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CORRELATION BETWEEN AIR POLLUTION (CARBON MONOXIDE), PRECIPITATION AND EVAPOTRANSPIRATION USING SENTINEL-5 SATELLITE DATA IN HARYANA, FROM JANUARY 2022 TO DECEMBER 2022

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ABSTRACT

*The gases found in the atmosphere are in definite quantity and proportion. When there is a change in their quantity and proportion due to any reason, it is called air pollution. Carbon monoxide gas is produced when fuels such as oil, coal or wood do not burn completely. Carbon monoxide is formed on unburnt fuel. The origin of carbon monoxide in the state of Haryana is also the burning of crop residues by the farmers. Haryana is a state in North India. Its borders are connected with Punjab and Himachal Pradesh in the north, Rajasthan in the south and west. Its geographical extension is from **27°39'** north to **30°55'** north latitudes, and from **74°28'** east to **77°36'** east longitudes. The area of the state is **44,212** square kilometers, which is **1.4** percent of the total geographical area of the country. The main objective of this research work is to determine the month-wise amount of carbon monoxide in the study area Haryana state on the basis of Sentinel-**5** Satellite data and to determine its correlation with the amount of rainfall and evapotranspiration. Multiple Regression statistics tool has been used by the researcher to check the validity of his research hypothesis. On the calculation of Multiple Regression between the amount of carbon monoxide, rainfall and transpiration variables in the study area, the value of Multiple R is **0.683979** and the value of R Square is **0.467822**, which makes it clear that there is a positive correlation between the amount of carbon monoxide, rainfall and evapotranspiration in the study area. Ultimately the hypothesis of the researcher is proved to be true.*

Keywords: *Stubble Burning, Air Pollution, Carbon Monoxide, Evapotranspiration, Remote Sensing.*

Introduction

Humans and other living beings need clean air to survive. We get this clean air from the atmosphere.[i] The gases found in the atmosphere are in definite quantity and proportion. When there is a change in their quantity and proportion due to any reason, it is called air pollution.[ii] It includes different types of gases, particles of carbon, smoke, particles of minerals etc.[iii] At present, the main cause of air pollution is the gases and other harmful substances released into the air by various human activities, such as carbon dioxide, carbon monoxide, sulfur dioxide, hydrocarbons, ammonia etc.[iv] In the research work presented by the researcher, the concentration of carbon monoxide has been assessed in the state of Haryana. Carbon monoxide gas is produced when fuels such as oil, coal or wood do not burn completely.[v] Carbon monoxide is formed on unburnt fuel.[vi] The origin of carbon monoxide in the state of Haryana is also the burning of crop residues by the farmers.[vii] In the months of March, April, May, September, October and November, there is also smoke emitted from old vehicles and industries.[viii] When carbon monoxide is breathed in, it enters the blood with your breath and combines with hemoglobin (the red blood cells that carry oxygen around your body) to form 'Carboxyhaemoglobin'.[ix] When this happens, there is no oxygen left in the blood and the body's cells and tissues die from lack of oxygen. This is the reason why it is very important to keep the amount of carbon monoxide as per the prescribed standard.[x] Along with this, it is also necessary to find out the correlation of the amount of carbon monoxide with other climatic factors so that the amount of carbon monoxide in the study area can be understood more comprehensively.

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Research Objectives and Hypothesis

The main objective of this research work is to determine the month-wise amount of carbon monoxide in the study area Haryana state on the basis of Sentinel-5 Satellite data and to determine its correlation with the amount of rainfall and evapotranspiration.

Similarly, the researcher has assumed in his research hypothesis that there is a positive correlation between the month-wise amount of carbon monoxide, rainfall and evapotranspiration in the study area Haryana state.

Research Methodology

This research work is based on the data obtained from image processing of 'Sentinel-5P OFFL CO'[xi] dataset obtained from 'Sentinel-5P satellite[xii] established by 'European Union/ESA/Copernicus' available on 'google earth engine platform'[xiii]. A comparative study of Sentinel-5P satellite month-wise images has been carried out to assess the concentration of carbon monoxide in the atmosphere of the study area. The time period of these pictures is from January 2022 to December 2022. Through these photographs on google earth engine platform, the month-wise amount of carbon monoxide has been obtained in the study area. For this, the satellite 'CO_column_number_density' band of Sentinel-5P has been used, whose measurement unit is mol/m2, as well as maps have been created from these images through QGIS Desktop 3.28.2[xiv] open source GIS software. On the basis of this, a comparative study of carbon monoxide in the study area can be done on a periodic basis. Multiple Regression statistics tool has been used by the researcher to check the validity of his research hypothesis-

$$Y_i = b_0 + b_1X_{1i} + b_2X_{2i} + b_nX_{ni} + u_i$$

Y_i = dependent variable
b_0 = Intercept
$b_1 \ldots b_n$ = Coefficient of Regression
$X_{1i} \ldots X_{ni}$ = independent variable
u_i = disturbance error

Study Area

Haryana state is located in North India. Its borders are connected with Punjab and Himachal Pradesh in the north, and Rajasthan in the south and west.[xv] The Yamuna River defines its eastern boundary with the state of Uttar Pradesh. The National Capital Delhi is surrounded by Haryana on three sides and consequently, the southern region of Haryana is included in the National Capital Region for the purpose of planned development. Its geographical extension is from 27°39' north to 30°55' north latitudes, and from 74°28' east to 77°36' east longitudes.[xvi] The area of the state is 44,212 square kilometres, which is 1.4 per cent of the country's total geographical area, making it the 20th largest state in India by area.[xvii] The altitude of Haryana ranges from 700 to 3600 feet (200 m to 1200 m) above sea level.[xviii] Geographically, Haryana can be divided into four parts: the Yamuna-Ghaggar plains in the northern part of the state, a belt of Shivalik hills in the far north, the Bangar region in the south-west and the culmination of the Aravalli ranges in the southern part, which The horizontal extension is from Rajasthan to Delhi.[xix]

The soil of the state is generally deep and fertile.[xx] However, the hilly areas of the northeast and the sandy areas of the southwest are exceptions. Most of the state's land is cultivable, but it requires a lot of irrigation.[xxi] Yamuna is the only perennial river of the state, which flows along its eastern border.[xxii] The climate of Haryana is similar to that of the Gangetic plains throughout the year, with very hot summers and moderately cool winters.[xxiii] The hottest months are May and June when temperatures reach 45 °C (113 °F). The coldest months here are December and January. While the hottest months are May and June.[xxiv]

Result

It is known from the observation of Table-1 that in the study area Haryana state, in the year 2022, the amount of carbon monoxide recorded in the month of January was 0.03813 mol/m2. Similarly, in the month of February, the amount of carbon monoxide was recorded at 0.03712 mol/m2, which is 0.026 per cent more than in the month of January. The amount of carbon monoxide was recorded at 0.03914 mol/m2 in the month of March, which is 0.054 per cent higher than the month of February. In the month of April, the amount of carbon monoxide was recorded at 0.03822 mol/m2, in comparison to the

month of March -0.023 per cent decrease was marked in the month of April. In the month of May, the amount of carbon monoxide was recorded at 0.03907 mol/m2, which is 0.022 per cent more than in the month of April. In the study area, the amount of carbon monoxide recorded in the month of June was 0.03711 mol/m2, in this month -0.050 decrease was marked as compared to the month of May. In the month of July, the amount of carbon monoxide was recorded at 0.03602 mol/m2, which is -0.029 per cent less as compared to the month of June. In the study area, the amount of carbon monoxide was recorded at 0.03321 mol/m2 in the month of August, which is -0.078 per cent less as compared to the month of July. In the month of September, the amount of carbon monoxide was recorded at 0.03492 mol/m2, which is 0.051 per cent less than in the month of August. In the study area Haryana state, the amount of carbon monoxide recorded in the month of October was 0.03724 mol/m2, which is 0.066 per cent less as compared to the month of September. The amount of carbon monoxide recorded in the month of November 2022 was 0.03824 mol/m2, which is 0.026 per cent more than in the month of October. In comparison, -0.053 per cent is less.

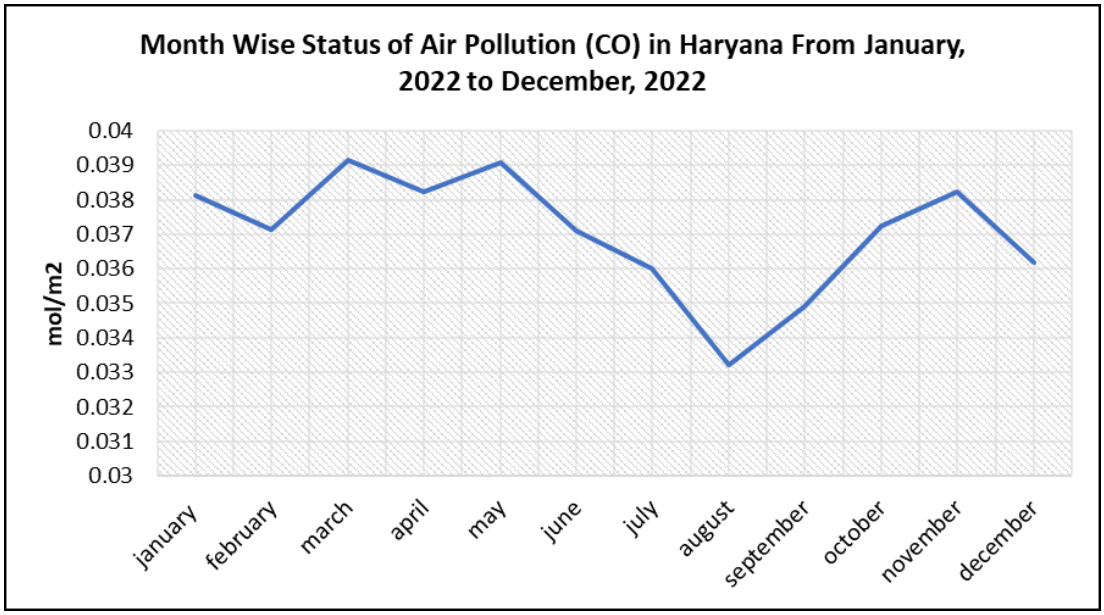
Maps 1, 2 and 3 show the month-wise regional pattern of CO concentrations obtained from the Sentinel-5P OFFL CO dataset in the study area.

Table 1: Month-wise Distribution of Carbon Monoxide Content in Haryana, January 2022 to December 2022

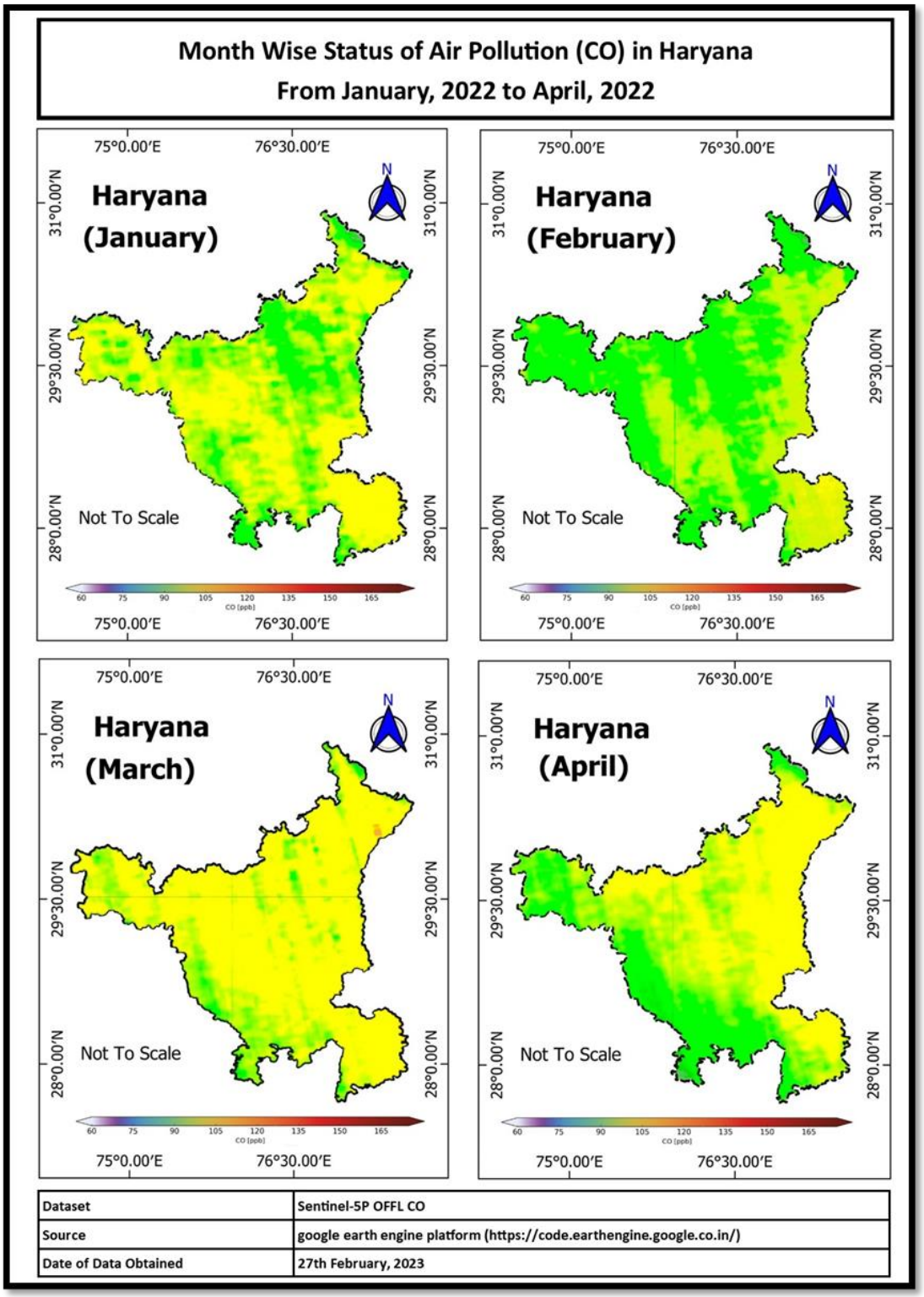
Month	Amount of Carbon Monoxide ($mol/m^{2)}$	Rate of Change (In per cent)
January	0.03813	-
February	0.03712	-0.026
March	0.03914	0.054
April	0.03822	-0.023
May	0.03907	0.022
June	0.03711	-0.050
July	0.03602	-0.029
August	0.03321	-0.078
September	0.03492	0.051
October	0.03724	0.066
November	0.03824	0.026
December	0.03618	-0.053

Source: Sentinel-5P OFFL CO' dataset

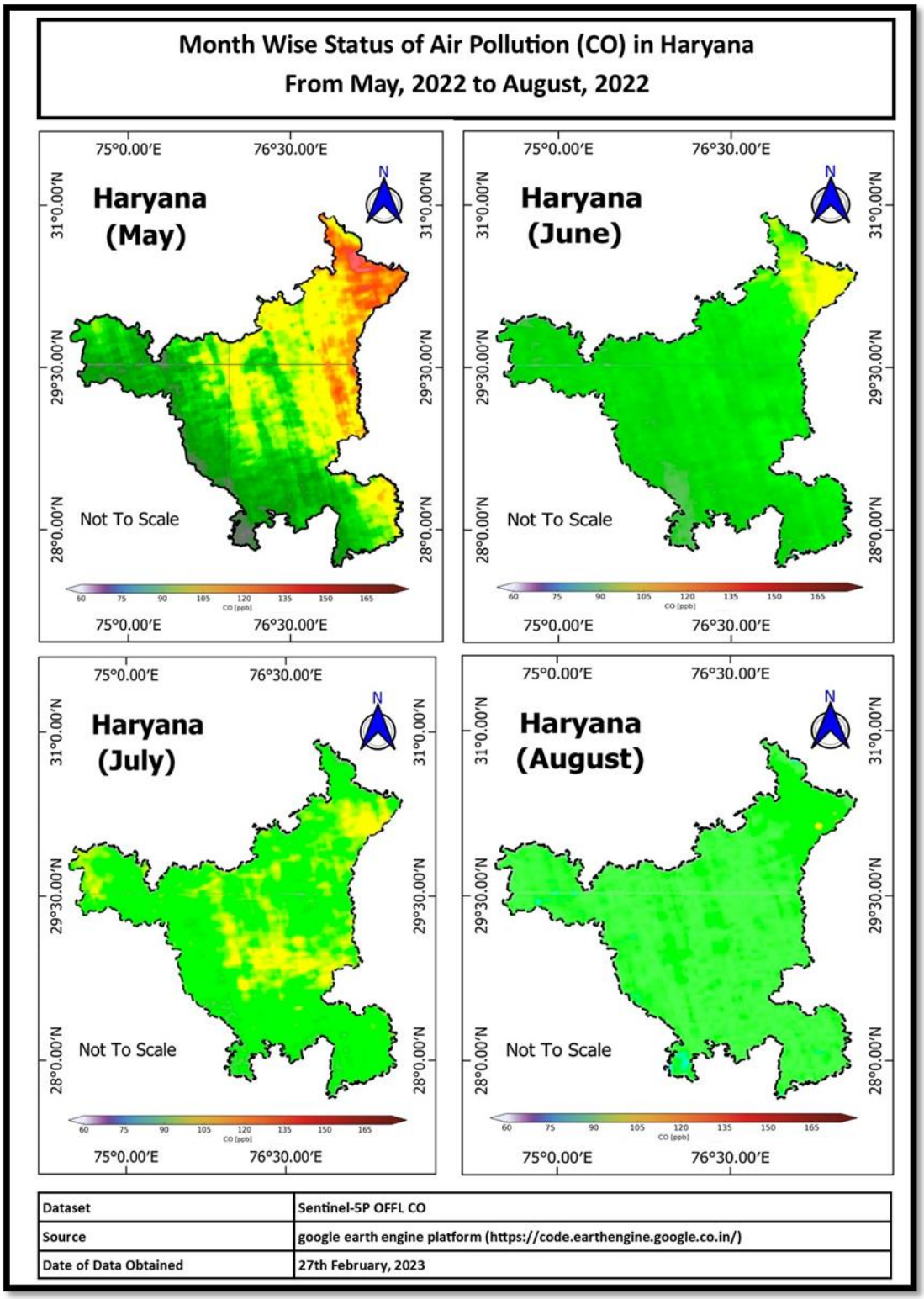
Fig. 1



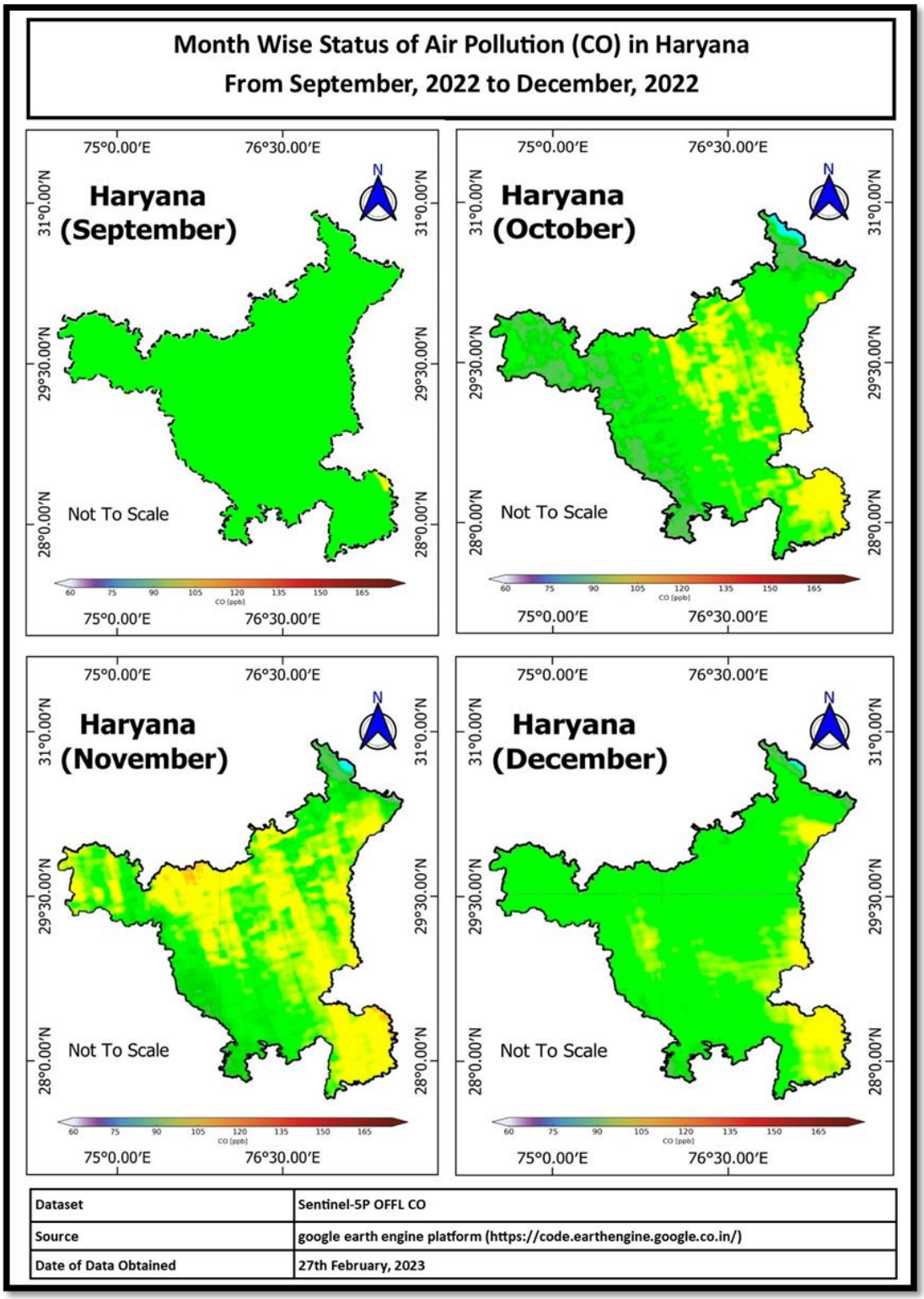
Map 1


Month Wise Status of Air Pollution (CO) in Haryana
From January, 2022 to April, 2022
Haryana (January)
Haryana (February)
Haryana (March)
Haryana (April)
75°0.00'E
76°30.00'E
31°0.00'N
29°30.00'N
28°0.00'N
N
Not To Scale
60 75 90 105 120 135 150 165
CO (ppb)
Dataset
Sentinel-5P OFFL CO
Source
google earth engine platform (https://code.earthengine.google.co.in/)
Date of Data Obtained
27th February, 2023

Map 2


Month Wise Status of Air Pollution (CO) in Haryana
From May, 2022 to August, 2022
Haryana (May)
Haryana (June)
Haryana (July)
Haryana (August)
75°0.00'E
76°30.00'E
31°0.00'N
29°30.00'N
28°0.00'N
N
Not To Scale
60 75 90 105 120 135 150 165
CO [ppb]
Dataset
Sentinel-5P OFFL CO
Source
google earth engine platform (https://code.earthengine.google.co.in/)
Date of Data Obtained
27th February, 2023

Map 3


Month Wise Status of Air Pollution (CO) in Haryana
From September, 2022 to December, 2022
Haryana (September)
Haryana (October)
Haryana (November)
Haryana (December)
75°0.00'E
76°30.00'E
31°0.00'N
29°30.00'N
28°0.00'N
N
Not To Scale
60 75 90 105 120 135 150 165
CO [ppb]
Dataset
Sentinel-5P OFFL CO
Source
google earth engine platform (https://code.earthengine.google.co.in/)
Date of Data Obtained
27th February, 2023

Observing the amount of evapotranspiration and rainfall in the study area Haryana state in the year 2022, it is shows that 80.75 mm of rainfall was recorded in the month of January in the study area and 1.01 mm of evapotranspiration was recorded. Similarly, in the month of February, 19.49 mm of rainfall and 1.54 mm of evapotranspiration was recorded. In the month of March, 0.23 mm of rainfall and 0.87 mm of evapotranspiration were recorded. In the month of April, rainfall was recorded 0.53 mm and evapotranspiration was 0.39 mm. In the study area, Haryana state received 37.68 mm of rainfall and 0.65 mm of evapotranspiration in the month of May. Similarly, in the month of June, 43.13 mm of rainfall was recorded in the state of Haryana and the amount of evapotranspiration was recorded at 1.13 mm. In the month of July, maximise amount of rainfall was recorded in the study area at 221.99 mm and maximum amount of evapotranspiration was also recorded at 3.62 mm in the same month. In the month of August, the amount of rainfall has been recorded 77.38 mm and the amount of evapotranspiration has been recorded 3.59 mm. In the month of September, the amount of rainfall recorded in the study area was 158.66 mm and the amount of evapotranspiration was recorded 1.9 mm. In the month of October, the amount of rainfall has been recorded 38.57 mm and the amount of evapotranspiration has been recorded 2.6 mm. In the month of November, the amount of rainfall was recorded 0.2 mm and the amount of evapotranspiration was 0.45 mm. In the study area, the lowest amount of rainfall was recorded in the month of December at 0.05 mm and the amount of evapotranspiration was also the lowest at 0.13 mm in the same month. From January 2022 to December 2022, a total of 678.66 mm of rainfall and a total of 17.88 mm of evapotranspiration were recorded in the study area. In the study area Haryana State, the average amount of rainfall from January 2022 to December 2022 has been recorded as 56.55 mm and the average amount of transpiration has been recorded as 1.49 mm.

Table 2: Month-wise distribution of Evapotranspiration and Rainfall in Haryana, January 2022 to December 2022

Month	Evapotranspiration (in mm)	Rainfall (in mm)
January	1.01	80.75
February	1.54	19.49
March	0.87	0.23
April	0.39	0.53
May	0.65	37.68
June	1.13	43.13
July	3.62	221.99
August	3.59	77.38
September	1.9	158.66
October	2.6	38.57
November	0.45	0.2
December	0.13	0.05
Total	17.88	678.66
Avg.	1.49	56.55

Source: India Water Resources Information System[xxv]

Fig. 2

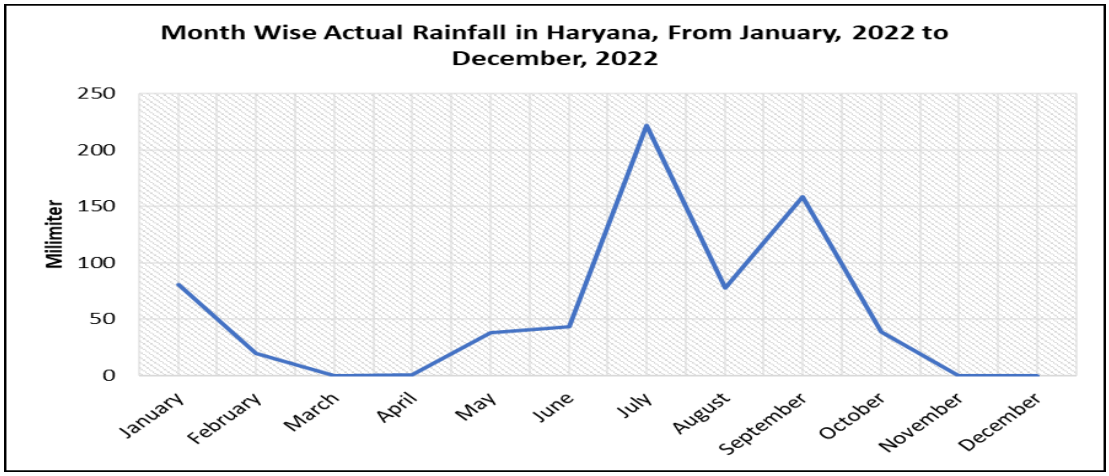
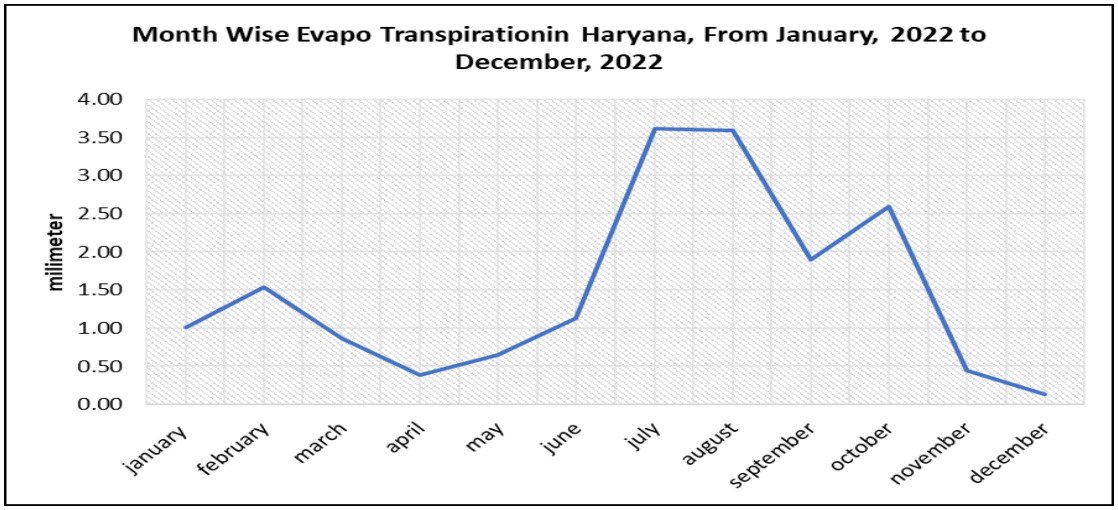


Fig. 3



Checking the Validity of the Research Hypothesis

The researcher has assumed in his research hypothesis that there is a positive correlation between month wise amount of carbon monoxide, rainfall and evapotranspiration in the study area Haryana state. Multiple Regression statistics tool has been used by the researcher to check the validity of his research hypothesis. Whose calculation has been displayed under Table-3.

Table 3: Calculation done by Multiple Regression Statistics Method to Check the Validity of the Research Hypothesis

Regression Statistics	
Multiple R	0.6839
R Square	0.4678
Adjusted R Square	0.3495
Standard Error	0.0014
Observations	12

ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***
Regression	2	1.5693	7.85	3.95583	0.05851
Residual	9	1.7851	1.98		
Total	11	3.3544			

After studying Table 3, it is known that after calculating the Multiple Regression between the amount of carbon monoxide, rainfall and transpiration variables in the study area, the value of Multiple R is 0.68397 and the value of R Square is 0.467822, which makes it clear that the study there is a positive correlation between the amount of carbon monoxide, precipitation and transpiration variables in the region. Ultimately the hypothesis of the researcher is proved to be true.

Conclusion

The amount of carbon monoxide present in the study area is more than the desired amount of 0.3 mol/m2. Which is a matter of serious concern. Studying the month-wise amount of carbon monoxide, precipitation and vapour emissions in the study area shows that the amount of carbon monoxide has a negative correlation with precipitation. In the study area, the amount of carbon monoxide decreases in the months in which the amount of precipitation is high, whereas in the months where the amount of precipitation decreases, there is a significant increase in the amount of carbon monoxide in the same months. Similarly, the amount of carbon monoxide in the study area has a positive correlation with the amount of transpiration. The months in which there is an increase in the amount of evapotranspiration in the study area, there is also an increase in the amount of carbon monoxide in those months. While the months in which there is a decrease in the amount of evapotranspiration, there is also a decrease in the amount of carbon monoxide in those months.

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