Report on Emissions in Rwanda : Data Analysis: Part-1

Introduction:

Rwanda, a small East African nation, has a relatively low carbon footprint compared to many other countries in the region. However, the country's emissions have been steadily increasing in recent years, driven by population growth, economic development, and urbanization. Several studies have examined carbon emissions in Rwanda.

A 2014 study by the World Resources Institute (WRI) found that Rwanda's total greenhouse gas (GHG) emissions in 2010 were 7.3 million metric tons of carbon dioxide equivalent (MtCO2e). The study also found that the agriculture sector was the largest contributor to GHG emissions, accounting for 45% of total emissions.

A more recent study, published in the journal "Climate Policy" in 2020, found that Rwanda's GHG emissions had increased to 9.4 MtCO2e in 2016. The study also found that the energy sector was the fastest-growing source of emissions, accounting for 23% of total emissions in 2016. Both of these studies highlight the need for Rwanda to take action to reduce its carbon emissions. The country has set a target of reducing its GHG emissions by 38% by 2030, and it is developing a number of policies and programs to achieve this goal.

Objectives of the study

- Assess the current state of carbon emissions in Rwanda
- Identify the main sources of carbon emissions in Rwanda
- Analyze the trends in carbon emissions in Rwanda

Study area

Rwanda is a small, landlocked country located in Central Africa. It is bordered by Uganda to the north, Tanzania to the east, Burundi to the south, and the Democratic Republic of the Congo to the west. Rwanda has a population of over 12 million people and a land area of 26,338 square kilometers.

Materials and methods:

Every row of train contains four index columns (latitude, longitude, year and week_no), 70 features and a target (emission). The 70 features come in 8 groups of various sizes.

The following table has been taken from the NO2 data description and explains the NO2 sub-features (the other features are similar):

Name	Units	Min	Max	Description
NO2_column_number_density	mol/m^2	-48*	0.24*	NO2 vertical column density at ground level, calculated using the DOAS technique.
NO2_column_number_density_amf	mol/m^2	0.1*	3.397*	Weighted mean of cloudy and clear air mass factor (amf) weighted by intensity-weighted cloud fraction.
NO2_slant_column_number_density	mol/m^2	-0.147*	0.162*	NO2 ring corrected slant column number density.
cloud_fraction	Fraction	0*	1*	Effective cloud fraction.
sensor_azimuth_angle	deg	-180*	180*	Azimuth angle of the satellite at the ground pixel location (WGS84); angle measured East-of-North.
sensor_zenith_angle	deg	0.09*	67*	Zenith angle of the satellite at the ground pixel location (WGS84); angle measured away from the vertical.
solar_azimuth_angle	deg	-180*	180*	Azimuth angle of the Sun at the ground pixel location (WGS84); angle measured East-of-North.
solar_zenith_angle	deg	8*	80*	Zenith angle of the satellite at the ground pixel location (WGS84); angle measured away from the vertical.
NO2_column_number_density_15km	mol/m^2			NO2 vertical column density at 15km, calculated using the DOAS technique.

7 of the groups correspond to the main features (measurements) of the data description page:

- Sulphur Dioxide
- Carbon Monoxide
- Nitrogen Dioxide
- Formaldehyde
- UV Aerosol Index
- Ozone
- Cloud

The groups contain different sub-features, but four sub-features appear in every group:

'sensor_azimuth_angle',

'sensor_zenith_angle',

'solar_azimuth_angle',

'solar_zenith_angle',

The sub-features are necessary to interpret the measurements. As the data was measured by a satellite which is not directly above the measured location, the angle of the satellite affects the measurement. The measurements are further influenced by the angle of the sun and by clouds.

The satellite measures the concentration of several gases in the atmosphere, but it does not measure CO2. Our task is to predict the CO2 emission for every location and point in time based on the concentration of the other gases.

We do not know how the CO2 emissions were measured. They are not measured by the Sentinel-5P satellite. They could be measured by stations on the ground or by some other satellite.

Methods adopted to achieve the objectives:

- Geo visualization
- Time Series Analysis

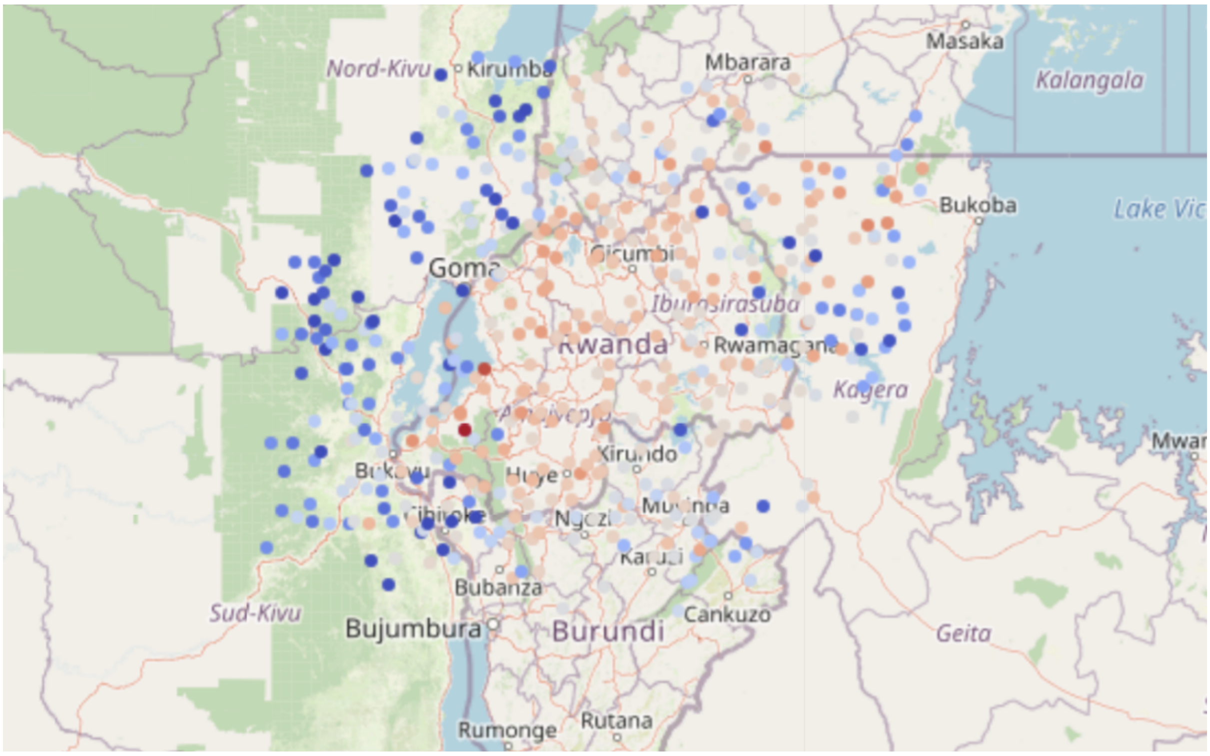
Results and Discussion

We see that

- There are 497 geographical points (latitude-longitude pairs). The points are the same in train and test.
- For every geographical point, there are 159 rows with observations in train and 49 rows in test.
- The 159 training rows correspond to three years (2019, 2020, 2021) with 53 weeks each (numbered from 0 to 52).
- The 49 test rows correspond to weeks 0 to 48 of 2022.
- 497 * 3 * 53 = 79023, the size of the training dataset.
- 497 * 49 = 24353, the size of the test set.

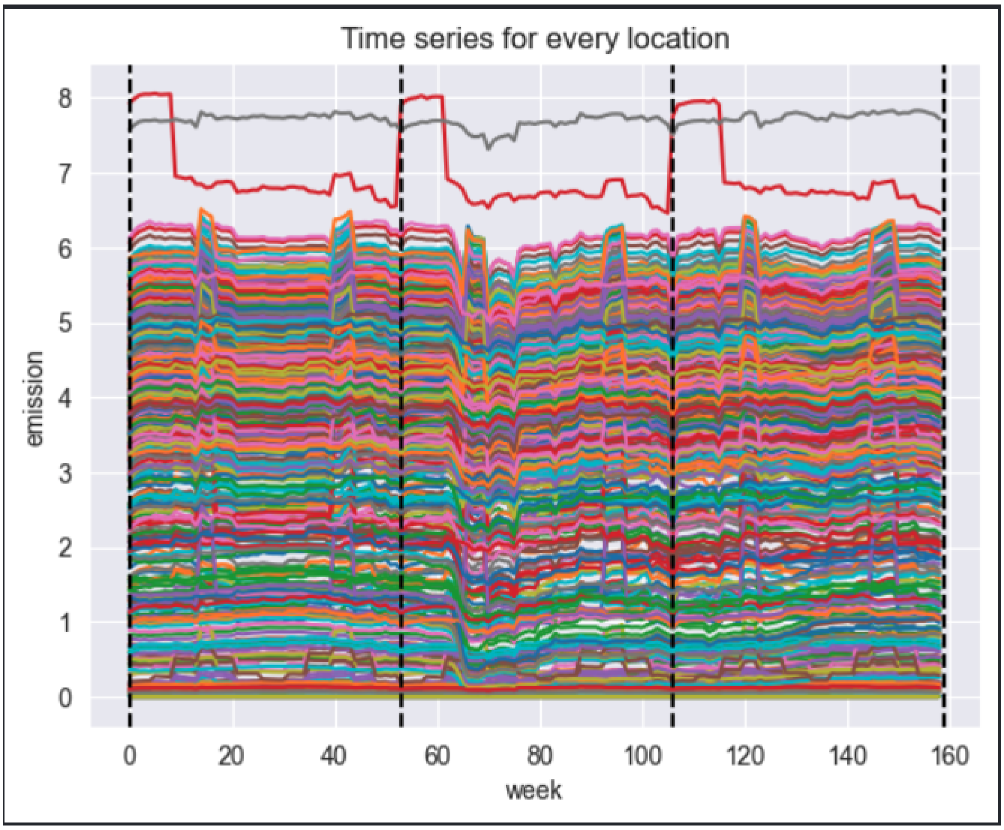
Plotting mean emission per location on the map. The emissions are color-coded: blue = low emission; red = high emission. We see that the emissions are clustered:

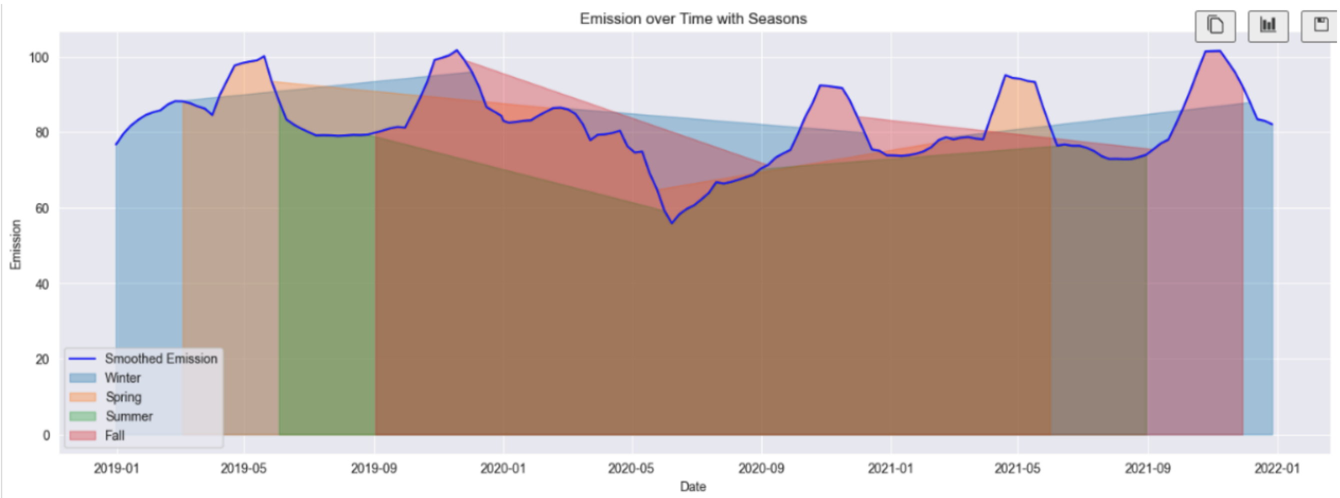
- Points in the west (Democratic Republic of the Congo) all have low emissions.
- The two red points with the highest emissions are both near Lac Kivu.



The time series of the emissions for every location. The plot shows:

1. The two locations with very high emissions have special patterns (red and gray); all other locations look similar.
2. Seasonality: There are yearly patterns (which repeat every 53 weeks).





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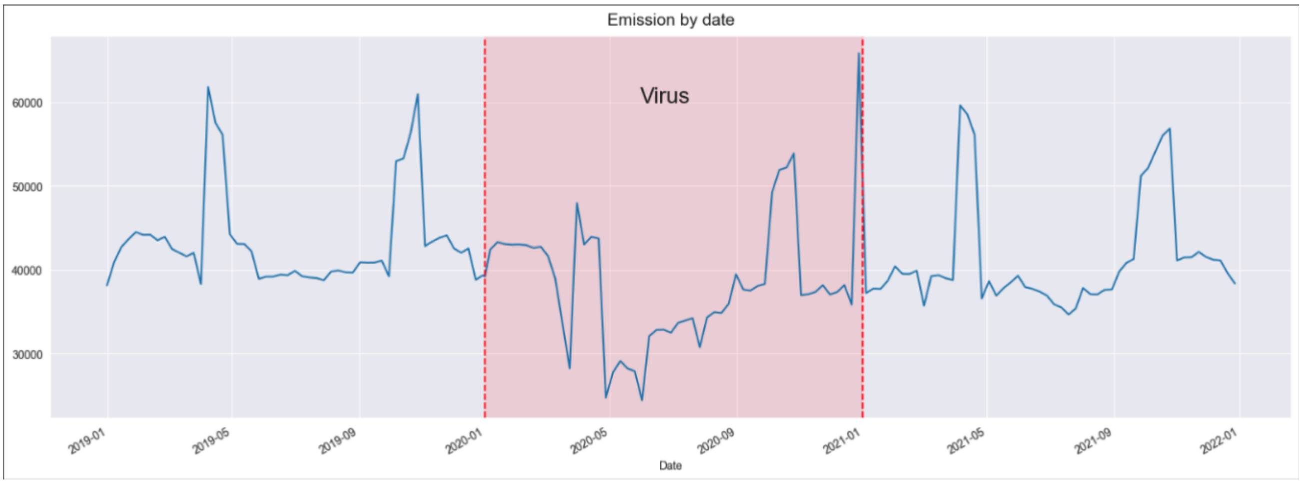
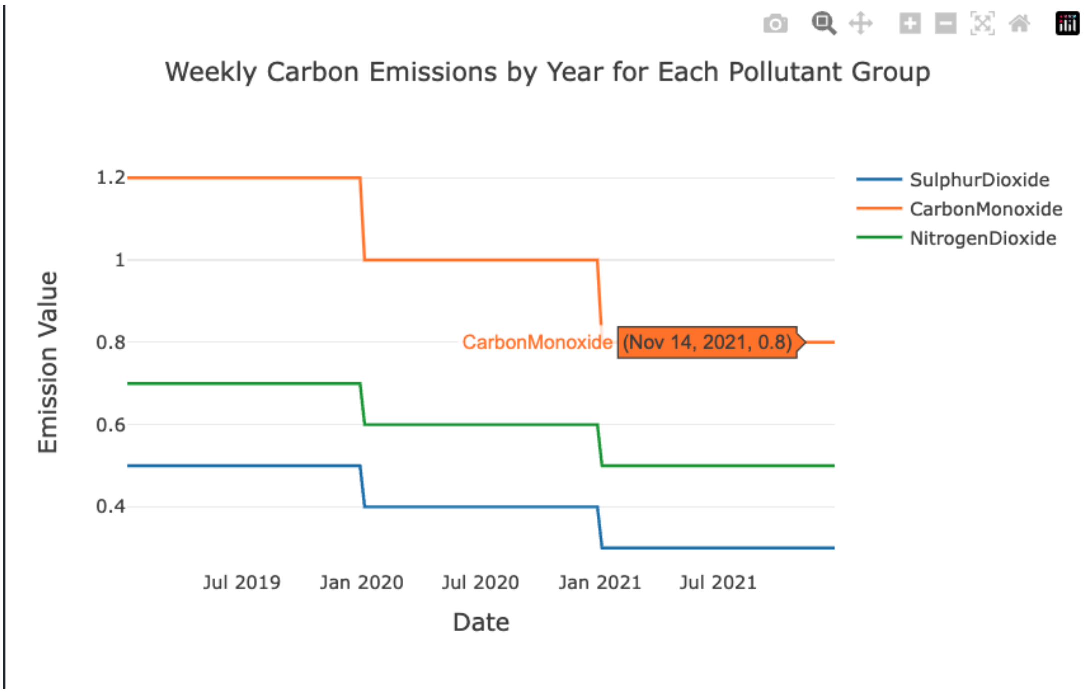
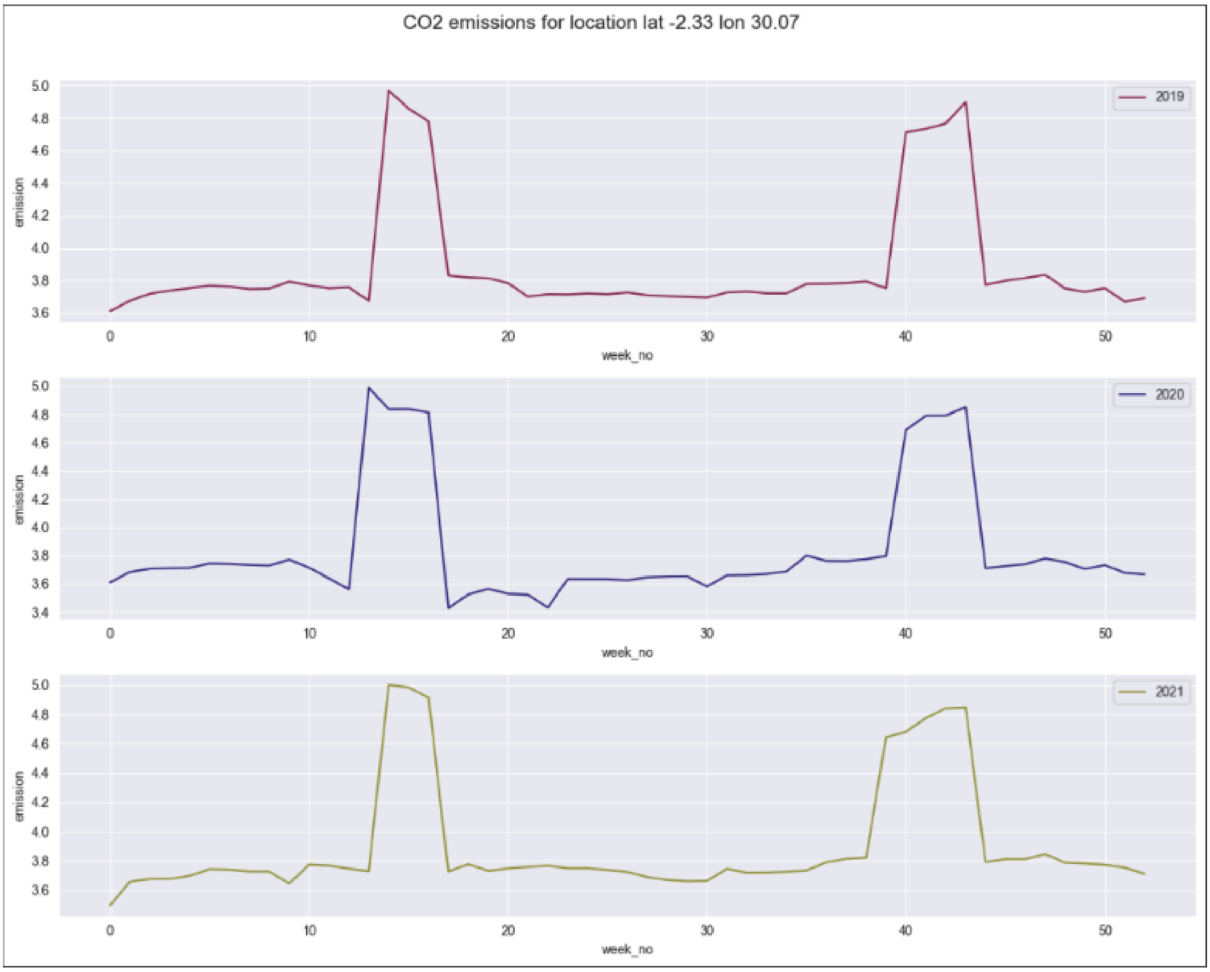


- Nobody can predict the lockdown in 2020 after fitting a model to 2019 and 2021. Nobody can predict that there was no lockdown in 2019 after fitting a model to 2020 and 2021.
- Due to heavy downfall in transportation sector, during Covid, there's a drastic drop in emission range.
- CO2 emissions measured during the lockdown must be treated as outliers. They are useless for training a model.

Among Carbon Monoxide, Sulphur Dioxide, Nitrogen Dioxide, Carbon Monoxide is the main source of Carbon emissions in Rwanda and Nitrogen Dioxide is second source.





Time Series Analysis:

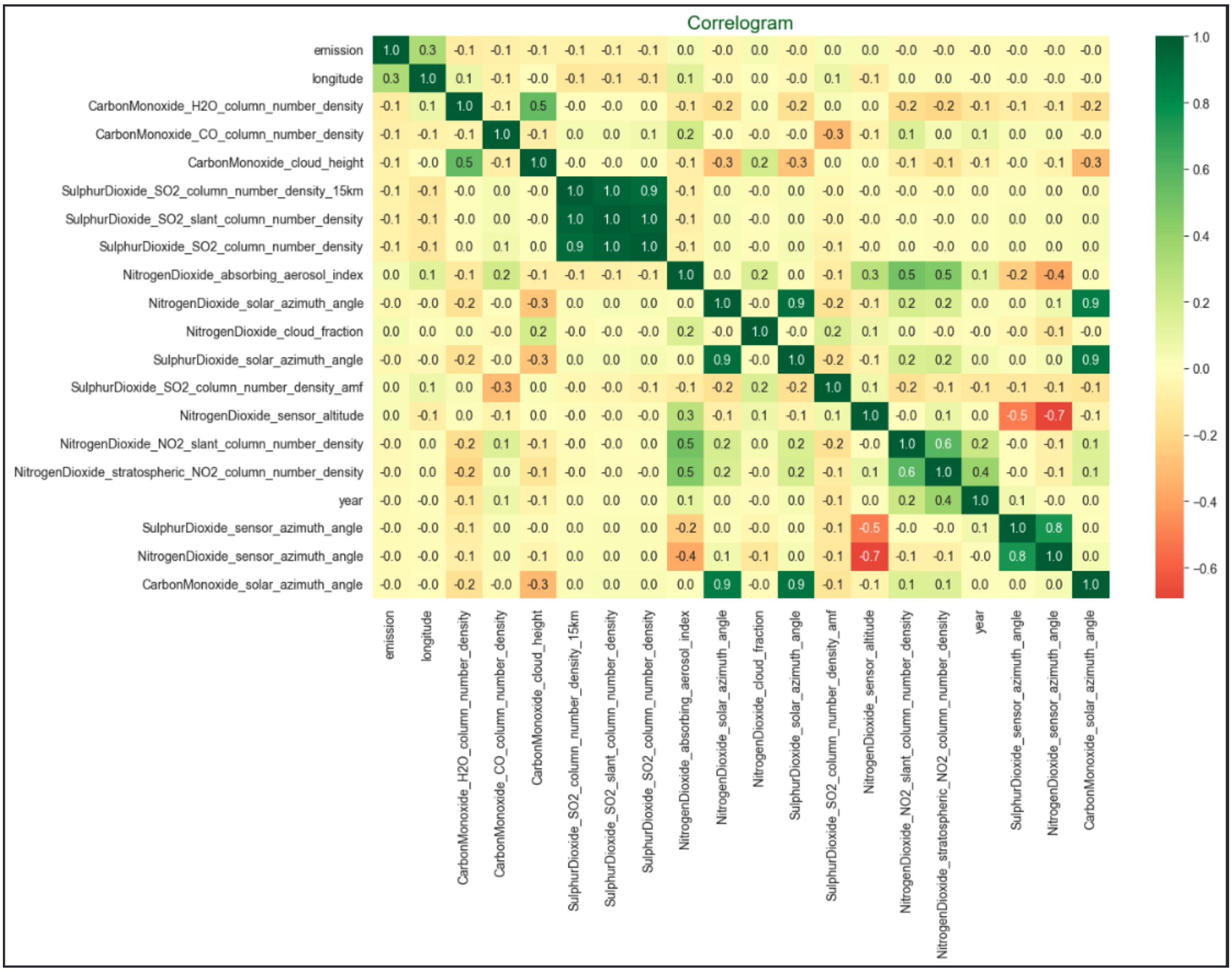
We can see during 2nd quarter and last quarter, there's a huge increase in CO2 emissions.

And the trend is the same across all 3 years.

The agriculture and energy sectors are the largest contributors to CO2 emissions in Rwanda.

During agriculture, after harvesting the leftover waste is burnt which results is emission of harmful gases into the atmosphere.

Correlation between the 3 gases (CO, NO2, SO2).



Acknowledgements

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References

Darius Moruri, Amy Bray, Walter Reade, Ashley Chow. (2023). Predict CO2 Emissions in Rwanda. Kaggle. https://kaggle.com/competitions/playground-series-s3e20