Synthetic surface growth and its effect on ambient particulate matter in Delhi-NCR region: A geospatial investigation

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Abstract
Particulate matter concentration over the Delhi-National Capital Region has witnessed a significant rise in recent years which is thought to be the primary cause of air pollution. Present study endeavors to appreciate the biennial particulate matter variation of this region from 2017 to 2018 from the observational data set of eight air quality monitoring stations spread across the landscape. The data portrays consistent increase in the particulate matter activity for all the stations instead of their varied physiographical set up. However, the stations with vegetated surroundings display lesser pollution of the ambient air mass. The research tries to establish the interlinkage between synthetic surface growth and observed increased pollutant activity from land cover change around the monitoring stations. The analysis portrays a similar behavior to that of the particulate matter variation indicating distinct impervious surface growth for all the stations across the terrain.

This finding implies that positive change in synthetic surface has enhanced the air pollution albeit with varied degree of influence. While the anthropogenic alterations seem to increase the degree of air pollution, natural entities such as surrounding forested land inhibit the pollutant activity. This is amply suggested by the fact that highest and least polluted locations of the capital region do not necessarily coincide with the maximum and minimum spatial dispositions of synthetic surface growth.

Keywords: Particulate Matter, Synthetic Surface, Delhi-NCR, GIS, DEM.

Introduction

Aerosols, also known as particulate matter (PM), are combinations of particles, gaseous molecules and chemical ions which are present in air. These particles play an important role in the change of atmospheric or weather conditions[2-8]. When present in greater concentration, they contribute to pollution and have noteworthy influence on human health. PM comes from a variety of natural and anthropogenic sources in the troposphere such as smoke (produced by burning of coal and wood), dust etc. Significant research on many aspects of PM dynamics has been carried out for National Capital Region (NCR) of India because of the persisting higher concentration for the last several years.

Balachandran et al[1] have investigated the respirable as well as thoracic fraction of atmospheric particles in Delhi. In Delhi, industries are one of the major sources of emission[9]. Concentrated exponential anthropogenic alterations of topography such as urban development, industrial growth etc. are witnesses for the past several decades for this landscape[23-26]. Optical remote sensing has lent a great helping hand in the identification, measurement and monitoring of such changes. Present study endeavors to map such a change in the synthetic surface of Delhi-NCR around various monitoring stations of air quality measurement and establish its interrelationship with aerosol activity, particularly $PM_{2.5}$ if any[10-15]. The underlying hypothesis is that increase in synthetic surface contributes positively to ambient particulate matter concentration.

Site Description: Delhi-NCR is one of the most polluted regions of the world. Pollution Control Boards (PCB) of the Central Government and that of various States have established monitoring stations for real time air quality measurement. Present study considers air quality data from eight such monitoring stations across Delhi-NCR namely: Anand Vihar, Dwarka, Delhi Technological University (DTU), Noida Sector-125, Noida Sector-62, Faridabad, Gurugram and Amity University Haryana (AUH). The research also involves the land cover change around these monitoring stations with a buffer zone of 1 KM.

Out of these stations, AUH and its neighborhood have less population density in comparison to the rest as it is located in the outskirt of the capital region with a general rural set up. It is surrounded by the hills of Aravalli range and forested area on three sides whereas the fourth one includes the nearby village population.

The rest of the stations are situated within densely populated urbanized localities and witness heavy vehicular movements and varied industrial emissions as well. In comparison, however, AUH has witnessed major landscape change with the establishment of the educational institute which has contributed to the establishment of buildings, roads and supporting service amenities. The total capital region is witnessing significant urbanization and industrialization for the past several decades.

At AUH, the contribution of anthropogenic activities to air pollution is less but on other seven locations, there is a significant impact of secondary sources on ambient particulate matter concentration. The local climate of Delhi-NCR belongs to semi-arid type receiving scanty rainfall throughout the year. The terrestrial coverage of the study for all the stations combined extends from 28.105^0 N to 28.921^0 N latitude and 76.604^0 E to 76.853^0 E longitude (Figure 1).

Material and Methods

The research involves analysis of biennial (2017-2018) variation in PM concentration over Delhi-NCR region and the corresponding changes in synthetic surface around the monitoring stations (with a buffer radius of 1 Km). The activity of PM over the stations (except AUH) is obtained from the observations as published by the corresponding organizations. The data analyzed is the annual average concentration for daily observations. The PM observations at AUH are of 15-minute resolution which has been averaged out to calculate the mean annual activity over the area. These observations have been analyzed in a spatial coordinate system in Geographical Information System (GIS) with longitudes representing X-axis and latitudes representing the Y-axis.

The Digital Elevation Models (DEM) created from these analyses portray the PM concentration as Z-axis. Ordinary kriging interpolation method is used to create the DEMs which follow a stretching method based on histogram equalization technique for representation of the maps. The $PM_{2.5}$ concentration in the maps follows a specific pattern wherein blue represents lower activity and red indicates higher concentration[16-22].

Global Positioning System (GPS) is used to get the positional information of the monitoring stations. A buffer zone of 1 Km radius is constructed around the stations to carve out area of interest from the satellite images used for mapping the synthetic surface. The satellite images were obtained from the Google Earth Pro high-resolution imageries. The categorization of landscape to synthetic surface is carried out based on supervised image classification wherein *in situ* sampled ground control points of man-made constructions such as roads, buildings, canals, play courts etc. are provided as input. The classified images containing synthetic surface are finally manually edited and digitized to obtain the synthetic surface map around an observational station.

Results and Discussion

Analysis of the data portrays DTU as the most polluted area and AUH as the least polluted one. For both the years, the two observational sites recorded the highest and lowest concentrations of $PM_{2.5}$ respectively (Table 1). The spatial interpolated maps of $PM_{2.5}$ hence portray an enhanced activity across the northern part of the study area (Figure 2). However, there is a distinct increased activity of $PM_{2.5}$ from 2017 to 2018 for all the observational stations indicating a gradual increase in the pollution level across the Delhi-NCR region (Table 1 and figure 3).

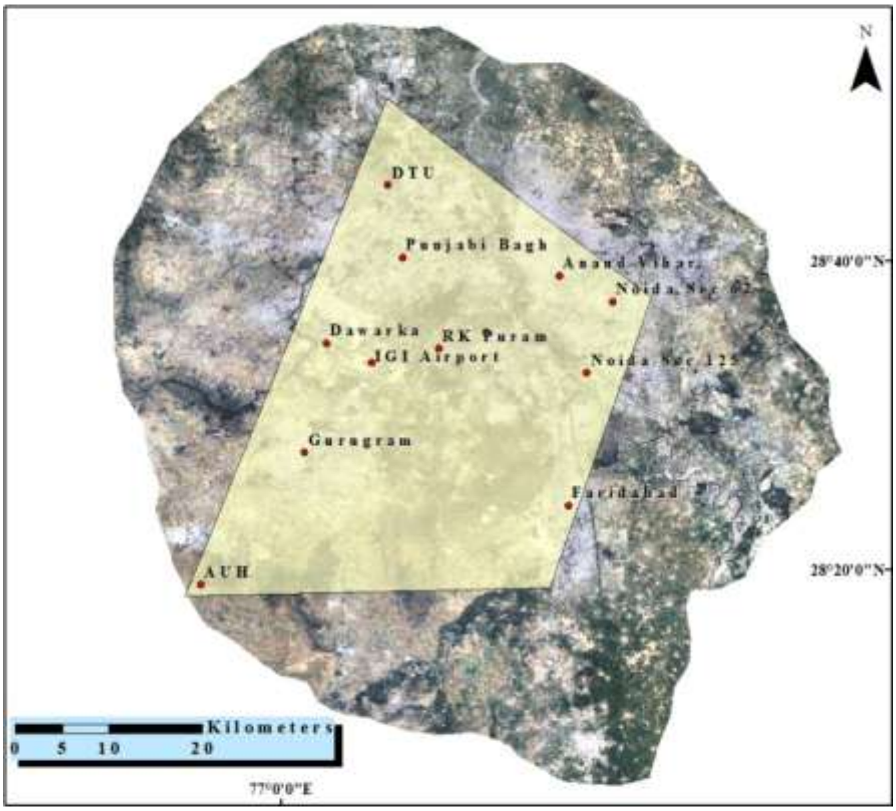


Fig. 1: Regional setting of study site

Table 1
Spatio-temporal variation of particulate matter ($PM^{2.5}$) at different stations

Location	2017	2018	Change
AUH	93.69	129.84	36.15
Faridabad	187.21	229.81	42.6
Gurugram	120.06	214.96	94.9
Noida Sec 62	125.73	198.92	73.19
Noida Sec 125	166.44	289.98	123.54
Anand Vihar	199.9	302.37	102.47
Dawarka	168.96	241.26	72.3
DTU	201.45	355.34	153.89

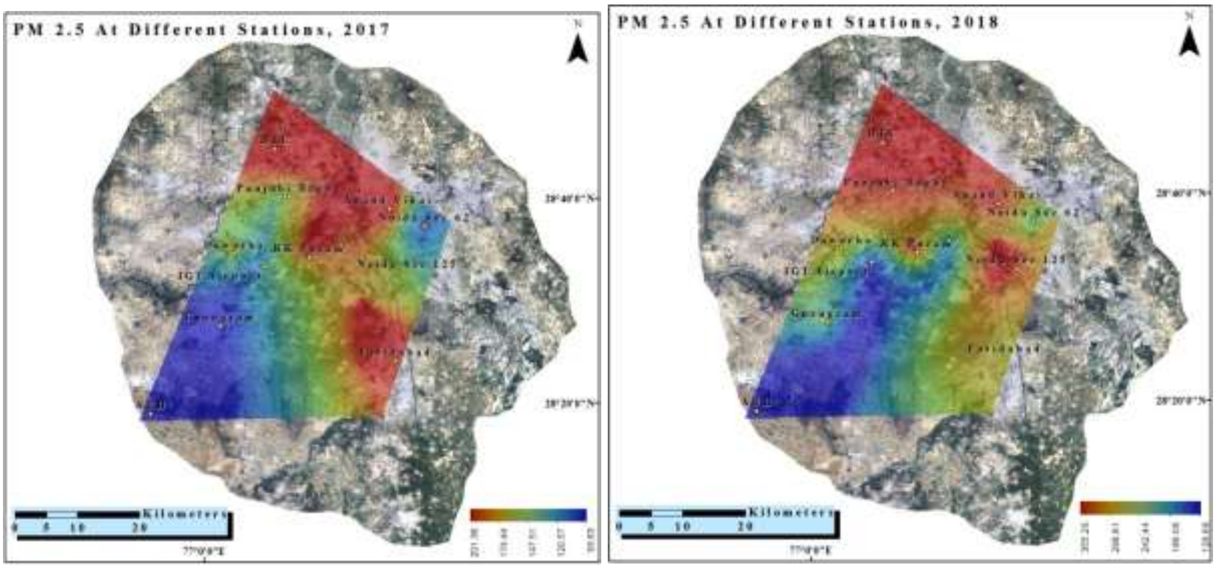


Fig. 2: Concentration of particulate matter at different stations for 2017 and 2018

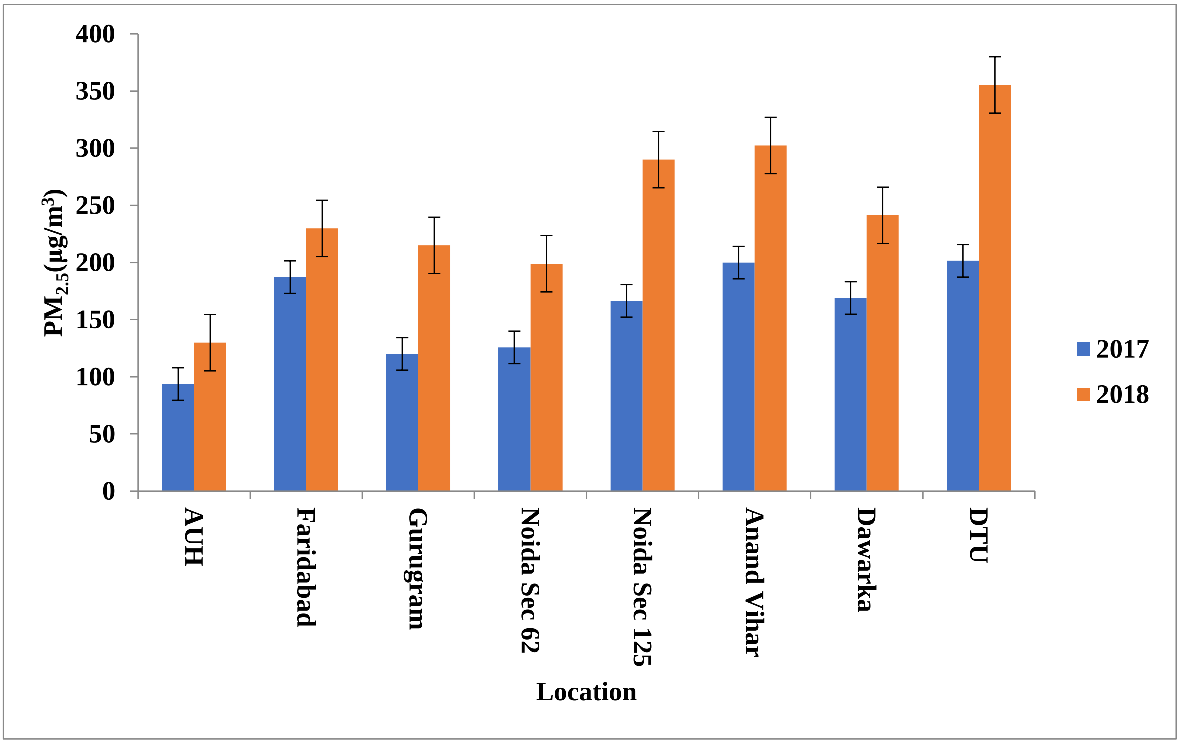
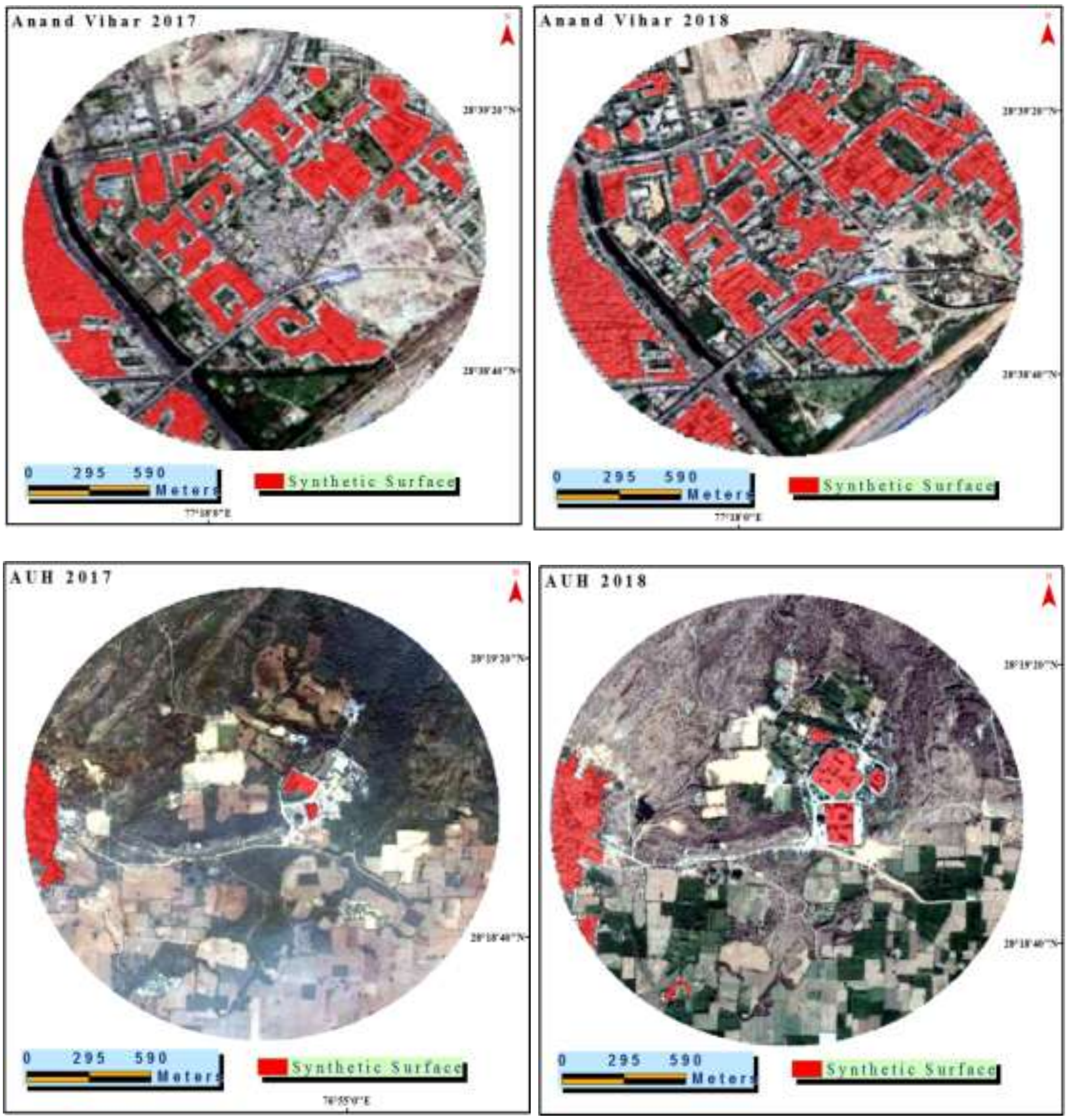


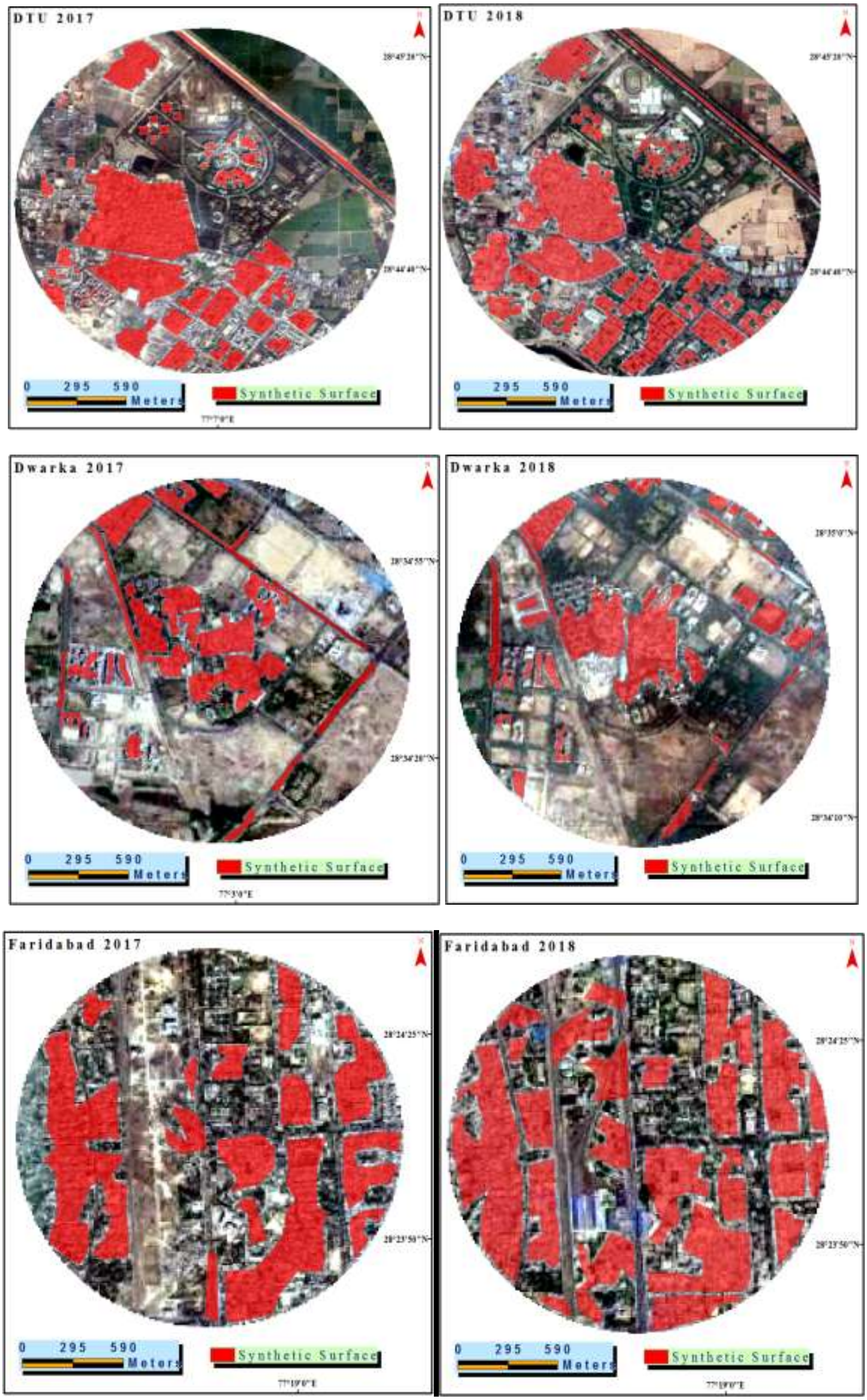
Fig. 3: Bar graph for variation of particulate matter in 2017 and 2018

Analysis of land cover change for synthetic surface indicates a steady increase across all the observational stations. This observation, in turn, points to the fact that there has been a noteworthy increase in human population and related anthropogenic activity such as vehicular emissions in the Delhi-NCR region from 2017 to 2018. Hence, the research findings of increase in synthetic area as well as that of air pollution across the region implies that positive change in man-made constructions has significant effect on the ambient PM concentrations leading to increased pollution of the air mass. However, although, DTU and AUH portray the maximum and minimum $PM_{2.5}$ concentrations for the concerned years respectively, Faridabad and Gurugram represent the highest and least change in anthropogenic alterations respectively (Table 2 and figure 4).

Table 2
Synthetic surface change (m^2)

Location	2017	2018	Change
Gurugram	2251365	2265467	14102
Dwarka	562729	614695	51966
AUH	92323	221065	128742
DTU	890019	1063539	173519
Anand Vihar	905147	1150727	245580
Noida Sec62	1097257	1393546	296289
Noida Sec125	446584	752804	306219
Faridabad	1255183	1727649	472465

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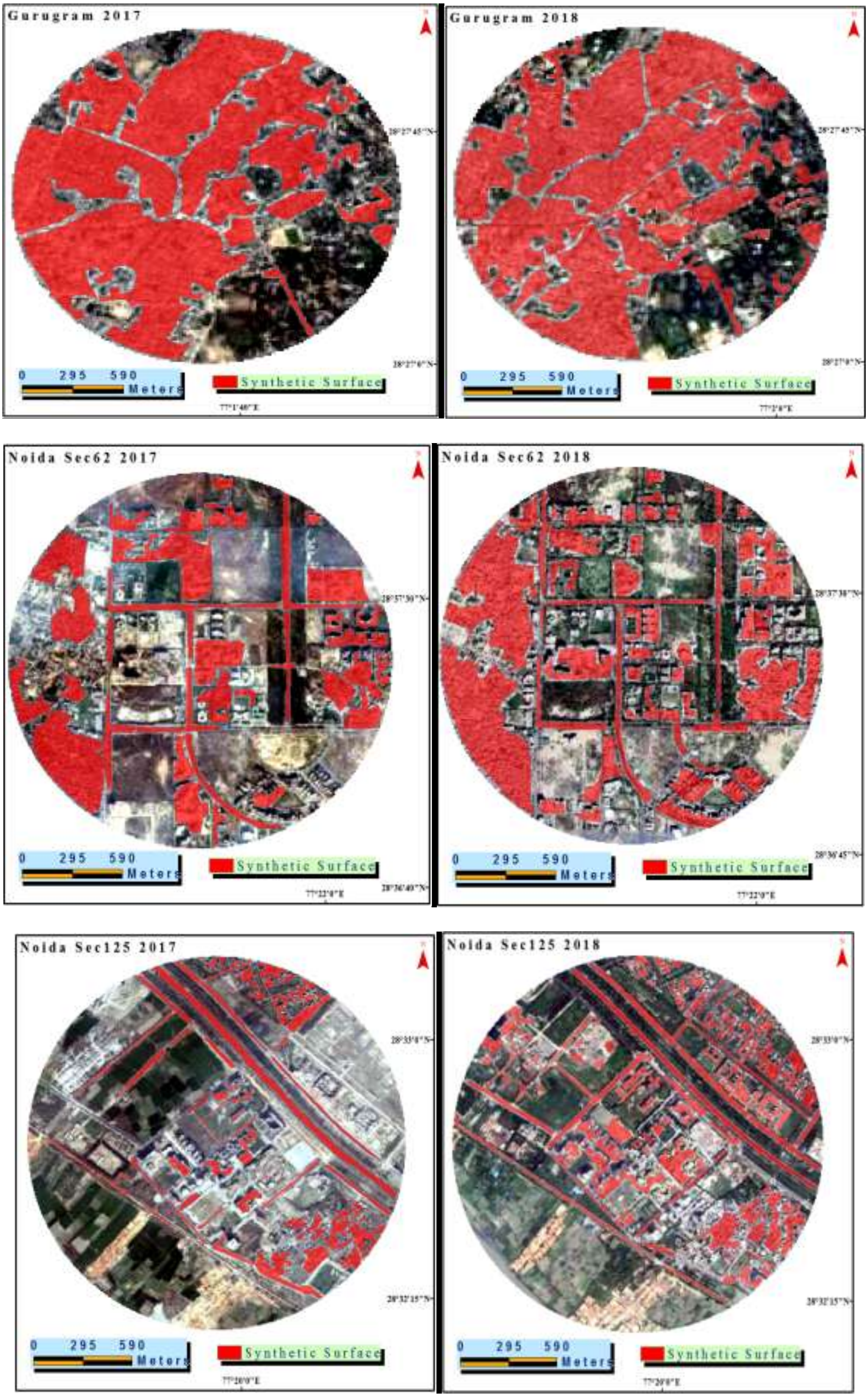

Fig. 4: Synthetic area covered at different locations for the years 2017 and 2018

Therefore, it can be concluded that many other factors, both, natural and human, induced affect the quality of city air. While the city of Faridabad has witnessed the maximum urbanization, it exists beside a prominent forested area which is also the case for AUH. However, in case of DTU and Gurugram, the land cover change is not proportional to the pollution as they already are developed centers of urbanization witnessing increasing human activity with time but limited expansion (Figure 4).

Conclusion

Present research endeavors to appreciate the biennial PM concentration variation over the Delhi-NCR region and its intricate interrelationship with synthetic surface growth across the landscape. The spatial analysis of the PM data from eight of the monitoring stations indicates DTU as the most polluted place whereas the AUH exhibits cleanest air mass at the fringes of the capital region. The analysis does reveal that there is an increase in ambient air pollution from 2017 to 2018 at all the observational stations. Spatial land cover analysis for synthetic surface around the monitoring stations reveals a similar picture with increase in the man-made surfaces across the region. These findings indicate that there is a direct correlationship between synthetic surface growth with that of the increased air pollution.

However, the places of highest and least pollution are not in sync with the places of highest and least growth of synthetic surface while DTU and AUH represent the highest and least polluted locations respectively Faridabad and Gurugram depict the centers of maximum and minimum anthropogenic surface growth. This, in turn, implies that impervious surface growth enhances ambient air pollution; natural entities and processes such as forested land place an inhibiting effect on the extent of air pollution which is the case for AUH. However, it should be noted down that the present time series analysis considers only two of the previous years' data.

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