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Vehicular Carbon Emission Assessment and its Impact on Rainfall and Temperature in Ranchi, Jharkhand

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Abstract: ***Climate change is very serious problem to mankind as it is affecting climatic variables such as rainfall and temperature and which affects agriculture and livelihood of humans. The main reason of climate change and global warming is the increased greenhouse gas (GHG) emission. Greenhouse gases contain 72.4% carbon dioxide, making it the major component of GHG. Energy sector and transport sector are the two main emitter of CO_2. The vehicular carbon emission of Ranchi is calculated for year 1997-2020 and is correlated against rainfall and temperature. The results shows that the vehicular carbon emission of Ranchi is increasing exponentially. The bi-variate correlation of CO_2 signifies no significant correlation with rainfall however temperature is moderately correlated with CO2 emission. The partial correlation signifies the moderate influence of CO_2 on rainfall and temperature of Ranchi.***

Keywords: Pearson Correlation test, Partial correlation test, Carbon emission, Rainfall, Temperature

1. Introduction

Climate change is becoming a concern for the environment and livelihood of humans. Climate change is affecting pattern of rainfall and hence affecting the agriculture. Rainfall variability is major concern for humans as it is the natural source which recharges the ground water level. Monsoon is very important climatic phenomenon occurring in India as India is heavily dependent on rainfall for irrigation. A strong correlation is observed between monsoonal rainfall and agricultural production in India [1]. Climate change is also affecting the temperature of the earth. IPCC reported that the global surface warming is happening at the rate of 0.74 ± 0.18ºC during the period 1906-2005 [2]. It also reported that climate change in Asia is associated with rapid urbanization, industrialization and economic development. The urbanization process and its growth have increased in last 90 years [3]. The transportation sector, energy sector and industrial sector has grown rapidly due to increased urbanization and it led to multifold rise in the amount of air pollution [4]. The main reason of climate change and global warming is the increased greenhouse gas (GHG) emission [5]. Greenhouse gas and enhanced aerosol emission leads to increase in temperature which is found responsible for the climate change [6]. IPCC reported that the greenhouse gas emission in 21st century is depending upon the socio-economic development and climate policy [7]. The ongoing emission of greenhouse gases will further cause global warming and impact all climate variables [7]. Greenhouse gases contain 72.4% carbon dioxide, making it the major component of GHG. GHG contains 19% Nitrous oxide, 7.2% Methane and 1.4% Chlorofluorocarbon. Activities like burning of fossil fuels like coal, petrol, diesel, oil, natural gas, ethanol results in formation of CO_2. India is the third largest emitter of CO2 in the world after United States and China. Study shows that the CO_2 emission of India in 2015 was the maximum leaving behind United States and China by emitting 2.3 giga tones CO_2 [8]. Carbon emission from urban cities has sharply increased due to the rapid urbanization and motorization. The vehicular emission is the third largest greenhouse gas emission sector which accounts for 13% of the global GHG emission. Energy sector and industrial sector are the top two GHG emitter. The poor infrastructure of public transport is one of the main reasons of growing private vehicles. The share of small-occupancy vehicles such as two wheelers is high in India. Cars are also dominating the automobile transportation in cities as it is linked with social status for owning cars and poor public transportation system. The increased vehicles are putting pressure on the local air pollution and increasing GHG emission.

The urban environment of Ranchi is being deteriorated by increase in suspended particulate matter and high concentration of aerosol all because of rapid increase in human and vehicular population [9]. These changes affect the absorption of solar radiation, surface temperature and evaporation rates which resulted in alteration of local climate.

Therefore, Carbon emission from increased vehicular traffic is calculated for Ranchi and its impact on temperature and rainfall pattern is analyzed in this research work.

2. Study Area

Ranchi is the capital of Jharkhand state in India and is situated at the Chota Nagpur plateau of eastern India. The district is stretched in 5097 sq km having latitude 22º52'-23º45' North and longitude 84º45'-85º50' East. The district is situated at mean sea level height ranging from 500 to 700m. The average annual rainfall and average annual temperature of Ranchi are respectively 1300mm and 24ºC [10]. The Jharkhand became a separate state on 14 November 2000 and Ranchi emerges as the capital city of the state. Ranchi saw sudden increase in urbanization and immigration which resulted in multifold (4461.4% during the period 1997-2010) increase in vehicular population [11].

3. Data and Methodology

The daily rainfall and average temperature data of Ranchi is obtained from the website of National Centre For Environmental Information (https://www.ncdc.noaa.gov/cdo-web/) for the period 1997-2020. The data were then analyzed to find out yearly rainfall and yearly average temperature of Ranchi. The number of registered vehicles in Ranchi from the period 1997-2009 is obtained from DTO, Ranchi and for the period 2016-2020 is obtained from "Ranchi District Statistical Handbook, 2021" [12]. The registered vehicle data for year 2015 is obtained from "Jharkhand a Statistical Profile 2020" [13]. The number of registered vehicles from the period 2010 to 2014 is calculated by interpolation method.

The source of carbon emission in this paper is considered as the vehicular carbon emission. The CO2 emission from vehicles is calculated from the data of registered vehicles in Ranchi. The method used for the calculation of CO2 is based on the methods suggested by Federal Highway Administration (FHWA) and United State Environmental Protection Agency (EPA). The method and underlying data are updated time to time by both the agencies. The latest method and underlying data are used to calculate vehicular CO_2 emission in this paper. FHWA (2021) reported that the average vehicle miles travelled (VMT) for all vehicles is 11094 miles [14]. The average mileage for all vehicles is 18 miles per gallons of gasoline and one gallon of gasoline emits 8.89*10-3 tons CO2. EPA,2022 reported that the ratio of CO2 emission to total greenhouse gas emission for passenger vehicles is 0.993 [15]. The conversion factor for calculation of CO2 emission from number of vehicles is as follows:

Conversion factor = 8.89×10^{-3} tons CO2/ gallon gasoline × 11094 VMT × 1/18 miles per gallon × 1 CO2, CH4 and N2O /0.993 = 5.517 tons CO2E/ vehicle/ Year

The calculated CO2 data were then analyzed together with yearly rainfall and average temperature data to find out impact of CO2 on these climatic variables. To find out intercorrelation between these variables. Partial Correlation test is applied. Rainfall and temperature are considered as dependent variable while CO2 is considered as control variable.

Pearson's Correlation Test

It is a bivariate correlation which measures the linear correlation between two sets of data. It is the ratio between the covariance of two variables and the product of their standard deviation. Pearson correlation between two data points X and Y is given by:

Correlation (X ,Y) = $\frac{Cov(X,Y)}{\sigma_X \times \sigma_Y}$

Where Cov(X ,Y) is covariance of X and Y and is given by

Cov(X ,Y) = $\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})$

Where $\bar{x}$ and $\bar{y}$ are mean of data set X and Y respectively and n is the sample size.

And σ_X and σ_Y are standard deviation of X and Y respectively.

The Pearson Correlation is the actual correlation value that denotes magnitude and direction, the Sig.(2-tailed) is the *p*-value that is interpreted to check the significance of correlation. If the *p*-value is less than 0.05, then correlation is statistically significant between the two data set and the *p*-value is more than 0.05, then the correlation is not statistically significant association between the two data set.

Partial Correlation Test

It is a measure of the strength and direction of a linear relation between two continuous variables while controlling for the effect of one or more other continuous variables known as covariate or control variables. A simple way to compute the partial correlation for some data is to solve the two associated linear regression problems and calculate the correlation between the residuals.

Let X and Y be real valued random variables and let Z be the n-dimensional vector valued random variable. The (n+1) dimensional regression coefficient vector for variable X and Y is givens respectively

$$W_X^* = \arg\min\left\{\sum_{i=1}^{N}(x_i - < W, Z_i >)^2\right\}$$

$$W_Y^* = \arg\min\left\{\sum_{i=1}^{N}(y_i - < W, Z_i >)^2\right\}$$

Where N is the number of observation and $< W, Z_i >$ is the scalar product between the vector W and Z_i.

The residuals are the given as follows:

$$e_{X,i} = x_i - < W_X^*, Z_i >$$

$$e_{Y,i} = y_i - < W_Y^*, Z_i >$$

Then the partial correlation of variables X, Y and Z is given as

$$\hat{\rho}_{XY,Z} = \frac{N\sum_{i=1}^{N} e_{X,i}e_{Y,i} - \sum_{i=1}^{N} e_{X,i}\sum_{i=1}^{N} e_{Y,i}}{\sqrt{N\sum_{i=1}^{N} e_{X,i}{}^2 - (\sum_{i=1}^{N} e_{X,i})^2}\sqrt{N\sum_{i=1}^{N} e_{Y,i}{}^2 - (\sum_{i=1}^{N} e_{Y,i})^2}}$$

$$= \frac{N\sum_{i=1}^{N} e_{X,i}e_{Y,i}}{\sqrt{N\sum_{i=1}^{N} e_{X,i}{}^2}\sqrt{N\sum_{i=1}^{N} e_{Y,i}{}^2}}$$

4. Results

The carbon emission from registered vehicles in Ranchi is calculated (Table 1). The vehicular carbon emission of Ranchi increased 1237 times since 1997-98 to 2020-21. The first spike in CO2 emission is observed in 1999-2000 when Ranchi became state capital of Jharkhand. The CO2 emission increased by 40% from 4733967tons in 1998-99 to 6905410 tons in 1999-2000. The first dip in CO2 emission is seen in 2007-08, a decrement of 0.95%. Again, a decrement in CO2 emission was seen in year 2019-20 and 2020-21, which was mainly because of COVID pandemic. The CO2 emission in Ranchi is increasing exponentially (Fig1). The data were then analyzed to find out annual mean of Rainfall, Temperature and CO2 emission. The annual mean rainfall and annual average temperature of Ranchi for the period 1997-2020 are respectively 1039.31 mm and 24ºC. The annual mean CO2 emission is 33967044 tons (Table 2).

The Pearson's correlation test was applied on these data set to find out inter-relation among them. The correlation among these three variables signifies that the rainfall is significantly negatively correlated with temperature with correlation coefficient -0.399 and is non-significantly positively correlation with CO2 with correlation coefficient 0.137 (Table 3). Temperature is moderately correlated with CO2 with correlation coefficient 0.320.

To find out influence of CO2 in the correlation of rainfall and temperature, partial correlation is applied considering CO2 as control variable. The correlation coefficient between rainfall and temperature is now -0.471 with p-value 0.023 which suggests that the correlation is significant (Table 4).

Table 1: Vehicular Carbon Emission in Ranchi

Years	Number of registered vehicles	Carbon emission (tons)	% Change
1997-98	7735	4733967	0
1998-99	8021	4909004	3.697479
1999-2000	11283	6905410	40.66825
2000-01	12234	7487440	8.428609
2001-02	15911	9737834	30.05558
2002-03	22632	13851214	42.24122
2003-04	26856	16436382	18.66384
2004-05	29738	18200221	10.73131
2005-06	36827	22538824	23.83819
2006-07	41923	25657673	13.83767
2007-08	41522	25412253	-0.95652
2008-09	46853	28674926	12.83898
2009-10	51289	31389842	9.46791
2010-11	56119.04	34345919	9.417304
2011-12	61403.94	37580379	9.417304
2012-13	67186.54	41119437	9.417304
2013-14	73513.7	44991779	9.417304
2014-15	80436.7	49228792	9.417304
2015-16	88011.67	53864816	9.417304
2016-17	96300	58937430	9.417304
2017-18	123506	75588019	28.2513
2018-19	126713	77550764	2.596635
2019-20	110235	67465914	-13.0042
2020-21	95750	58600819	-13.1401

Table 2: Annual mean of Rainfall, temperature and carbon emission

Variables	Mean	Standard deviation
Rainfall	1039.31 mm	239.39
Temperature	23.94ºC	0.51
CO2 emission	33967044 tons	22637648.3

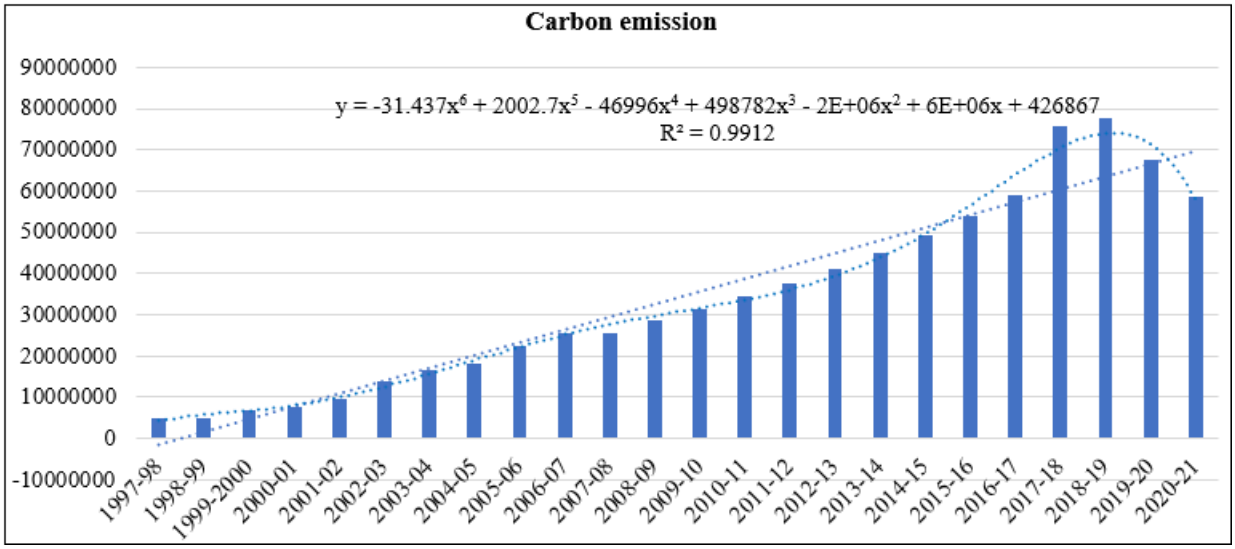

Figure 1: Carbon emission from 1997 to 2020 in Ranchi

Table 3: Pearson's Correlation statistics

Correlation (Without control variable)		Rainfall	Temperature	CO2
Rainfall	Correlation	1	-0.399	0.137
	p value	.	0.054	0.522
Temperature	Correlation	-0.399	1	0.320
	P value	0.054	.	0.128
CO2	Correlation	0.137	0.320	1
	P value	0.522	0.128	.

Table 4: Partial correlation statistics considering CO2 as control variable

Correlation (CO2 as control variable)		Rainfall	Temperature
Rainfall	Correlation	1	-0.471
	p value	.	0.023
Temperature	Correlation	-0.471	1
	p value	0.023	.

5. Conclusion

The rainfall, temperature and CO2 data are analyzed to find out intercorrelation among these variables. The result signifies that rainfall and temperature are significantly correlated but rainfall is not significantly correlated with CO2 emission. However, temperature is moderately correlated with CO2 emission. To find out influence of CO2 emission on rainfall and temperature, partial correlation test is applied on the data set, which emphasizes that rainfall gets relatively more correlated with temperature when considering CO2 as control variable. The correlation between rainfall and temperature is -0.399 with p value 0.054 but when we consider CO2 as control variable, the correlation becomes -0.471 with p value 0.023. Hence, the vehicular carbon emission is moderately affecting the rainfall and temperature of Ranchi.

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