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Mapping and Estimation of Road Traffic Emissions in Caraga Region using Sentinel 5P Satellite Images

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Abstract: *Mapping and estimating road traffic emissions pose significant challenges, requiring extensive observation, research, and focus, and will spare for months in order to understand and achieve accurate measurements of each pollutant's concentrations level, due to the difficulty of generating a working code for us in order to extract data images. This study will present a new spatiotemporal dataset that is being collected and processed from a sentinel 5P remote sensing platform. Lately, due to the outbreak of coronavirus, that's why the pollutant concentration has been lessened day emitting to the atmosphere, by limiting public and private transport the reasons of the decreased level concentration in the Caraga region. The main objective of this study is to evaluate the effectiveness of Sentinel-5 Precursor Tropomi (Tropospheric Monitoring Instrument) satellite images for air quality monitoring. To meet the main objective of this study, generating a map and chart showing the carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2) pollutants concentration levels to evaluate before, during, and after COVID-1 through change detection analysis starting from the year 2018 to 2021 semi-annually. Visualization/Extraction of Sentinel-5P data is done using Google Earth Engine. The generated maps and charts reveal improved pollutant concentrations during the pandemic, providing valuable insights to authorities regarding the detrimental impact of vehicle emissions on human health.*

Keywords: Sentinel-5P, Atmospheric Pollution, Carbon monoxide (CO), Nitrogen dioxide (NO2), Sulfur dioxide (SO2)

1. INTRODUCTION

Atmospheric pollution is one of the major problem worlds facing many decades has been past till up to these days that it is an incredibly serious natural resource and environmental challenge to individuals it will an ongoing rise in the average earth's temperature, and climate change is the well-known description. A blanket of pollution has been trapped in the Earth's atmosphere, one of the main sources is due to rapid vehicle emission coming from developing or industrialized place in the world that produces smog were can affect human health. One of the primary contributors to the atmosphere's particulate matter is road traffic. Despite its importance, there are significant challenges in the quantitative evaluation of its contributions to airborne concentration [1]. Road transport accounts for a consequential portion of air pollution in cities and towns, causing serious pollution problems like carbon monoxide and smog due to population growth [2], the increasing number of people using private cars, the accelerating contribution of traffic fumes that contain harmful chemicals are observed that pollutes the atmosphere. Road traffic emissions produce greenhouse gases that contribute to global warming [3] especially the highly urbanized cities that used up even more than 70% of Carbon Dioxide Globally [4]. Moreover, the Department of Environmental and Natural Resources (DENR) constantly conducts Air Quality Index (AQI) monitoring [5].

Sentinel-5P the sixth satellite that is launched by the Copernicus program and the first one that can measure atmospheric chemistry and greenhouse gases concentrations, a single satellite [6] and the first Copernicus mission dedicated to monitoring the atmosphere carrying the tropospheric monitoring instrument also known as TROPOMI, that can map multiple and provides information about atmospheric trace gases such as the Carbon Dioxide (CO2), Carbon Monoxide (CO), Sulfur Dioxide (SO2), Ozone (O3), Nitrogen Dioxide (NO2), Methane (CH4), Aerosols, Formaldehyde (HCHC) and other trace gases that can be found at the troposphere that affecting the health of an individual, environment especially the climate[7]. Copernicus Sentinel-5 Precursor's main objective is to perform the measurement of the atmosphere with a high spatiotemporal resolution that is to be used and focuses on air quality, ozone together with UV radiation, and Climate monitoring as well as for forecasting [8].

TROPOMI is a space-borne, nadir-viewing, imaging spectrometer that covers the wavelength bands between ultraviolet and the shortwave infrared. It has a single payload of the Sentinel-5 Precursor spacecraft that uses passive remote sensing techniques in order to attain the objectives for measuring the Top of the Atmosphere (TOA), solar radiation is reflected by and radiated from the earth. This instrument is operating in a push-broom configuration or non-scanning, having a swath width of 2600 km on the earth's surface, and the typical pixel size (near nadir) would be 7x3.5 km^2 for all the spectral bands having an exception of the UV1 band which is 7x28km^2 and SWIR bands which is 7x7 km^2. [9].

2. STUDY AREA

This Study will focus on the Caraga Region which is located on the northeastern side of Mindanao that bounded by the North Sea of Bohol, on the east of the Philippine Sea and Pacific Ocean, on the West of the Province of Misamis Oriental and Bukidnon, and on the South of Davao, Compostela Valley, and Davao Oriental that can be traveled on air, water, and land. This region is the youngest among the sixteen (16) regions in the country, created under RA 7901 dated February 23, 1995

[10] that compromises five provinces: Agusan del Norte, Agusan del Sur, Surigao del Norte, Surigao del Sur, and Dinagat Islands; six Cities: Bayugan, Butuan, Cabadbaran, Surigao, Tandag and lastly Bislig [11]. Caraga is one of the most highly urbanized regions in the country.

Figure 1. Map of Caraga Region

This study presents the process that is needed in undergoing the research and also presents the methods and data that is being used in obtaining information. Subsequently, it provides optimum data and information for estimating the road traffic emissions in entire Caraga Region.

High-resolution monitoring and mapping can contribute remarkably to air quality management in terms of pollution abatement, exposure, and risk assessment. Real-time measurements were collected and interpolated using an inverse distance weighted (IDW) model to analyze the spatial differences. A study of spatial and temporal variability would ideally be based on continuous data using a relatively dense network of monitors placed in multiple locations [12].

3. METHODOLOGY

3.1. Overview

Showing in Figure 2 is the methodological flowchart of this study. Which is the Visualization/Extraction of Sentinel 5P NRTI data using Google Earth Engine. The output of the first part is the map that shows the tropospheric carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2) from the year 2018 up to June 2021 in the Caraga region semi-annually. Evaluation of the changes in vehicle emissions in the Caraga Region is the second part which is the output of the previous part is being used. And the final output of this study is the changes in vehicle emissions in the Caraga Region using the generated output which are the map of each pollutant from the year 2018 up to June 2021.

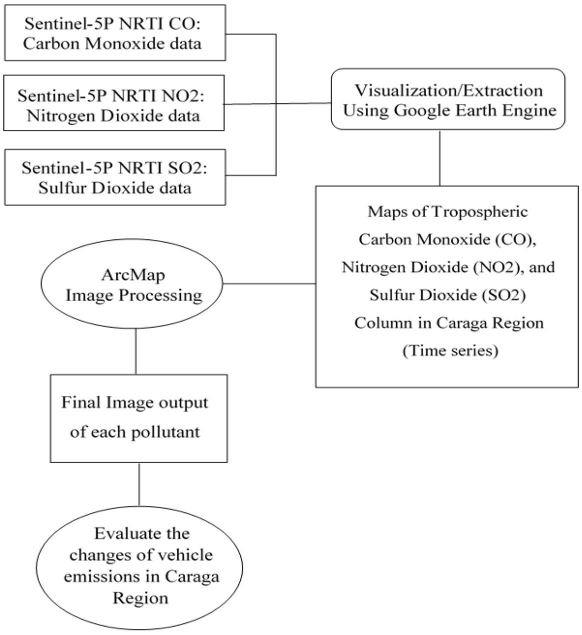

Figure 2. Overview of the Methodology

3.2 Data Collection

The Sentinel 5P near real-time (NRTI) carbon monoxide (CO), nitrogen dioxide (NO2) and sulfur dioxide (SO2) data used in this study are those data that are free to access through Copernicus Open Access Data Hub (Open Access Hub (Copernicus. eu)). Sentinel 5P near real-time (NRTI) carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2) data from the year 2018 up to July 2021 are being used in this study. The Google Earth Engine (GEE) code editor at https://code.earthengine.google.com is a web-based Integrated Drive Electronics (IDW) for the Earth Engine JavaScript API. This kind of tool is being used in this study for visualizing the sentinel 5P near real-time carbon monoxide, nitrogen dioxide, and sulfur dioxide data for creating the map for monitoring and evaluating the semi-annually average/mean pollutants concentrations in Caraga Region.

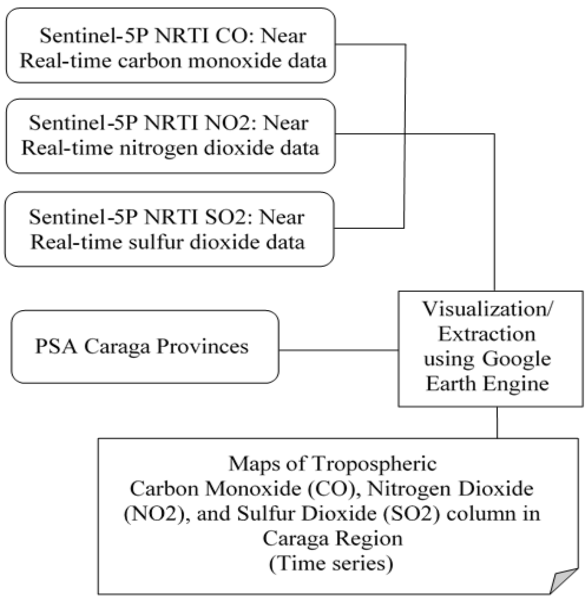

Figure 3. Visualization/Extraction of Sentinel 5P NRTI data using Google Earth Engine flowchart

3.3 Evaluate the changes in vehicle emissions in the Caraga region.

This part is the evaluation of the changes in vehicle emissions in the Caraga Region using the generated output which is the map of each pollutant from the year 2018 up to 2021. The tropospheric Carbon monoxide (CO), Nitrogen Dioxide (NO2), and Sulfur Dioxide (SO2) values in mol/m2 in road traffic emissions in the entire Caraga Region are evaluated to determine each important feature of the maps of every pollutant in the Caraga Region semi-annually, and it will be compared and being analyzed.

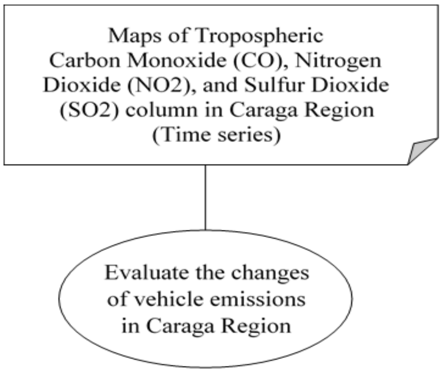

Figure 4. Evaluation of the changes of vehicle emissions flowchart

4. RESULTS AND DISCUSSION

4.1 Time series Maps of Tropospheric CO, NO2, and SO2 column in the Caraga Region

The Study generated maps of tropospheric Carbon Monoxide (CO), Nitrogen Dioxide (NO2), and Sulfur Dioxide (SO2) values in mol/m2 in Caraga Region using Sentinel-5P data. Figure 5 to 14 shows the graphs and charts of vehicle data and emissions that are being classified by the Department of Transportation in the entire Caraga region from the year 2018 to 2020. Figure 15 to 17 shows the generated maps of the pollutant concentrations level from the year 2018 to 2021 semi-annually in the entire Caraga region.

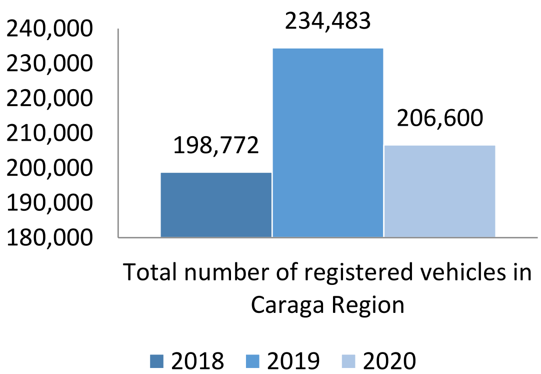

Figure 5. RV's are classified by the LTO for registration into three groups: Private, For-Hire, and Government. Source: Land Transportation Office Caraga (2020) [14]

In Figure 5. Shows the number of total registered vehicles (RVs) in the Caraga Region from 2018 to 2020. The year 2019 has the highest number of registered vehicles in the region, increasing the number of road traffic emissions. From 198,772 RVs in 2018 increased to 234,483 RVs in 2019 and decreased to 206,600 RVs in 2020 recorded by the LTO due to the pandemic that the transaction has been terminating for months.

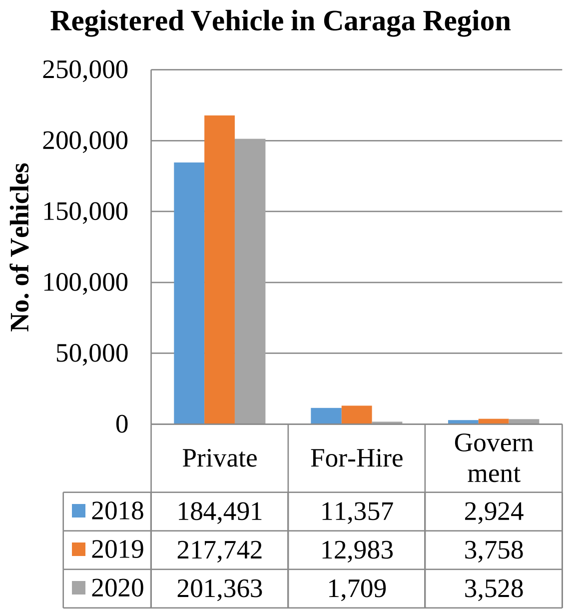

Figure 6. Number of registered vehicles by RV's Type, 2018-2020. Source: Land Transportation Office Caraga (2020) [14]

The increase in vehicle registration is caused to the growth of the population especially in urbanized areas to cater to the transport needs of each individual. Although to that situation the government already takes action for that matter, more national roads and bridges have been improved and built throughout the years, the main roads remain heavily congested, particularly during rush hours which can cause more vehicle emissions as the travel time increases. The growth of purchase and registration of vehicles specifically motorbikes contributed to the registered vehicles being faster, using less road space, and consuming less fuel compared to private cars.

No. of Vehicle
Fuel type used: Year 2018

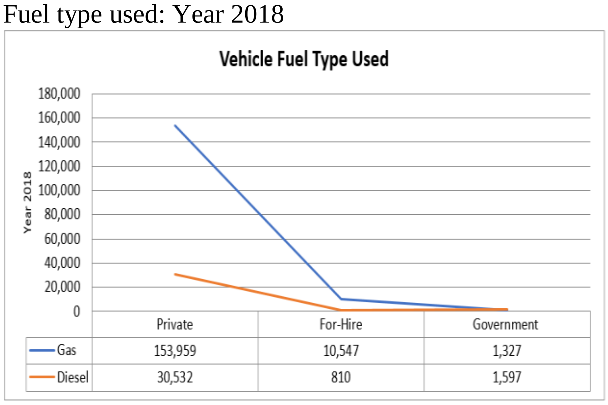

Figure 7. Showing that gas is the highest number of vehicle fuel types used compared to diesel in the year

2018. Source: Land Transportation Office Caraga (2020) [14]

No. of Vehicle
Fuel type use: Year 2019

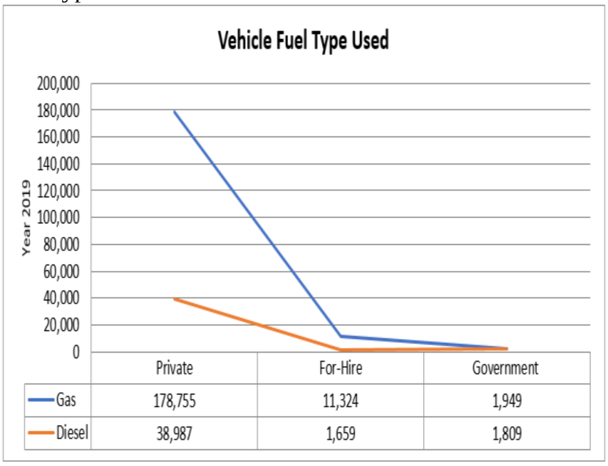

Figure 8. Showing that gas is the highest number of vehicle fuel types used compared to diesel in the year 2019. Source: Land Transportation Office Caraga (2020) [14]

No. of Vehicle
Fuel type used: Year 2020

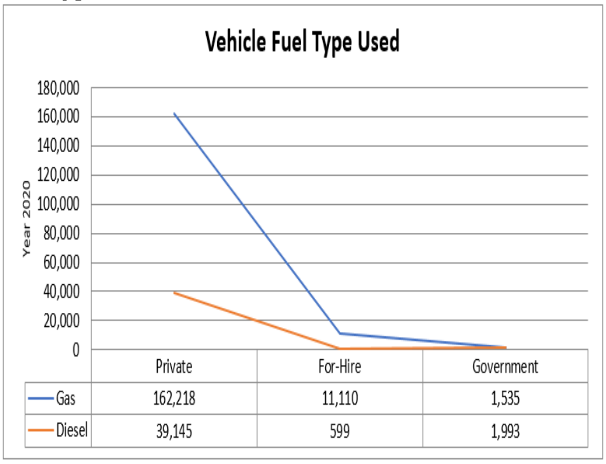

Figure 9. Showing that the gas is the highest number vehicle fuel type used compared to diesel in a year 2020. Source: Land Transportation Office Caraga [14]

4.2 Emissions inventory

The Environmental Management Bureau (EMB) is obliged to conduct an emissions inventory once every three years under RA 8749. The emissions inventory estimates the emissions coming from vehicle emissions, stationary, and the areas.

Based on the latest National Emissions Inventory (NEI) source conducted in the year 2018, the majority of air pollutants which is (74%) are coming from vehicles. The (15%) were contributed coming from by stationary sources such as power plants and factories. The (11%) were contributed coming from construction activities, open burning of some solid wastes, agriculture and Forestry, Commercial, Residential, Electricity, and others.

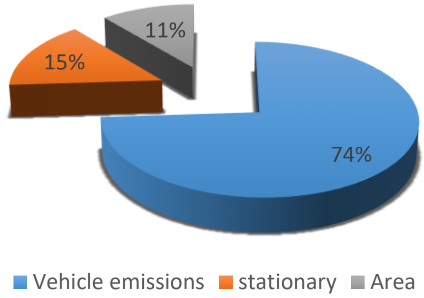

Figure 10. National Emissions Inventory, by source, 2018

On the other hand, the Emissions Inventory for Caraga Region in the year 2018 revealed that the vehicle sources contributed a lot which is 90.86%, the stationary is 3.71% and the 5.43% is coming from the area. (See Figure 7).

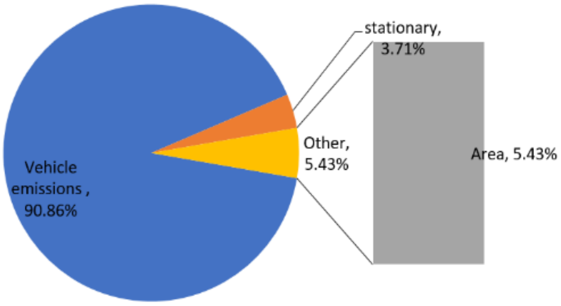

Figure 11. Caraga Region Emissions Inventory, by source, 2018

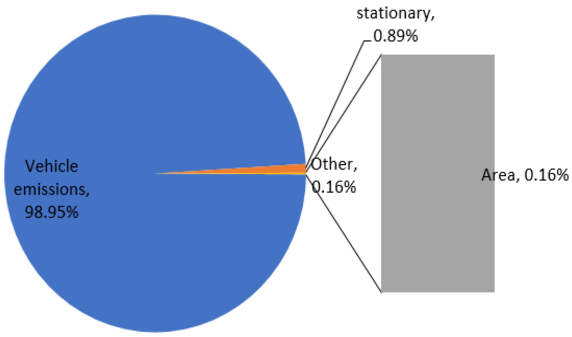

Figure 12. Caraga Region Emissions Inventory of Carbon Monoxide (CO), by source, 2018

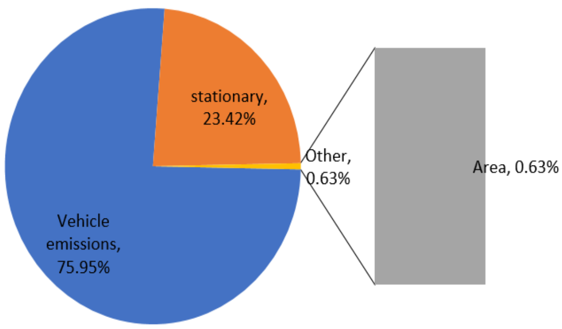

Figure 13. Caraga Region Emissions Inventory of Nitrogen Dioxide (NO2), by source, 2018

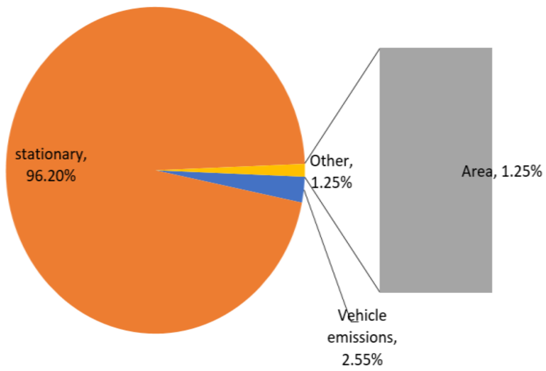

Figure 14. Caraga Region Emissions Inventory of Sulfur Dioxide (SO2), by source, 2018

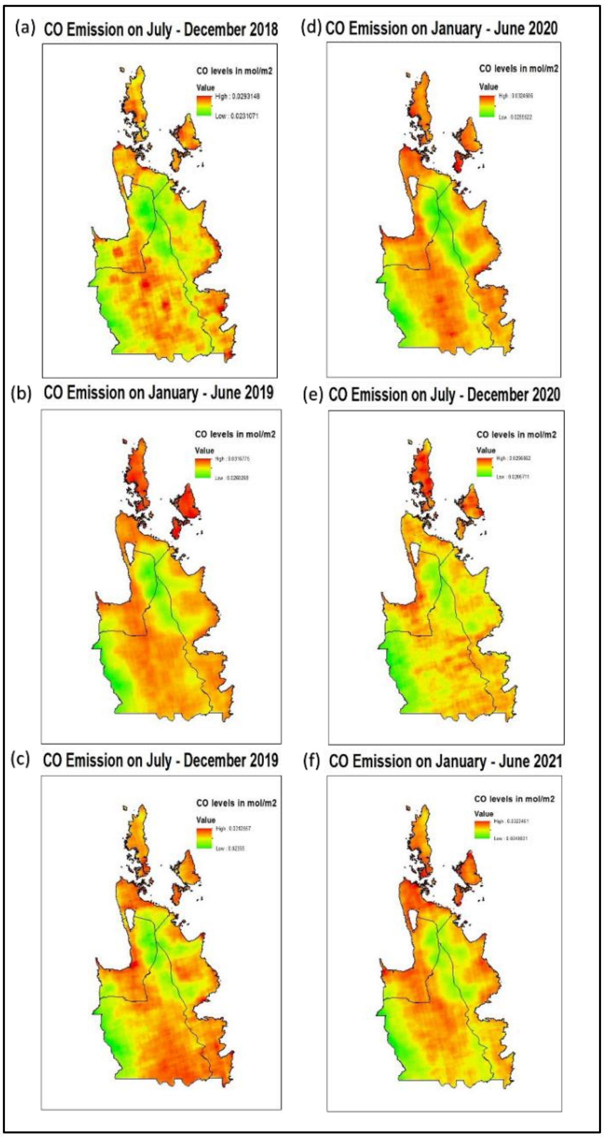

Figure 15. Maps of Carbon Monoxide (CO) pollutant concentration levels in the Caraga Region in filter date of July 1, 2018, up to June 13, 2021.

Figure 15 shows generated maps of carbon monoxide pollutant concentration levels in the Caraga Region in a filter date of July 1, 2018, up to June 13, 2021. It shows that in the figure (a) 0.0293148mol/m2 is the highest value of CO concentration level and 0.0231071mol/m2 is the lowest, (b) 0.0316775mol/m2 is the highest value of CO concentration level and 0.0260269mol/m2, (c) 0.0312557mol/m2 is the highest value of CO concentration level and 0.02355mol/m2, (d) 0.0324606mol/m2 is the highest value of CO concentration level and 0.0255522mol/m2 is the lowest, (e) 0.0256662mol/m2 is the highest value of CO concentration level and 0.0206711mol/m2 is the lowest, and lastly for (f) 0.0323451mol/m2 is the highest value of CO concentration level and 0.0249831mol/m2 is the lowest, and in the maps above shows in the legend indicated that the highest pollutant concentration level area is those areas with the color red and the color green is the lowest.

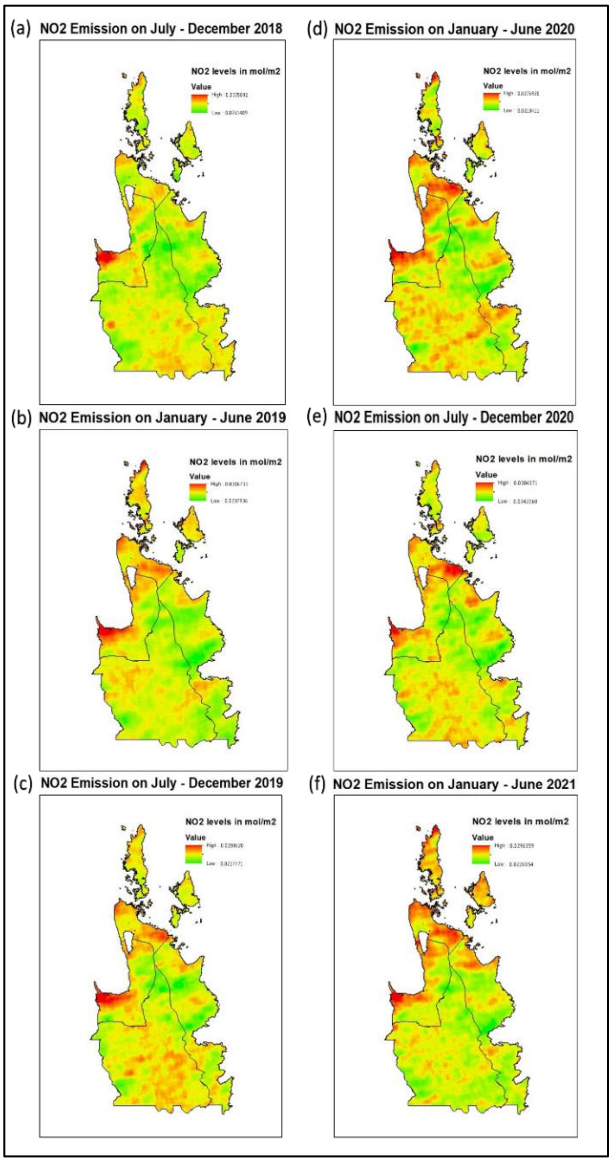

Figure 16. Maps of Nitrogen Dioxide (NO2) pollutant concentration levels in the Caraga Region in filter date of July 1, 2018, up to June 13, 2021.

Figure 16 shows generated maps of nitrogen dioxide pollutant concentration levels in the Caraga Region in a filter date of July 1, 2018, up to June 13, 2021. It shows that in figure (a) 0.0335892mol/m2 is the highest value of NO2 concentration level and 0.0261409mol/m2 is the lowest, (b) 0.0306731mol/m2 is the highest value of NO2 concentration level and 0.0237936mol/m2, (c) 0.0288620mol/m2 is the highest value of NO2 concentration level and 0.0217771mol/m2, (d) 0.0276920mol/m2 is the highest value of NO2 concentration level and 0.0218411mol/m2 is the lowest,

(e) 0.0304371mol/m2 is the highest value of NO2 concentration level and 0.0242268mol/m2 is the lowest, and lastly for (f) 0.0296359mol/m2 is the highest value of NO2 concentration level and 0.0226554mol/m2 is the lowest, and in the maps above shows in the legend indicated that the highest pollutant concentration level area is those areas with the color red and the color green is the lowest.

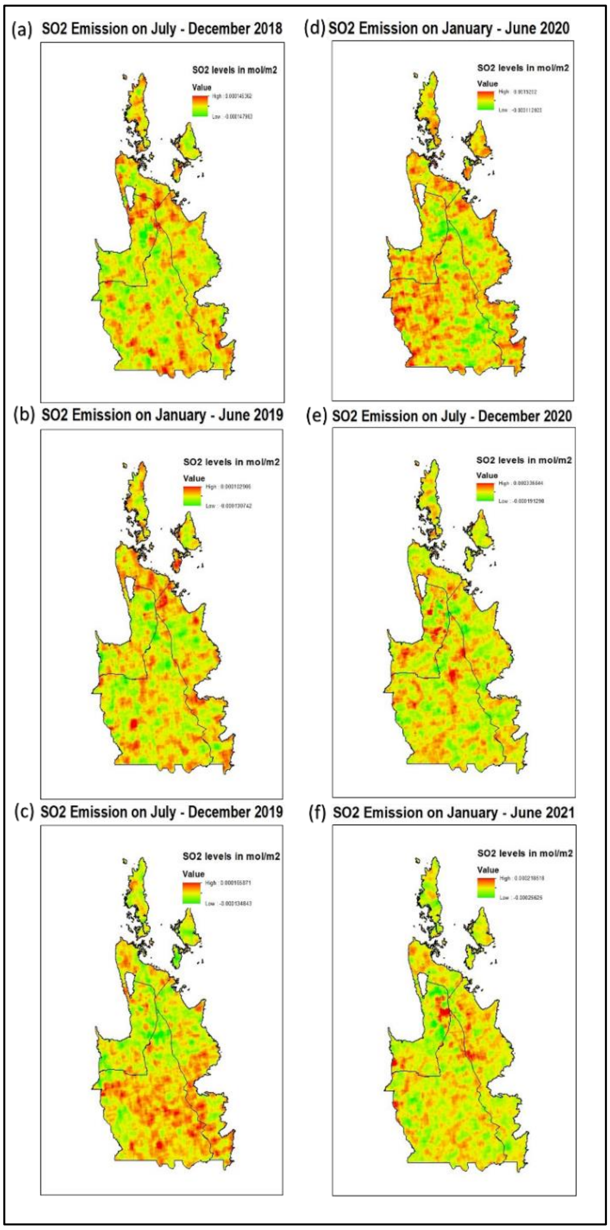

Figure 17. Maps of Sulfur Dioxide (SO2) pollutant concentration levels in the Caraga Region in filter date of July 1, 2018, up to June 13, 2021.

Figure 17 shows generated maps of nitrogen dioxide pollutant concentration levels in the Caraga Region in a filter date of July 1, 2018, up to June 13, 2021. It shows that in figure (a) 0.0000145362mol/m2 is the highest value of SO2 concentration level and -0.000147963mol/m2 is the lowest, (b) 0.000102906mol/m2 is the highest value of SO2 concentration level, and -0.000130742mol/m2, (c) 0.000165871mol/m2 is the highest value of SO2 concentration level and -0.000134843mol/m2, (d) 0.0615282mol/m2 is the highest value of SO2 concentration level and -0.000112923mol/m2 is the lowest, (e) 0.000336644mol/m2 is the highest value of SO2 concentration level and -0.000191296mol/m2 is the lowest, and lastly for (f) 0.000218518mol/m2 is the highest value of SO2 concentration level and -0.00025625mol/m2 is the lowest, and in the maps above shows in the legend indicated that the highest pollutant concentration level area is those areas with the color red and the color green is the lowest.

5. CONCLUSIONS

This study evaluated the effectiveness of Sentinel-5 Precursor Tropomi (Tropospheric Monitoring Instrument) satellite images for air quality monitoring and estimated the road traffic emissions in Caraga Region semi-annually by visualizing/extracting Sentinel-5P near real-time (NRTI) data using the Google Earth Engine and mapping the carbon monoxide, nitrogen dioxide, and sulfur dioxide, and combining all the maps generated to compare the changes of vehicle emissions in entire Caraga Region. It presents the process that is needed, the methods, and the data used in obtaining information in the mapping and estimation of road traffic emissions in the Caraga Region. This will provide a clear assessment of the employment of Sentinel-5P that the map generated will be a great help to the government agencies in the Caraga Region, Philippines like the Department of Environment and Natural Resources (DENR) for the increment of conservation, management, development, and proper use of the country's environment and natural resources.

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