Assessing the Impact of CO concentration on Land Surface Temperature in the region of Punjab, Haryana, and Delhi

Introduction

Stubble burning is the technique of igniting the straw stubble that remains after the harvesting of grains such as rice, wheat, and others. The burning of agricultural biomass residue, also known as crop residue burning (CRB), has been identified as a major environmental issue by the United Nations Organization. Crop residue burning releases carbon dioxide (CO2), carbon monoxide (CO), oxides of sulfur (SOX), particulate matter, and black carbon. Burning crop residue creates significant pollution in the atmosphere, as well as important nutritional loss and soil health deterioration. These gases impact human health because they produce a general decline in air quality, which worsens eye and skin disorders, and very tiny particles can cause chronic heart and lung ailments.

The presence of Carbon Monoxide (CO) in the atmosphere plays a significant role in the formation of the tropospheric greenhouse gas (GHG) i.e. ozone. More than 50% of CO emissions are due to anthropogenic activities besides other natural and chemical reasons. The reaction of CO with hydroxyl (OH) radicals in the atmosphere, reduces their abundance which increases the lifespan of strong GHGs like methane and thus indirectly affects global warming. Globally, the densely populated regions have shown a higher concentration of CO and contribution to the increasing land surface and atmospheric temperature, and therefore assessing the impact of CO on the Land Surface Temperature (LST) provides an important aspect to regional to global change studies. LST is a measure of heat emitted by surface land cover classes. It provides vital information regarding the physical properties of the surface, balancing high temperatures and climatic changes (Chejarla et al., 2016).

This study aims to quantitatively establish the correlation between CO concentration in the atmosphere and Land Surface Temperature. The pre-established notion of CO being the independent variable and Land Surface Temperature being dependent on CO is taken into consideration for the year of 2021. Due to limitations in time and resources the study ignores the impact of other external factors and only takes a single gas into assessment.

Datasets Used

In this study, satellite data for CO concentration is from Sentinel-5 Precursor missions which carry the Tropomi instrument to map a multitude of trace gasses including carbon monoxide. The images are extracted from Google Earth Engine with a resolution 1.13 km. The LST map is generated from Band 4, Band 5, and Band 10 of Landsat-8 satellite images. Though the images are available at a resolution of 30m, the images were resampled during extraction into the same resolution as that of Sentinel 5P to increase the ease of functioning in the later stages of the study. Reducing the resolution of the Landsat image reduces the amount of data that needs to be handled, furthermore, if the resolution of Sentinel 5P were to be increased to that of Landsat it would have increased the data load without contributing much to the quality of spatial data in the study.

Study Area

The burning of farm residue is a major source of air pollution in regions of North India. Though the majority of the emission sources are located in the parts of Punjab and Haryana, it is the capital city with a population of 1.6 crore (approx.) (Census of India, 2011) of Delhi that faces major problems. Stubble burning continues in several parts of Punjab and Haryana, despite rising levels of pollution in Delhi (Seema et al., 2018) . Punjab and Haryana are two of India's most important agricultural states, both of which are located in the Indo Gangetic Plain region, where considerable crop waste burning occurs every year (Singh et al., 2020 a,b, c). This region has two crop residue burning patterns: (i) post-harvest paddy residue burning (October-November) and (ii) wheat residue burning (April-May). Crop residue burning practices are a public health problem to the masses. Since the creators of this environmental crisis and its bearers are not evenly distributed spatially, it is important that we establish the impact of CRB practices on LST.

Methodology

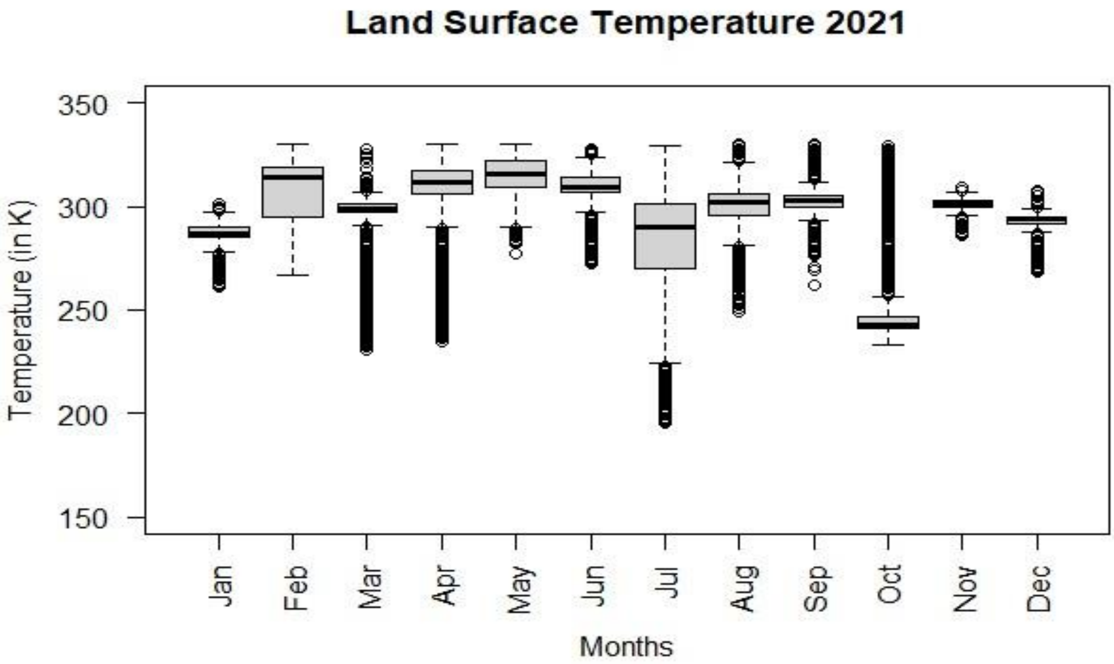
Data acquisition is done using Google Earth Engine code editor. LANDSAT 8 collection 1 Tier 1 Raw scenes data for the area of interest was selected for every month of the year 2021 *(Appendix I and II)*. The tiles available for the study area for each month are mosaiced, compromising the cloud cover on certain months. Three bands of the dataset Band 4, Band 5 and Band 10 for all twelve months are downloaded. Carbon Monoxide Concentrations are obtained from the Sentinel-5P NRTI CO: Near Real-Time Carbon Monoxide dataset by averaging, it for a month and downloading the monthly mean data for twelve months of 2021.

In order to adjust the extent and ensure proper overlay of the images the entire downloaded dataset is clipped to the extent of area of interest (AOI) using Python. The clipped data is further used to estimate the LST using predefined methods found in the USGS Algorithms. The LST calculation requires information from Band 4, Band 5 and Band 10 as inputs. Band 4 and Band 5 also known as the red and NIR (near infrared) bands are used to calculate NDVI. NDVI is then used to assess the emissivity. The top of the atmosphere (TOA) spectral radiance is computed from the thermal band of LANDSAT 8 (Band 10) using the Band-specific multiplicative and additive rescaling factors from the metadata. The TOA and K1, K2 constants of band 10 are used in the calculation of Brightness Temperature (BT). Finally, LST is calculated from BT and emissivity. Twelve LST files, one for each month of 2021 are obtained in csv and tiff formats. The computed LST and Carbon monoxide concentration data for all 12 months are imported as arrays from csv files into the code to calculate correlation. The image arrays are converted into a one-dimensional list. This is done to reduce the 3rd form function data into a second-form function in order to correlate the data. The lists containing rearranged information of the image of each month for LST and CO are correlated to find the monthly correlation between the two variables with LST as the dependent variable on CO. In order to find the correlation for the information of the entire year the lists of each month are appended into a new array. Hence two new arrays (for CO and LST) with 12 entries, each containing the list of images for twelve month is created. This dataset can be interpreted as each column representing the LST and CO values for the entire year by moving down across the rows. This array is then transposed in order to run the coefficient function along months and not pixels. A predefined library for assessing correlation is used in Python among the two datasets which returns the Pearson Correlation Coefficient.

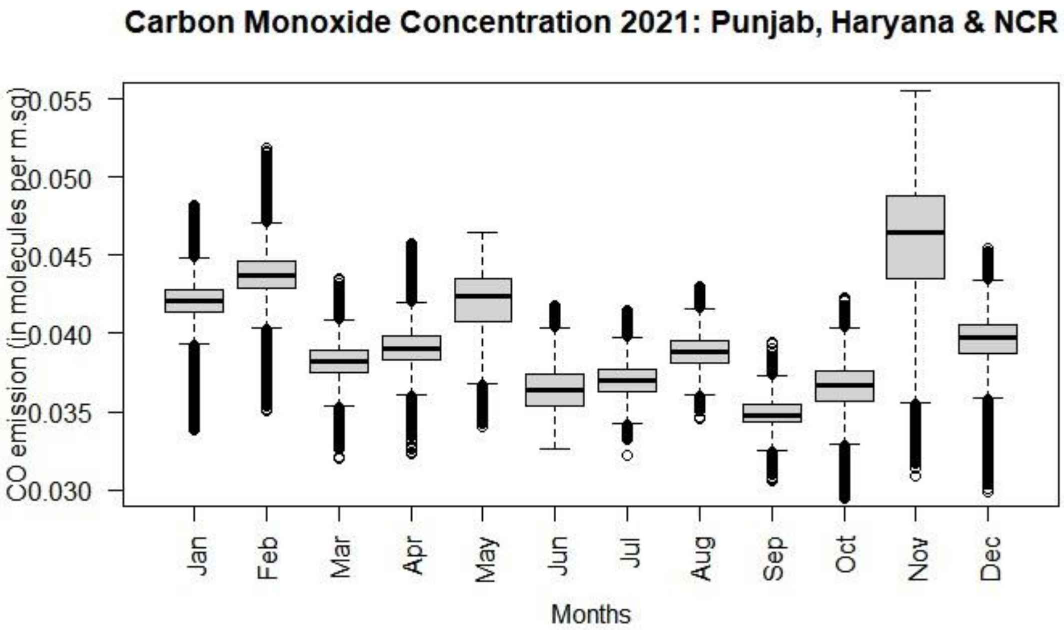
Results and Conclusion

The resultant data helps us plot the LST and CO concentration in the form of a box plot. This provides us with the median and the distribution of observations across the area of interest. The mentioned plot in figure 4 and figure 5 are created using R with the codes mentioned in Appendix III.

Box-plots showing the variations in LST and CO to assess the quality of input data and its trend throughout the year of 2021 are given in Figure 4 and Figure 5 respectively.



Boxplot showing Data distribution and trend for Land Surface Temperature for 2021



Boxplot showing Data distribution and trend for Carbon Monoxide Concentration for 2021

The correlation coefficient is obtained between each month's LST and CO concentration which are as follows:

Month	Correlation coefficient between LST and CO
January	0.998
February	0.870
March	0.983
April	0.995
May	0.995
June	0.986
July	0.987
August	0.791
September	0.820
October	0.997
November	0.993
December	0.997

Since the correlation coefficient of each month is positive and greater than 0.75, it can be established that CO concentration and LST are strongly positively correlated. This correlation is further backed by the overall correlation coefficient of 0.944 for the area of interest. This can be interpreted as an increase in concentration of carbon monoxide in the atmosphere is bound to increase the land surface temperature which may be further multiplied by the urban heat island effects of Delhi. Hence it is critically important for the north Indian region to come up with methods to limit the increase in concentration of CO in the atmosphere.