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Gagan Vernekar
Department of Civil Engineering. RV College of Engineering Bengaluru, India, gaganvernekar.cv18@rvce.edu.in

Dhanush B. Naidu
Department of Civil Engineering RV College of Engineering Bengaluru, India, dhanushbnaidu.cv18@rvce.edu.in

K Galajalaxmi Prof.
Department of Civil Engineering RV College of Engineering Bengaluru, India, gajalakshmik@rvce.edu.in

Kiran K
Department of Civil Engineering RV College of Engineering Bengaluru, India, kirank.cv18@rvce.edu.in

Manjunatha Havinal
Department of Civil Engineering RV College of Engineering Bengaluru, India, manjunathah.cv19@rvce.edu.in

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Simulating the Impact of Urban Sprawl in Spatiotemporal Variation of Air Pollution in Bangalore Region using ML and GIS.

Gagan Vernekar
Department of Civil Engineering.
RV College of Engineering
Bengaluru, India
gaganvernekar.cv18@rvce.edu.in

Kiran K
Department of Civil Engineering
RV College of Engineering
Bengaluru, India
kirank.cv18@rvce.edu.in

Dhanush B Naidu
Department of Civil Engineering
RV College of Engineering
Bengaluru, India
dhanushbnaidu.cv18@rvce.edu.in

Manjunatha Havinal
Department of Civil Engineering
RV College of Engineering
Bengaluru, India
manjunathah.cv19@rvce.edu.in

Prof. K Galajalaxmi
Department of Civil Engineering
RV College of Engineering
Bengaluru, India
gajalakshmik@rvce.edu.in

***Abstract*—The rapid expansion of urban areas due to rise in population and economic growth is increasing the additional demand on natural resources thereby causing land-use changes especially in megacities. Bengaluru, being a city of India's high-tech industry has been facing deteriorating environmental conditions. This paper deals with studying the problems by designing the Machine Learning (ML) model which helps in detecting the Green Cover Change, Urban sprawl, Air Quality Parameters concentration in Bangalore region for the future and analyse them with Geographic Information System (GIS) data's using Remote Sensing (RS) satellite images of various years of Bangalore city along with some mitigation**

Keywords- Air Quality Parameters; Geographic Information system; Machine Learning; Remote Sensing;

I. Introduction

In this modern era, environmental pollution is a main concern to mankind. Industrialization is the main reason for environmental pollution in both developed and developing countries. The presence of poor air quality can cause critical and chronic illness to human beings. According to the latest data of World Health Organization (WHO), ambient air pollution has resulted in 4.2 million deaths every year worldwide and 91% of world's population is still living in regions where the air quality is over the WHO guideline limits. Hence it is significant to determine the air quality of a region and the data should be made available to the public as a matter of safety concern. Bengaluru, being a city of India's high-tech industry has been developing economically, scaling up the luxuries of living lifestyle. Due to the rapid development of this city, it has been facing deteriorating environmental conditions.

Thus all these problems are studied by designing the Machine Learning (ML) model which helps in detecting the Green Cover Change, Urban sprawl, Air Quality Index AQI) in Bangalore region and analyse them with Geographic Information System(GIS) data's using Remote Sensing(RS) satellite images of various years of Bangalore city along with some mitigation.

A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). Remote Sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance and finally Machine learning (ML) is the study of computer algorithms that can improve automatically through experience and by the use of data. It is seen as a part of artificial intelligence.

A. Study Area

Bangalore shown in Figure 1, the cultural, educational, industrial and administrative capital of Karnataka, India, is located between 12.9716° N and 77.5946° E longitudes and at an altitude of 920m above mean sea level. In summer the temperature ranges from 18° C to 38° C, and in winter temperature ranges from 12° C to 25° C. Thus, Bangalore has a good climate around the year. With its most parks and abundant greenery, it is also called as the "garden city" of India. The urban agglomeration had an overall population in 2011 of 8.4 million, including a workforce of 6.2 million, and a literacy rate of 87.6 percent according to the recent census.

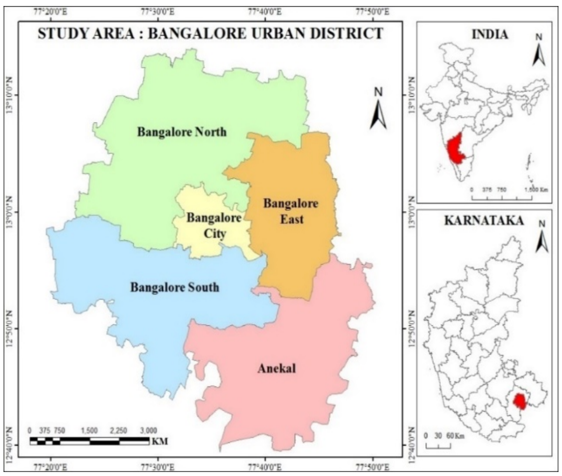


Figure 1: Study Area for Bengaluru Region

The monitoring of the ambient Air quality at 10 different monitoring stations (Figure 1.2 and Table I) located at Bangalore is being carried out with the help of Central Pollution Control Board; Karnataka State Pollution Control Board, Pollution Control Committees, and National Environmental Engineering Research Institute (NEERI), Nagpur. The analysis is based on concentration of 6 pollutants, including Particulate Matter (PM 2.5, PM 10), Sulfur dioxide (SO2), Nitrogen dioxide (NO2), Carbon monoxide (CO) and Ozone (O3). The pollutants were monitored for 24 hours.

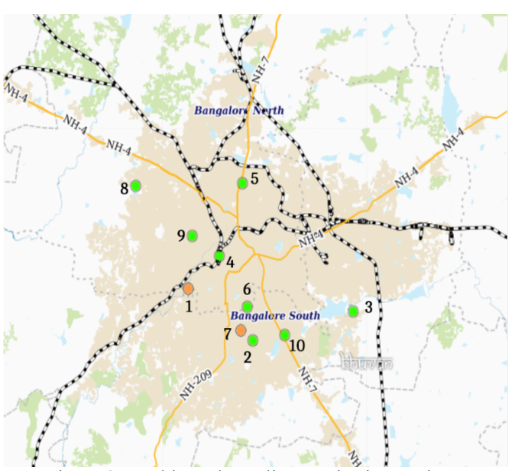


Figure 2: Ambient air quality monitoring stations.

TABLE I. AIR QUALITY MONITORING STATIONS DETAILS.

Ambient Air Quality Monitoring Station No	Station Name
1	Bapuji Nagar, Bengaluru
2	BTM Layout, Bengaluru
3	BWSSB Kadubeesanahalli, Bengaluru
4	City Railway Station, Bengaluru
5	Hebbal, Bengaluru
6	Hombegowda Nagar, Bengaluru
7	Jayanagar 5th Block, Bengaluru
8	Peenya, Bengaluru
9	Saneguruva Halli, Bengaluru
10	Silk Board, Bengaluru

II. METHODOLOGY

A. *Spatial Data*

Polygon shape file of Bengaluru from Karnataka Geographic Information System (K-GIS), Bengaluru different region division shape file. Satellite images from Sentinel 2 and CARTOSAT-1, distance from main road, Central Business District (CBD) map, Population map for the year 2001, 2011, 2019 and 2032, restricted area map.".

B. *Non Spatial Data*

Air Quality Data sets of CO, NO2, SO2, PM2.5, PM10 and O3 parameters from 10 monitoring stations in Bengaluru namely Bapuji Nagar, BTM, Bwssb Kadubeesanahalli, City Railway Station, Hebbal, Hombegowda Nagar, Jayanagar 5th block, Peenya, Saneguruvanahalli and Silkboard which is monitored by Karnataka State Pollution Control Board (KSPCB) and Central Pollution Control Board (CPCB) jointly.

1) Analysis of Air pollution parameters: This study involves the analysis of six major air quality parameters which are CO, NO2, SO2, PM2.5, PM10 and O3 in Bengaluru city from 10 local monitoring stations. Air Quality pollutants are measured under the National Ambient Air Quality Program (NAMP) by local monitoring stations on a regular basis. Karnataka State Pollution Control Board (KSPCB) publishes the annual average of pollutants CO, NO2, SO2, PM2.5, PM10 and O3 on its website. The pollution trends were derived based on the data obtained from 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022. The data obtained from the local monitoring stations were daily average records of the year by Karnataka State Pollution Control Board (KSPCB).

Data which is collected from KSPCB and CPCB website is in the form of csv file. Then the data collected is arranged and given nomenclature accordingly for data interpretation to be easy. Then with the suitable code, the AQI of each parameter is determined by using a formula from the website https://www.airnow.gov/aqi/aqi-calculator-concentration. The code is worked on the jupyter notebook platform, which is an easy python platform to work on.

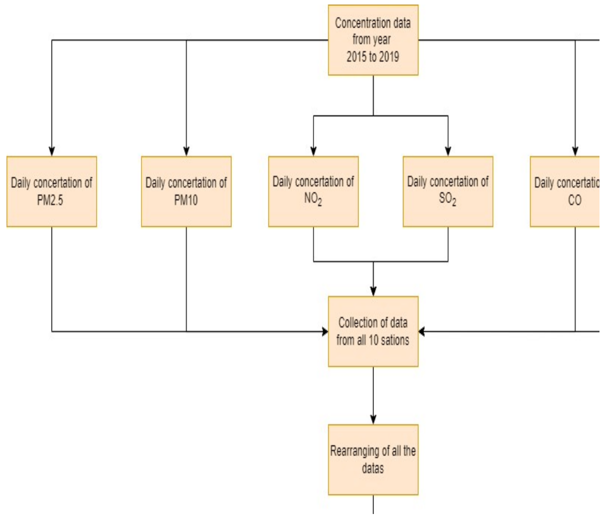


Figure 3: Flowchart regarding data collection.

Plotting of data is done by fitting SARIMAX fitting function for all the stations of existing data.(Figure 4). SARIMAX forecasting data for a given period of year for all the parameters of all stations are acquired. Next step is

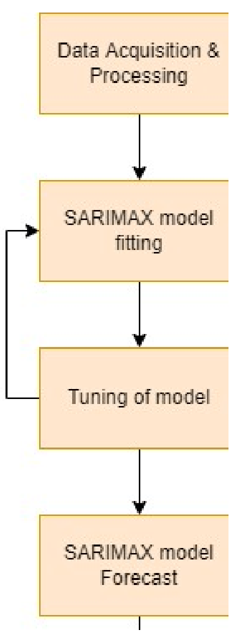


Figure 4: Flowchart of SARIMAX model

plotting a graph and making a heat map of obtained data and forecasted data in QGIS and analysing the trend.

Then by using IDW interpolation, trend analysis of air pollution parameters is carried out in QGIS. The translation of the Inverse distance weighted (IDW) leads to the assumption that close objects are more similar than those far apart. To predict the value of any unrestricted area, IDW uses the approximate values around the forecast area. Estimated values near the forecast area have a greater impact than predicted than remote ones. IDW assumes that each measured point has a local influence that decreases with distance. It provides high weights at points very close to the forecast point, and the weight decreases as a distance function, which is why the word opposite the distance has weight.

C. *Forecasting of Urban Growth*

Sentinel 2 satellite image is used for the analysis of the urban growth and green cover for the Bangalore region for the year 2031. The satellite images for the year 2015 and 2021 was acquired From USGS website from the following link https://earthexplorer.usgs.gov/. The resolution of Sentinel 2 satellite images used is 20m. Details of bands used for the analysis are given in the below table II

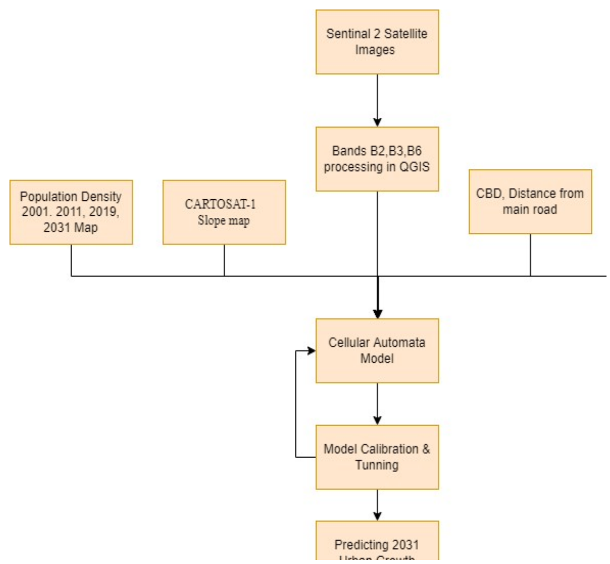


Figure 5: Flowchart of Cellular Automata model

Satellite images of the band B3 B4 and B6 were used for detecting green cover built up area and groundwater respectively. Firstly, the satellite images was acquired were clipped using the Bangalore shapefile and then the thresholding was conducted to separate the built-up area, green cover and groundwater and then exported in the form of a file and the particular code was given for all of them.

TABLE II. SENTINAL 2 BAND DETAILS

Band	Resolution	Central wavelength	Description	Used for
B3	20 m	560 nm	Green	Green Cover
B4	20 m	554 nm	Red	Built up area
B6	20 m	740 nm	Visible and near infrared	Ground water resources

Cellular automata is a mathematical model which studies the cell along with the provided factors based on the threshold provided by the user and decides what will be the status of the cell in the future. To get better accuracy 2015 urban growth file was used to predict 2021 urban growth and the accuracy was checked by using trial and error method the thresholding for all the above five factors considered by a considered sequentially changed and their respective accuracy was noted by following the same step until and unless we get the accuracy of more than 80%. Once the required accuracy was obtained, we shifted from 2015 to 2021 satellite image and then urban growth for the year 2031 was predicted.

There were 5 factors considered by us for the prediction of the urban sprawl for the year 2031 they are as follows.

1. Central Business District
2. Distance from main road map
3. Population Density
4. Elevation/Slope map
5. Restricted area

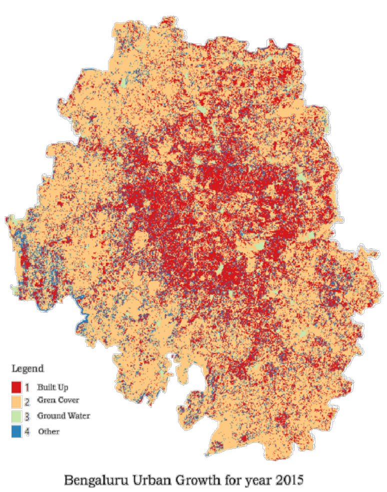


Figure 6 : Bengaluru urban growth for 2015

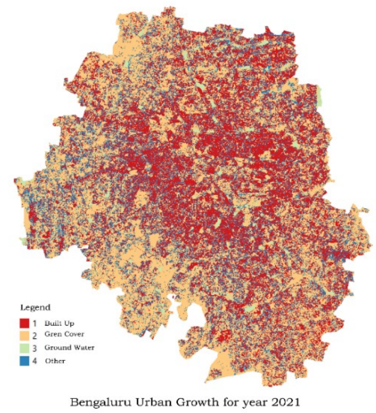


Figure 7: Bengaluru urban growth for 2021

D. Detecion of Sog Tower

After all the other steps our last goal was to find the optimum location for a Smog Tower in the Bengaluru region for the year 2031 Why using the data obtained from SARIMAX model and cellular automata 2011 quality parameters and urban growth for 2031 respectively. Out of the six parameters considered pm 2.5 because it had the highest concentration for the respective year and Smog Tower is used in order to reduce the particulate matter concentration in the air.

We considered a grid of size 25x25 which is the range of the smog tower which is 500m radius and the minimum distance between two smog towers as 2.5 km. The optimum location was found out by summing up all the values in the grid from the PM 2.5 spatio-temporal map obtained from QGIS and further if any of the cell has been converted into built up area for the year 2021. The above sum value was incremented by a factor of 1 as infrastructure will lead to increase in in pm 2.5 in the atmosphere. The Smog tower was look catered in the Barren land or the place where there is no built-up area no green covers no groundwater and the range of the Smog Tower was highlighted by a separate value and also the centre of the Smog Tower is depicted by a different value. Thus, this was the result which we obtained by aggregating the values of air quality parameters, urban growth and the factors that influence the location of the Smog tower.

III. RESULTS AND DISCUSSION

In all the 10 stations concentration values for PM10 is exceeding national ambient air quality standards 60.0 µg / m3 for the years 2016-19 and the NO2 parameter target is within the national limit of 40.0 µg / m3 years from 2018-19 & 2020-21. Concentration values for SO2 are within NAAQM standards (50.0 µg / m3) for the entire estimated year 2016-2022. At the city railway station, flyover construction continues, which is why, the concentration of PM10 has crossed national boundaries. Traffic was reduced as buses approached the satellite bus station in Peenya, Mysore Road and Shanthinagar. Therefore the focus of pollutants such as SO2, NO2, PM10 show a decrease in trend compared to 2019-20. There was increase in concentration of PM10 in Peenya due to industrial activities and vehicular emissions. PM10 was within the standards only during the year 2020-2021 due to nationwide imposition of lockdown. The trend analysis of air parameters are shown in subsequent pages.

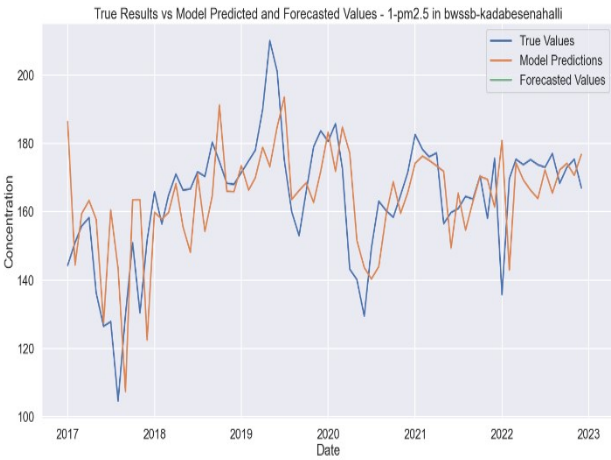
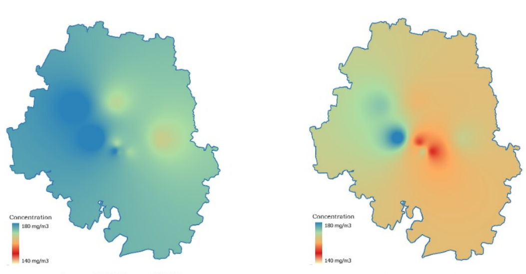


Figure 8: Predicted values for PM2.5 for BWSSB kadabesanahalli

The figure 8 gives the details about the True value and Predicted value by the SARIMAX model, it can be observed the model predicts the values to some degree of accuracy. Similarly, the graphs were plotted for all the 10 stations and all 6 available air pollution parameters for respective stations.

A. *Air Pollution Parameter Forecast*

The following images are the forecasted values for PM 2.5 for the year 2031 which is depicted in 6 months. We can see PM2.5 concentrations are higher in the month of January, than compared to other months.



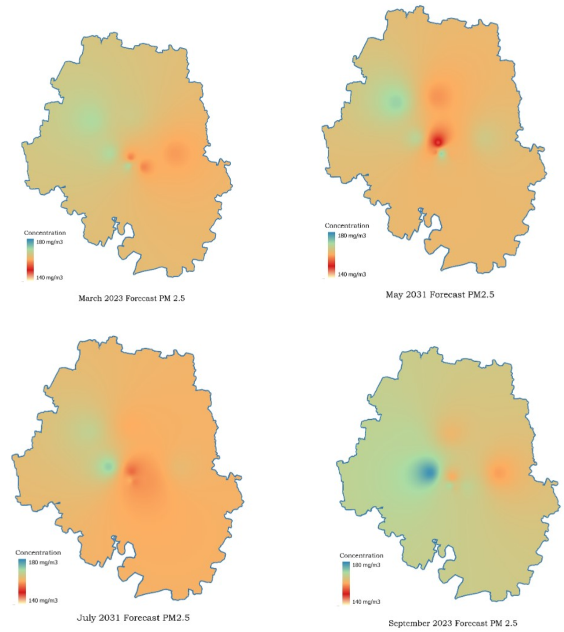


Figure 9: Forecast analysis of PM2.5 for 2031

We can see PM2.5 concentrations are higher in the month of January, than compared to other months. Similarly forecast analysis for other pollution parameters can be done.

B. *Urban Growth and Green Cover Analysis*

The Urban Growth and Green Cover change was analyzed by Cellular Automata and the accuracy achieved was about 81% which is a good accuracy score for a mathematical model. The conclusion drawn from the output for the year 2031 is that there will be an increase in 120 km^2 of built-up area around the Bengaluru region and they will be a decrease of about 17 km^2 of green cover across the Bengaluru region. The order of growth is more towards CBD in most of the region. There was significant change use of land from other purposes to builtup area by year 2031. Due to increase in the construction and decrease in green cover across the region and increase in pollution level is evident in harming human population and environment.

TABLE III. CHANGE IN AREA IN BENGALURU REGION

Details	2015 (km^2)	2021 (km^2)	2031 (km^2)	Difference (2031-2021)
Builtup area	713	745	865	120
Green Cover	103	82	65	17

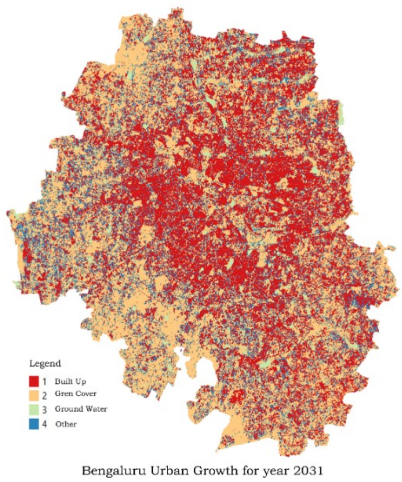


Figure 10: Urban growth for the year 2031 in Bengaluru region

C. *Smog Tower Location*

Once all the above stated output data were obtained based on this the optimum location for smog tower was achieved the detailed of the same is given in the fig3.4. As shown red color square depicts the range of smog tower that is 500m radius. The location of smog tower is shown in image given below. Green square represents the centre location of smog tower and the range of greyscale represents the concertation of PM2.5 in terms of ratio. Thus a total of 6 optimum location has been identified by using the output data's of urban growth and air pollution parameters.

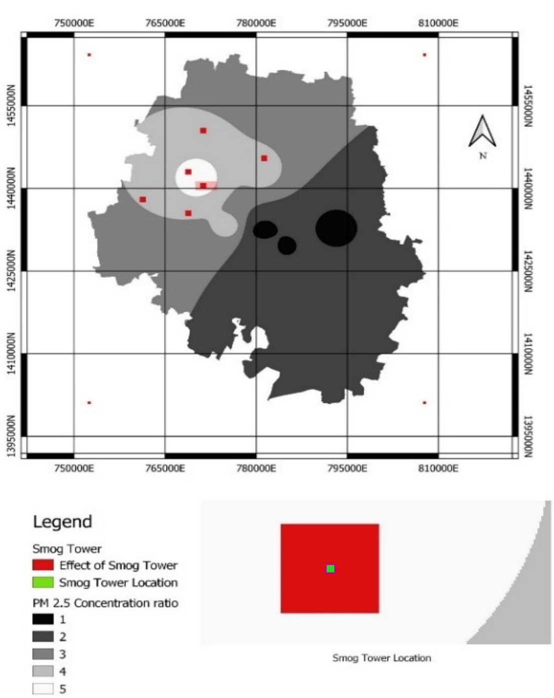


Fig 11: Location of Smog Tower

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