MACHINE LEARNING APPLICATION FOR CARBON ESTIMATION – A CASE STUDY

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ABSTRACT

Climate change is a most global challenging issue. In this regard, a study on carbon dioxide, one of the pollutants causing the climate change is demonstrated in two different states of India viz., Visakhapatnam district (AP) and Shastri Nagar (RJ) for the period of April 2022 to January 2023. Carbon dioxide (CO_2) is experiential on hourly and monthly basis for different seasons – summer (April), rainy (July) and winter (December). Most of air pollutants include NO_2, CO_2, $PM_{2.5}$, PM_{10} etc. that are the major cause for climate change. The air quality in these zones is very poor, highly polluted and risk to humans. The study proved that CO_2 is found comparatively low in rainy season over other. The machine learning regression models were modelled for Visakhapatnam and best models obtained are 1. Step-wise Linear Regression model with MSE (4.51E-28), RMSE (2.12E-14) and R-Squared (1) identified for rainy month. 2. Neural Network Narrow model with MSE (0.462), RMSE (0.680) and R-Squared (0.999) for winter month. 3. Linear Regression model with MSE (0.108), RMSE (0.329) and R-Squared (0.999) for summer. Similarly, the best models for Shastri Nagar for monthly data are 1. Step-wise Linear Regression with RMSE (20.292), MSE (411.774) and MAE (12.524) for April & May (summer), 2. Neural Network Narrow model had RMSE (3.399), MSE (11.554) and MAE (2.141) for July (rainy). 3. Neural Network Bilayered model with RMSE (1.618), MSE (2.619) and MAE (0.593) for November & December (winter). The results obtained were very efficient and reliable.

1. INTRODUCTION

Global warming is caused by hasty increase in carbon dioxide and other GHG produced by burning oil, gas, coal, fossil, industries and so on. Global warming further causes climate change, one of major issue world-wide. Abnormal climate change brings disaster and harm to humankind (Zhao, 2019). Thereby, global warming is triggering changes in rains, snow patterns and rising sea levels (Letcher, 2021). Thus, one have to build low-carbon and resilient cities to lower the global warming (Lee, 2013 & Yoro, 2020) and protect the planet. The huge impact on global warming is due to high emission of CO_2. The transport and industry sector are significant contributor for CO_2 emission (Lee, 2013 & Yoro, 2020) and carbon monoxide (CO) (Wang, 2021). Vehicles produce CO_2 from engine combustion that is harmful carbon monoxide (CO) from incomplete combustion to CO_2 (Wang, 2021). CO_2 and CH_4 are significant emitters for GHG effect (Chapman, 1996). Furthermore, CO poisoning leads to long-term neurological (Rose, 2017); and cardiovascular diseases (Wang, 2021). In atmosphere, high temperature sensitivity results due to weak CO_2 adsorption of pure carbonaceous materials (Kanjilal, 2020). Let's ponder on few remarkable reasons for emission of CO_2.

Firstly, ICT contributes 1.8% to 2.8% of global GHG emissions to environmental pollution, global warming and ultimately climate change. Research indicates the carbon footprint is produced by production and use-phase electricity consumption (Sutton-Parker, 2022). All analysts agree that ICT emissions will not reduce without the determined efforts of political and industrial (Freitag, 2021).

Secondly, carbon credit trading (Chonde, 2016) is for controlling and reducing GHG emission that contributes to global climate change (Robinson, 2006). CO_2 is a concern that happens to be most important GHG produced by combustion of fuels. The other gases emitted from industries include CO_2, NO_2, CH_4 and hydro fluorocarbons (Chonde, 2016). Carbon credit allows one ton of CO_2 to be discharged into the air. A great deal of businesses buying/ selling carbon credits for excess emissions has encouraged carbon trading globally. India is among emerging leader for the developing countries in designing innovative strategies and portfolios for carbon trading (Gupta, 2011). From the middle of the 18th century, the concentration of CO_2 with two factors, land use changes and the burning of fossil fuels have been increasing. The higher atmospheric concentrations of CO_2 are absorbed by the oceans (Breeze, 2017).

Thirdly, for amending environmental change, CO_2 capture is considered as the key technology (Kanjilal, 2020). The other is industry penetration of solvent absorption technology for CO_2 captures (Scholes, 2020). The low partial pressure of CO_2 and reduced separation driving force in flue gas applications also hampers the development of membrane technology in industrial applications (Scholes, 2020).

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Climate change and air pollution are the biggest environmental concern globally (Coelho, 2021). The study of pollution discusses the negative impacts on environment (Brusseau, 2019). Fourthly, the practice of conservation of forest and soil that enhance the storage of carbon or reduce CO_2 emissions is accomplished with terrestrial carbon sequestration (Sundquist, 2008).

2. DISCUSSION AND RESULTS

CO_2 remains longer in the atmosphere than any pollutants; this warms the earth causing climate change. Industrial revolution (IR) is related closely to emission of CO_2 causing the pollution. IR increased CO_2 by 50% because of burning fuel, electricity, heat and transportation. Humans have generated an estimated 1.5 trillion tons of CO_2. CO_2 effects human health including headaches, dizziness, restlessness, breathless, and sudden rise in blood pressure.

In this study of monthly and hourly air quality index (AQI) vs CO_2 and CO for Visakhapatnam (AP) and Shastri Nagar (RJ) for April, July, December and January 2023 were collected from https://app.cpcbccr.com/AQI_India/ and ML regression models were developed shown in tables (1, 2, 3, 4). The best models for hourly data are RMSE of SVM–L (5.1594) for April, GPR–SE for July (0.0002) and December (0.0038), and NN-N (0.1932) for January. The response plot of CO_2 vs AQI is shown in figures A.1 in Appendix -A. The model number in each table represents the corresponding graph in Appendix-A and Appendix-B.

For monthly data, the RMSE of best models were LR (0.329) for April & May, SLR model (2.12E-14) for July, NN-N (0.680) for November and December is shown in tables (5 to 7). Visakhapatnam has three seasons with excessive humidity from southern part whereas Shastri Nagar has moderate rains with high heat in summer.

Let's discuss a little on regression models

Linear Regression, is a relationship between the response and explanatory parameters, and is represented by

$$y = ax + b \quad \text{---------- (1)}$$

or

$$y = m_0 + m_1 x_1 + m_2 x_1^2 \quad \text{--------- (2)}$$

where 'y' is the output, constant is denoted by 'b' and 'm_0' and slope by 'a' and 'm_1'.

Stepwise linear regression does multiple regressions a number of times, every time it removes the weakest correlated variable. It is represented by

$$b_{j,std} = b_j \frac{sx_j}{sy} \quad \text{---------- (3)}$$

where s_{xi} and s_v are the standard deviation for response and explanatory variables.

Tree – fine/ medium model uses a decision tree to represent how different input variables can be used to predict a target value. Machine learning uses tree-based models for both classification and regression problems.

Support vector machine (SVM) –Linear regression model is a ML tool for classification and regression and is considered a nonparametric technique because it relies on kernel functions. It expressed as

$$f(x) = x'\beta + b \quad \text{----- (4).}$$

Gaussian process regression (GPR) models are utilized for statistical modeling and are nonparametric kernel-based probabilistic models with a finite collection of random variables with a multivariate distribution.

Neural Network model is a computational system that is organized into layers of nodes.

2.1 Visakhapatnam models based on the hourly data

It was interesting to note with hourly data on December 2, 2022, the value of CO started with 48 (ppm) at 4:00 am, decrease to 8 (ppm) at 11:00 am, later gradually increased to 36 (ppm) at 9:00 pm. July month had the value of CO to 5 (ppm) on July 24, 2022 with almost < 35 (ppm) the entire month. On April 26, 2022 the highest value of CO (60 ppm) was found with the entire month higher than 31 (ppm). January 6, 2023 had 108 (ppm) at 1:00pm. Hence, it is clear that rainfall washes the pollutant CO in the atmosphere and CO is found less in rainy season.

Visakhapatnam hourly – AQI and CO predictions for April 25 to 30, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	5.310	28.197	0.516	1.595
2.2	LR–I	5.820	33.881	0.418	2.241
2.4	SLR	5.545	30.756	0.472	1.881
2.5	Tree – Fine	5.767	33.262	0.429	1.447
2.6	Tree – Medium	5.714	32.660	0.439	2.045
2.8	**SVM –L**	**5.159**	**26.619**	**0.543**	**0.811**
2.9	SVM–Q	5.181	26.845	0.539	0.932
2.16	GPR-SE	5.521	30.488	0.476	1.434
2.18	GPR-E	5.463	29.849	0.487	1.257
2.20	NN–N	12.871	165.683	-1.842	2.338
2.23	NN–B	13.010	169.282	-1.904	2.027
2.24	NN–T	6.118	37.430	0.357	1.098

***V** = Validation

Table 1. Regression models for April month

Visakhapatnam hourly – AQI and CO predictions for July 20 to 25, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	2.43E-14	5.91E-28	1	2.05E-14
2.2	LR– I	2.21E-14	4.88E-28	1	1.70E-14
2.4	**SLR**	**2.12E-14**	**4.51E-28**	**1**	**1.62E-14**
2.5	Tree – Fine	1.071	1.147	0.993	0.788
2.6	Tree –	2.190	4.796	0.974	1.771

	Medium				
2.8	SVM – L	1.145	1.311	0.993	0.927
2.9	SVM – Q	1.499	2.247	0.988	1.316
2.16	**GPR-SE**	**0.0002**	**4.42E-08**	**1**	**0.000**
2.18	GPR-E	0.669	0.448	0.997	0.374
2.20	NN–N	0.008	7.73E-05	1	0.001
2.23	NN–B	0.002	4.92E-06	1	0.000
2.24	NN–T	0.260	0.067	0.999	0.042

***V** = Validation

Table 2. Regression models for July month

Visakhapatnam hourly – AQI and CO predictions for December 1 to 6, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	6.79E-14	4.62E-27	1	4.88E-14
2.2	LR–I	6.74E-14	4.54E-27	1	5.22E-14
2.4	SLR	6.74E-14	4.54E-27	1	5.22E-14
2.5	Tree – Fine	5.998	35.981	0.993	4.063
2.6	Tree – Medium	11.150	124.323	0.977	8.283
2.8	SVM–L	6.062	36.749	0.993	4.636
2.10	SVM –C	8.130	66.107	0.987	7.058
2.16	**GPR-SE**	**0.0038**	**1.46E-05**	**1**	**0.002**
2.18	GPR-E	2.592	6.719	0.998	1.271
2.20	NN–N	0.117	0.013	0.999	0.015
2.23	NN–B	0.510	0.261	0.999	0.093
2.24	NN–T	0.882	0.778	0.999	0.215

***V** = Validation

Table 3. Regression models for December month

Visakhapatnam hourly – AQI and CO predictions for January 1 to 6, 2023					
Model	Model Type	RMSE (V)	MSE (V)	RSq (V)	MAE (V)
2.1	LR	5.285	27.932	0.99	3.918
2.2	LR–I	1.408	1.988	0.99	1.020
2.4	SLR	1.467	2.152	0.999	1.017
2.5	Tree – Fine	6.640	44.093	0.992	4.061
2.6	Tree-Medium	18.628	347.011	0.941	11.400
2.8	SVM-L	6.108	37.317	0.994	5.639
2.9	SVM-M	5.146	26.484	0.996	4.468
2.16	GPR-SE	0.643	0.414	0.999	0.482
2.18	GPR-E	1.985	3.940	0.999	1.075
2.20	**NN–N**	**0.193**	**0.037**	**0.999**	**0.047**
2.23	NN–B	0.720	0.519	0.999	0.410
2.24	NN–T	0.712	0.507	0.999	0.314

***V** = Validation

Table 4. Regression models for January month

2.2 Visakhapatnam models based on the monthly data

Visakhapatnam monthly-AQI and CO predictions for April & May 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	**LR**	**0.329**	**0.108**	**0.999**	**0.170**
2.4	SLR	0.343	0.118	0.999	0.183
2.5	Tree – Fine	6.875	47.274	0.921	4.433
2.6	Tree – Medium	11.095	123.119	0.796	8.359
2.8	SVM–L	1.723	2.969	0.995	1.241
2.9	SVM-Q	1.736	3.015	0.995	1.374
2.16	GPR-SE	0.382	0.146	0.999	0.199
2.18	GPR-E	4.290	18.410	0.969	1.800
2.20	NN-N	0.594	0.353	0.999	0.180
2.23	NN-B	0.626	0.392	0.999	0.192
2.24	NN-T	0.433	0.188	0.999	0.199

***V** = Validation

Table 5. Regression models for April and May month

Visakhapatnam monthly-AQI and CO predictions for July 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	2.43E-14	5.91E-28	1	2.05E-14
2.4	**SLR**	**2.12E-14**	**4.51E-28**	**1**	**1.62E-14**
2.5	Tree – Fine	1.071	1.147	0.993	0.788
2.6	Tree – Medium	2.190	4.796	0.974	1.771
2.8	SVM–L	1.145	1.312	0.993	0.927
2.9	SVM–Q	1.499	2.247	0.988	1.316
2.16	GPR-SE	0.0002	4.42E-08	1	0.0001
2.18	GPR-E	0.669	0.448	0.997	0.374
2.20	NN–N	0.008	7.73E-05	1	0.001

2.23	NN–B	0.002	4.92E-06	1	0.0008
2.24	NN–T	0.260	0.067	0.999	0.042

***V** = Validation

Table 6. Regression models for July month

Visakhapatnam monthly –AQI and CO predictions for November & December 2022					
Model	Model Type	RMSE (V)	MSE (V)	RSq (V)	MAE (V)
2.1	LR	9.723	94.543	0.973	8.288
2.4	SLR	10.256	105.186	0.970	8.499
2.5	Tree – Fine	13.517	182.733	0.949	10.302
2.6	Tree – Medium	23.988	575.457	0.840	17.432
2.8	SVM–L	9.548	91.164	0.974	8.112
2.9	SVM–Q	7.407	54.864	0.984	6.060
2.16	GPR-SE	5.520	30.478	0.991	3.444
2.18	GPR-E	8.109	65.762	0.981	6.207
2.20	**NN–N**	**0.680**	**0.462**	**0.999**	**0.136**
2.23	NN–B	1.439	2.072	0.999	0.484
2.24	NN–T	1.484	2.204	0.999	0.372

***V** = Validation

Table 7. Regression models for November & December month

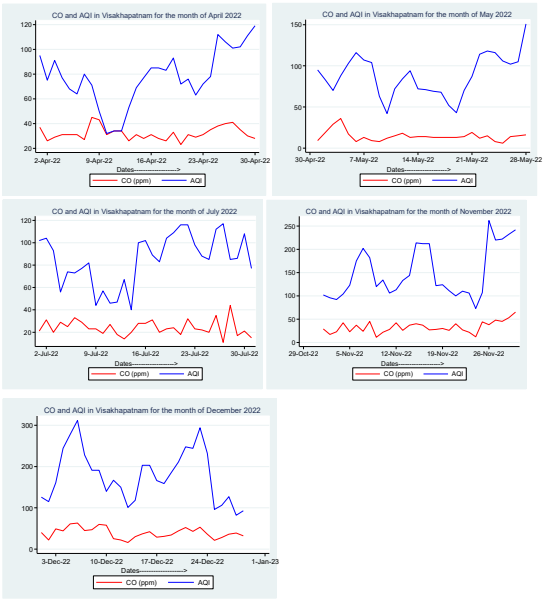

Figure 1. Trends for Visakhapatnam

The monthly trends of CO and AQI for visakhapatnam are plotted using STATA shown in figure 1 for the months of April, May, July, November and December 2022. AQI and CO seems to be severely bad in December month.

2.3 Shastrinagar hourly outcomes

The value of CO in shastri nagar was found higher on December 2, 2022 with 108 (ppm) at 4:00pm and during the month of January, January 6 had highest 73 (ppm) at 4:00pm and 17 (ppm) on January 3 & 4, 2023. The entire July month had the values between 20 (ppm) to 46 (ppm). The entire april month had the values between 21 (ppm) to 100 (ppm) on April 27, 2022 at 5:00pm and decreased to 28 (ppm) at 9:00pm. Shastri nagar being the dry region has more pollution than Visakhapatnam.

Shastrinagar hourly -AQI and CO predictions for April 25-30, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	3.267	10.673	0.983	2.574
2.2	LR – I	1.733	3.005	0.995	0.963
2.4	SLR	1.763	3.111	0.995	0.955
2.5	Tree – Fine	2.430	5.909	0.991	1.628
2.6	Tree – Medium	3.240	10.500	0.984	2.557
2.8	SVM-L	3.257	10.609	0.984	2.577
2.9	SVM-Q	3.357	11.273	0.983	2.810
2.16	**GPR-SE**	**1.545**	**2.389**	**0.996**	**0.699**
2.18	GPR-E	1.653	2.734	0.995	0.745
2.20	NN-N	1.693	2.866	0.995	0.789
2.23	NN-B	1.884	3.552	0.994	0.814
2.24	NN-T	1.793	3.217	0.995	0.820

***V** = Validation

Table 8. Regression models for April month

Shastrinagar hourly -AQI and CO predictions for July 20-25, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	3.433	11.787	0.886	2.739
2.2	LR-I	2.544	6.476	0.937	2.005
2.4	SLR	2.475	6.128	0.940	2.026
2.5	Tree – Fine	2.135	4.559	0.955	1.496
2.6	Tree – Medium	3.146	9.901	0.904	2.419
2.8	SVM-L	3.387	11.477	0.889	2.514
2.9	SVM-Q	2.528	6.395	0.938	1.882
2.16	GPR-SE	1.554	2.415	0.976	1.037
2.18	**GPR-E**	**1.398**	**1.957**	**0.981**	**0.968**
2.20	NN-N	2.190	4.798	0.953	1.481
2.23	NN-B	2.047	4.190	0.959	1.383
2.24	NN-T	3.328	11.078	0.892	1.815

***V** = Validation

Table 9. Regression models for July month

Shastrinagar hourly --AQI and CO predictions for December 1-6, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	**LR**	**2.450**	**6.005**	**0.979**	**0.764**
2.2	LR – I	2.695	7.266	0.975	1.071
2.4	SLR	2.482	6.164	0.979	0.828
2.5	Tree – Fine	3.116	9.714	0.967	1.719
2.6	Tree – Medium	3.732	13.931	0.952	2.585
2.8	SVM-L	2.591	6.717	0.977	1.110
2.9	SVM-Q	3.055	9.337	0.968	1.516
2.16	GPR-SE	2.492	6.212	0.978	0.644
2.18	GPR-E	2.572	6.616	0.977	0.694
2.20	NN-N	2.704	7.314	0.975	1.081
2.23	NN-B	2.564	6.576	0.977	0.787
2.24	NN-T	3.320	11.026	0.962	0.905

***V** = Validation

Table 10. Regression models for December month

Shastrinagar hourly -AQI and CO predictions for January1-6, 2023					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	3.429	11.759	0.984	2.906
2.2	LR – I	3.015	9.09	0.987	1.473
2.4	**SLR**	**1.822**	**3.321**	**0.995**	**1.354**
2.5	Tree – Fine	4.302	18.513	0.976	2.888
2.6	Tree – Medium	7.640	58.373	0.926	6.145
2.8	SVM-L	3.483	12.137	0.983	3.037
2.9	SVM-Q	5.966	35.597	0.952	2.774
2.16	GPR-SE	4.97	24.701	0.967	0.957
2.18	GPR-E	3.089	9.547	0.987	1.063
2.20	NN–N	1.828	3.342	0.995	0.187
2.23	NN-B	5.193	26.974	0.964	0.757
2.24	NN-T	2.437	5.941	0.992	0.593

***V** = Validation

Table 11. Regression models for January month

2.4 Monthly outputs of Shastrinagar

Shastrinagar monthly --AQI and CO predictions for April & May, 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	20.706	428.768	0.778	13.376
2.2	LR – I	25.674	659.173	0.658	14.947
2.4	**SLR**	**20.292**	**411.774**	**0.784**	**12.524**
2.5	Tree – Fine	27.287	744.616	0.592	17.839
2.6	Tree – Medium	31.381	984.767	0.460	20.984
2.8	SVM-L	20.222	408.968	0.788	11.024
2.9	SVM-Q	17.769	315.764	0.836	9.174
2.16	GPR-SE	22.674	514.138	0.733	13.272
2.18	GPR-E	23.378	546.570	0.717	13.438
2.20	NN–N	46.377	2150.86	-0.113	15.211
2.23	NN-B	187.287	35076.42	-17.155	42.675
2.24	NN–T	65.108	4239.08	-1.194	22.971

***V** = Validation

Table 12. Regression models for April and May month

Shastrinagar monthly--AQI and CO predictions for July 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	6.085	37.039	0.792	3.688
2.2	LR- I	8.202	67.285	0.622	4.822
2.4	SLR	5.574	31.073	0.819	3.911
2.5	Tree – Fine	6.890	47.479	0.724	5.673
2.8	SVM-L	6.377	40.678	0.771	3.996
2.9	SVM-Q	6.033	36.402	0.795	3.631
2.16	GPR-SE	3.951	15.615	0.912	2.923
2.18	GPR-E	3.416	11.673	0.934	2.27
2.20	**NN–N**	**3.399**	**11.554**	**0.935**	**2.14**
2.23	NN-B	17.705	313.482	-0.757	6.289
2.24	NN–T	5.145	26.479	0.851	3.055

***V** = Validation

Table 13. Regression models for July month

Shastrinagar --monthly-AQI and CO predictions for November & December 2022					
Model	Model Type	RMSE (V)	MSE (V)	R-Sq (V)	MAE (V)
2.1	LR	8.549	73.096	0.950	6.276
2.2	LR- I	7.302	53.330	0.964	4.658
2.4	SLR	8.500	72.250	0.951	5.213
2.5	Tree – Fine	18.667	348.457	0.766	10.924
2.8	SVM-L	9.852	97.068	0.934	5.158
2.9	SVM-Q	9.983	99.662	0.933	4.927

2.16	GPR-SE	6.924	47.942	0.967	3.140
2.18	GPR-E	9.159	83.902	0.943	5.291
2.20	NN–N	4.522	20.449	0.986	1.762
2.23	**NN–B**	**1.618**	**2.619**	**0.998**	**0.593**
2.24	NN-T	3.616	13.076	0.991	1.333

***V** = Validation

Table 14. Regression models for November and December month

From the tables 8 to 11, the RMSE of best models for hourly data of CO2 and AQI for Shastri nagar were GPR-SE (1.545) for April, GPR-E (1.398) for July, LR (2.450) for December and SLR (1.822) for January. The response plot is plotted for CO2 and AQI is shown in figure B.1 in Appendix -B. Similarly from tables 12 to 14, RMSE of monthly best models were step-wise LR (20.292) for April & May, NN Narrow (3.399) and NN Bilayered (1.618) for November & December.

The global roadmap is set for 2025 to have no new coal plants and by 2050 to have clean green energy sources and affordable energy, to achieve the net carbon zero globally.

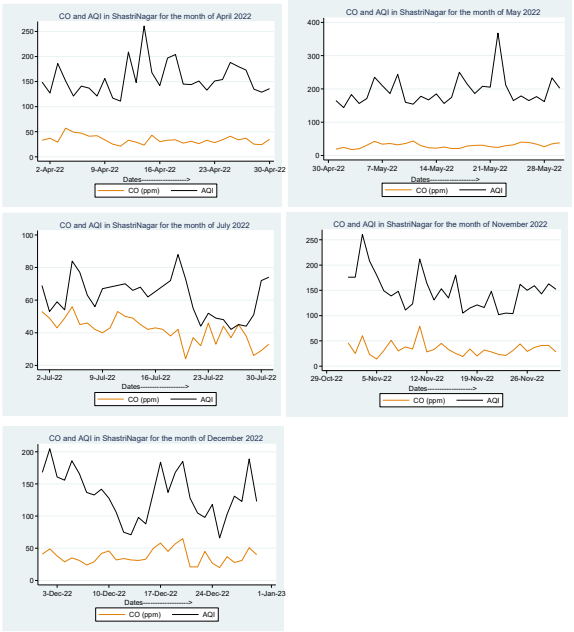

Figure 2. Trends in Shastri Nagar

The monthly trends of CO and AQI for Shastri Nagar is shown in figure 2 for the months of April, May, July, November and December 2022. CO is high in July and December whereas in May, CO is comparatively low. In May month, AQI is severely poor than other months.

The figure 3 shows the trends of CO (ppm) and AQI for the Visakhapatnam and ShastriNagar from the year 2017 to 2023. AQI seems to be severe in the year January 2019 (AP) whereas AQI is severely bad in the year September 2020 (RJ).

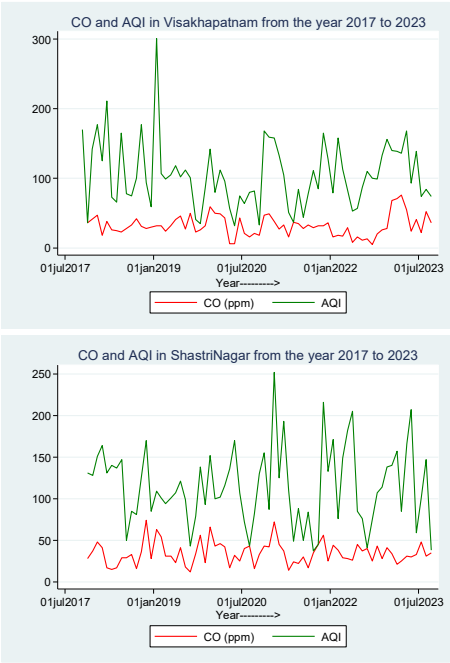

Figure 3. The trends of CO and AQI in AP and RJ.

3. CONCLUSION

It is very clear that CO_2 is very risky for human health by studying two different states – moderate and dry climate regions. It is further observed that one need to minimize the emission of CO_2 to protect the planet to attain net zero carbon and let other generations to live on this planet. This regression models will help the researchers, government official and global health organization to make necessary requirements for the highly polluted areas. The best regression model obtained for Visakhapatnam hourly 1. For rainy month, GPR-SE model obtained MAE (0.0001). 2. GPR-SE model with MAE (0.002) for December and Neural Network –Narrow model MAE (0.047) for January. 3. SVM –L with MAE (0.811), for summer. Similarly, the best models for Shastri Nagar for hourly data are 1. Gaussian Process Regression –Square Exponential with MAE (0.699) for summer month, 2. For rainy month, Gaussian Process Regression –Exponential model obtained MAE (0.968). 3. Linear regression with MAE (0.764) for December & Stepwise Linear Regression with MAE (1.354) for January (winter).

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ABBREVIATION

List of regression models used

Linear Regression	LR
Linear Regression – Interaction	LR-I
Stepwise Linear Regression	SLR
SVM - Linear	SVM-L
SVM – Medium	SVM-M
SVM – Quadratic	SVM-Q
SVM – Cubic	SVM-C
Gaussian Process Regression – Squared Exponential	GPR-SE
Gaussian Process Regression – Exponential	GPR-E
Neural Network – Narrow	**NN-N**
Neural Network - Bilayered	NN-B
Neural Network – Trilayered	NN-T

APPENDIX -A

VISAKHAPATNAM— JULY MONTH GRAPHS

Figure A.1 Visakhapatnam monthly– AQI and CO predictions for July, 2022

APPENDIX -B

SHASTRINAGAR – JULY MONTH GRAPHS

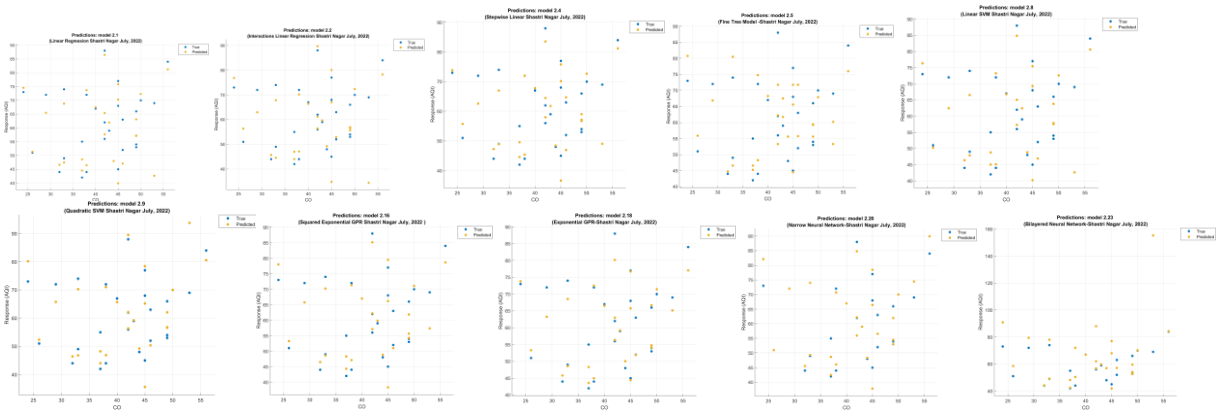

Figure B.1 Shastrinagar monthly-AQI and CO Predictions for July 2022