceous fuels, including those utilized in automobiles, heating apparatus, and industrial operations (Akça et al., 2015). The environmental consequences of CO are considerable, as an air pollutant, CO deteriorates air quality and endangers human health. In urban areas, heightened concentrations of CO have been linked to a rise in hospital admissions for respiratory ailments, especially chronic obstructive pulmonary disease (Tian et al., 2014). Although the earthquake may have caused immediate emissions of carbon monoxide and dioxide, the results show a reduction in monthly CO levels compared to the averages from 2019 to 2022 (Figure 2d). This decline may also be associated with a decrease in human and industrial activities in the affected area.

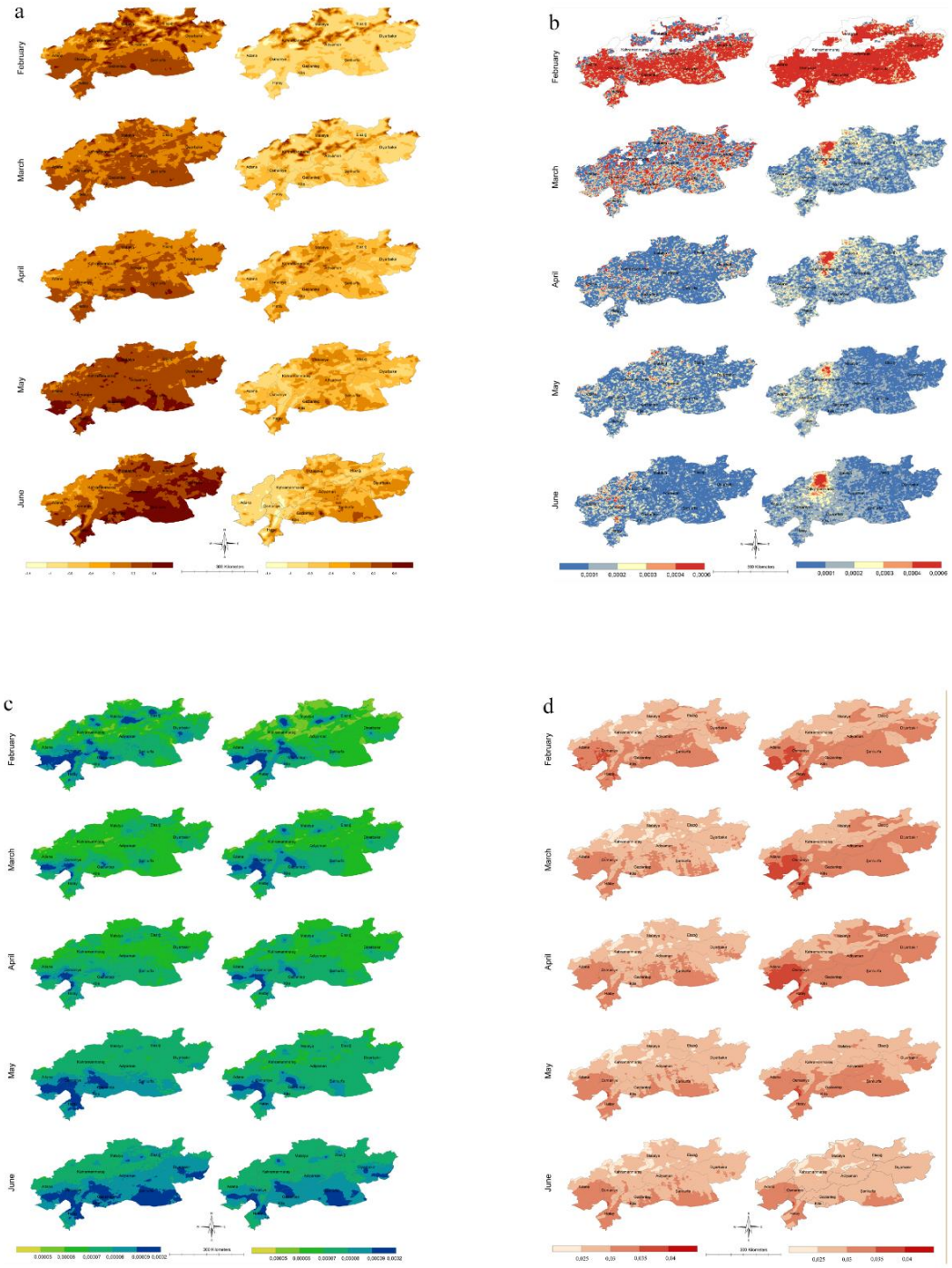

Figure 2. Comparison between the monthly measurements of AAI (a), SO_2 (b), NO_2 (c), and CO (d), the left columns with each image represent the measurement of 2023, while the right columns represent the averages from 2019 to 2022.

Formaldehyde (HCHO) is a colorless, combustible gas with a potent odor, presenting significant health hazards. Studies have demonstrated that exposure to HCHO might result in many detrimental health effects. It is recognized to cause irritation to the eyes, skin, and respiratory tract, with symptoms appearing even at minimal doses (Marcon et al., 2014).

Prolonged exposure has been associated with more severe consequences, including respiratory illnesses and an elevated risk of malignancies, especially in the nasopharynx and sinonasal areas (Jalali et al., 2020). HCHO is produced by industrial processes, automotive emissions, and the combustion of wood, coal, and various fuels. It is moreover a result of some chemical reactions taking place in the environment. It facilitates the formation of ground-level ozone and other harmful air pollutants in the atmosphere (Salthammer et al., 2010). The results indicate that there was a slight rise in HCHO levels in February, March, and April, followed by a decrease (Figure 3a).

Methane (CH_4) is a powerful greenhouse gas that substantially impacts climate change, possessing a global warming potential that far exceeds that of carbon dioxide (CO_2) over a brief period. CH_4 is generated by natural processes, such as decomposition in wetlands, and anthropogenic activities, including agriculture particularly from the digestive processes of ruminant animals, landfills, and the extraction and transportation of coal, oil, and natural gas (Kirschke et al., 2013). The results show that the CH_4 concentrations have increased notably in the affected region since February (Figure 3b). Although earthquakes can induce methane emissions, the elevated mortality rate may also substantially augment this increase.

Ozone (O_3) is a serious air contaminant that adversely impacts human health and the environment. The impact is most pronounced in urban areas where ground-level ozone concentrations can attain detrimental levels due to emissions from cars, industrial operations, and several other sources (Monks et al., 2015). The health consequences of O_3 exposure are extensively established, with research demonstrating a clear association between elevated ozone levels and respiratory and cardiovascular death. A 10-ppb increase in ozone concentration was linked to a 0.52% rise in daily mortality in Ahvaz, Iran (Goudarzi et al., 2015). The impacts of ozone are not confined to human health; they also affect plant life and ecosystems. Exposure to ozone can cause discernible leaf damage and disrupt plant physiological functions, therefore affecting agricultural yield (Duque et al., 2021). The findings show that the ozone concentrates were below the average in February 2023, then raised in March, the reduced again below the average from 2019 to 2022 (Figure 3c).

The analysis of the air and soil temperatures shows that the monthly averages of both air and soil temperatures in 2023 were less than the measurements of 2022 and the average of the last 10 years (Figures 4 & 5). However, in March, the air and soil temperatures significantly increased above 2022 and the average of the last 10 years. Then, for the rest of the years, the temperatures were close to their average levels. The high concentrations of air pollutants such as AAI and CH4 may played a role in the increasing temperature observations.

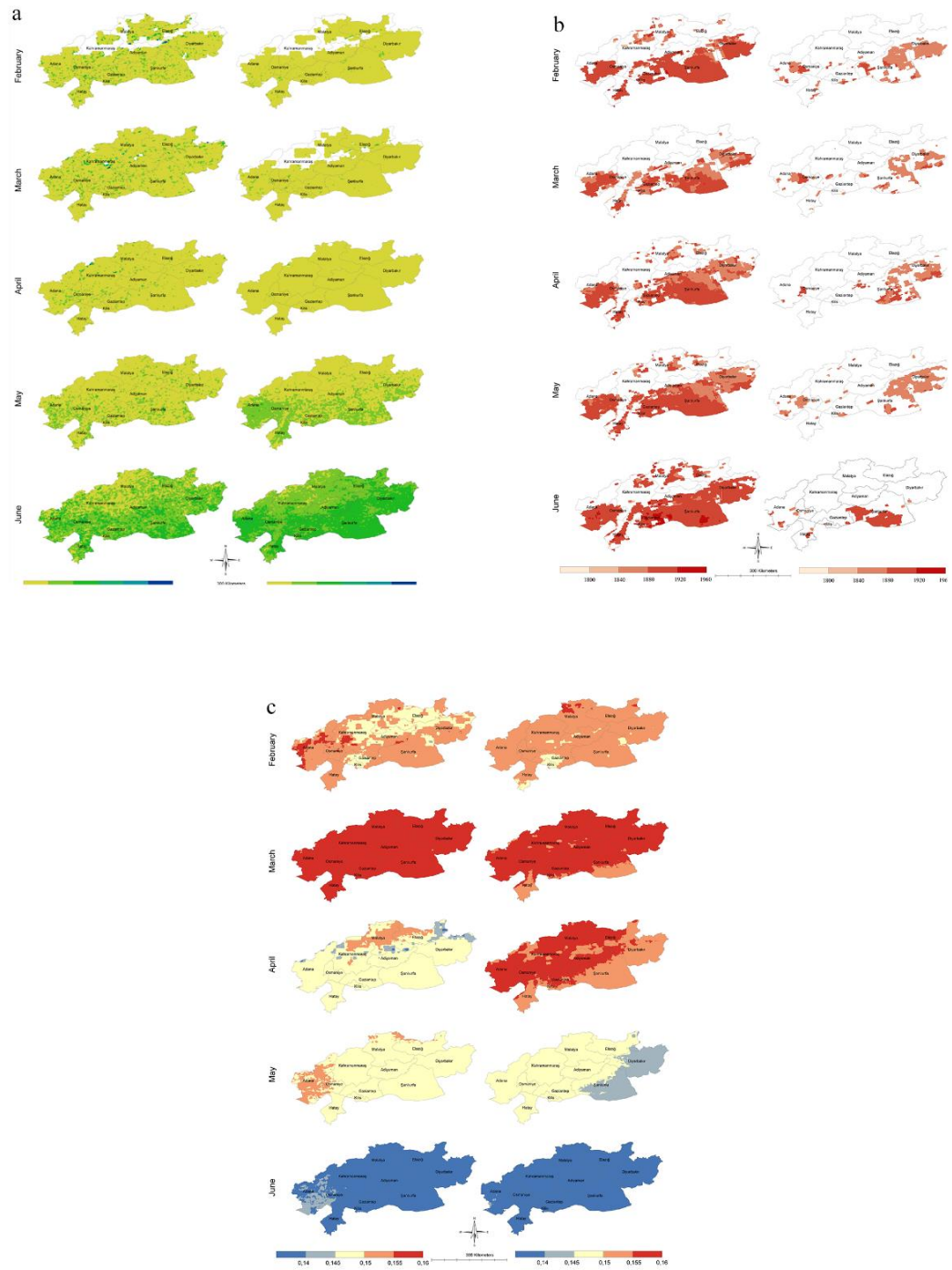

Figure 3. Comparison between the monthly measurements of HCHO (a), CH_4 (b), and O_3 (c), the left columns with each image represent the measurement of 2023, while the right columns represent the averages from 2019 to 2022.

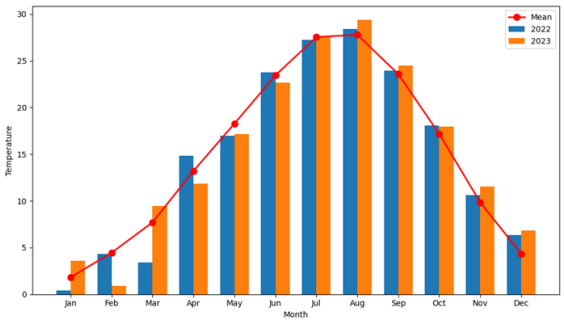

Figure 4. The monthly air temperature averages for 2022, 2023, and the last ten years from 2013 to 2022.

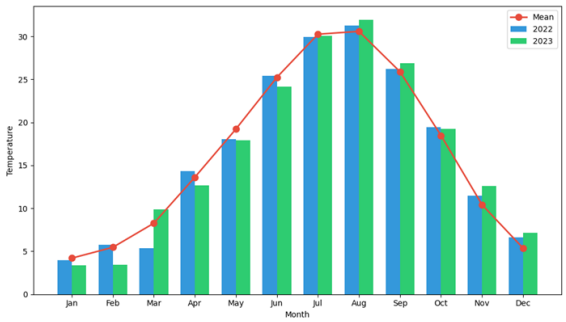

Figure 5. The monthly soil temperature averages for 2022, 2023, and the last ten years from 2013 to 2022.

Conclusion and Recommendation

The recent earthquakes in Türkiye have resulted in significant casualties, property damage, environmental issues, and health complications. 9 million people in 11 provinces were affected by the two earthquakes. Not only humans were impacted by this disaster but also the environment and ecosystems were impacted as well. This study examined the impact of these earthquakes on air quality through investigating several air pollutants such as UV aerosol index, sulfur dioxide, carbon monoxide, nitrogen dioxide, Ozone, formaldehyde, and methane. Air quality observations of the Sentinel-5P TROPOMI satellite sensor was accessed through GEE and monthly averaged, then the monthly measurements of 2023 were compared with the monthly average observations of the years between 2019 and 2022. The results of the study emphasized that while some pollutants increased other pollutants decreased. UV aerosol index was notably increased as well as methane. While due to reduced human and industrial activities, pollutants like nitrogen dioxide, carbon monoxide, and sulfur dioxide were relatively diminished. Moreover, the analysis of the air and soil temperature measurements shows that in March just a month after the disaster, the temperatures were significantly raised in comparing to 2022 and to the average of last 10 years. In seismically active regions such as Türkiye, it is essential to develop strategies for mitigating air pollution hazards associated with seismic occurrences.

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