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A remote sensing-based methodological approach to characterize the association between fuel prices and air pollution

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Abstract: Carbon monoxide (CO) is recognized as a major source of air pollution that, depending on the degree to which it is inhaled, can potentially cause cardiovascular diseases. CO is primarily produced as a by-product of the incomplete combustion of gasoline and diesel in vehicles. The aim of the present study is to investigate the relationship between fuel prices and vehicle-based CO emissions in Türkiye in 2022. For that purpose, CO levels were monitored by remote sensing data from S5P TROPOspheric Monitoring Instrument (TROPOMI). The spatial distribution of CO levels was computed from 2019 to 2022 by employing the Google Earth Engine Code Editor. A linear regression analysis was performed to explain the relationship between fuel consumption and CO levels. The analysis revealed a negative association between fuel prices and CO emissions, with coefficients of $r = -0.71$ ($R^2 = 0.4084$) for gasoline and $r = -0.64$ ($R^2 = 0.5047$) for diesel, respectively. The study has focused on both economic aspects and remote sensing techniques in terms of the impact of fuel prices on air quality. Based on these findings, the current study highlight the effective use of satellite-based remote sensing for monitoring CO levels in the atmosphere.

Keywords: Remote sensing; fuel prices; Air pollution; environmental monitoring; carbon monoxide

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1. Introduction

Air pollution, commonly characterized with particulate matter (PM), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), and carbon dioxide (CO_2) concentrations (Chen et al., 2007) in the atmosphere, is considered a global threat to human health and the environment. The World Health Organization reported that almost 7 million people were affected by air pollution-related diseases annually (WHO, 2020). Poor air quality has the potential to cause cardiovascular, neurological, and respiratory illnesses (Kopnina 2017; Shmuel et al. 2017; Pasqua et al., 2020). Long-term exposure to lower air quality raises the likelihood of requiring medical care. The growing number of medical treatments leads to an increase in medical expenditures (Liu et al., 2021). It also has a distinct impact on each economy since the source of the pollution and demographic characteristics vary from location to location. Overall, the literature shows that increases in air pollution cause significant decreases in economic activity, mostly due to reductions in per capita production. Air pollution control policies can contribute significantly to economic growth and complement other mainstream structural policies. As a result, the policies should be addressed to reduce the economic cost of air pollution in the long term (Saurabh & Maurya 2018; Dechezleprêtre et al., 2019). Nowadays, developed and developing countries are becoming increasingly concerned about air quality and adopting guidelines, directives, and standards to inform and assist policymakers in mitigating the

adverse effects of air pollution on human health and the national economy (WHO, 2006; Mesas-Carrascosa et al., 2020).

The environmental impact of air quality can be observed prominently in densely populated areas with a large population density, extensive motor vehicle use, and rapid industrialization (Gurjar & Lelieveld 2005; Gurjar et al., 2008). Hewitt et al. (2020) also associate the increase in air pollution with the expansion or growth of urban settlements, the increase in the number of diesel vehicles, and driving distances. Motor vehicle emissions have been recognized as the primary source of urban air pollution in China by the State Environmental Protection Administration (SEPA) (SEPA, 2004). According to Brunekreef (2005), vehicle-based toxic emissions account for almost 50% of all emissions in developing countries. In addition, transportation sources create 77% of CO emissions in the U.S. (Kebede et al., 2022). Various reports emphasize that 70-80% of the urban air pollution in the big cities in developing countries have resulted from poorly maintained and relatively older vehicles, as well as insufficient infrastructure and poor fuel quality (Gulia et al., 2015). In consequence, traffic-related pollutants play an important role over the adverse impacts of air pollution (Amato et al., 2014). A complex mixture of gaseous and particulate pollutants is emitted into the atmosphere during the complete or incomplete combustion of gasoline and diesel fuel by vehicles. CO is produced as a by-product of incomplete combustion (Godish et al., 2014). CO diffusion is increased while driving long distances and having frequent braking during the journey (Jeniffer et al., 2019; Signoretta et al., 2019; Li et al., 2020). 60% of all CO emissions come from anthropogenic sources such as fossil fuel usage, waste disposal, cigarette smoke, and charcoal fires (Vreman et al., 2000). The toxic effect of CO emissions on the environment has been studied recently. In these studies, a potential association between tropospheric urban CO concentration and cardiac diseases was revealed (Andre et al., 2010).

The severe health impacts of fossil fuel-based air pollution alert policymakers to adopt various policies and scenarios to minimize air pollution (Small & Kazimi 1995; Shaw et al., 2018). Although motor vehicles are the primary source of anthropogenic CO emissions, only a limited number of studies have examined the relationship between vehicle use, fuel prices, and air pollution. Liu (2012) developed an energy-economy simultaneous equations model based on the supply-demand theory to examine the impact of energy price fluctuations on the Chinese economy, as well as energy conservation and emission reduction. According to the research, a rise in energy prices can reduce energy consumption, which has a tightening effect on potential production capacity via supply channels. The negative impact of persistent increases in all types of energy prices on potential output, energy consumption, energy intensity, and carbon emission intensity tends to rise. It is stated that, a rise in oil prices leads to less usage of oil, resulting in decreased carbon emissions (Leng Wong et al., 2013; Mensah et al., 2019). More specifically, increased fuel prices have a favorable impact on air quality. It is also defined as "Price Elasticity" in Economics (Hirota & Poot, 2004). According to Barnett & Knibbs (2014), a strong negative correlation was observed between fuel prices and CO and NO_2 in Brisbane. Rising prices lower the number of vehicles on the road and reduce traffic-related emissions directly. Increased gasoline prices may also encourage more people to utilize public transportation, which would lead to a reduction in pollution levels.

Significant number of fatalities due to air pollution should essentially be monitored (WHO, 2020). The state of the art in remote sensing technology enables tracking air quality with space-borne satellites. CO has been continuously observed from space through the Measurement of Pollution in the Troposphere (MOPITT) instrument since the launch of NASA's Terra satellite in 2000 (Edwards et al., 2004). MOPITT, which retrieves CO concentrations using thermal infrared (TIR) radiation, was later complemented by several other TIR-based sensors, including the Atmospheric Infrared Sounder (AIRS) (McMillan et al., 2005) operational since 2002, the Tropospheric Emission Spectrometer (TES) (Beer,

2006) operating between 2004 and 2018, the Infrared Atmospheric Sounding Interferometer (IASI) (Clerbaux et al., 2009) series launched from 2006 onwards, and the Cross-track Infrared Sounder (CrIS) (Gambacorta et al., 2014) since 2011. Although these instruments have made significant contributions to atmospheric and climate research (Hedelius et al., 2021), their sensitivity to near-surface CO levels remains limited. Despite this limitation, IASI and MOPITT data are incorporated into the CAMS model, providing valuable insights into large-scale CO transport and distribution.

In contrast, sensors operating in the shortwave infrared (SWIR) spectral range offer enhanced sensitivity to surface-level CO, making them particularly relevant for air quality assessments. The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) (de Laat et al., 2006) was the first spaceborne SWIR instrument, collecting data from 2002 to 2012. However, with a footprint of approximately 30 × 120 km, SCIAMACHY's spatial resolution was insufficient for detailed analysis of CO variations at the urban scale. In addition to these sensors, the European Space Agency (ESA) launched the Sentinel-5 Precursor (S5P) in 2017 to provide data on air quality, the climate, and the ozone layer using the TROPOspheric Monitoring Instrument (TROPOMI) (Karppinen et al., 2024). For instance, Wang et al. (2022) investigated global CO levels throughout June 1, 2018, and May 31, 2021 by utilizing TROPOMI. Statistical modeling revealed an R^2 of 0.48, with high values above 0.1 mol/m^2 of CO. The novelty, according to Wang et al. (2022), was the effectiveness of TROPOMI in detecting atmospheric CO, which offers worldwide coverage, supporting the potential for new indicators that might support future research and public policy pertaining to global changes. In addition, Al-Alola et al. (2022) compared the TROPOMI, Landsat-8, MODIS, and MERRA-2 satellites in terms of their effectiveness to measure Saudi Arabia's air quality by investigating NO_2, SO_2, and CO levels in May 2021. An average R^2 of 0.66 was found in statistical modeling. Al-Alola (2022) stated that, the most trustworthy collection levels were shown by TROPOMI in comparison to Landsat-8, MODIS, and MERRA-2. Furthermore, Kaplan & Avdan (2020) determined the anthropogenic CO emission in North Macedonia to monitoring air quality by employing Sentinel 5P TROPOMI. Based on the results, the NO_2 and population statistics have a strong positive correlation (r = 0.78; R2 = 0.61), whereas the altitude and CO values in the research area have a strong negative correlation (r = -0.9; R^2 = 0.80). The effect of COVID-19 on air quality, resulting from reduced human mobility, was also investigated using TROPOMI data. Prakash et al. (2021) used the TROPOMI and MODIS satellites to measure the NO_2, CO, and SO_2 levels in the Indian cities of Calcutta, Delhi, Bengaluru, Mumbai, and Chennai between March 2019 and April 2020. Their objective was to investigate how the COVID-19 outbreak affected air pollution. While NO_2 decreased from March 2019 (0.0000884 mol/m^2) to April 2020 (0.0000703 mol/m^2), data modeling produced differences in R^2 of 0.55 (Bengaluru), 0.50 (Mumbai), 0.53 (Delhi), 0.50 (Chennai), and 0.51 (Calcutta). Wang & Su (2020) utilized TROPOMI data to quantify NO_2 levels in China from December 19, 2019 to March 15, 2020, reporting an R^2 value of 0.84. Their analysis revealed that COVID-19 restrictions significantly reduced economic activity, which consequently lowered air pollutant concentrations. Specifically, CO concentrations (1.5 mg/m^3) declined by 6.2%, while NO_2 levels dropped to 24 μg/m^3, corresponding to a 25% reduction.

Additionally, there are studies that have utilized TROPOMI data to analyze atmospheric conditions in Türkiye. For instance, Güllüdağ et al., (2025) investigated the potential risks of fossil fuel usage in Socially Fragile Areas in the country by employing TROPOMI data from 2019 to 2023. The study is aimed to demonstrate the potential negative consequences of abundant fossil fuel usage in the high social vulnerability index areas by evaluating NO_2, SO_2, and CO concentrations. As a result of this study, the neighborhoods were categorized according to the air quality risk levels. In addition, Yilmaz et al., (2023) focused on the Mediterranean region, specifically covering the areas of

Manavgat, Gündoğmuş, Marmaris, Bodrum, and Köyceğiz, where severe wildfires occurred in 2021. In this research, TROPOMI data were utilized to determine the CO levels before and after the fires. The average CO column number density was found 0.03 mol/m^2 in all regions prior to the fires, and this value increased to 0.14 mol/m^2 after the fire. The results showed the effective usage TROPOMI usage in environmental studies.

1.1. The objective of the research

Crude oil and its derivatives are used in practically every industry, notably transportation and energy generation. Therefore, fossil fuels usage has a significant influence on the global economy. Oil-importing countries are substantially more influenced by variations in oil prices. The primary energy source in Türkiye is fossil fuels. Almost three-quarters of Türkiye's energy demand is supplied by oil-exporting countries. Therefore, the oil price change has a direct impact on Türkiye's economy. The structure of the global oil market is extremely complicated and dynamic. Price fluctuations are influenced by a variety of causes, including political, technical, and socio-cultural influences. Fuel prices in Türkiye are determined by global oil prices, currency rates, and taxes (Bayraç & Çemrek, 2022). Fuel prices in Türkiye had sharp increase from the end of 2021 to July 2022. The rapid increase and fluctuation in fuel prices in the country has become an important topic in the economic and political agenda. The impact of the variation in fuel prices is also considered as a critical research area for environmental studies. The direct effect of fuel prices on the vehicle-based air pollution attracted the attention of researchers. In this context, the evaluation of fuel price fluctuations emerges as an important parameter for estimating air pollution. This study therefore aims to present the association of fuel prices with air quality in terms of CO levels through employing TROPOMI-based data across Türkiye. Previous studies examining the relationship between fuel prices and air quality have mainly relied on ground-based measurements, focusing on localized or regional minor scales. In contrast, this research proposes a different methodology to measure CO levels by integrating both local and national-scale analyses using satellite-based data. The current study's findings provide valuable insights on how satellite-based remote sensing data can be utilized to conduct air quality research. Furthermore, the study promotes the use of remote sensing data and GIS tools in economic research specifically on environmental and energy-related issues.

2. Materials and Methods

2.1. Study area

Türkiye is a transcontinental country located primarily on the Anatolian Peninsula in Western Asia, with a tiny fraction on the Balkan Peninsula in Southeast Europe. It is bounded to the north by the Black Sea, to the northeast by Georgia, to the east by Armenia, Azerbaijan, and Iran, to the southeast by Iraq, to the south by Syria and the Mediterranean Sea, to the west by Greece and Bulgaria, and to the northwest by Greece and Bulgaria. Türkiye's current population is almost 85 million. Türkiye's population density map is demonstrated in Figure 1.

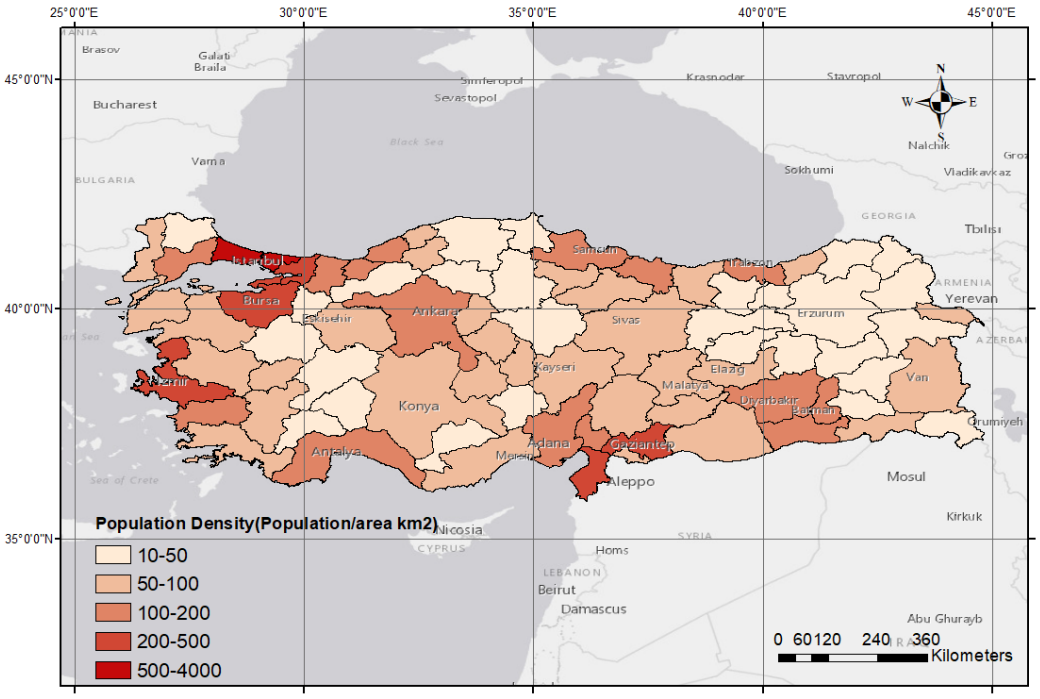


Figure 1. Türkiye's population density map

2.2. Data

Sentinel 5P-TROPOMI, which is a space-borne spectrometer, was launched in October 2017. It was funded by the Netherlands Space Office and the ESA. TROPOMI has a wide range of spectral wavelength bands, from ultraviolet to near-infrared. The instrument was designed to obtain data about air quality and climate change. TROPOMI can monitor aerosols in the atmosphere, cloud characteristics, CO, formaldehyde (CH2O), NO2, O3, SO2, and CH4. For air quality applications, Tropospheric Vertical Column Density (VCD), which is defined as the number of molecules of a certain atmospheric gas between the on-board sensor of the satellite platform and the Earth's surface per unit area, is used (Lamsal, 2015). The spatial resolution of the continuous image is 7x7 km (Griffin 2019). The swath is almost 2600 km from the Earth's surface, and its temporal resolution is 24 hours. The data is open access and can be downloaded from the ESA Copernicus Open Access Hub (https://scihub.copernicus.eu/). Before using the data, no additional pre-processing is required (Voors et al., 2017).

Figure 2 depicts the variations in Türkiye's fuel prices between the end of 2021 and July 2022. Turkish Petroleum (TP) is an official governmental organization for petroleum and its derivatives. The TP website is a reliable source to retrieve former fuel price data. Fuel prices are influenced by global oil prices, currency rate fluctuations, refinery and logistics costs, national taxes, and the profit margins of distribution companies. While fuel prices are determined by the distribution companies themselves, the Energy Market Regulatory Authority monitors them to ensure fair competition. The logistics costs may vary between cities depending on their proximity to supply sources; however, the general trend of price increases or decreases tends to be similar across all regions. In the specified time interval, fuel prices increased nationwide. Despite minor differences resulting from logistic costs, the overall rate of increase was similar across all cities. For this reason, Ankara was selected as a benchmark city due to its central location. The fuel prices are published daily; however, in terms of clarity and it is represented on a monthly average basis. The basic information from TP showed that the gasoline and diesel prices have

increased dramatically since the end of 2021. Fuel prices slightly decreased at the beginning of June 2022 (TPPD, 2022).

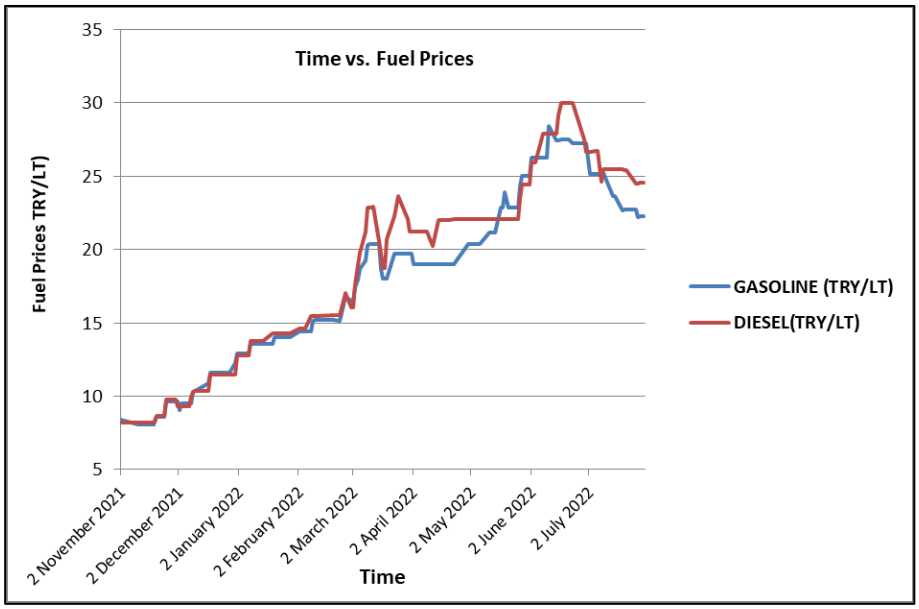


Figure 2. Fuel prices variations from November 2021 to July 2022

2.3. Method

In the current study, Google Earth Engine (GEE) code editor was employed. Türkiye was chosen as the study area. According to the Sentinel 5P TROPOMI datasets, the first reliable data has been available since 2019. For that reason, the study focuses on the years 2019 through 2022 to identify anomalies for each year. "COPERNICUS/S5P/NRTI/L3 CO" was deployed as a collection image. CO_column_number_density was applied to introduce the CO function. The cloudy pixels were eliminated using the <.5 cloud fraction function. The best pixels were chosen with the assistance of the Quality Assurance (QA) band. Monthly mean values for the corresponding years were chosen. A scatter plot is developed to show the monthly differences between the years. Solid insight into Türkiye's overall situation and the most CO-producing regions in accordance with the population-based numbers were mapped. CO minimum and maximum levels were measured. An additional feature was implemented to distinguish CO levels. The entire analysis was based on gasoline and diesel prices. The R-square value for both diesel and gasoline is determined using Linear Regression. In Figure 3, the workflow of the current study was presented.

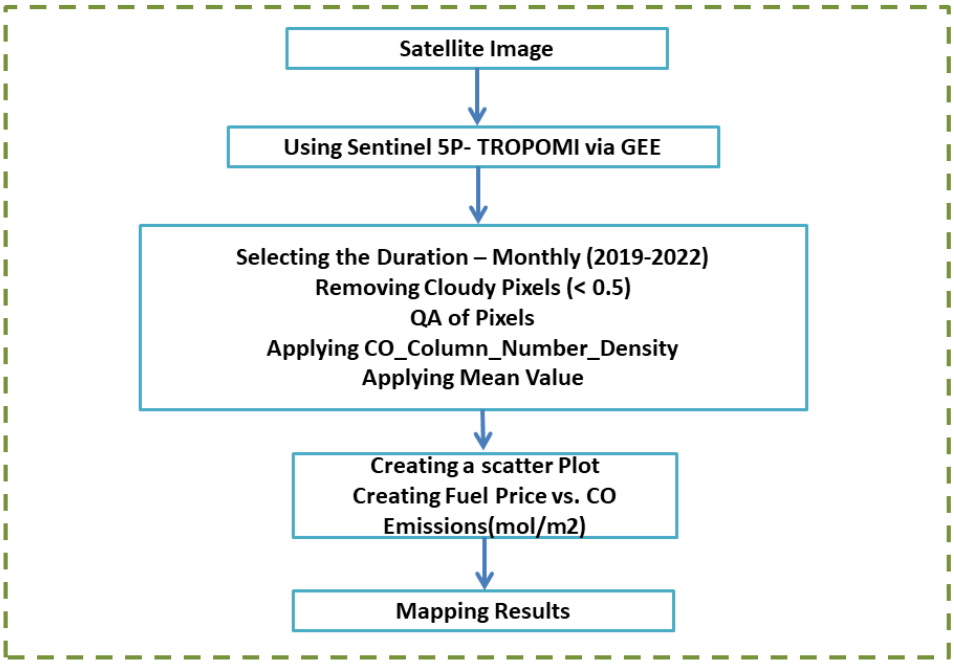


Figure 3. Workflow of the current study

3. Results

The most recent dataset is presented to make a monthly comparison of the CO emission results. Despite the mobility restrictions during the COVID period, it is inferred that CO emissions observed in 2022 were comparatively lower than the previous years. In this context, the reduction in CO levels may be associated with the rising fuel prices. The spatial distribution of CO VCD (mol/m2) for the consecutive years (2019, 2020, 2021, and 2022) is demonstrated in Figure 4. The average monthly CO emission represents the cumulative of daily emissions of each month.

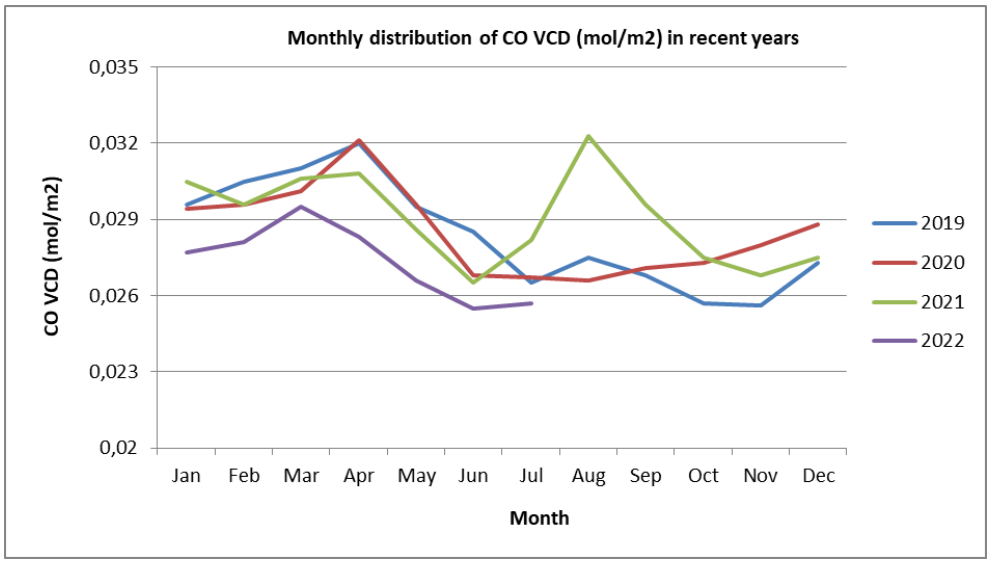


Figure 4. The spatial distribution of CO VCD for in recent years (mol/m^2)

The mean values of tropospheric CO (mol/m^2) in Türkiye obtained from S5P TROPOMI versus gasoline and diesel prices from 1st January 2022 to 31 July 2022 were depicted in Figure 5 and Figure 6. The analysis revealed a strong negative association between fuel

prices and CO emissions, with coefficients of r = –0.71 (R^2 = 0.4084) for gasoline and r = –0.64 (R^2 = 0.5047) for diesel, respectively. The dataset in fact covers approximately 210 days on a daily basis. For clarity and comparability, the data were aggregated into monthly means. The fuel prices are presented on a monthly average basis.

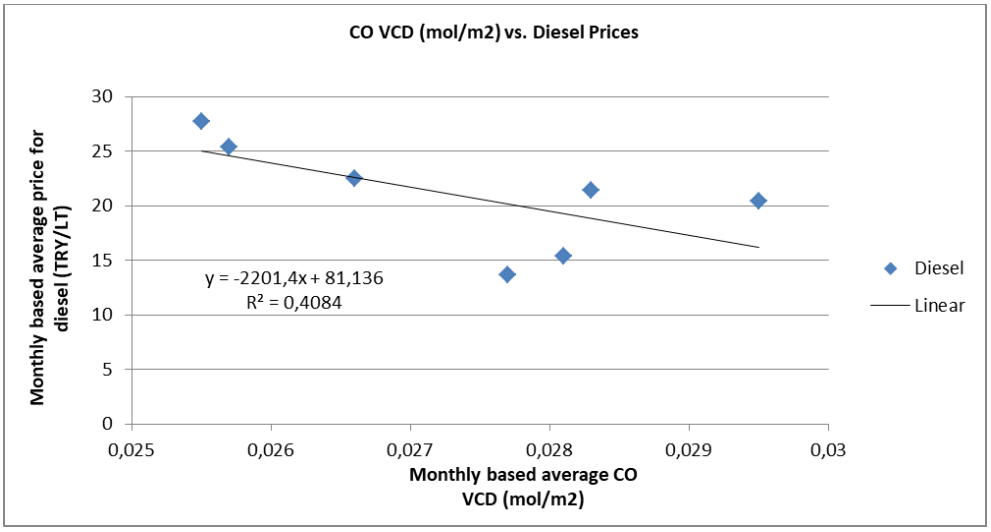


Figure 5. Linear regression between CO VCD and diesel prices

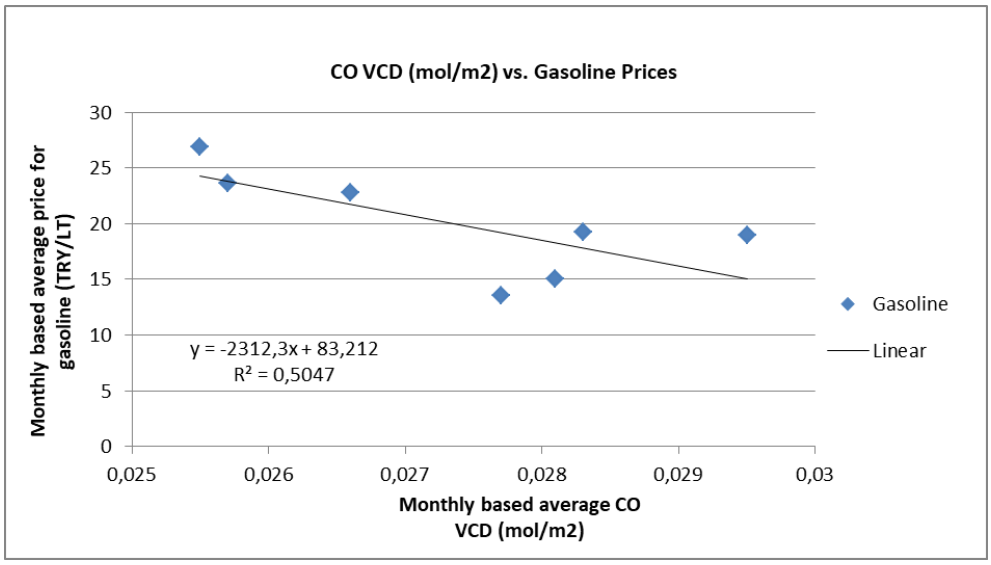


Figure 6. Linear regression between CO VCD and gasoline prices

Figure 7 shows that the mean CO distribution of Türkiye in 2022 (from 1st of January to 31st of July) ranges from 0.019 to 0.042 mol/m^2. The results are divided into five categories to highlight regional differences in relative CO concentration across the country. The Marmara Region exhibited the highest CO concentrations (0.033–0.042 mol/m^2), approximately 15–20% above the country's mean, which can be attributed to intensive industrial activity and urban traffic emissions. Comparable values were observed along the Aegean and Mediterranean coastal zones (0.033–0.042 mol/m^2), while the inner parts recorded lower concentrations (0.025–0.033 mol/m^2), about 10–20% below coastal averages. The Central Anatolia Region also showed moderate CO levels (0.025–0.033 mol/m^2), roughly 15–25% lower than those in Marmara, reflecting the relatively cleaner air. Similarly, the Black Sea Region presented a mixed pattern, with coastal areas close to Marmara region and inner zones showing slightly lower values within the same range (0.025–0.033 mol/m^2). In contrast, the Eastern Anatolia Region displayed the lowest CO

column densities (0.019–0.028 mol/m^2), corresponding to 35–40% below the national average, while the Southeastern Anatolia Region showed slightly higher values (0.025–0.030 mol/m^2), approximately 25–30% below the country's mean.

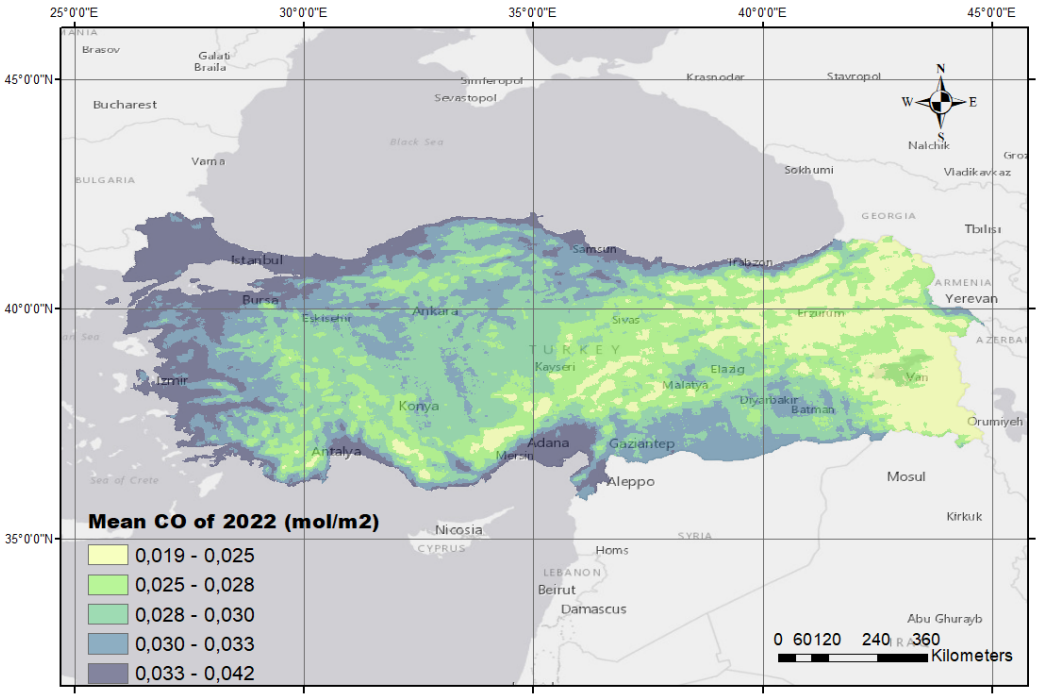


Figure 7. Mean CO emissions of Türkiye in 2022 (from January 1st to July 31st)

4. Discussion

The current study's findings demonstrated that the fluctuations in the fuel consumption of both vehicles and industrial activities can be monitored regularly by means of remotely sensed satellite data. The spatial distribution of CO VCD for consecutive years (mol/m^2) in Türkiye was demonstrated with a scatter plot. When compared to previous years, the results showed that CO emissions were significantly reduced in 2022. Aside from vehicle-based CO emissions, industrial activity, and population can be regarded as other CO producers. The population-based mean CO emissions were computed. Figure 7 depicts the very significant results of Türkiye's city-based CO distribution. According to TURKSTAT (2024), the total number of registered motor vehicles in Türkiye is 31,381,389. Nearly 15 million of these vehicles are concentrated in the metropolitan provinces of İstanbul, Ankara, İzmir, Antalya, Bursa, Adana, and Mersin, which together account for approximately 40% of the national population. In contrast, the provinces of Bitlis, Batman, Siirt, Ardahan, Bayburt, Tunceli, Hakkâri, and Iğdır, with a combined population of 2,101,479, host only about 300,000 motor vehicles. In light of these numbers, a strong correlation between population and the number of vehicles are observed. According to the Turkish Statistical Institute (TURKSTAT) (2022) report, Türkiye's coastal sides have more vehicles than the other areas. City-based mean CO emissions in the current study demonstrate a correlation with TURKSTAT reports.

The global supply chain system is being harmed by rising demand and decreased production. Energy production was hampered by a lack of raw materials and inadequate funding in new sectors. As a result, prices for oil and gas tend to rise. It has created a serious impact on fuel prices. Vehicle-based anthropogenic emissions of CO were investigated in the current study in terms of fuel price elasticity. The results of the linear regression were evaluated primarily to determine the association between fuel consumption and CO emissions. The increase in fuel prices has a negative impact on

people's tendency to use their vehicles in their daily routine. Similarly, Odeck & Johansen (2016) studied the short and long term effects of the fuel price changes on fuel saving and travel demand in Norway. According to the elasticity of fuel demand with respect to price is −0.26 in the short term and −0.36 in the long term. For travel demand, the respective elasticities are −0.11 in the short term and −0.24 in the long term. Moreover, Autoregressive Distributed Lag (ARDL) estimation models were employed by Raeissi et al. (2022) to investigate the impacts of gasoline and diesel prices on the traffic-related pollutants such as CO, NO_2, and particulate matter 10 micrometers or less (PM10). A 1% rise in gasoline costs results in a 0.02 and 0.012% drop in CO and PM10 concentrations, respectively.

The current study has some limitations. Firstly, air quality and climatic changes can be tracked regularly by S5P TROPOMI. However, the spatial resolution of the continuous image is 7x7 km. Higher-resolution satellite images should be required to identify the quantity ranges for local regions. Therefore, S5P TROPOMI cannot be taken into account as a functional approach to track particular areas with limited coverage. Secondly, CO levels were highest in the most densely inhabited cities. Anthropogenic sources that produce CO can be classified as fossil fuel usage for transportation, heating, waste disposal, and cigarette smoke, and charcoal fires. In the current study, the impact of fossil fuel usage was considered in terms of the increase on fuel prices. However, the percentage of vehicle-oriented CO to the total CO amount cannot be determined by employing S5P TROPOMI. It is acknowledged that omitting such variables may potentially affect the magnitude of estimated relationships. The increasing fuel prices may effect on industrial activities (both production and logistic wise), touristic travels. Nevertheless, the study's findings provide preliminary evidence on how fuel price dynamics may influence air quality patterns, which can serve as a basis for more detailed future studies. Future research could use multiple regression analysis and multi-sectoral datasets at the national level to better classified the relative contributions of these factors to total emissions and integrate meteorological parameters (temperature, rainfall, and wind speed) and economic activity indicators (industrial production, transport intensity, and tourism mobility) through a panel data or spatial econometric approach to better disentangle the causal pathways between fuel prices and CO emissions. Thirdly, the Ministry of Environment and Urbanization has 382 ground stations in 81 cities to monitor air quality by calculating CO, NO_2, SO_2, PM10, and O_3. A few of these stations are equipped with CO sensors. For instance, in cities such as Bilecik, Edirne, Yalova, Ardahan, Muş, and Sivas, CO level is not monitored. For other cities it is only monitored at limited locations to observe traffic-related CO. These results are provided hourly for city-based. It is inferred from the results that during rush hours when there is heavy traffic, especially in highly populated cities, CO levels are significantly higher. The lack of or limited ground-based CO sensors in the whole study area, it is challenging to establish the relationship between ground-level information and satellite-received data. The constraint on comparing ground-based information with TROPOMI data could be characterised as a final limitation for the research.

Although many previous studies focused on air quality by observing PM, NO_2, and CO levels, there were a few studies focused on satellite-based monitoring. Besides, several studies in the literature are conducted from either economic or remote sensing perspectives. However, current study has focused on both economic aspects and remote sensing techniques in terms of the impact of fuel prices on air quality. Based on these findings, the study allows the effective use of satellite-based remote sensing for monitoring air quality in terms of CO levels in the atmosphere. The current study's findings have theoretical and practical contribution to the literature and industry. These findings can be used as a guideline for policymakers and business leaders to assess the impact of traffic-related CO emissions. Moreover lower consumption of fossil fuels in traffic should be encouraged, and individuals should be supported to use public transportation. In addition,

electrical vehicles should be integrated into the traffic environment as soon as possible to meet the local and global carbon zero targets.

5. Conclusions

Oil-producing countries supply over 75% of Türkiye's energy requirements. Therefore, changes in oil prices have a direct influence on fuel costs in the country. The impact of the variation of fuel price on air pollution in Türkiye has been demonstrated in the research by monitoring and analysing tropospheric CO concentrations from 1st January to 31st July 2022. Data from the TROPOMI on-board the Sentinel-5P satellite platform were used in the study to investigate the spatio-temporal variation of CO. It is presented in the study that fuel prices have a negative impact on CO emissions. CO levels were reduced during the defined time interval while there is a variation on fuel prices.

Although the current study seeks to reveal vehicle-based CO emissions, the research also indicates that large population cities with significant industrial activity have higher CO emissions. The satellite images demonstrated a significant concentration of CO in Istanbul, which has the highest population density and the biggest share of industrial activities in Türkiye. Other hotspots with high CO concentrations have also formed above densely populated cities.

According to the current study, S5P TROPOMI can be defined as a convenient tool to track air quality. However, for small or medium size coverage, the more detailed classification can be performed by employing high-resolution satellite data.

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Author Contributions:

H. O. Aydınlı: Conceptualization, Methodology, Writing—original draft, Visualization.

S. N. Çabuk: Conceptualization, Methodology, Writing—original draft, Visualization

O. Meçik: Conceptualization, Methodology, Writing—original draft, Visualization

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Research and publication ethics statement: In the study, the authors declare that there is no violation of research and publication ethics and that the study does not require ethics committee approval.

Conflicts of Interest: The authors declare no conflicts of interest.

Data Availability: The data presented in this study are available on request from the corresponding author.

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