Final Report on

Carrying Capacity of Air Environment, NCT Delhi

(VOLUME -I)

Sponsored by:

Delhi Pollution Control Committee

School of Planning & Architecture, New Delhi

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Preface

The National Capital Territory of Delhi is situated in the Northern Plains which is surrounded by the Himalayas in the North and the Deccan Plateau in the South which traps the air pollution in its bowl like formation. Being one of the most populous and dense metropolitan cities in semi-arid climate, the air pollution levels are consistently high and is a matter of great concern. The study has been conducted to assess the Carrying Capacity of NCT Delhi w.r.t Air Environment with the support of the Delhi Pollution Control Committee. Air pollution levels in any urban settlement is a result of sources outside and within the settlement. Some studies estimate that about one third of the air pollution in NCT Delhi is from sources within the settlement based on monitoring data available during lockdown. In a dense settlement pollution also concentrates in areas due to air flow modulation as a result of the landuse, built form and resultant micro-climatic conditions. The study has looked into sources of air pollution at Regional, City and Local levels, alongwith listing of landuse activities. Analysis of land use, built form and activities around monitoring stations of Delhi before and after lockdown has brought forth the need to have more detailed study to further understand the co-relation in a scientific manner.

The study concludes with strategies and recommendations to take forward the National Policies and regulations by embedding them into all the sectors of development. Identification and addressing the sources in all sectors some of which are currently unaccounted would help in arriving at specific areas, landuses and activities that need to be phased out or controlled. The study also puts forth methods to control and regulate exposure to air pollution which could be further strengthened by more detailed studies.

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TEAM MEMBERS:

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Abbreviations

AERMOD- Atmospheric dispersion modeling system
AP-42- Air Pollutant Emission Factors
BAU- Business As usual
BRTS- Bus Rapid Transit System
BVOC- Biogenic volatile organic compounds
CBO- Community Based Organisations
CEEW- Council on Energy, Environment and Water
centre
CMAQ- Community Multiscale Air Quality Modelling System
CPCB- Central Pollution Control Board
CSE- Centre for science and Environment
DDA- Delhi Development Authority
DG- Diesel generator
DPCC- Delhi Pollution Control Board
EI- Emission Inventory EC- Elemental carbon
EIP- Economic Incentive Programs policy
EPCA- Environment Pollution Prevention and Control Authority
FO- Furnace oil
FY – Financial Year
GHG- Greenhouse gases
GNCTD- Government of National Capital Territory of Delhi
GRAP- Graded Response Action Plan
HSD- High Speed Diesel
IPT- Intermediary Public Transport
IUPAC- International Union of Pure and Applied Chemistry
LCZ- Land classification Zone
LDO- Light diesel oil
MCD- municipal Corporation of Delhi
MSW- Municipal solid waste
MPD- Master Plan of Delhi
NCAP- National Clean Area Program
NCTD- National Capital Territory of Delhi
NEERI- National Environmental Engineering Research Institute
NMVOCs - Non-methane volatile organic compounds
OC- Organic carbon
PM10 = particulate matter less than or equal to ten microns in diameter
PM2.5 = particulate matter less than or equal to 2.5 microns in diameter
PSP- Public & Semi- Public
RWA- Residents Welfare Organisation

SA- Source Apportionment
SAFAR- System of Air Quality and Weather Forecasting And Research
SD/FF- Spray Dryer/Fabric filter
SIP- State Implementation Plans
SPA- School of Planning and Architecture, New Delhi
TCM- Transportation control measures
TDFS- Transport Demand Forecast Study
TERI- The Energy and Resource Institute
UNEP- United Nations Environment Program
URDPFI- Urban and Regional Development Plans Formulation and Implementation
USEPA- United States Environmental Protection Agency
UTTIPEC- Unified Traffic and Transportation Infrastructure (planning & engineering)
VKT- Vehicle kilometers travelled
VMEP- Voluntary Mobile Source Emission Reduction Program policy
WHO –World Health Organization
WMCs- Waste Minimization Circles
WRF- Weather Research and Forecasting
ZDP- Zonal Development Plan

Units:
ppm = parts per million
ppmdv = parts per million (by) dry volume
scf = standard cubic foot or feet
scfd = standard cubic foot or feet (per) day
scfh = standard cubic foot or feet (per) hour
scfm = standard cubic foot or feet (per) minute
scmd = standard cubic meter or meters (per) day
TSP = total suspended particulate (matter)
TSS = total suspended solids
MMBtu = million British thermal units
MMBtu/hr = million British thermal units per hour
MMCFD = million cubic feet per day

Glossary

Air Quality Index (AQI) - A nationally uniform index for reporting and forecasting daily air quality. It is used to report on the four most common ambient air pollutants that are regulated under the Clean Air Act: ground-level ozone, particle pollution (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), and sulfur dioxide (SO2). The AQI focuses on health effects that may be experienced within a few hours or days after breathing polluted air.

Aerosol: Particles of solid or liquid matter that can remain suspended in air from a few minutes to many months depending on the particle size and weight.

Air Basin: A land area with generally similar meteorological and geographic conditions throughout. To the extent possible, air basin boundaries are defined along political boundary lines and include both the source and receptor areas.

Air Quality Standard (AQS): The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health as established by both federal and state governments. (See also ambient air quality standards.)

Ambient Surrounding: It is used to describe physical properties of air (temperature, humidity, pressure, etc) or air pollution concentration in the open air, as against, at the point of emission or indoors, for example, ambient temperature, ambient air quality.

Chimney (Stack) Height, -The effective height of a chimney is the sum of its actual physical height and the plume rise. The latter is the rise of the effluent due to buoyancy and efflux velocity.

Carbon monoxide (CO) - A colorless, odorless gas that can be harmful when inhaled in largeamounts. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks, and other vehicles or machinery that burn fossil fuels.

Coarse particles (also known as PM_{10}-2.5) - Particles with diameters generally larger than 2.5 micrometers (µm) and smaller than, or equal to, 10 µm in diameter.

Diffusion a) On the scale of molecules, diffusion is a mixing of substances caused by molecular motion (Molecular Diffusion). b) In atmosphere it implies the spread of pollutants by turbulence or eddy motion (also called Atmospheric Diffusion).

Dispersion -The method by which a pollutant spreads from its point of emission and becomes diluted in the atmosphere. It includes transport by winds and simultaneous spread by turbulence (atmospheric diffusion).

Electrostatic Precipitator (ESP): An air pollution control device that removes particulate matter from an air stream by imparting an electrical charge to the particles for mechanical collection at an electrode.

Emission Factor: For stationary sources, the relationship between the amount of pollution produced and the amount of raw material processed or burned. For mobile sources, the relationship between the amount of pollution produced and the number of vehicle miles traveled. By using the emission factor of a pollutant and specific data regarding quantities of materials used by a given source, it is possible to compute emissions for the source. This approach is used in preparing an emissions inventory.

Emission Inventory: An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year.

Emission Offsets (also known as Emissions Trading): A rule-making concept whereby approval of a new or modified stationary source of air pollution is conditional on the reduction of emissions from other existing stationary sources of air pollution. These reductions are required in addition to reductions required by best available control technology.

Emission Rate: The weight of a pollutant emitted per unit of time (e.g., tons/year).

Emission Standard: The maximum amount of a pollutant that is allowed to be discharged from a polluting source such as an automobile or smoke stack.

Energy Content: The amount of energy available for doing work. For example, the amount of energy in fuel available for powering a motor vehicle.

Fine particles (also known as $PM_{2.5}$) - Particles that are generally 2.5 µm in diameter or smaller. This group of particles also encompasses ultrafine particles and nanoparticles which are generally classified as having diameters less than 0.1 µm.

Fugitive Dust: Dust particles that are introduced into the air through certain activities such as soil cultivation, or vehicles operating on open fields or dirt roadways. A subset of fugitive emissions.

Fugitive Emissions: Emissions not caught by a capture system which are often due to equipment leaks, evaporative processes, and windblown disturbances.

Inversion - An atmospheric condition where a layer of cooler air is trapped near the ground by a layer of warmer air above. When the air cannot rise, pollution at the surface also is trapped and can accumulate, leading to higher concentrations of ozone and particle pollution.

National Ambient Air Quality Standard (NAAQS) - The Clean Air Act requires EPA to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The EPA has set National Ambient Air Quality Standards for six criteria pollutants: sulfur dioxide (S02), particulates ($PM_{2.5}$/PM_{10}), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O3), and lead (Pb). Periodically, the standards are reviewed and may be revised.

Particle pollution (also known as particulate matter or PM) - General term for a mixture of solids and liquid droplets suspended in the air.

$PM_{2.5}$: Includes tiny particles with an aerodynamic diameter less than or equal to a nominal 2.5 microns. This fraction of particulate matter penetrates most deeply into the lungs.

PM_{10} (Particulate Matter): A criteria air pollutant consisting of small particles with an aerodynamic diameter less than or equal to a nominal 10 microns (about 1/7 the diameter of a single human hair). Their small size allows them to make their way to the air sacs deep within the lungs where they may be deposited and result in adverse health effects. PM_{10} also causes visibility reduction.

Precipitator: Pollution control device that collects particles from an air stream. (See Electrostatic Precipitator.)

Primary fine particles - Fine particles that are emitted directly from a source, such as construction sites, unpaved roads, smokestacks, or fires.

Remote sensing- Detection or measurement of a property of a medium like atmosphere such as temperature, concentration of pollutants, etc. For example, using Radar, rain can be detected or using Laser beam, concentration of pollutants can be measured along the path of the beam by analysing the scattered radiation from the beam. This is in contrast to in situ sampling or measurement where the sensor measures the property in the immediate vicinity of the sensor.

Secondary fine particles - Fine particles that form in complicated reactions in the atmosphere of chemicals, such as sulfur dioxides and nitrogen oxides, that are emitted from power plants, industries, and automobiles.

Sensitive groups (also called at-risk populations) - A term used for a category of persons at increased risk of experiencing adverse health effects related to air pollution exposures. These groups can be at increased risk due to intrinsic factors (biological), extrinsic factors (external, non-biological), higher exposure, and/or increased dose at a given concentration. The severity of the health effects that these groups experience may be much greater than in the general population.

Micrograms per cubic meter (μg/m3): The mass in micrograms of a substance contained within a cubic meter of another substance or vacuum. This is the standard unit of measure for the mass density (concentration) of particles suspended in air; also sometimes used for the concentration of gases in air.

Total suspended particulates (TSP): Particles of solid and liquid matter suspended in air. TSP is collected on filtration media and analyzed by weight only. Particle sizes represented by the method are up to 100 μm in aerodynamic diameter.

Urban Airshed Model (UAM): A three-dimensional grid-based photochemical computer model of the production of ozone from precursors (VOCs and NOx) and the dispersion of air pollution in a specific geographic area over a period of one or two days.

Urban Heat Island- A zone of excess warmth within a city over the suburban and rural environs. The warmer air in this region rises upwards and then spreads radially outwards. The colder air from the surrounding countryside at the surface flows inwards towards the heat island to replace the rising and outspreading warm air. This occurs when the heat islands are intense. This circulation is known as Urban Heat Island Effect.

Ventilation a) The process of replacing contaminated or stale air by fresh air. b) The movement and circulation of outdoor air. c) The volume of air entering or leaving the lungs in one respiratory cycle.

Ventilation Coefficient - It is defined as a product of mixing height and average wind speed.

Vehicle miles traveled (VMT): The number of vehicles that travel in a particular geographic region in a specified period of time (usually a year) multiplied by the number of miles each vehicle traveled. A measure of the total distance covered by vehicles in that area during that period. Normally the phrase refers only to travel by on-road motor vehicles.

Volatile organic compound:
An organic compound (meaning a chemical combination of carbon and other elements, whether natural or manmade) which is volatile, meaning it readily produces vapors at room temperature. Many VOCs react in the atmosphere with nitrogen oxides in the presence of heat and sunlight to form ozone. Methane and other compounds determined by EPA to have negligible photochemical reactivity are excluded from the EPA definition of VOCs. Examples of VOCs include gasoline fumes and solvents from oil-based paints.

Zoning - A method of abating air pollution at a location by a systematic planning of sites for dwellings and for factories/Industries which discharge effluents taking into account the micro-meteorological conditions in and around the location.

MANDATE & SCOPE

Subsequent to Source Apportionment Studies for Delhi carried out by (i) IIT Kanpur in May,2016, (ii) The Energy and Research Institute (TERI) in August,2018 and (iii) Centre for Science and Environment (CSE) in 2019, Hon'ble National Green Tribunal in a matter of: News Item Published in the The Times of India authored Sh. Vishwa Mohan titled ***"NCAP with multiple timelines to clean air in 102 cities to be released around August 15"***, had issued directions for study to assess Carrying Capacity of NCT Delhi on the environmental aspects. .**(Order dated 20.11.2019,w.r.t OA No. 681/2018 (I.A. No. 411/2019) with O.A No. 10/2019(EZ))** In response to the direction of the NGT order, Delhi Pollution Control Committee (DPCC), Delhi issued the work order for the project **"Study on Carrying Capacity of Air Environment in NCT Delhi" to School of Planning and Architecture, New Delhi**.

As per the Work Order dated 6th March 2020; the duration of the project was 21 days from the date of acceptance of the order and the methodology to be followed for the assessment of Carrying Capacity would include **the proposed methodology prepared by Central Pollution Control Board (based on IIT Guwahati's framework) and the methodology submitted by School of Planning and Architecture New Delhi .**

MEETINGS AND PRESENTATIONS

19th March 2020 - The First meeting was held at the Conference Room DPCC, when a presentation was made on the methodology of the study and request for latest data w.r.t. Source apportionment studies; Meteorological data, emission factors, transport, industries, DG sets etc. was made. While the work was in progress the imposition of Lockdown w.e.f from 22nd March 2020 effected the pace of the work as data was not easily available and discussions with officials could not take place.

28th March 2020 - The First Draft Report was submitted incorporating whatever data was available by that time. Comments and observations to the report were received vide mail dated 6th of May2020, mentioning about certain anomalies in the data, need for incorporation of latest measures undertaken by DPCC in control of air pollution and need to clarify the basis of the observations especially w.r.t quantitative assessments. A request was made to DPCC to allow for extension of work to incorporate the changes. It was also requested that since during the lockdown the air pollution levels showed a substantial dip (perhaps the lowest ever recorded till then), hence an assessment w.r.t to activities and pollution could be possible and may be added to the scope of the study. The same was agreed upon.

15th July 2020 - Draft Final Report was submitted incorporating the suggestions along with work done related to the lockdown period.

13th October 2020 - The draft Final Report was again reviewed and presentation was made to Chairman DPCC. It was emphasised that **recommendations specific to Master Plan of Delhi** should be emphasised upon. Subsequent to the meeting the report was discussed and modified with inputs from DPCC.

5th February 2021- Presentation of the report was made to member Secretary DPCC and suggestions were incorporated and the Final Report was submitted in two volumes for final acceptance

18th March 2021 – A meeting including presentation was fixed with Chairman and Member Secretary DPCC at Delhi Secretariat for finalization of the report. The present report is being submitted incorporating all the suggestions received.

1. BACKGROUND

Urban areas are characterized by high population density and economic development. The resulting pollutant emissions place an increasing pressure in the air quality of these areas. Whereas in the past the major reasons for poor air quality were industrial activity and domestic heating but, nowadays as a result of the rapid increase in mobility the major current urban air pollutants come from road traffic (Sturm et al., 1997). This is particularly significant for developing countries, where the rapid rates of both urbanization and growth in vehicle fleet (Faiz, 1993) are expected to be the highest in the world (World Health Organization/United Nations Environment Program, 1992). The simple reason being means of transportation is an important infrastructural facility. These play a very important role in the overall development of a country. As the numbers of vehicles are increasing rapidly, it has slowly but surely started hindering our atmospheric purity with the vehicular and noise pollution. The pollutants emitted from these are transported, dispersed or deposited by meteorological and topographical conditions. Thus, the resulting ground level concentration patterns have to be estimated to save the environment and indirectly the human race. It's for this reason that the assessment of carrying capacity is urgently required.

1.1. Concept of Carrying Capacity

The concept of carrying capacity is very important for developmental planning and hence needs to be defined properly. Carrying capacity, in broad terms, is an indicator of potential for future growth keeping in view the resources such as air, water, land etc. Air environment is important as most of the developmental activities tend to have an impact on the surrounding air quality.

1.1.1. Framework for Carrying Capacity based Development Planning

The development of framework for carrying capacity-based planning involves, mainly, identification of the resources of the region and scope of their utilization vis-à-vis environmental impacts. The carrying capacity of air environment gives a rough estimate of the emission load (from various sources; man-made and natural) it can sustain under a set of specific conditions (resource allocation, topographic and atmospheric). We should put our efforts to explore strategies for planned and sustainable development within the carrying capacity.

1.1.2. Supportive Capacity Dimensions of Air Environment

Supportive capacity determines the developmental potential of a region and economic progress and quality of life. Supportive capacity includes Urban Land and Shelter Resource, Urban Social, Physical and Communication Infrastructure, Urban Utilities and Human and Institutional Resource. The aspects have been assessed based on comparison with existing norms and standards arriving on adequacy/ deficiency, above or below standards. This has been followed by recommendations relating to assessment.

1.1.3. Assimilative Capacity Dimensions of Air Environment

Assimilative capacity refers to the ability of the environment or a portion of the environment (such as a stream, lake, air mass, or soil layer) to carry waste material without adverse effects on the environment or on users of its resources. Assimilative capacity includes Air Environment, Water Environment, Land/Soil Environment, Biological Environment and Acoustic Environment. The term "assimilative capacity" of the atmosphere is believed to be used interchangeably with the "carrying capacity". The assimilative capacity of the atmosphere gives roughly an idea of the extent to which the atmosphere is capable of sustaining the pollution load from various emission sources. Thus, a thorough study of the assimilative capacity is essential for judging proper sitting of new industrial units and for regulating the operating of the industries according to the atmospheric conditions. The assimilative capacity depends on various physical parameters such as the atmospheric stability, the topography of the region etc. The atmospheric stability is a crucial parameter which is based on solar insulation, mean wind speed and temperature profile. The assimilative capacity of the atmosphere is directly proportional to the ventilation coefficient and inversely proportional to the pollution potential. Further, the ventilation coefficient is expressed as a product of the mixing height and the transport wind speed within the mixing layer. The use of atmospheric stability for the estimation of assimilative capacity is manifested in the mixing height and the transport wind. A region with large pollution potential would have less carrying capacity.

1.1.4. Resource Allocation Strategies

Optimum and proper utilization of the resources is an important aspect of the carrying capacity based development. For an integrated approach towards sustainable development there is a need to evolve proper strategies for balanced allocation of the resources in the region. The knowledge of assimilative capacity would be desirable for determining the resource allocation strategies for various parts of the region. This is very essential for decision making related to overall regional development .

1.2. Study Area: National Capital Territory of Delhi

Delhi faces a severe air pollution problem due to the number of sources which are impacting the ambient air quality. Vehicular pollution in Delhi has grown from 64% to 72% from 1990 to 2000, whereas petrol and diesel consumption have grown by 400% and 300% respectively. Other sources such as biomass burning, refuse burning, construction dust and other unregulated sources are becoming major sources in some areas of high pollution levels. Two previous studies (IIT Kanpur and TERI) show considerable trend in the emission inventory of the city, which further needs to be enhanced and reciprocated in upcoming years.

1.3. Approach

- **Source Apportionment Study:** The source apportionment study of NCT of Delhi has already been carried previously. Two studies (CPCB and IIT Kanpur) were limited to Delhi and three (Guttikunda, SAFAR, and TERI) to the NCR. Among the studies of the NCR, Guttikunda (2018) covered only urban areas of NCR - Gurugram, Faridabad, and Ghaziabad - and excluded rural areas. The SAFAR study considered Gurugram, Faridabad, Sonepat, and Jhajjhar (Haryana) and Ghaziabad, Baghpat, and Gautam Buddha Nagar (Uttar Pradesh). These studies extensively provide the information of various sources of pollution in Delhi. They can be used for analysing the trend of pollutants and emission sources over the course of time.
- **Baseline Study:** It includes the comprehensive studies of land-use, demography, transportation, tourism and air pollution trend. These parameters are required to carry out the correlation between air pollution, land use, economic activities and infrastructure. It will serve as a determinant for formulation of carrying capacity framework and establish carrying capacity of Delhi city.
- **Projections:** The projections for the above mentioned parameters would be calculated for short term (5 years), medium term (10 years) and long term (20 years).
- **Analysis** Operating air quality monitoring stations for measurement of air quality is highly resource intensive in terms of time and cost. The appropriate spatial interpolation techniques can be used to estimate concentration where air quality monitoring stations are not available. Spatial mapping of air pollutants and the above mentioned parameters (land-use, transportation, etc.) would help in establishing correlation between the same.
- **Development of suitable framework for calculating carrying capacity:** Based on the above mentioned baseline data, a suitable framework would be developed considering the air environment for Delhi city. As of now, there is no carrying capacity framework established with respect to air environment.
- **Carrying capacity assessment:** The terms "Carrying Capacity" and "Assimilative Capacity" of the atmosphere are interchangeably used. Assimilative Capacity of the atmosphere gives roughly an idea of the extent to which atmosphere is capable of sustaining the pollution load from various emission sources. The assimilative capacity depends upon the various physical parameters such as atmospheric stability and the topography of the region. Understanding of both the capacities is essential for establishing action plans.
- **Recommendations:** As per the estimated carrying capacity and assimilative capacity interventions would be suggested at different scales and suitable action plans (short, medium and long term) will be formulated.

1.4. Scope of work

The study is limited only to NCT Delhi and does not cover National Capital Region. The scope of work includes: Study of existing source apportionment reports (IIT-K,2016 & TERI 2018), Compilation & baseline study for 2019, Projections for short, medium and long term of all the selected parameters, Spatial mapping of Parameters & Overlay Analysis of Pollutants, Revision in carrying capacity assessment framework, carrying capacity assessment and proposing action plan and recommendations.

1.5. Methodology

SNO.	ASPECTS	PARAMETERS	ELEMENTS
1	LITERATURE STUDY: SOURCE APPORTIONMENT STUDY REPORT	2016	PM10, PM2.5,
		2018	PM10, PM2.5,
2	BASELINE STUDY (DELHI)	Study Area Profile	Physiography, Climate & Natural Resources
		Demography	Existing Population And Projections - Domestic & Floating Population
		Land Use Study	Residential, Commercial, Psp, Industry, Mixed Use & Recreational
		Transportation	Traffic Movement, Modal Split, V/C Ratio
		Industries	Type Of Industries And Their Emissions
		Tourism	Trend
		Air Pollution (Emission Loads)	Emission Inventory (As per secondary survey)
3	PROJECTIONS	Short Term (2025)	Projections Of Above Mentioned Parameters (land-use, demography, infrastructure, transportation, tourism, air pollution)
		Medium Term (2030)	
		Long Term (2040)	
4	ANALYSIS	Demography	Spatial Mapping of Parameters and Overlay Analysis of Pollutants
		Landuse	
		Urban Built-Form	
		Wind Speed & Direction	
		Transportation	
		Emission Estimations	
		Air Pollution	Air Quality at all monitoring stations with respect to land use and local activities, Air Quality During COVID-19 Pandemic Lock-down In Delhi and Effect of lockdown at few monitoring stations selected based on predominant landuses
5	DEVELOPMENT OF SUITABLE FRAMEWORK FOR CALCULATING CARRYING CAPACITY*	*(Note: The existing urban land carrying capacity formulated by IIT Guwahati represents only the urban aspect and doesn't consider the air environment hence a framework for addressing air environment needs to be worked out)	
6	CARRYING CAPACITY ASSESMENT	Based on the framework developed	
7	SCALES OF INTERVENTIONS	Regional, City and Local level	
8	ACTION PLAN	SHORT TERM (2025)	Recommendations
		MEDIUM TERM (2030)	
		LONG TERM (2040)	

2. INTRODUCTION

Delhi, with an area of 1483 km sq.km, is located in North India within the latitude 28°24'17" and 28°53'00"N, and longitude 77°45'30" and 77°21'30"E. Delhi is jointly administered by the Central and State Government and as per Census 2011, has a population of 16.3 million people; thus becoming the second most populous city and second most populous urban agglomeration in India. However, due to rapid development, Delhi is also facing serious challenges in terms of air pollution. To tackle the situation, Delhi has taken several steps to reduce the air pollution level during the last 10 years. However, more concerted efforts are still required to reduce the pollution level.

This document constitutes the report that has addressed all important points of scope of work and methodology for carrying out the carrying capacity with respect to land-use. The study extensively used spatial techniques using GIS and have concluded with strategies and recommendations to take forward the National Policies and regulations by embedding them into all the sectors of development. The study

analyses the data of PM2.5 and PM10 of 2019, carried out for 37 monitoring stations (CPCB, DPCC and IMD) spread all over the city.

Some major findings of sources of air pollution at regional, city and local levels, emission inventory, analysis based on landuse, built form and activities around monitoring stations of Delhi before and after lockdown and future projections are summarized in subsequent paragraphs.

3. LITERATURE STUDY

3.1. Carrying Capacity

Carrying capacity is defined as the population level that can be supported, given the quantity of food, habitat, water and other infrastructure present. In context of human population, carrying capacity refers to the number of individuals who can be supported in each area within natural resource limits, and without degrading the natural social, cultural and economic environment for present and future generations. There have been many approaches to assess Carrying Capacity of Urban Areas, however due to many variables each approach needs to be suited to the characteristics of the area. Thus the methodology needs to be formulated for a particular assessment within the broader frame. Carrying Capacity is assessed in two dimensions – Assimilative Capacity and Supportive Capacity.

- **Assimilative Capacity Dimension**

Assimilative capacity refers to the ability of the environment or a portion of the environment (such as a stream, lake, air mass, or soil layer) to carry waste material without adverse effects on the environment or on users of its resources. Assimilative capacity includes Air Environment, Water Environment, Land/Soil Environment, Biological Environment and Acoustic Environment.

- **Supportive Capacity Dimension**

Supportive capacity determines the developmental potential of a region and economic progress and quality of life. Supportive capacity includes Urban Land &Shelter Resource, Urban Social, Physical and Communication Infrastructure, Urban Utilities and Human & Institutional Resource.

Table 1: : Carrying Capacity Constituents of an Urban Area

CARRYING CAPACITY CONSTITUENTS OF AN URBAN AREA	
ENVIRONMENTAL COMPONENTS/ RESOURCES	**COMPONENTS DEFINITION**
Assimilative Capacity Dimension	
Air Environment	Local Air shed – How many times Air Quality Parameters are within acceptable limits?
Water Environment	Local Ground and Surface Water Regimes – How many times/ in which seasons and in which areas the Water Quality Parameters are within acceptable limits?
Land/Soil Environment	Urban land and Soil regime – Productivity for agriculture, Suitability for Use (land use suitability) and land reclamation potential
Biological Environment	Local Ecosystem and flora and fauna – Sink Potential and Recycling Capacity therein against Pollution Loads
Acoustic Environment	Urban Landscape – to attenuate Outdoor Noise Levels to acceptable limits

CARRYING CAPACITY CONSTITUENTS OF AN URBAN AREA	
ENVIRONMENTAL COMPONENTS/ RESOURCES	**COMPONENTS DEFINITION**
Supportive Capacity Dimension	
Urban Land and Shelter Resource	
Land	Land Supply within and around Urban Areas to support Population and Activities in terms of acceptable density norms. (Area of land available for development as per land suitability and the population it can support)
Housing	Urban Residential Space – Its Quantity and Quality to support Needs and Demands of Population Groups (Demand and Supply)
Urban Social, Physical and Communication Infrastructure	
Social Amenities/Infrastructure	Availability of Urban Health, Educational, Recreational and Public Security Services – Quality and Quantity in terms of acceptable norms.
Physical Infrastructure **(transport)**	Road/ Rail/ Air/ Water Linkage and Services between Urban Area and Other Population and Economic Center to support Adequate and Efficient Movements of Population Groups Urban Road and Transportation Facilities – to support Adequate and Efficient Movement of Population and Goods across Different Parts (Volume by capacity ratio to be less than 1 , no congestion points)
Communication	Post, Telegraph, Telephone and Other Communication Facilities of Urban Area – to support Adequate and Efficient Communication Within and Outside (Coverage)
Urban Utilities	
Water Supply	Water Resources and its Delivery System Across Urban Areas to have adequate and affordable supply in terms of acceptable norms (Quantity generated vs quantity disposed/ treated/recycled etc. and area covered and comparison with norms and standards)
Sewage	Sewage, Storm Drainage and Solid Waste Management – Adequate and Hygienic Disposal in terms of acceptable norms(Quantity generated vs quantity disposed/treated/recycled etc. and area covered and comparison with norms and standards)
Electricity	Electricity and Non-Conventional Energy System – Adequate and Affordable generation and distribution Supply to meet Peak Hour Demands and Households Establishments and Public Streets and Open Space (Coverage)
Human & Institutional Resource	
Manpower and Capacity	Manpower Supply in Urban Area – to have Adequate Quantity and Quality for Sustained Economic Development Industrial, Commercial and Service Activities of Organized and Non-Formal Sector to have adequate Employment, Income and GNP generation Urban Municipalities and/or Development Agencies to have Adequate and Human Resource

3.2. Source Apportionment Studies

Delhi overall have observed improvement in air quality over the years. The following tables have been provided based on study done by IIT Kanpur from 2013-14 and TERI from 2016. The figures for year 2019 have been estimated based on projections and conversion values of emission load (kg/day) to $PM_{2.5}$ and PM_{10} concentration as provided from model done by IIT Kanpur.

3.2.1. Source Apportionment study by IIT Kanpur, 2016

The Government of National Capital Territory of Delhi (NCTD) and Delhi Pollution Control Committee (DPCC), Delhi have sponsored the study "Comprehensive Study on Air Pollution and Green House Gases in Delhi" to IIT Kanpur in 2016. Objectively the project GHG aimed to achieve the following:

A. Identification of source/sinks of greenhouse gases (GHG) (CO2, CH4, N2O, and anthropogenic fluorinated gases);

B. Development of GIS-based gridded emission inventory of GHG (2 km × 2 km resolution) from identified sources;

C. Estimation of losses of GHG through various sinks;

D. Generation of GIS-based carbon emission maps from various sources, such as transportation, industrial, residential, commercial, and power plants;

E. Develop reduction strategies for GHG;

F. Develop a control plan for GHG mitigation.

Emission inventory (EI) is a basic necessity for planning GHG control activities. EI provides a reliable estimate of total emissions of different GHGs, their spatial and temporal distribution, and identification and characterization of main sources. This information on EI is an essential input to climate models and for developing strategies and policies. In this chapter, GHG EI of city of Delhi for the year 2014 is presented.

Methodology :The stepwise methodology adopted for the study is presented in Figure

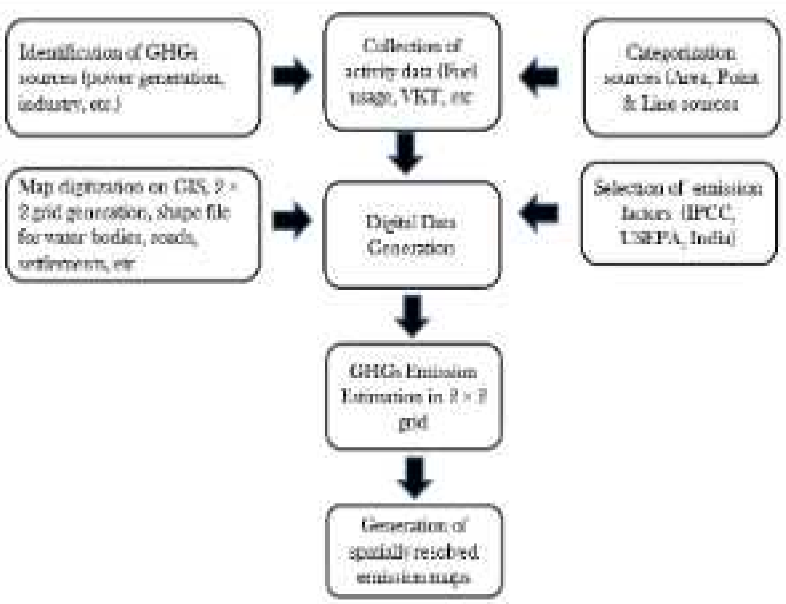


Figure 1: Stepwise methodology adopted for the study

Source: Comprehensive Study on Green House Gases (GHGs) in Delhi

Table 2: Overall Baseline GHG Emission in the Delhi City (in tonnes): year 2014

Sources	CH_4	CH_4 (%)	CO_2 X 10^6	CO_2 (%)	N_2O	N_2O (%)	HCF	tCO_2e X 10^6	tCO_2e (%)
Power Sector									
(1a) Power Plants (Within Delhi)	1105	3.0	13.40	40.1	160	2.1	-	13.48	35.6
(1b) Power Consumption (From Outside Delhi Sources)	315	0.8	2.88	8.6	47	0.6		2.90	7.6
Total	**1420**	**3.8**	**16.28**	**48.7**	**207**	**2.7**		**16.38**	**43.2**
Vehicles	6606	17.8	9.98	29.9	7132	91.5	-	12.27	32.4
MSW Burning	1077	2.9	3.05	9.1	142	1.8	-	3.12	8.2
Domestic	148	0.4	2.44	7.3	36	0.5	-	2.45	6.5
Refrigerant	0	0.0	0.00	0.0	0	0.0	875	1.25	3.3
Livestock	22693	61.2	-		-		-	0.57	1.5
Industry (Area source)	38	0.1	0.52	1.6	17	0.2	-	0.53	1.4
Cropland	176	0.5	0.35	1.1	126	1.6	-	0.39	1.0
Incinerator	88	0.2	0.26	0.8	12	0.2	-	0.27	0.7
Green Cover	147	0.4	0.16	0.5	72	0.9	-	0.18	0.5
Restaurant	19	0.1	0.17	0.5	3	0.0	-	0.17	0.5
Landfill	3263	8.8	0.00	0.0	30	0.4	-	0.09	0.2
Agriculture	873	2.4	0.06	0.2	2	0.0	-	0.08	0.2
DG Set	3	0.0	0.05	0.1	1	0.0	-	0.05	0.1
Cremation	1	0.0	0.04	0.1	2	0.0	-	0.04	0.1
Industrial (point source)*	2	0.0	0.03	0.1	1	0.0	-	0.03	0.1
Aircraft	11	0.0	0.01	0.0	0	0.0	-	0.01	0.0
Drain	493	1.3	-		-		-	0.01	0.0
Wetland	18	0.0	0.01	0.0	11	0.1	-	0.01	0.0
Total	**37078**	**100**	**33.41**	**100**	**7794**	**100**	**875**	**37.91**	**100**

Source: Comprehensive Study on Green House Gases (GHGs) in Delhi

City Level GHG Emission Inventory:

The tCO2e emission load in the city is estimated to be 37.91 million tonnes for the year 2014. The top four contributors to tCO2e emission are Power plants (43%), Vehicles (32%), MSW burning (8%) and Domestic cooking (7%); these are based on annual emissions. Seasonal and daily emissions could be variable. For example, MSW burning is more frequent in winter than in summer. The estimated emission suggests that there are many important sources and a composite emission abatement including most of the sources will be required to reduce the GHG emission. CH4 emission in the city is estimated to be 37078 tonne/yr. The top three contributors to CH4 emissions are livestock (61%), vehicles (18 %), and landfills (9%); these are based on annual emissions. Seasonal and daily emissions could be variable. N2O emissions are lower than CH4 emission ~ 7794 t/d. Nearly 92% of emissions are attributed to vehicular emissions. Power plants contribute 3% to N2O emission and are followed by domestic emission (0.5%).

GHG emission in Delhi and comparison with other cities:

In Delhi, the total annual GHG emission was estimated to be 37.91 million tonne of tCO2e. The fossil fuel consumption of coal and natural gas for electricity generation and fuels used in vehicles accounted for the major emissions in the city (82%). The per capita emission of Delhi city is 2.26 tonne per year tCO2e, which is lower than many of the top GHG emitting cities:
The green areas of the Delhi consist of forests, plantations, avenue trees, gardens and parks. The total estimated green area is 327.62 sq. km; of which, 176.62 sq. km is forest and 151 sq. km is mixed species in gardens, parks and major avenues. The data related to annual CO2

capture by trees and plants in the city of Delhi are estimated as: (i) total biomass: 1.7 million tonnes; (ii) total carbon: 0.85 million tonnes and (iii) total CO2 captured 3.1 million tonnes.

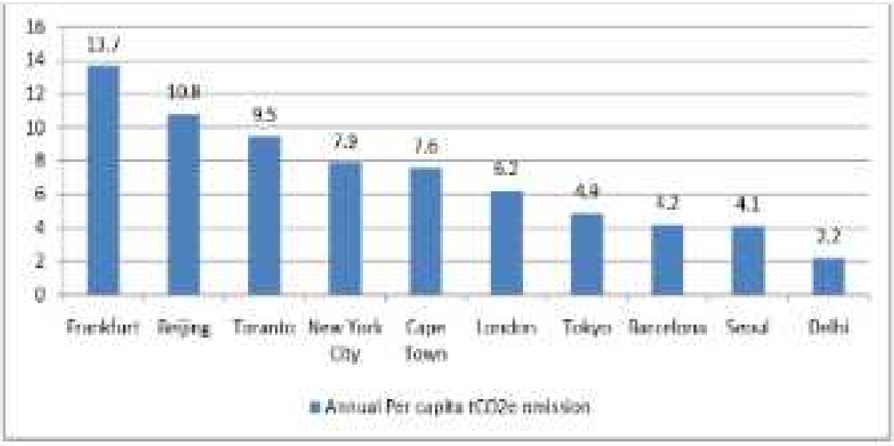


Figure 2: Annual per capita tCO2e emission of different cities (http://www.unep.org/)

Source: Source: Comprehensive Study on Green House Gases (GHGs) in Delhi

The GHG mitigation measures for various sources were analyzed. These sources include: power plants, livestock, coal usage, domestic fuel, street lights, burning of MSW, and vehicles. The major reduction in emission can be achieved by

(i) successive use of low carbon fuels (switching from coal to natural gas in power plants) followed by shifting about 20% generation to solar energy (estimated reduction of 11 million tones tCO2e i.e. 27% of total tCO2e emission) and

(ii) stop burning of MSW and converting the MSW into energy (estimated reduction of 3.12 million tonne tCO2e i.e. 8% of total tCO2e emission).

Table 3: Summary of Emission Load from Area Sources (kgs/day)

	PM 10	PM 2.5	NOx	SO2	CO
Industrial Stack	13681	6576	161838	128762	11646
Vehicle	12914	11623	113443	1155	322434
Road Dust	79626	22165	0	0	0
Hotels/Restaurants	3493	1758	1105	2710	6179
Domestic	7381	6940	7682	1232	25401
Aircraft	54	54	5416	380	4112
Industrial Areas	1614	1367	1893	5616	185
DG Sets	1387	1248	19604	1293	4234
MSW Burning	1968	1771	738	123	10332
Cremation	346	312	96	33	2129
Construction/Demolition	5167	1292	0	0	0
Concrete Batching	14370	3594	0	0	0
Agricultural Soil Dust	1353	0	0	0	0
Medical Incinerators	38	34	103	317	27
Total	143392	58734	311918	141621	386679

Source: Source: Comprehensive Study on Green House Gases (GHGs) in Delhi

Dispersion Modeling for Existing Scenario by IIT Kanpur:

USEPA's AERMOD model (described later) was run for PM_{10}, $PM_{2.5}$ and NOx to understand the impact of emissions occurring within Delhi on the ambient air at multiple locations.

Figure 3 and 4 show the highest 24-hr concentration isopleths for PM_{10} and $PM_{2.5}$ respectively. Although there are high pollution levels all around in Delhi, this analysis can be used for finding hotspots in the city. The hot spot for PM level point of view is Shahdara, East Delhi, Badarpur, Rithala and Badli Samaypur.

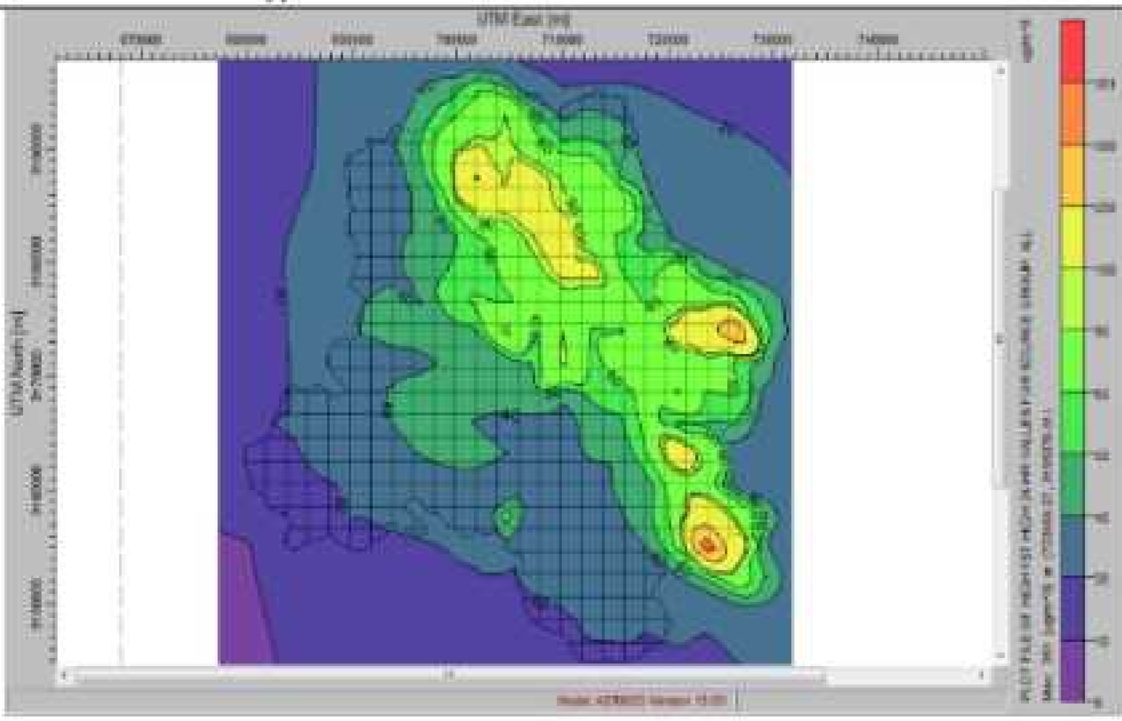


Figure 3: Isopleths of highest 24-hr values of PM_{10}

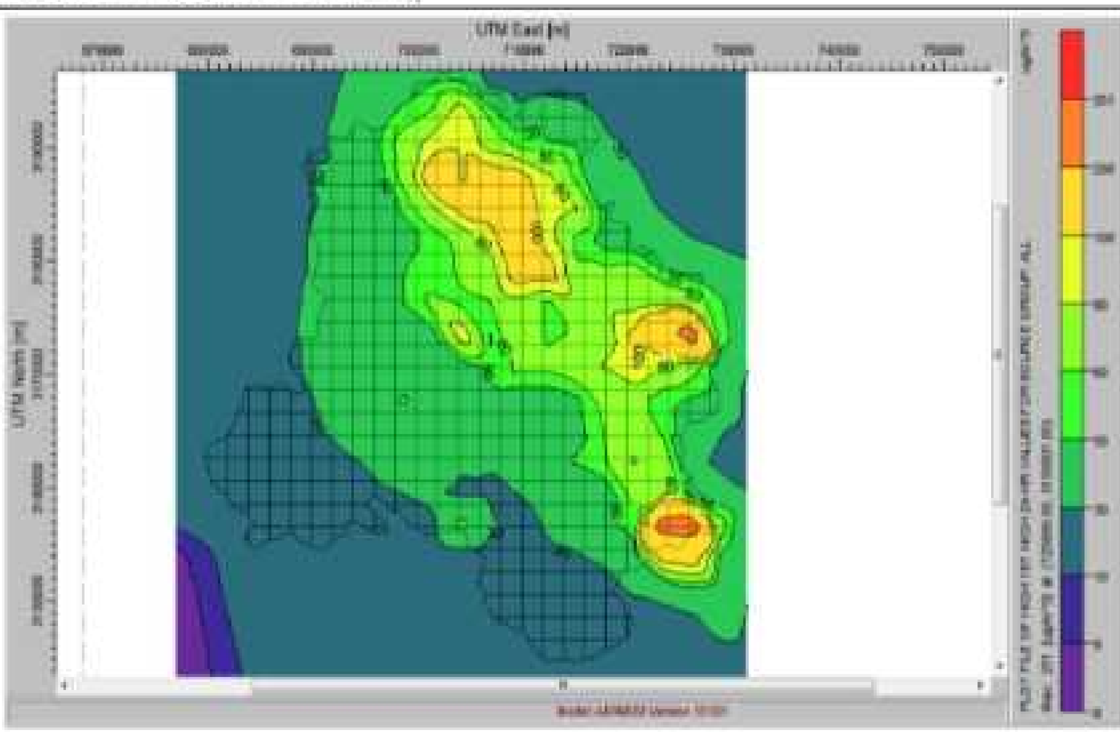


Figure 4: Isopleths of highest 24-hr values of $PM_{2.5}$

Source: Source: Comprehensive Study on Green House Gases (GHGs) in Delhi

A liner relationship between observed and computed levels of PM_{10} and $PM_{2.5}$ in winter months with R-square 0.53 – 0.88 shows that model describe the physics of dispersion and captures the impact of emission quite well.

The observed concentrations are much higher 1.6 to 3.0 times for PM_{10} and 1.4 to 2.8 times for $PM_{2.5}$ than the model computed concentrations in terms of slope of the best fit lines (as provided in SA Study by IIT Kanpur). This although not a desirable situation but at the same time not uncommon that the models under predict (CPCB, 2010; Behera et al., 2011). The model under prediction suggests incomplete emission inventory and/or missing sources. Although all efforts we made to account for all sources, uncertainties both in activity data and emission factor exist. Since the model does not account formation of secondary particles, this provides a plausible reason for under prediction.

What is interesting to note is that the best fit lines have very high intercepts; 170 µg/m3 and about 100 µg/m3 for $PM_{2.5}$. Since model performance in terms linear association is established for observed and computed concentrations, the large intercept concentration can be attributed to the background pollution in Delhi that appears to be contributed from outside Delhi. In other words, almost about one-third of pollution PM levels can be attributed to emissions from outside the Delhi. This analysis makes it clear that pollution control will have to focus both inside and outside Delhi for improvements in air quality not only in Delhi but the entire NCR.

3.2.2. Source Apportionment study by TERI

There was a study named "Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major in 2018 done by "The Automotive Research Association of India" and "The Energy and Resources Institute" who carried out source apportionment of $PM_{2.5}$ and PM_{10} concentrations in Delhi-National capital region (NCR) using two modelling-based approaches. The first approach relied upon monitoring and chemical characterization of $PM_{2.5}$ and PM_{10} samples. The chemically speciated samples along with source profiles were fed into the receptor model to derive source contributions. In the second approach, source-wise emission inventory, along with meteorological inputs and boundary conditions were fed into a dispersion model to simulate PM_{10} and $PM_{2.5}$ concentrations.

Air Quality Monitoring:

A comprehensive exercise of air quality monitoring was carried out for a period of two seasons in one year at 20 representative locations (9 in Delhi City, 4 in Uttar Pradesh, 7 in Haryana) in the NCR including kerbside, industrial, commercial, residential, and reference sites, which has different land use pattern and sources of activity.

In summer season, average concentration of PM_{10} at all monitoring sites across Delhi-NCR was 188 ± 37 µg/m3. Concentration of PM_{10} varied from 131 to 263 µg/m3. Similarly, average concentration of $PM_{2.5}$ in summer season was 90±17 µg/m3 varying from 65 to 130 µg/m3.

In winter season, average concentration of PM_{10} across all monitoring sites in Delhi-NCR was 314±77 µg/m3. Average maximum concentration was 441µg/m3 while minimum average concentration was 201µg/m3. Similarly, in $PM_{2.5}$, average concentration was 168±45 µg/m3 varying from92 to 254 µg/m3. Both PM_{10} and $PM_{2.5}$ average concentrations were found to be more than the prescribed standard limit by the Central Pollution Control Board (CPCB).

Site No.	Location	Site ID
1	ITO square	ITO
2	R. K. Puram, Sector 2	RKP
3	Bahadurgrah	BHG
4	Shahdara	SHD
5	Mayurvihar, Phase 1	MYR
6	Janakpuri	JNP
7	Chandani Chowk	CHN
8	Panipat	PNP
9	Naraiana Industrial Sector	NRN
10	Wazirpur Industrial Sector	WZP
11	Rohini, Sector 6	RHN
12	Sonipat	SNP
13	Ghaziabad 1	GHZ-1
14	Ghaziabad 2	GHZ-2
15	Noida- Sector 6	NOI-1
16	Noida- Sector 1	NOI-2
17	Huda sector, Gurgaon 1	GRG-1
18	Palam Vihar, Gurgaon 2	GRG-2
19	Faridabad 1	FBD-1
20	Faridabad 2	FBD-2

Figure 5: Location of the monitoring sites

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Chemical analysis of samples:

Chemical speciation of particulate matter samples collected on filter paper can be separated into the three most common categories: elements, ions (sulphates, nitrates, ammonium, etc.) and carbon fractions. Average chemical composition of PM_{10} and $PM_{2.5}$ at Delhi-city and NCR Towns in summer season:

PM_{10}: OC (organic carbon) was similar (~17%) at Delhi-city and NCR Towns. EC (elemental carbon) was found to be slightly higher at NCR Towns (~12%) compared to Delhi-city (~10%). contribution of crustal elements in Delhi City was 9% and in NCR Towns it was about 10%.

$PM_{2.5}$: Average chemical composition was found to be similar in both Delhi-city and NCR Towns. Both OC (~16%) and EC (~14%) were found to be similar. Both crustal elements (~4%–5%) and other elements (~6%–7%) were found to be similar. Chemical composition of PM_{10} and $PM_{2.5}$ at Delhi-city and NCR Towns in winter season:

PM_{10}: OC was found to be higher in Delhi-city, that is, ~19% compared to ~16% in NCR Towns. EC was found to be higher in Delhi-city (~14%) compared to ~12% in NCR Towns. Both crustal elements (~6%–7%) and other elements (~3%–4%) were found to be similar.

$PM_{2.5}$: contribution of OC was found to be about 20% in both Delhi city and NCR Towns. Similarly contribution of EC was about 15%. Contribution of crustal elements was found to be lower i.e. about 2% in Delhi city and about 3% in NCR Towns.

Receptor modeling

The fundamental principle of receptor models is that mass conservation can be assumed and a mass balance analysis carried out to identify and apportion sources of airborne particulate matter in the atmosphere. The approach to obtain a data set for receptor modeling is to determine a large number of chemical constituents, such as elemental concentrations in a number of samples.

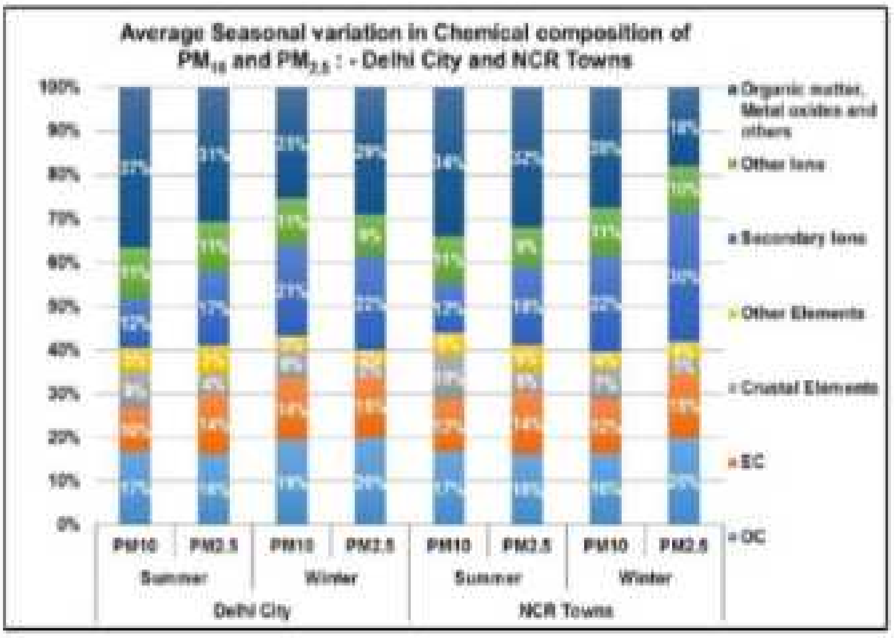


Figure 6: Average chemical composition of PM_{10} and $PM_{2.5}$ in NCR Towns (Panipat, Sonipat, Ghaziabad, Gurgaon, Noida, Faridabad and Bahadurgarh) and Delhi-city in summer and winter season

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Average source contribution to PM_{10} and $PM_{2.5}$ samples at representative sites in summer and winter season in Delhi-city and NCR Towns (Panipat, Sonipat, Ghaziabad, Gurgaon, Noida, Faridabad and Bahadurgarh)

PM_{10}:

Seasonal variation of PM_{10} shows higher contribution of dusty sources in summer (38%–42%) as compared to winter in Delhi-city as well as NCR Towns. This can be attributed to dry conditions and higher wind velocities resulting in entrainment of dust.

$PM_{2.5}$:

Seasonal variation of $PM_{2.5}$ shows significantly higher contribution of dusty sources in summer (31%–34%) as compared to winter (15%) in Delhi-city as well as NCR Towns. Higher contribution of dusty sources even in $PM_{2.5}$ can be attributed to dry conditions and higher wind velocities in summers resulting in contribution from far-off sources. Primary contribution of vehicles to $PM_{2.5}$ was higher in winter (20%–23%) in Delhi city and NCR Towns than in summer (18%–20%). Biomass burning contribution was significantly higher in winter in Delhi-city and NCR Towns (22%) than in summer (15%). contribution from industrial sources was similar in both summer and winter seasons in Delhi city (10%–11%) and NCR Towns (13%).

Variation in contribution of sources, such as vehicles, biomass burning, and dust, at various sites may be attributed to the variation in activities at the local level. Contribution from sources outside Delhi, such as agricultural waste burning, and dust particles may be expected.

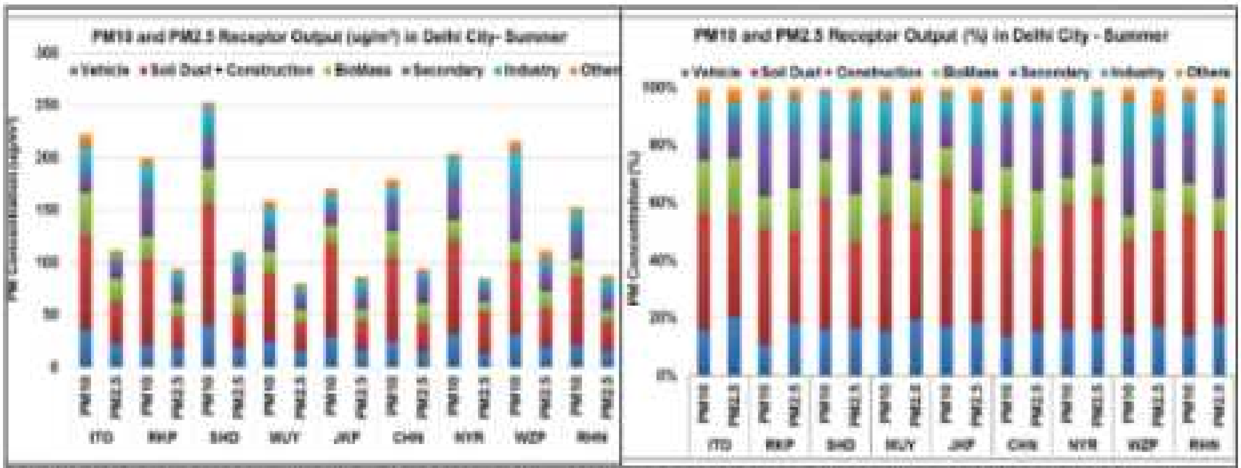


Figure 7: Receptor modeling output (µg/m3 and %) of PM_{10} & $PM_{2.5}$ in summer season at respective monitoring site in Delhi city

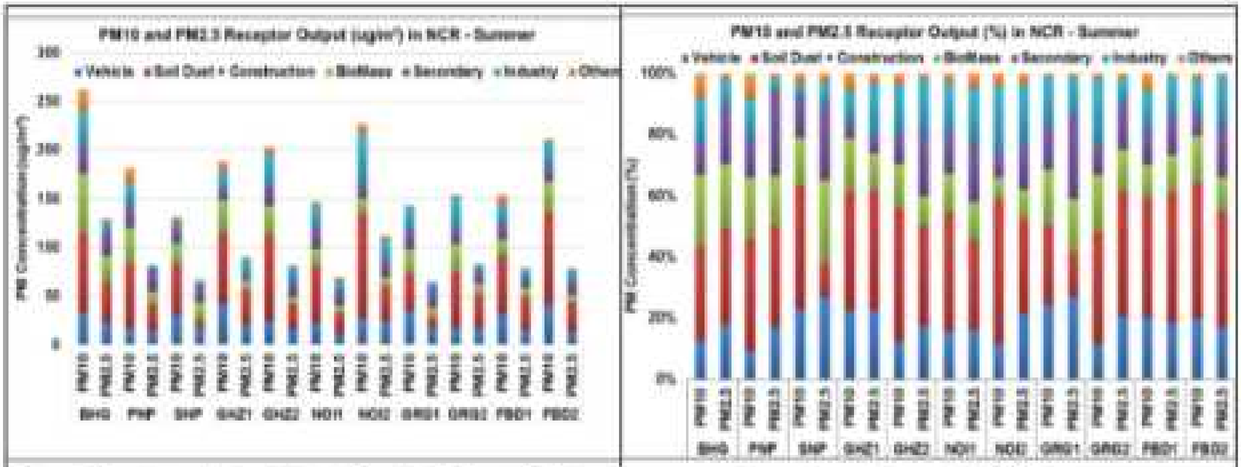


Figure 8: Receptor modeling output (µg/m3 and %) of PM_{10} and $PM_{2.5}$ in summer season at respective monitoring site in NCR Towns

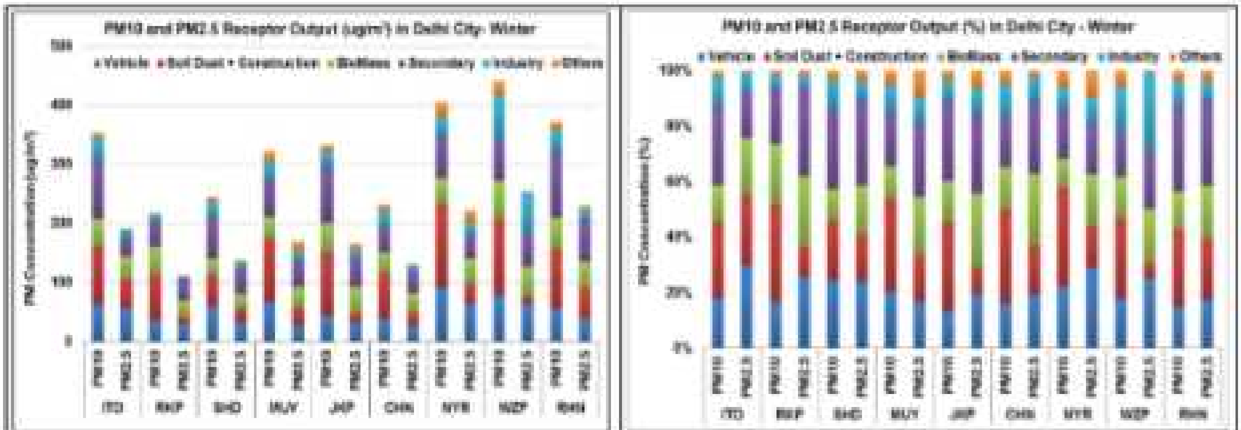


Figure 9: Receptor modeling output (µg/m3 and %) of PM_{10} and $PM_{2.5}$ in Winter Season at respective monitoring site in Delhi City

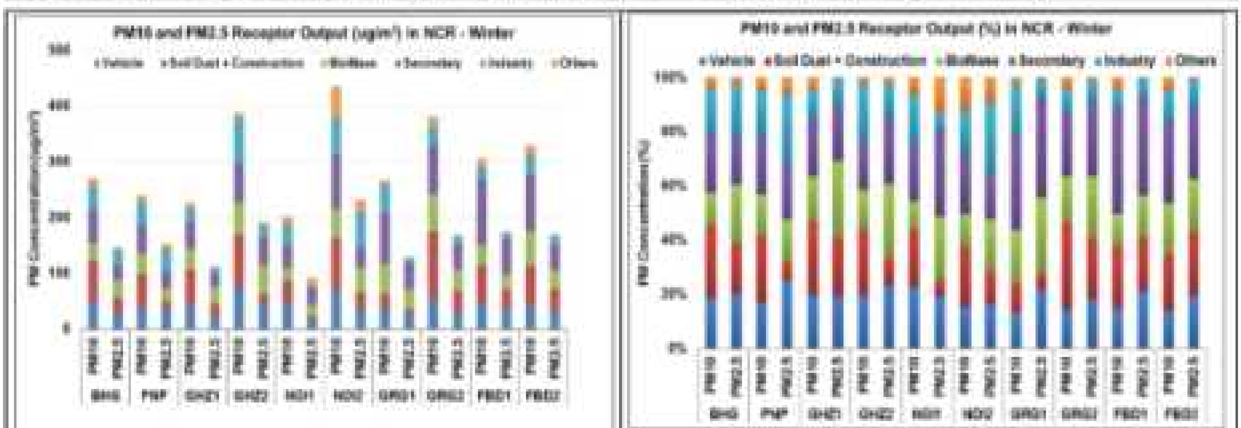


Figure 10: Receptor modeling output (µg/m3 and %) of PM_{10} and $PM_{2.5}$ in Winter Season at respective monitoring site in NCR Towns

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Emissions inventory

An emissions inventory of a given study region is a stock of all its pollution-emitting sources, such as vehicles, industries, power plants, road dust, construction dust, residential, diesel generator (DG) sets, biomass/waste burning, crematoria, and hotels. Developing an emissions inventory is a step in the bottom-up approach of apportioning sources. Apart from direct emissions estimates, emissions in these sectors are calculated by multiplying energy consumption with the emissions factor to derive the pollution per unit energy consumed. This information is an input to the dispersion model, which converts pollution estimates (mass/year) to ambient concentration (mass/volume). Ambient concentration is directly comparable to source apportionment estimated using receptor modeling.[1]
Source-wise multi-pollutants inventories of air pollutants have been prepared for the year 2016, at a high resolution of 4x4 km^2. Along with PM, inventories of sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs) have also been prepared to account for secondary particulates formation.

The major sectors which have been covered in the analysis are:
1)Residential,
2)Open agricultural residue burning,
3)Transport—tailpipe emissions ,
4)Construction,
5)Industries (including bricks and stone crushers),
6)Power plants- stacks, coal handling units and fly-ash ponds,
7)Road dust,
8)Diesel generators,
9)Refuse burning,
10)Crematoria,
11)Restaurants,
12)Airports,
13)Landfills,
14)Waste incinerators,
15) Solvents,
16) Ammonia emission sources, etc.
Ambient PM_{10} and $PM_{2.5}$ concentrations were simulated in this study using the WRF-CMAQ model combination. WRF model runs have been carried out to generate 3-dimensional meteorological fields over the study domain which acts as input to the CMAQ model along with emission inventories.

To account for contributions from outside NCR, India scale simulation runs have been carried out for the year 2016 using India-scale emissions inventory. In order to account for transport of pollutants from outside India, international boundary conditions have been adopted from global air quality products. Simulations have been performed for India and then for the NCR for the year 2016 to predict PM_{10} and $PM_{2.5}$ concentrations in NCR. The modeled concentrations were

1 Information used from: http://www.urbanemissions.info/publications/primer-on-pollution-source-apportionment

compared with the actual observations taken by ARAI for specific locations.

Table 4: Annual Emission Inventory of pollutants (kgs/day) in Delhi for 2016

SECTOR	PM10	PM2.5	NOX	SO2	CO	NMVOC
TRANSPORT	35068.4932	33972.6	347671.2	3013.699	1372877	937260.3
INDUSTRIES	3561.64384	3013.699	4383.562	12602.74	547.9452	0
POWER PLANTS	16712.3288	9589.041	30684.93	64657.53	9589.041	2465.753
RESIDENTIAL	7945.20548	5479.452	10136.99	547.9452	167397.3	34794.52
AGRICULTURAL BURNING	1369.86301	1095.89	273.9726	0	7397.26	821.9178
ROAD DUST	65753.4247	15890.41	0	0	0	0
CONSTRUCTION	38904.1096	7397.26	0	0	0	0
DG SETS	273.972603	0	1917.808	0	547.9452	273.9726
REFUSE BURNING	3835.61644	3287.671	1369.863	273.9726	12602.74	7397.26
CREMATORIUM	1095.89041	547.9452	273.9726	0	6027.397	3287.671
RESTAURANT	3835.61644	2191.781	1095.89	3561.644	6849.315	1095.89
AIRPORT	273.972603	273.9726	18082.19	1369.863	37260.27	19178.08
WASTE INCINERATORS	1369.86301	821.9178	11232.88	4383.562	2465.753	0
LANDFILL FIRES	4931.50685	4109.589	1643.836	273.9726	15890.41	6027.397
SOLVENTS	0	0	0	0	0	156986.3
TOTAL	184931.507	87671.23	428767.1	90684.93	1639452	1169589

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

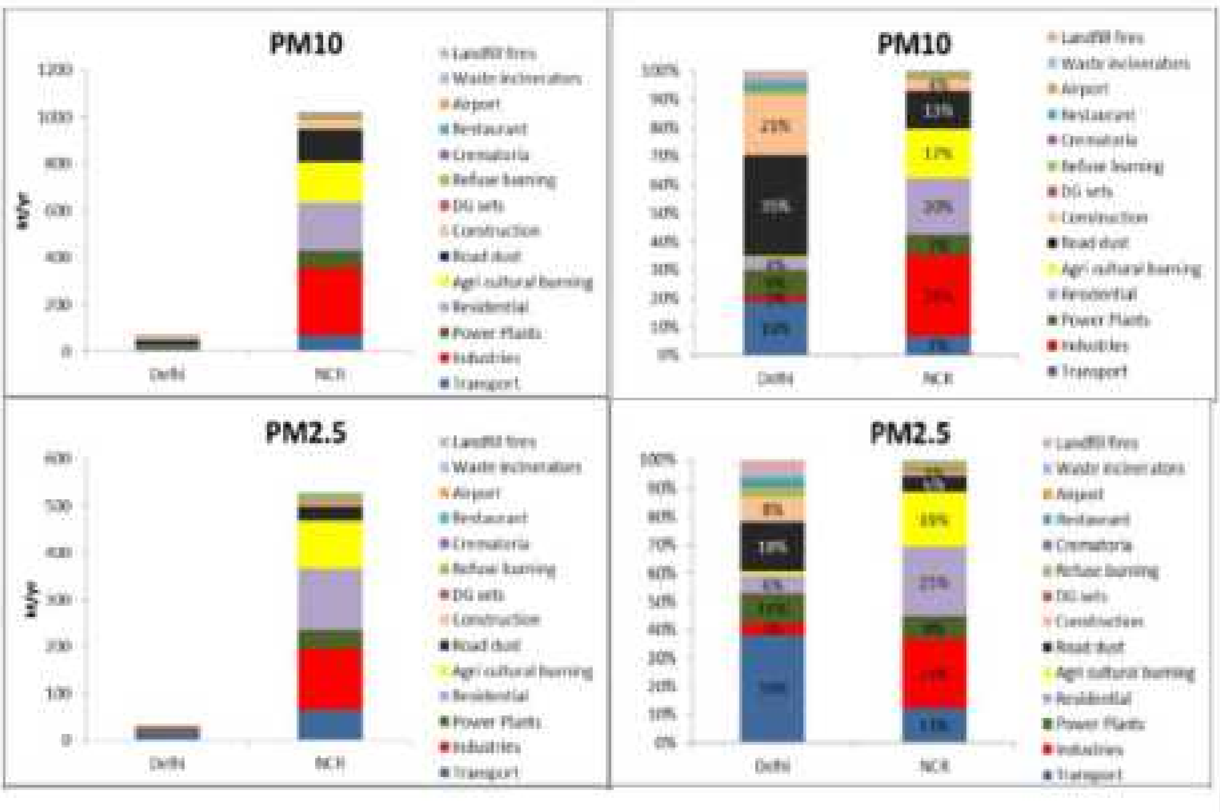


Figure 11: Absolute and percentage share of different sectors in overall inventory in NCR (including Delhi) and Delhi city

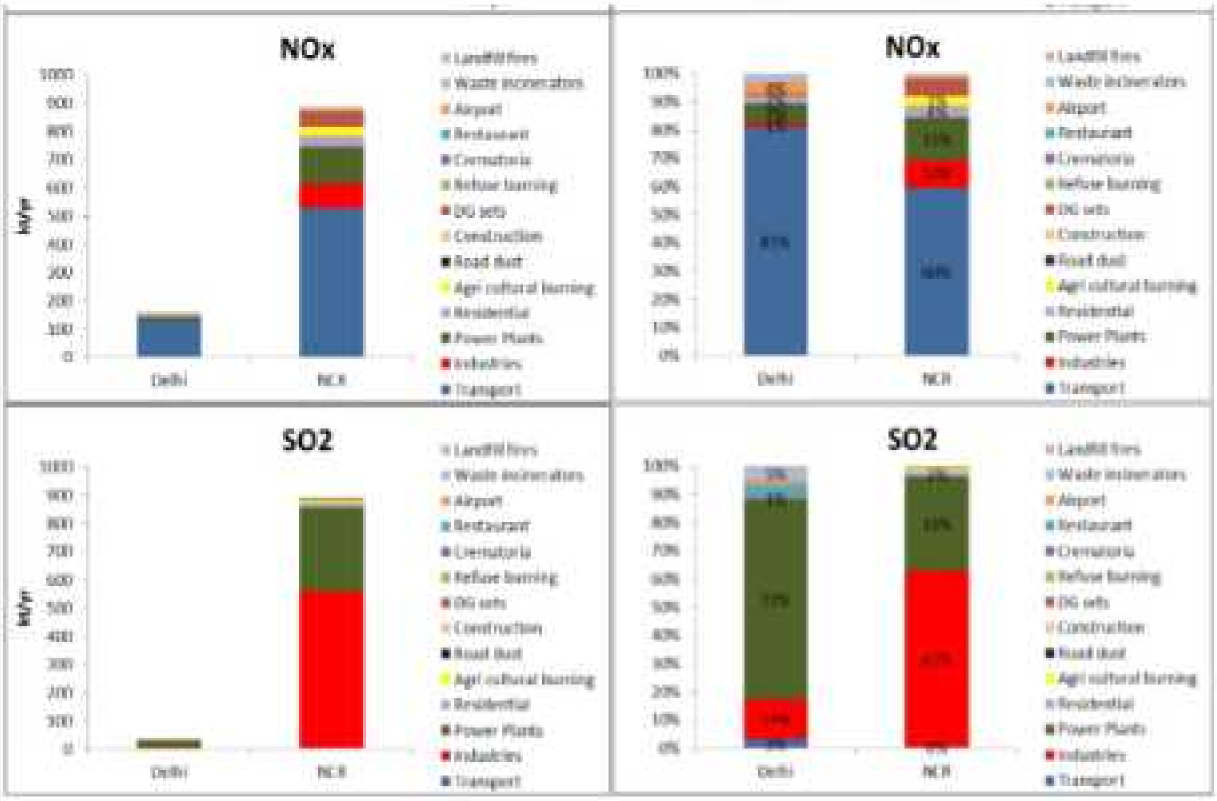


Figure 12: Absolute and percentage share of different sectors in overall inventory in NCR (including Delhi) and Delhi city

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Simulation of air quality: dispersion modeling:

Evidently, the concentrations are significantly higher during winter than in summer, due to adverse meteorological conditions. Reduction in wind speed and boundary layer height during winter reduces the dispersive capacity of the atmosphere and leads to higher concentrations of pollutants near the ground.

Table 5: Average sectoral contributions in $PM_{2.5}$ & PM_{10} concentrations in Delhi estimated using dispersion modeling during winters and summers

$PM_{2.5}$		
Sectors	**Winters**	**Summers**
Residential	10%	8%
Agri. Burning	4%	7%
Industry	30%	22%
Dust (soil, road, and const.)	17%	38%
Transport	28%	17%
Others	11%	8%
PM_{10}		
Sectors	**Winters**	**Summers**
Residential	9%	8%
Agri. Burning	4%	7%
Industry	27%	22%
Dust (soil, road, const.)	25%	42%
Transport	24%	15%
Others	10%	7%

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

The results of this study are broadly consistent with the IITK study with slight variations in magnitude. Contribution of dust in $PM_{2.5}$ concentrations is found to be somewhat higher in this study and share of biomass is lower. This is possibly because open agricultural burning activity could not be fully accounted for in the modeling period; also, there is reduction in residential biomass use due to enhanced LPG penetration in last few years. Dust contributions are understandably more in summers due to drier conditions and higher wind speeds, leading to dust suspension. Share of secondary particulates is higher in winter due to higher nitrate formation rates, than in summer.

Comparison of receptor and dispersion modeling results:

$PM_{2.5}$

The results of receptor modeling are also compared with the dispersion modeling. The receptor modeling results show primary sectoral contributions, and secondary particulates separately. It is to be noted that secondary particulates are also contributed by gaseous emissions from different sectors. The dispersion model was used to assess contribution of different sectors to secondary particulates. Using this, secondary particulates in the results of receptor modeling were allocated accordingly to different sectors to assess total sectoral contributions (primary and secondary).

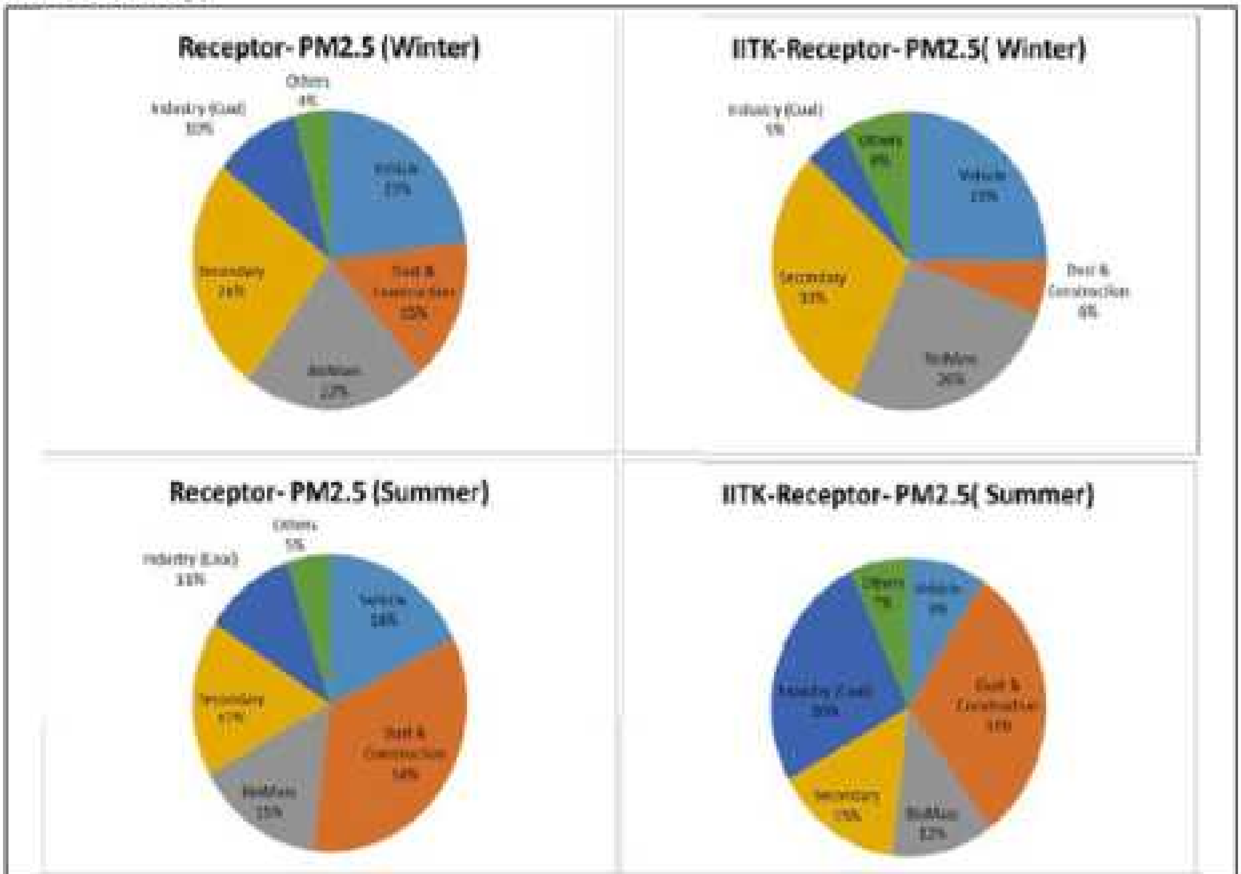


Figure 13: Average source contribution to $PM_{2.5}$ samples at representative sites in Delhi City

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

These two approaches are close for most sectors. It is to be noted that in the dispersion modeling approach, the industrial sector (which seems to be overestimated) includes biomass as an industrial fuel. Dust includes contributions from road dust re-suspension, construction activities, and trans-boundary international contributions. Based on the assessment of species, it may be concluded that in summers, trans-boundary contributions are mainly composed of dust. However in winters, there are also some trans-boundary contributions from sectors, such as biomass burning and industries also.

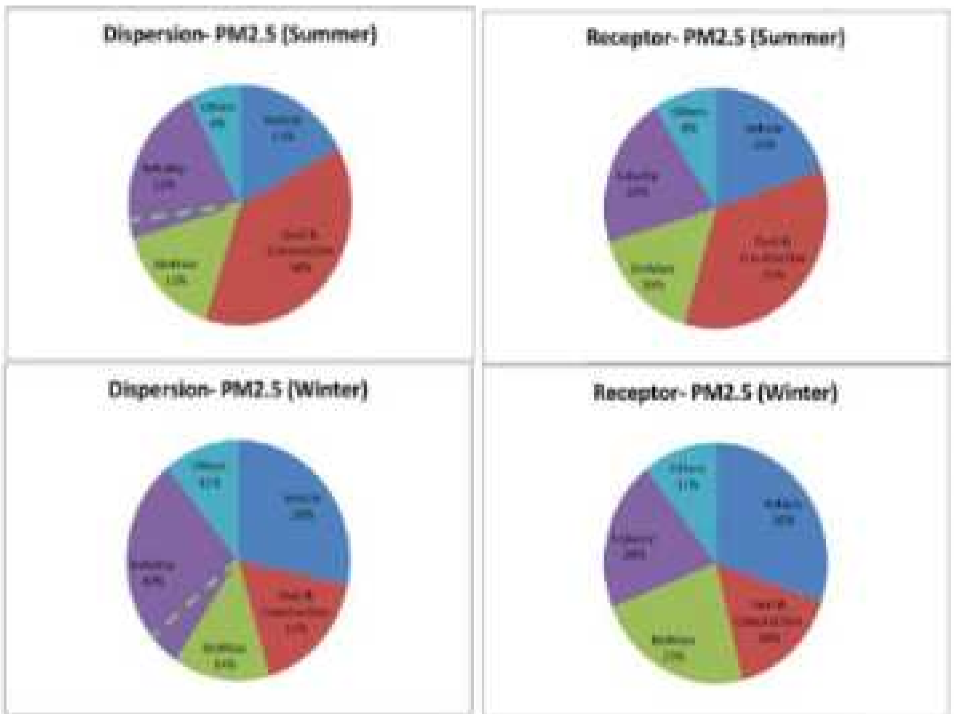


Figure 14: Comparison of results of dispersion and receptor model ling assessment for $PM_{2.5}$ in Delhi

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

* Green dotted line shows that some industries in NCR (which contribute to Delhi's air quality) also use biomass

Figure 14 shows that the results of the two approaches are close for most of the sectors. It is to be noted that in the dispersion modeling approach, the industrial sector (which seems to be overestimated) includes biomass as an industrial fuel. Dust includes contributions from road dust re-suspension, construction activities and natural dust contributions. Based on the assessment of species, it may be concluded that in summers, trans-boundary contributions are mainly composed of dust, However, in winters, there are also some contributions from sectors like biomass burning and industries as well.

Overall, the results of source apportionment seem to be consistent for most sectors in both the approaches. In the two seasons, the dispersion model shows contributions of transport sector as 17%-28%, in comparison to the receptor model estimations of 20%- 30%. These findings are higher than the contributions of the transport sector reported in IITK (2015) report, because in the present study they include secondary particulates along with the primary contributions. Results of source apportionment of PM_{10} show that dust is a major contributor to PM_{10} concentrations. The share of dust is 31% in winter, which increases to 42% in summer. The study shows lower contribution from industrial coal use, which may attribute to closure and limited operation of some of the power plants in the vicinity. Contribution of the transport sector to PM_{10} is somewhat higher in this study (15%-18%), than the IITK (2015) study (6%-20%).

PM_{10}

Comparison of results of dispersion modeling with receptor modeling for PM_{10} are shown in Figure 15. The results complement each other. Receptor modeling shows dust contributions of 31%-43%, which are shown to be in the range of 25%-41% by the dispersion modeling approach in the two seasons. The range of estimates for the transport sector is 15%-24% as per dispersion model runs in different seasons, while it is 17%-25% using the receptor model. Biomass burning consistently shows contributions in the range of 13%-15%. The two approaches show slight variation in industrial sector contributions, which ranges from 19%-27%. Green dotted line in figure 18 shows that some industries in NCR, (which contribute to Delhi's air quality) also use biomass

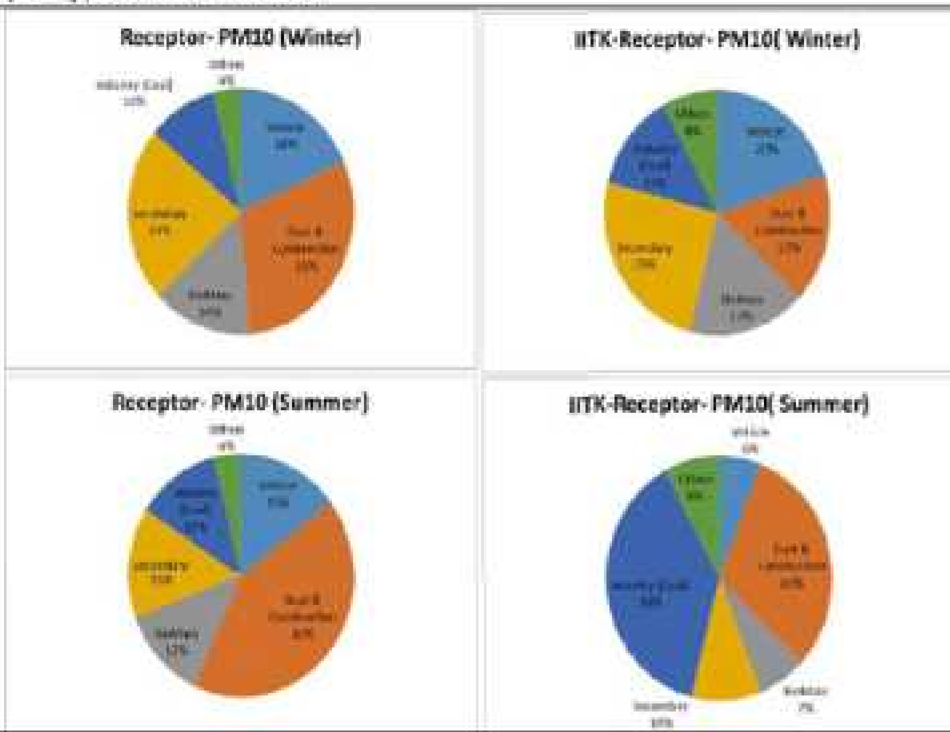


Figure 15: Average source contribution to PM_{10} samples at representative sites in Delhi City

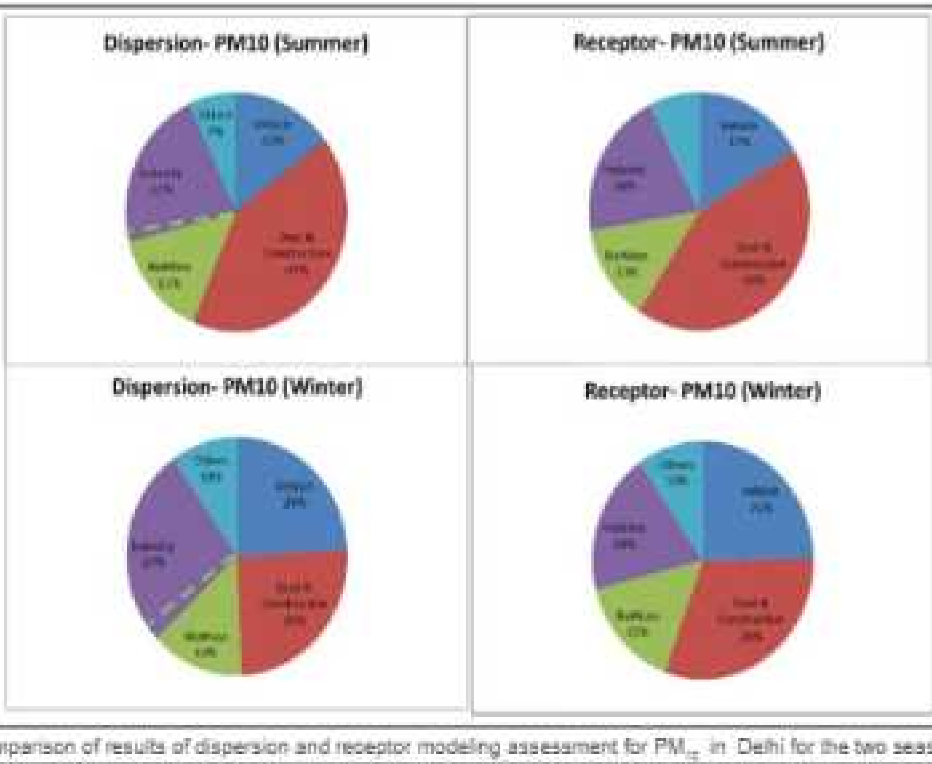


Figure 16: Comparison of results of dispersion and receptor modeling assessment for PM_{10} in Delhi for the two seasons

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Sub-sectoral contributions to PM_{10} and $PM_{2.5}$ concentrations in Delhi and NCR:

In the residential sector, biomass fuel is the dominant factor contributing to $PM_{2.5}$ and PM_{10} concentrations. It contributes to 8%–10% in $PM_{2.5}$ and 8%–9% in PM_{10} concentrations in the two seasons. Within the 30% contribution of the industrial sector in $PM_{2.5}$ concentrations (winter) in Delhi, 8% is contributed by bricks sector, 6% by power stations, 2% by stone crushers, while other industries (using coal, biomass, pet-coke, and furnace oil) contributed to about 14%. Later, in 2017, pet coke and furnace oil (FO) use were banned in the region. In the others category (within the overall contribution of 11% in winters $PM_{2.5}$ concentrations), DG sets (because of high PM and NO_x emissions) contribute significantly (5%), followed by refuse burning (3%), and the rest other sources contributed to less than 1% each, towards winters $PM_{2.5}$ concentrations. In the dust category, road dust and construction sectors have 4% and 1% contributions in $PM_{2.5}$ concentrations, respectively. Within the transport sector in Delhi, trucks have the highest share of 8%, followed by two-wheelers (7%), and three-wheelers (5%). This is due to their higher shares in either or both $PM_{2.5}$ and NO_x emissions.

Table 6: Sectoral shares estimated by dispersion and receptor modeling for various towns in NCR

NCR-Towns	Season	Parameter	Dispersion Modelling					Receptor Modelling				
			Vehicle	Dust	Biomass	Industries	Others	Vehicle	Dust	Biomass	Industries	Others
Bahadurgarh	Summer	PM_{10}	17%	49%	13%	16%	5%	14%	31%	24%	19%	12%
		$PM_{2.5}$	22%	39%	15%	19%	5%	20%	32%	21%	17%	10%
	Winter	PM_{10}	21%	40%	11%	22%	6%	20%	28%	13%	25%	14%
		$PM_{2.5}$	28%	26%	12%	27%	7%	24%	19%	23%	24%	10%
Panipat	Summer	PM_{10}	21%	31%	18%	25%	5%	10%	37%	21%	18%	14%
		$PM_{2.5}$	22%	33%	17%	23%	5%	20%	34%	18%	15%	13%
	Winter	PM_{10}	22%	25%	16%	31%	6%	18%	26%	16%	28%	14%
		$PM_{2.5}$	27%	12%	18%	35%	8%	29%	8%	16%	32%	15%
Ghaziabad	Summer	PM_{10}	8%	41%	12%	35%	4%	18%	42%	16%	17%	7%
		$PM_{2.5}$	10%	37%	14%	34%	5%	21%	36%	12%	23%	8%
	Winter	PM_{10}	13%	31%	16%	35%	5%	22%	27%	16%	24%	11%
		$PM_{2.5}$	18%	19%	18%	39%	6%	26%	16%	29%	18%	11%
Noida	Summer	PM_{10}	13%	47%	12%	22%	6%	15%	44%	10%	23%	8%
		$PM_{2.5}$	15%	46%	13%	20%	6%	20%	31%	12%	26%	11%
	Winter	PM_{10}	25%	29%	12%	25%	9%	21%	23%	12%	26%	18%
		$PM_{2.5}$	30%	20%	12%	28%	10%	23%	10%	22%	24%	21%
Gurgaon	Summer	PM_{10}	14%	52%	13%	13%	8%	19%	32%	19%	24%	6%
		$PM_{2.5}$	16%	49%	14%	13%	8%	26%	29%	16%	19%	10%
	Winter	PM_{10}	23%	30%	14%	26%	7%	16%	23%	20%	26%	15%
		$PM_{2.5}$	27%	20%	15%	30%	8%	26%	15%	27%	17%	15%
Faridabad	Summer	PM_{10}	9%	46%	18%	18%	9%	21%	42%	14%	16%	8%
		$PM_{2.5}$	10%	46%	18%	17%	9%	19%	41%	12%	21%	7%
	Winter	PM_{10}	21%	19%	18%	32%	10%	18%	23%	17%	24%	19%
		$PM_{2.5}$	24%	13%	18%	34%	11%	27%	23%	19%	18%	14%

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Note: Share of sources vary across cities because of sources and also because of changing meteorology as the period monitoring varied across three months within a season.

Table 7: Sub-sectoral contribution to $PM_{2.5}$ in Delhi in winter 2016

Sector	Sub-sector	Delhi
Residential		10%
	Biomass	9%
	Kerosene	1%
	LPG	0.1%
Agricultural burning	Biomass	4%
Industry		30%
	Power plant	6%
	Bricks	8%
	Stone crushers	2%
	Other industries	14%
Others		11%
	DG sets	5%
	Refuse burning	3%
	Crematoria	0.2%
	Restaurant	1%
	Airport	1%
	Waste incinerators	1%
	Landfill fires	0.4%
Dust		17%
	Road dust	4%
	Construction	1%
	Others	12%
Transport		28%
	Truck	8%
	Tractor	1%
	Bus	3%
	Cars	3%
	2 wheelers	7%
	3 wheelers	5%
	LCVs	1%

Table 8: Sub-sectoral contribution to PM_{10} in Delhi in winter 2016

Sector	Sub-sector	Delhi
Residential		7%
	Biomass burning in kitchen	6%
	Kerosene	1%
	LPG	0%
Agricultural burning	Biomass	4%
Industry		27%
	Power plant	5%
	Bricks	7%
	Stone crushers	3%
	Other industries	12%
Others		10%
	DG sets	4%
	Refuse burning	4%
	Crematoria	0.2%
	Restaurant	0.6%
	Airport	0.4%
	Waste incineration	0.6%
	Landfill fires	0.4%
Dust		22%
	Road dust	8%
	Construction	4%
	Others	11%
Transport		24%
	Truck	7%
	Tractor	1%
	Bus	2%
	Cars	3%
	2 wheelers	6%
	3 wheelers	4%
	LCVs	1%

Table 9: Sub-sectoral contribution to $PM_{2.5}$ in Delhi in summers 2016

Sector	Sub-sector	Delhi
Residential		8%
	Biomass burning in kitchen	7%
	Kerosene	1%
	LPG	0.1%
Agricultural biomass burning	Biomass	7%
Industry		22%
	Power plant	7%
	Bricks	5%
	Stone crushers	1%
	Other industries	8%
Others		8%
	DG sets	2%
	Refuse burning	4%
	Crematoria	0.2%
	Restaurant	0.4%
	Airport	0.2%
	Waste incineration	0.3%
	Landfill fires	0.5%
Dust		38%
	Road dust	3%
	Construction	2%
	Others	33%
Transport		17%
	Truck	5%
	Tractor	1%
	Bus	1%
	Cars	2%
	2 wheelers	4%
	3 wheelers	3%
	LCVs	1%

Table 10: Sub-sectoral contribution to PM_{10} in Delhi in summers 2016

Sector	Sub-sector	Delhi
Residential		6%
	Biomass	6%
	Kerosene	0.3%
	LPG	0.1%
Agri. Burning	Biomass	7%
Industry		22%
	Power plant	7%
	Bricks	5%
	Stone crushers	2%
	Other Industries	8%
Others		7%
	DG sets	2%
	Refuse burning	4%
	Crematoria	0.3%
	Restaurant	0.5%
	Airport	0.1%
	Waste incineration	0.2%
	Landfill fires	0.4%
Dust		42%
	Road dust	10%
	Construction	4%
	Others	28%
Transport		13%
	Truck	3%
	Tractor	1%
	Bus	1%
	Cars	2%
	2 wheelers	4%
	3 wheelers	3%
	LCVs	0.5%

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Geographical contributions:

The study done by TERI also estimated the contribution of various regions towards $PM_{2.5}$ and PM_{10} concentrations in Delhi and NCR Towns. The average contribution of Delhi's own emissions in Delhi's $PM_{2.5}$ concentrations was found to be 36% in winters and 26% in summers. However, there are variations across different places in the city (Figure 17). This finding is in-line with other recent studies for Delhi (Marrapu et al., 2014; IITK, 2015; Kiesewetter et al., 2017). In summers, the contribution of outside sources is higher on account of higher wind speeds and enhanced atmospheric transport of pollutants. In the NCR Towns, the contribution of emissions from Delhi city varies as per their location with respect to Delhi and prevailing wind directions. NOIDA city which is downwind of Delhi receives 28% and 40% of its $PM_{2.5}$ concentrations from Delhi-based sources, in summer and winter seasons, respectively. On the other hand, Panipat which is upwind of Delhi receives only 1% contribution from Delhi and shows 56%–70% contribution from the remaining NCR regions. Ghaziabad also receives its major (61%–70%) contribution from NCR only.

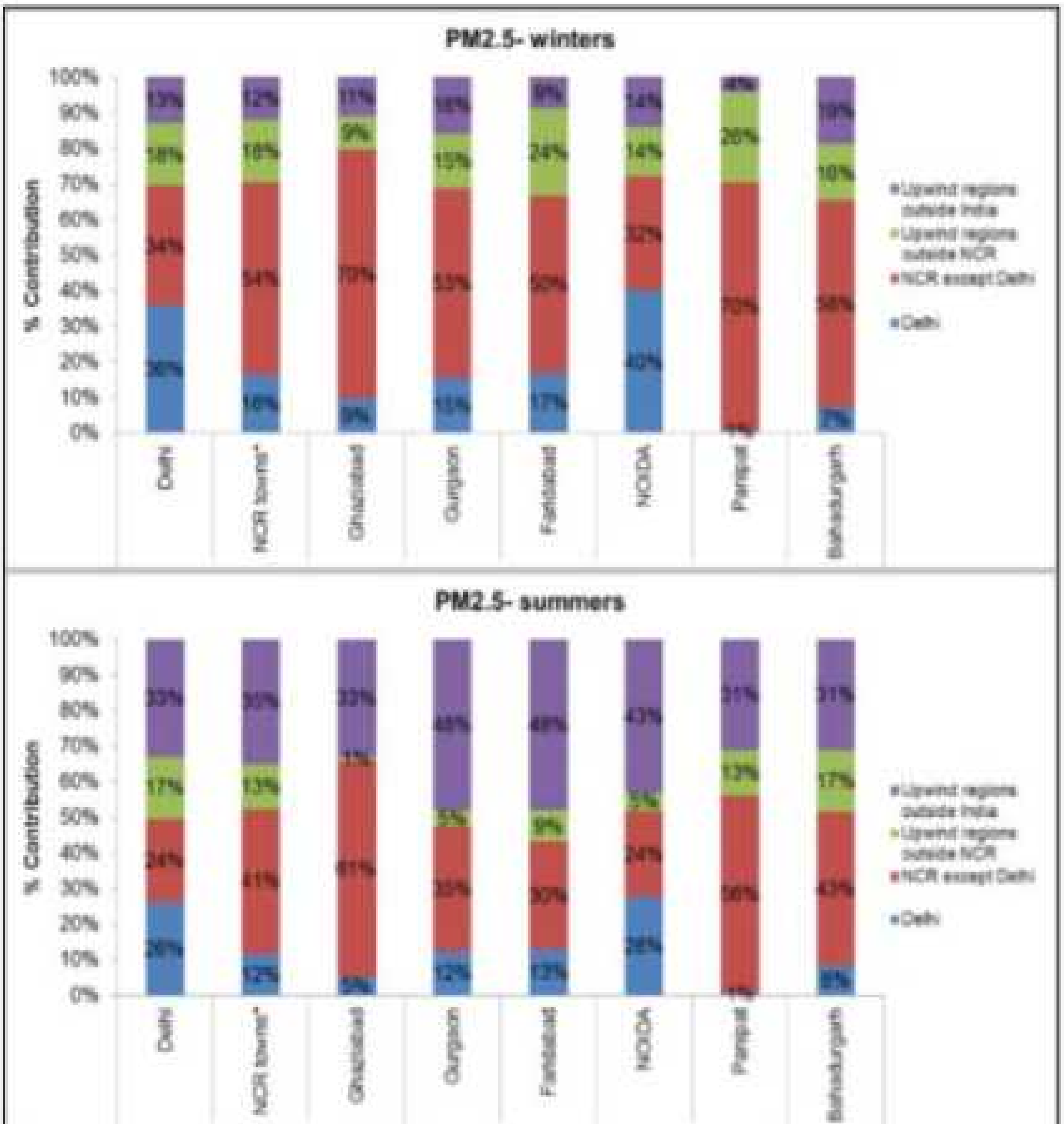


Figure 17: Contribution of various geographical regions in $PM_{2.5}$ concentrations in different towns during summer and winter seasons

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Note: Share of different regions vary across different cities because of sources and also because of changing meteorology as the period monitoring varied across three months within a season.
* Average of NCR towns excluding Delhi. The contribution of nearby districts like Gurgaon, Faridabad, Noida, Ghaziabad, Jhajjar, and Sonipat in Delhi's $PM_{2.5}$ concentration was 23%-24%.

3.3. Conclusions of Studies

Source Apportionment Studies

Air pollution levels are extremely high in Delhi and NCR, especially in winters.

The assessment of both the scientific approaches reveals that transport, biomass burning, and industries are the three major contributors to $PM_{2.5}$ concentration in Delhi NCR during winter. In summer, the contributions of dust from inside and outside of India eclipses the shares of these three major sectors in the $PM_{2.5}$ concentrations, however, the contributions still remain significant. The assessment for PM_{10} shows that other than transport, biomass burning, and industries, road dust and construction dust also contribute significantly to concentrations. Like $PM_{2.5}$, during summers, the contributions of dust from outside of India reduce the shares of these local sectors in the PM_{10} concentrations.

The study has quantified the contributions of different sources at present and in future time-frames (2025–2030). The $PM_{2.5}$ concentrations are expected to increase by 5% in 2025 and by 8% in 2030 with respect to 2016, in a BAU scenario. The PM_{10} concentrations are expected to increase by 16 and 23% in 2025 and 2030, respectively, in a BAU scenario. This is after accounting for growth in different sectors and also taking into account the possible enforcement of the interventions which have already been notified for control of air pollution. Discounting these planned interventions, the growth in $PM_{2.5}$ concentrations could be 30% higher in 2030.

The study analyzed various interventions and estimated their possible impacts over $PM_{2.5}$ and PM_{10} concentrations in Delhi and NCR. An alternative scenario has been developed considering the interventions which can provide maximum air quality benefits. The alternative scenario results in a reduction of 58% and 61% in $PM_{2.5}$ and PM_{10} concentrations in 2030, with respect to the BAU scenario, and achieves the daily ambient air quality standards for PM_{10} and $PM_{2.5}$.

The interventions which have identified as the ones with highest impact on PM concentrations in 2030 are:

- Complete phase out of biomass use in NCR by enhanced LPG penetration in rural households
- Use of agricultural residues in power plants and other industries to replace high ash coal and open burning in fields
- Introduction of gaseous fuels and enforcement of new and stringent SO2/NOx/$PM_{2.5}$ standards for industries using solid fuels
- Strict implementation of BS-VI norms
- Improvement and strengthening of inspection and maintenance system for vehicles
- Fleet modernization and retro-fitment programmes with control devices
- Enhanced penetration of electric and hybrid vehicles

- Reducing real world emissions by congestion management
- Stricter enforcement of standards in large industries through continuous monitoring
- Full enforcement of zig-zag brick technology in brick kilns
- Vacuum cleaning of roads, wall to wall paving of roads
- Control of dust from construction activities using enclosures, fogging machines, and barriers
- Elimination of DG set usage by provision of 24x7 electricity and control by innovative tail-pipe control technologies.

Emission Inventory Studies

Several emissions inventories have been developed for Delhi or larger areas that include the NCR. These inventories contribute to source apportionment studies. Often, this drive pollution control decision making in the region by statutory agencies such as the Environment Pollution Prevention and Control Authority (EPCA), Central Pollution Control Board (CPCB), and other State Pollution Control Boards (SPCB).

Few studies compare emissions inventories across anthropogenic and combustion related emissions of air pollutants or analyze uncertainties in inventory measurement (input parameters). Therefore, the extent of uncertainty in source apportionment (output parameter) is unclear.

Five inventories developed over the past decade for Delhi or the NCR (CPCB 2010; IIT Kanpur 2016; TERI 2018; SAFAR 2018; Guttikunda 2018) were studied by CEEW. All the studies used the bottom up approach to develop their emissions inventory.

Emissions of $PM_{2.5}$ and PM_{10} were compared from source sectors including transport, industries, power plants, residential, road dust, construction, DG sets, biomass/waste burning, crematoria, hotels, and others. These 10 categories were common to all the studies and were therefore suitable for comparison.

A description of the emissions inventories are presented in Table 11. The inventories were developed for different years ranging from 2007 to 2018. Each study developed the inventory for a particular year i.e. no multi-year inventories were available.

Table 11: Comparison of Emission Inventories of Delhi

	CPCB (2010)	Guttikunda (2012)	IIT Kanpur (2016)	TERI (2018)	SAFAR (2018)	Guttikunda (2018)
Year	2007	2010	2013-14	2016	2018	2018
Season	NA	Dispersion Modeling	Winter and Summer	Winter and Summer	Summer	Continually Updated
Area	Delhi	NCT Delhi	Delhi	Delhi	NCR	NCT Delhi, Gurgaon, Faridabad, Ghaziabad cities
Horizontal Resolution	2 x 2 km^2 Grid for 10 zones near monitors extrapolated to city	1 x 1 km^2 grid for entire city	2 x 2 km^2 grid for the entire city	4 x 4 km^2 Grid for entire study area of 292 km x 364 km^2	400 x 400 m^2 for an area of 70 km x 65 km^2	1 x 1 km^2 resolution for an area of 80 km x 80 km^2
Total PM_{10} Emissions (kt/year)	64.73	114	52.34	67.49	268.40	238.68

	CPCB (2010)	Guttikunda (2012)	IIT Kanpur (2016)	TERI (2018)	SAFAR (2018)	Guttikunda (2018)
Total $PM_{2.5}$ Emissions (kt/year)	NA	63	21.39	31.99	107.70	99.15
Total PM_{10} Emissions (kgs/day)	177000	312328.767	143392	184931.5068	732553.42	654000
Total $PM_{2.5}$ Emissions (kgs/day)	NA	172602.74	58734	87671.23	295304.11	271643.836

Source: Understanding Uncertainties in Emissions Inventories, CEEW

Two studies (CPCB and IIT Kanpur) were limited to Delhi and three (Guttikunda, SAFAR, and TERI) to the NCR. Among the studies of the NCR, Guttikunda (2018) covered only urban areas of Delhi - Gurugram, Faridabad, and Ghaziabad - and excluded rural areas. The SAFAR study considered Gurugram, Faridabad, Sonepat, and Jhajjhar (Haryana) and Ghaziabad, Baghpat, and Gautam Buddha Nagar (Uttar Pradesh).

In the SAFAR study, a primary survey was carried out with the help of 150 students guided by scientists to generate missing primary data, validate secondary data, and collect available secondary data. Information was found for 26 sources of air pollution, but the final estimate has been presented for six categories - transport, industries, power plants, residential, wind-blown dust, and others. The 'others' category contains the rest of the 20 sources of air pollution, such as slums, brick kilns, street vendors, hotels, dhabas, construction sites, hospitals, tourist places, shopping malls, traffic junctions, railways, airports, waste burning, burning of biomedical waste, crematoria, schools and colleges, diesel generator sets, mobile towers, and milk and vegetable vans.

The TERI study considered particulate formation through secondary pollutants. Secondary pollutants are formed by the chemical reaction when primary pollutants interact with the atmosphere. Photochemical smog, for example, is a secondary pollutant formed when the sun's ultraviolet rays react with nitrogen oxides in the atmosphere. Secondary particulate concentration is estimated through a model output. TERI used, in addition to the dispersion model, the Community Multiscale Air Quality Modeling System (CMAQ) as it can accept multiple pollutants simultaneously and also include photochemistry. Therefore, at the emissions inventory level, the numbers only represent the primary pollutants, which have been considered for comparison.

The CPCB study did not develop an inventory for $PM_{2.5}$. All other studies included inventories for particulate matter (PM_{10}), sulphur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons, and black carbon.

Variations in emissions inventories

Figures 18 and 20 display the variations in emissions inventory for PM_{10} and $PM_{2.5}$ across the five studies, and Table 12 details the maximum and minimum percentage values associated with each sector. For the analysis, the main sectors we consider are transport, industries, power plants, residential, road dust, construction, DG sets, biomass/waste burning, crematoria, and hotels and restaurants. The 'other' category includes emissions from landfills, airports, waste/ hospital incinerators, concrete batching, and agriculture.

Road dust contributes the maximum to the PM_{10} pollutant load, varying from 35 per cent to about 66 per cent across studies, and differing by a factor of two. The next biggest contributors include power plants and transportation. For $PM_{2.5}$, transport and road dust are the largest contributors to pollutant loads. Together, these two categories account for over 40 per cent of the total $PM_{2.5}$ load across all studies.

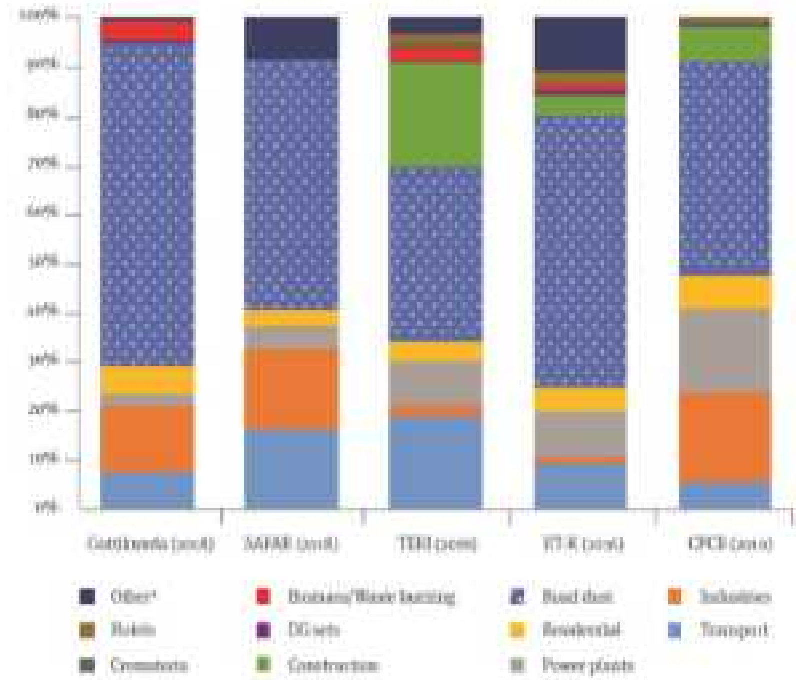


Figure 18: Sector-wise contribution to PM_{10} (%)

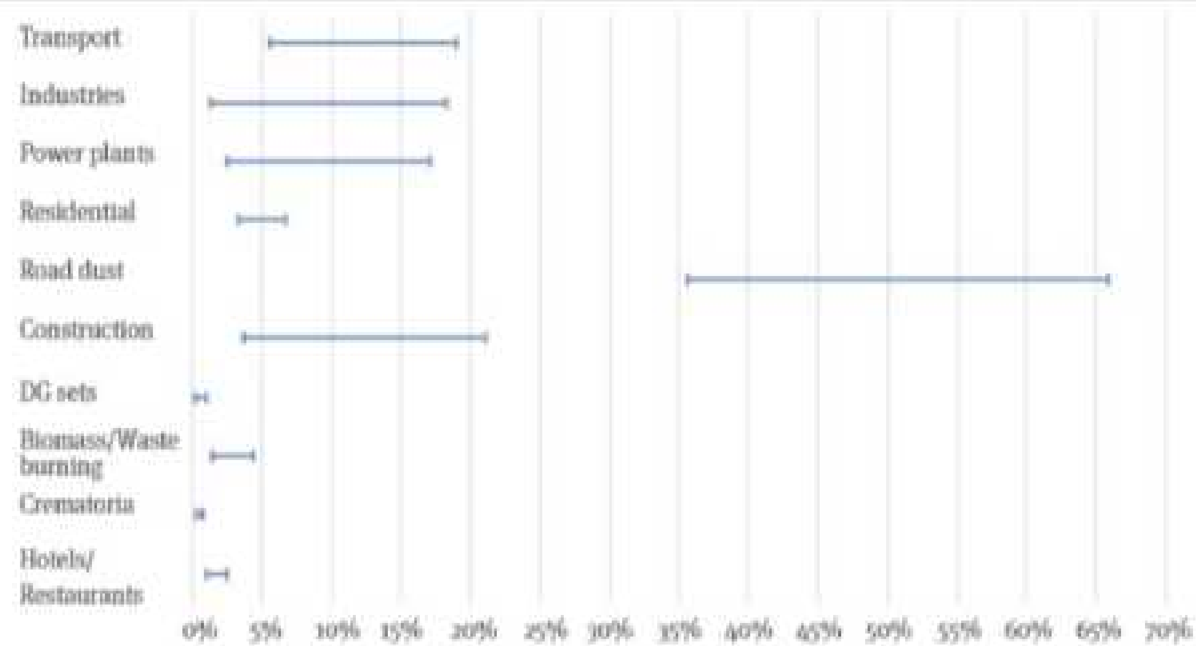


Figure 19: Sector-wise variation in the emission inventory for PM_{10} (%)

Source: CEEW analysis, 2019

Figure 19 shows the variation by sector for PM_{10} and Figure 21 for $PM_{2.5}$. The 'others' category has been dropped, as they are not comparable. It was observed that there is high variation across the major pollutant categories of transport, industries, power plants, road dust, and construction.

These variations in sectoral emissions can lead to a large variance in the concentration of pollutants and to uncertainty around the actual contribution of each source to pollution. This can also lead to ineffective policy measures as the primary sources of pollution remain contested.

Figure 20: Sector-wise contribution to $PM_{2.5}$ (%)

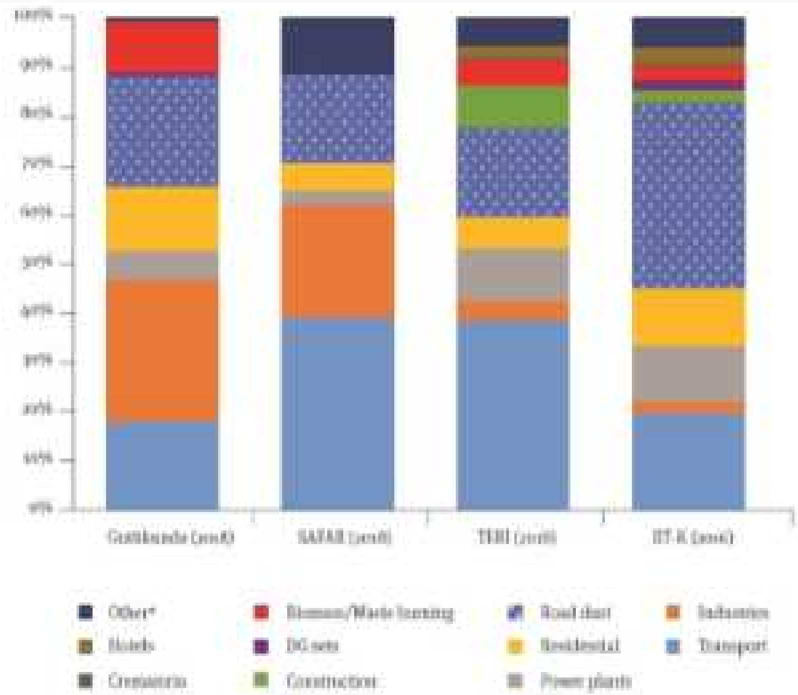
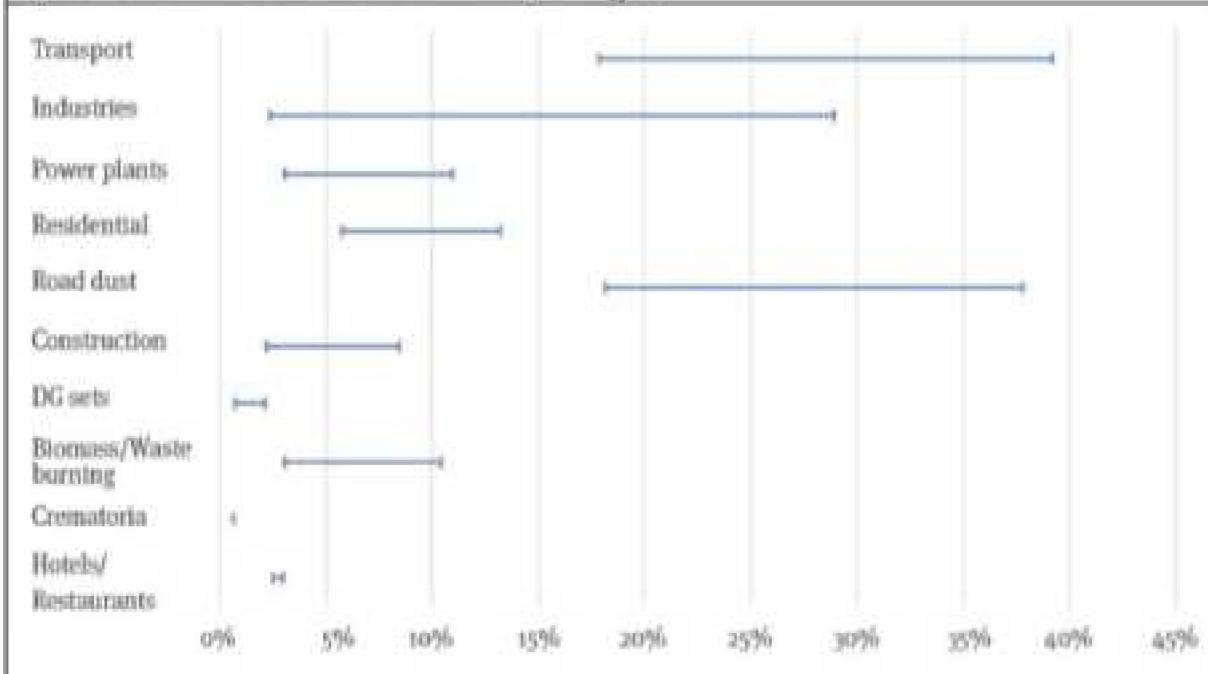


Figure 21: Sector-wise variation in the emission inventory for $PM_{2.5}$ (%)



Source: CEEW analysis, 2019

Table 12: Summary of variation in the emissions inventory for PM_{10} & $PM_{2.5}$ in five key sectors

Sector	Variation	
	PM_{10} (%)	$PM_{2.5}$ (%)
Transport	5.5-19.0	17.9-39.2
Industries	1.3-18.3	2.3-28.9
Power plants	2.5-17.0	1.1-11.0
Road dust	35.6-65.9	18.1-37.8
Construction	3.6-21.0	2.2-8.4

Source: CEEW analysis, 2019

3.4. Air Sheds

There was a study done in Philadelphia to reduce the air pollution and high temperature in the year of 1957-59, the brief study summaries here and the how the Airsheds model is working in metropolitan cities is described below.

The central phase of air pollution is linked to temperature inversion, during which the air near the ground does not rise to be replaced by clear nights with little wind, the earth is cooled by long-wave radiation and the air near the ground is cooled by the ground. During such temperature inversion with stable surface air layers, air movement is limited; In cities, pollution become increasingly concentrated. In 'Philadelphia' "significant" inversion occur in one night in three. Parallel and related to inversion is the incidence of high pollution levels, which occur on twenty four "episodes" from 2-5 days in duration between 1957 and 1959. The concentration of pollution sources in Philadelphia covers an area fifteen miles by ten miles with the long axis running approximately northeast. If it is assumes that sulphur oxide to be the indicator of pollution (830 tonnes per day produced), an air height of 500 feet as the effective dimension and an air volume of approximately 15 cubic miles to be replaced by a wind speed of 4 mph, selected as a critical speed. Then one cubic mile of ventilation is provided per mile of wind speed and it is seen to require 3 ¾ th hours for wind movement to ventilate the long axis, 2 and ½ hours to ventilate the cross axis. Thus the tributary to ensure clean air on the long axis is 15 miles beyond the pollution area, 10 miles beyond the cross axis. The wind rose for Philadelphia during inversion shows that the wind movement are preponderantly northeast, west and southwest, contributing 51.2% of wind movements; the other five cardinal and intercardinal points represent the remainder.

The areas that have in vegetative cover, notably forests, are distinctly cooler than cities in summer-a margin of 10°F is not uncommon. Air movements over such areas moving into the cities will bring cooler air. It can be said that the areas selected as urban airsheds are likely to be those selected as appropriate for amelioration of the urban microclimates. However to clear air pollution sources be prohibited or limited. To relieve summer heat and humidity, it is essential that these airsheds be substantially in vegetative cove, preferably forested.

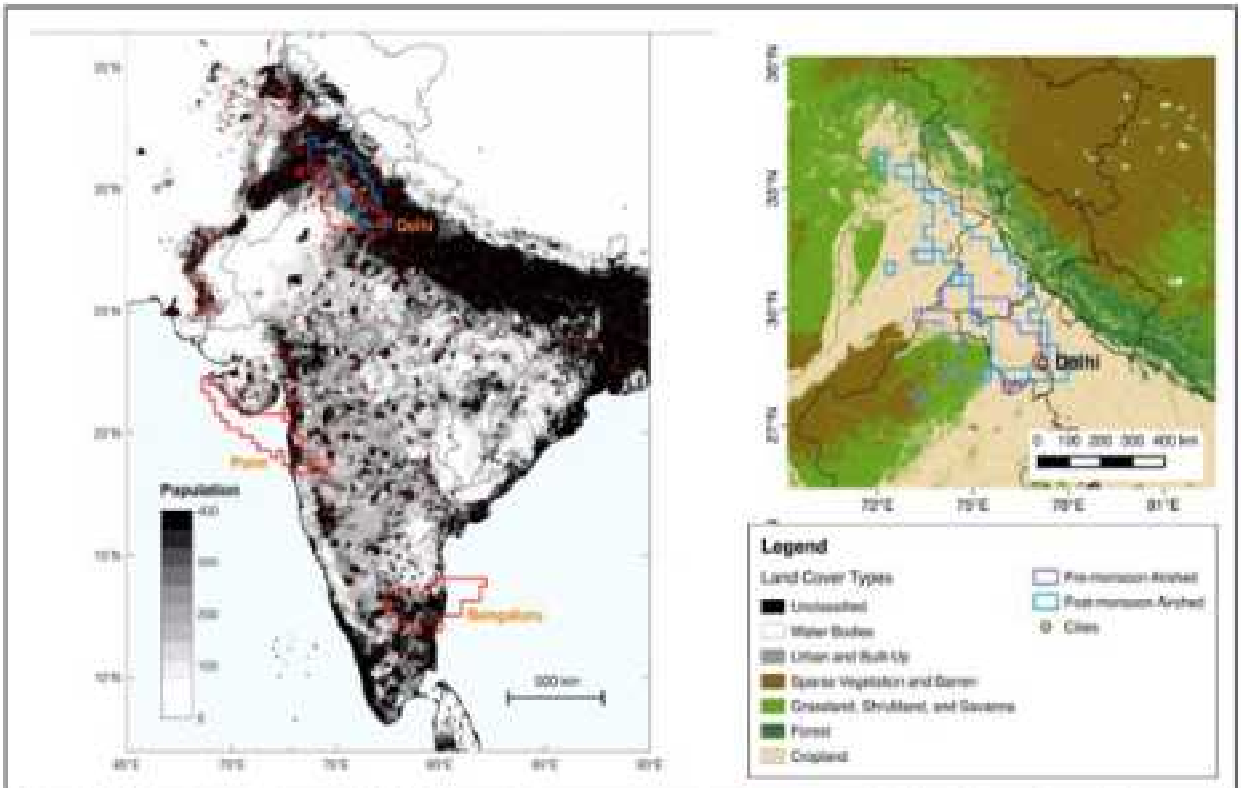


Figure 22: Estimates population count in Delhi composite pre-monsoon and post-monsoon airsheds and Bengaluru and Pune composite pre-monsoon airsheds

Source: Seasonal impact of regional outdoor biomass burning on air pollution in three Indian cities: Delhi, Bengaluru, and Pune, 2016

The areas that have in vegetative cover, notably forests, are distinctly cooler than cities in summer-a margin of 10°F is not uncommon. Air movements over such areas moving into the cities will bring cooler air. It can be said that the areas selected as urban airsheds are likely to be those selected as appropriate for amelioration of the urban microclimates. However to clear air pollution sources be prohibited or limited. To relieve summer heat and humidity, it is essential that these airsheds be substantially in vegetative cove, preferably forested.
The satisfaction of these two requirements, in the creation of urban air sheds as responses to atmospheric pollution control and microclimate control, would create fingers of open space penetrating from the rural hinterland, radially into the city. This is perhaps the broadcast conception of natural process in metropolitan growth and metropolitan open space distribution. Clearly, this proposal direct growth into the intrinsic between the air sheds corridors and suggests that metropolitan open space exist within them.

There are several factors can be observed. Normal urban growth tends to be incremental and unrelated to the natural process on the site. But aggregate consequences of such development are not calculate nor are they allocated costs to the individual development. While benefits do occur to certain developments that are deleterious to natural processes at large, these benefits are particular, while the results and costs are general. Thus, costs to large numbers of different and unrelated persons, corporations and levels of government. It is unlikely that long term benefits accrue from disdain of natural process; it is quite certain and provable that substantial costs do result from this disdain. Finally, in general any benefits that do occur-usually economic- tend to accrue to the private sector, while remedies and long-range costs are usually the responsibility of the public domain.

The purpose of this exploration is to show that natural process, unitary in character, must be so considered in the planning process. That changes to parts of the systems affect the entire system, that natural do represents values and that these value should be incorporates into a single accounting system.

The hypothesis, central to this study, is that the distribution of open space must respond to natural process. This conception should hold true for any metropolitan area, irrespective of location. In this particular case study directed to the Philadelphia Metropolitan Region, an attempt has been made to focus on the fundamental natural processes that show the greatest relevance to the problem of determining the form of Metropolitan growth and open space.
The problems lies not in absolute area but in distribution. We seek a concept that can provide an interfusion of open space and population. The low attribute value of open space ensure that it is transformed into urban use within the urban area at the perimeter. Customary urbanization excludes interfusion and consumes peripheral open space.
Yet as the area is a circle growth with the square of the radius, large open space increments can exist within the urban perimeter without major increase to the radius or to the time distance from city centre to urban fringe.
This case study reveals the application of the ecological view to the problem of selecting open space in a Metropolitan region. For the moment, it is enough to observe that this view could considerably enhances the present mode of planning, which disregards natural processes al but completely and which, in selecting open space, is motivated more by standards of acres per thousand for the place and face of nature in the metropolis.

Figure 23: Airshed delineation

Source: Design with Nature, Ian L. McHarg

4. BASELINE STUDY

4.1. Study area profile- NCT Delhi

Delhi, the Capital of India is situated between latitudes 28°24' 17" and 28°53'00 N and longitudes 76°50'24" and 77°20'37" E at 216 meters above the mean sea level (MSL). It is spread over an area of approximately 1500 sq. km. The city is surrounded by other major growth centres of adjoining states such as Haryana and Uttar Pradesh. The Yamuna River and terminal part of the Aravalli hill range are the two main geographical features of the city. The Aravali hill ranges are covered with forest and are called the Ridges; they are the city's lungs and help maintain its environment city (Delhi, 2006). In Delhi, key industries include Telecommunications, Hotels, Information Technology, Tourism, Media and Banking. The manufacturing and fabrication industries in Delhi are also in large in numbers like automobile industries, Power plants, Home Textiles sector, Leather industries, Home Consumable industries sector, Metals and Minerals etc.

Map 1: Map of NCT Delhi

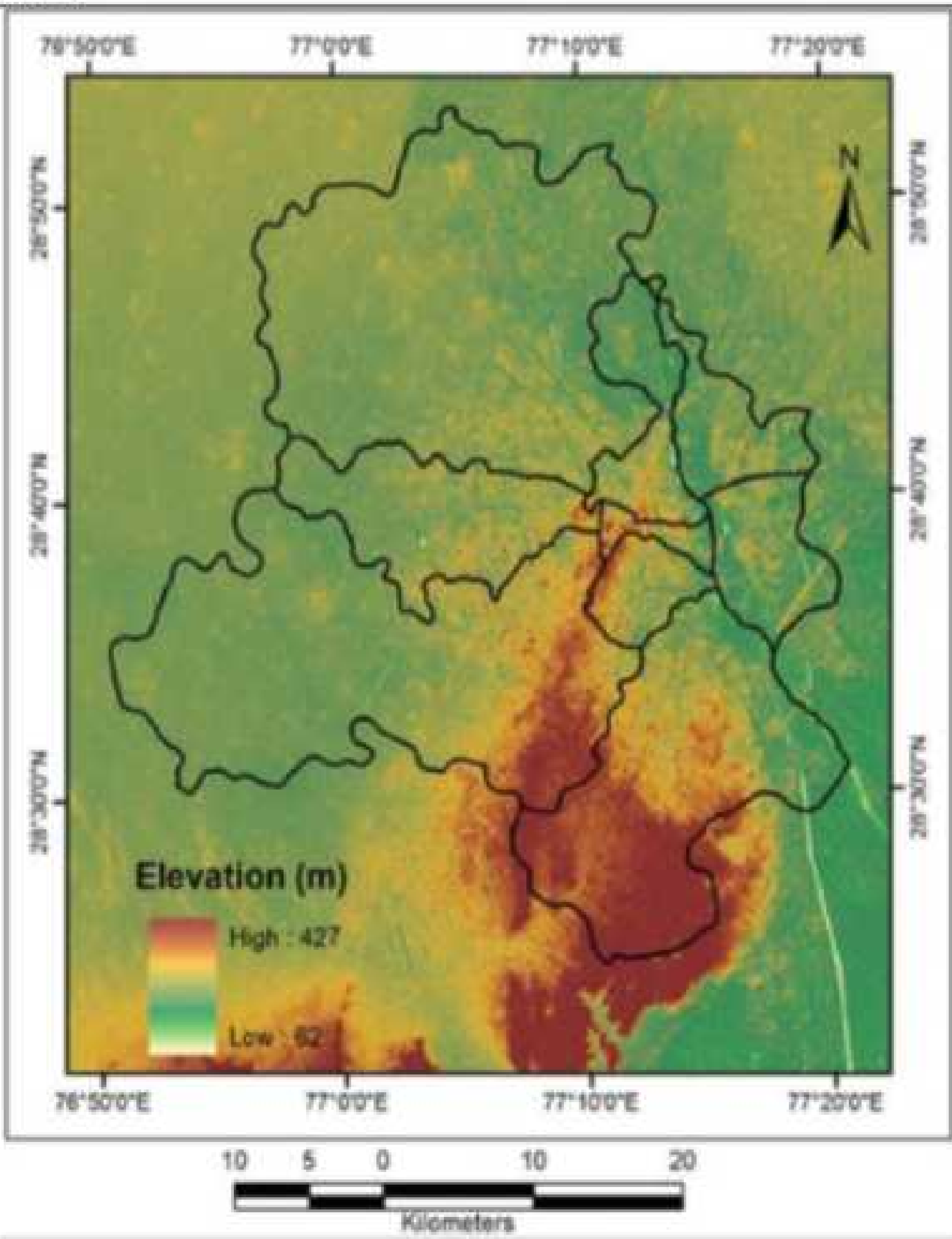
4.2. Physiography

Physiographically, Delhi lies between Indo-Gangetic alluvial plains in the north and east, the Thar Desert in the west and the Aravalli Range in the south.

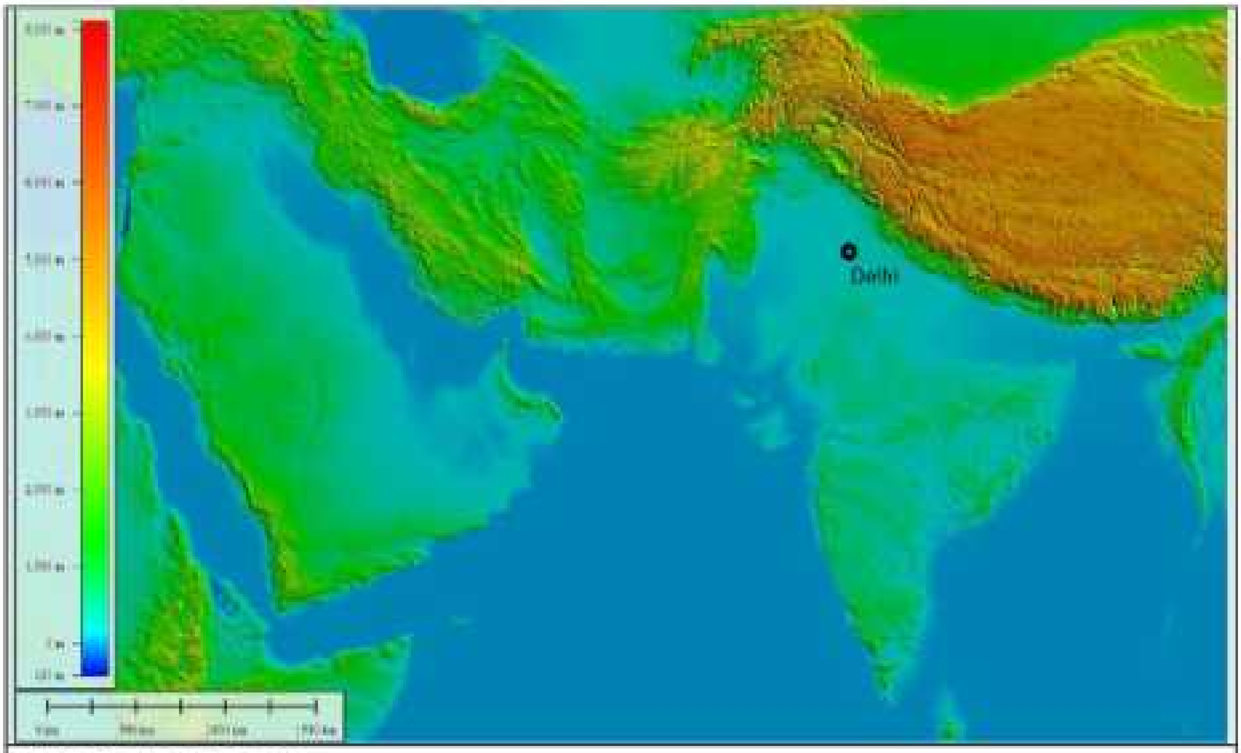
The Indo-Gangetic Plains (IGP) experiences frequent dust storms every year during the pre-monsoon season (March– June); (Bhattacharjee et al., 2007; Dey et al., 2004; Gautam et al., 2009; Kumar et al., 2015; Prasad et al., 2007; Singh, 2014; Singh et al., 2004).

Dust storms observed in India come either from the Thar Desert located in the western parts of India or from distant source of the Arabian Peninsula.

Depending upon the wind speed, dust is observed in the IGP from the west and is transported over the eastern parts of India, up to West Bengal. Sometimes, depending upon the wind pattern, dust is diverted to the Central parts of India (Kumar et al., 2015; Prasad & Singh, 2007a, 2007b).



Map 2: Elevation profile of Delhi



Map 3: Elevation profile of India

4.3. Climate

The average annual rainfall in Delhi is 714 mm, 3/4th of which falls in July, August and September. Heavy rainfall in the catchment area of the Yamuna can result in a dangerous flood situation for the city (Delhi, 2006). The maximum temperature ranges are experienced in summer from 41 to 45°C and minimum temperature in winter season is in the range of 3– 6°C in coldest period of December-January.

Meteorological Conditions

The meteorological conditions including average precipitation, temperature, wind speed, wind direction and relative humidity of NCT Delhi are represented in this section.

Due to the inland location, Delhi experiences extreme continental climate. It has 'semi-arid type' climate, wherein extreme dryness and intense temperatures are recorded in summers and winters are severely cold. The year can be divided into four seasons: winter season (November to March), summer season (March to June), monsoon season (July to September) and post-monsoon season (October to November). The temperature ranges from a minimum of 4 °C in January and maximum of 41 °C in May–June.

Humidity is relatively higher during the hot season, measuring an average of 34.9% than in the cold season when it measures an average of 28.2%. Visibility during the cold season is reduced to not more than 10km on average owing to the winds and foggy days experienced during the freezing days.

The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Delhi. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years.

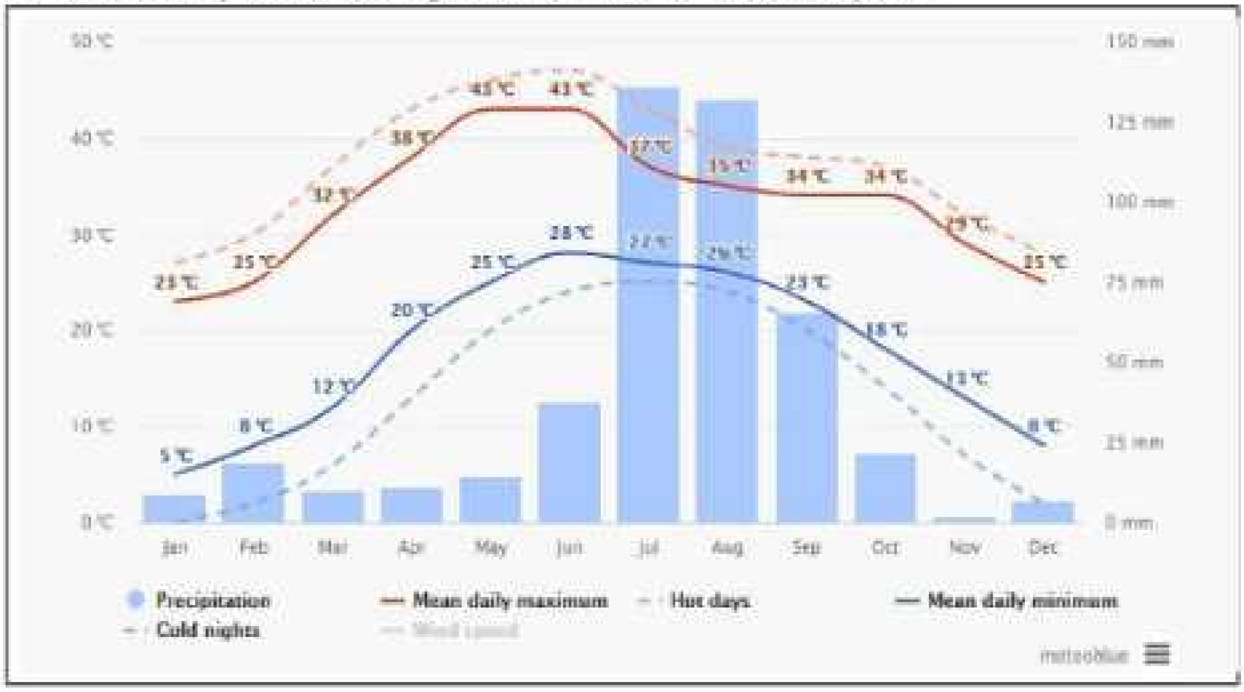


Figure 24: Temperature and Precipitation

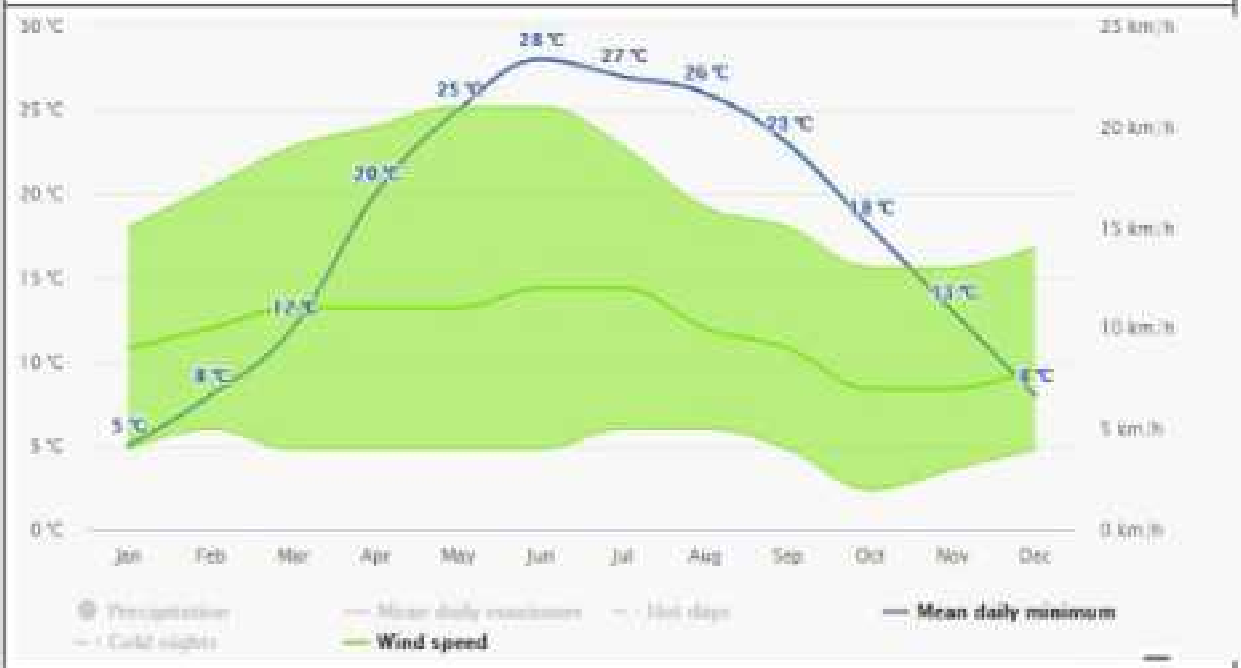


Figure 25: Wind speed

Source: Meteoblue

Figure 26: Wind Direction

Source: Meteoblue

Wind speed for Delhi is shown in the data above; and how it ranges throughout the year. Wind rose diagram (adjacent) shows how many hours per year the wind blows from the indicated direction. The pre-dominant direction in Delhi is North West direction.

Rainfall

Delhi receives average annual rainfall of 714 mm. It receives rain from both south western monsoon branch in summers (Bay of Bengal branch and Arabian Sea branch) and north-western monsoon branch in winters, i.e. western disturbances. The humidity level is generally low during the greater part of year, except monsoon months of July, August and September. Highest humidity is recorded in monsoon season while April and May are the driest months.

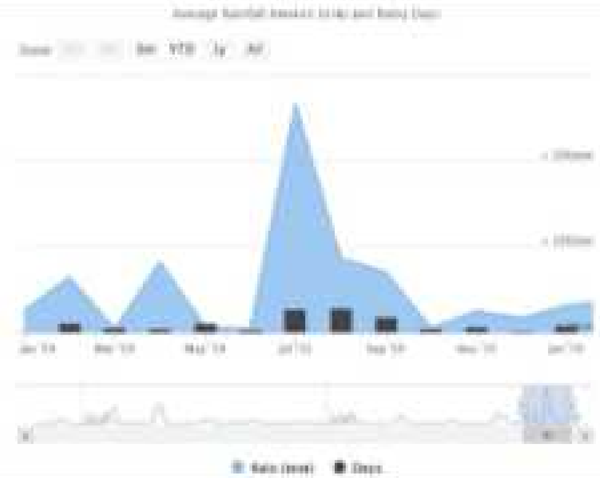


Figure 27: Rainfall Profile, 2019

Source: Worldweatheronline.com

4.4. Natural resources

The Delhi is endowed with rich forests and tree cover, diversity of flora. As per the Forest Survey of India (2011), 176.20 km² area is under forest cover, which is 11.88% of the total geographical area of Delhi. The forest and tree cover in Delhi have seen steep rise since 1999. From merely 22 km² in 1993, it has risen to over 299 km² in 2009 (Planning Department of Delhi 2013).

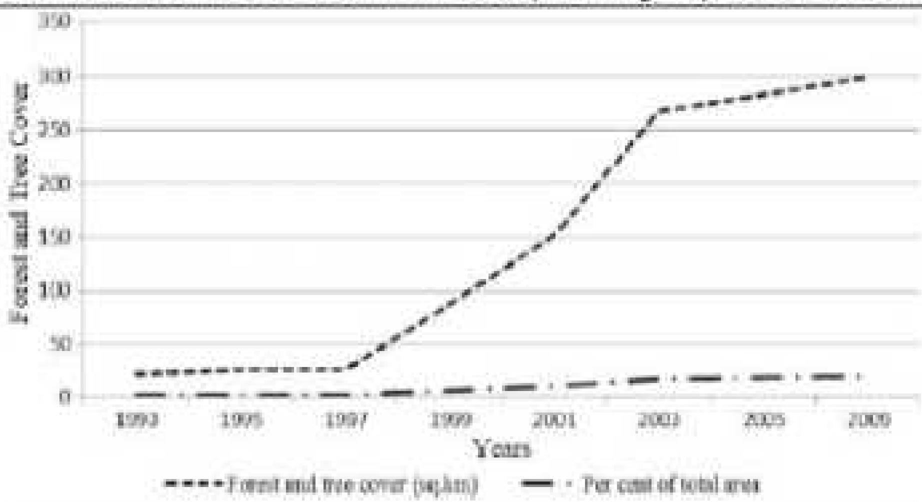


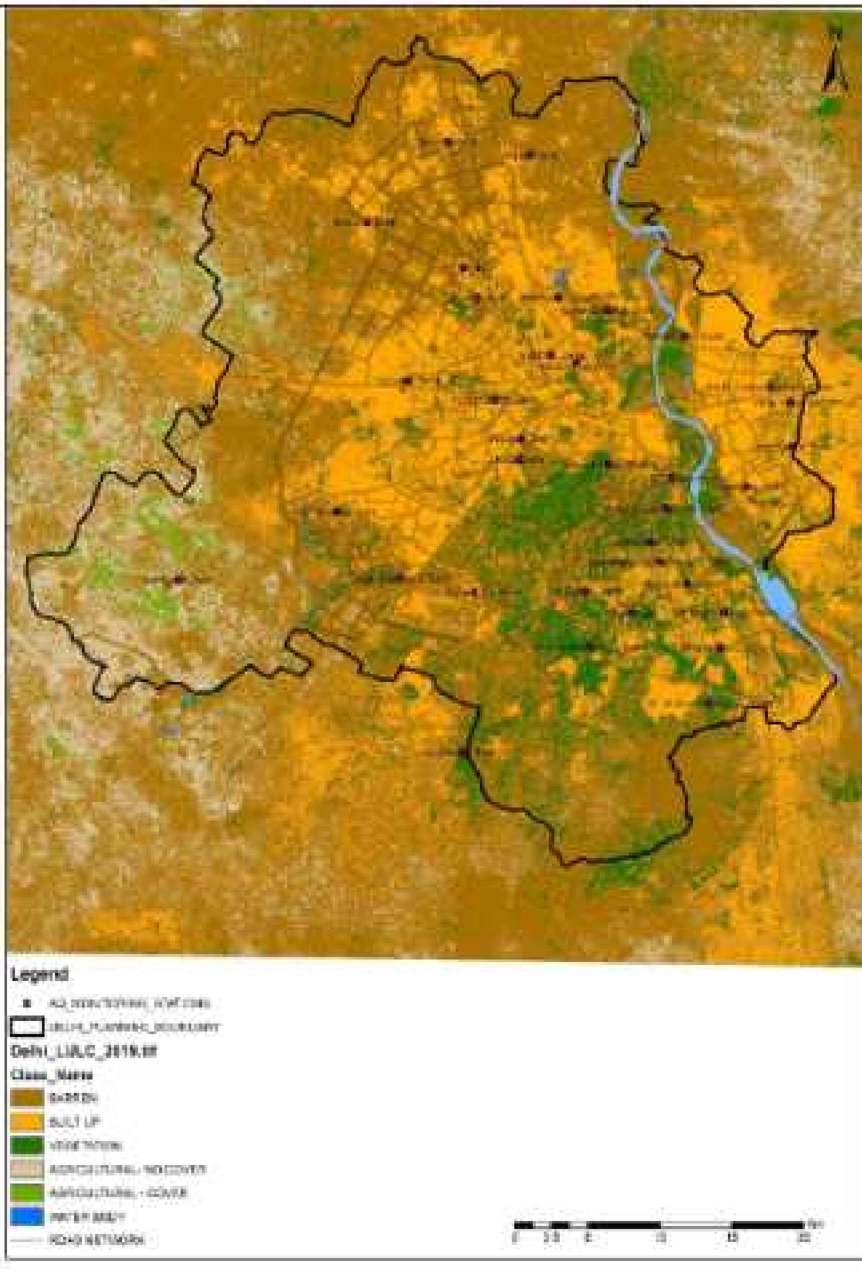
Figure 28: Growth of forest and tree cover in Delhi (1993-2009)

Source: Planning Department of Delhi (2013)

Districts	Forest cover (km^2)	Per cent of total geographical area
Central	05.05	20.20
East	02.99	04.67
North-East	04.10	06.83
North-West	16.49	03.75
New Delhi	16.31	46.60
North	04.82	08.15
South-West	41.80	09.93
South	78.32	31.33
West	06.33	04.91
Total	176.2	11.88

Figure 29: District wise distribution of forest cover in Delhi 2011

Source: Forest Survey of India, 2011



Map 4: LULC Map of Delhi

Source: Compiled by SPA Delhi

The Delhi ridge covers about 77.84 km² of area and has been notified as Reserve Forest. There are five sections of Aravalli range in Delhi. These are Northern ridge, Central ridge, South Central ridge, Nanakpura South Central ridge and Southern ridge. The Southern ridge covers maximum area (Forest Survey of India 2011). The Asola wildlife, sanctuary lies in the south Delhi district and covers an area of about 68.00 km² (Forest Survey of India 2011).
These forest or vegetation cover are also responsible for the biogenic emissions. The biogenic volatile organic compounds (BVOCs) emissions are functions of the species leaf mass, emission factors, temperature and light conditions.
BVOC emissions requires an emission inventory model with region-specific input databases and a high degree of spatial and temporal resolution.

4.5. Demography

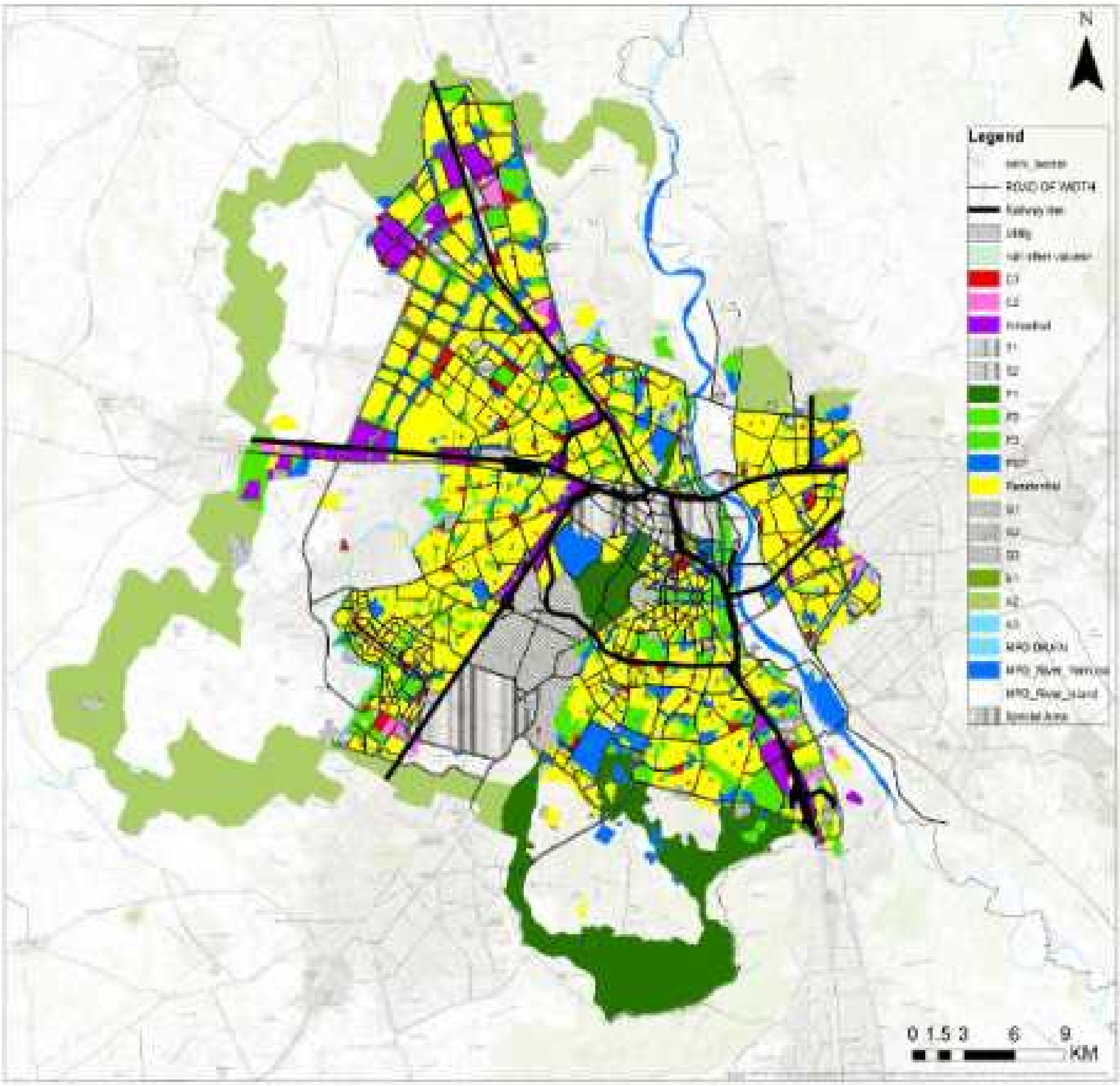
The population in Delhi increased rapidly. Population (in 2011) is 167,87,941 (Census-India, 2012). Literary rate in Delhi is approximately 86%. Delhi is divided into 11 districts and further in sub-divisions. Languages spoken in and around Delhi include Hindi, English, Urdu and some Bengali and Punjabi. The population trend has been shown in the table 13 below:

Table 13: Population Growth

Year	Population (in lacs)	Growth %
1951	17.44	
1961	26.59	52.44
1971	40.66	52.93
1981	62.2	53
1991	94.21	51
2001	138.51	47.02
2011	167.88	21.2

4.6. Land-use

Delhi as the National Capital has a distinct and unique character. It is a growing and expanding magnet of attraction for people from all across the country and also a hub for the region surrounding it. The physical potential for further urbanization within the NCT is reducing although there is a virtual urban continuum between Delhi and the surrounding areas, which lie in the States of Uttar Pradesh and Haryana.
With the imperatives of growth and development, the problems of Delhi have become complex, which have to be viewed both as a challenge in terms of the pressures of regular and floating in-migration, as well as an opportunity in terms of planning and development in a regional context. In order to control the development in Delhi, the areas were designated as one of the 27 use zones. These use zones have been classified broadly in nine categories of land uses namely Residential, Commercial, Industrial, Recreational, Transportation, Utility, Government, Public & Semi - Public Facilities and Agriculture & Water Body. As there was no study conducted on existing land-use of the city lately, so land-use as per the Mater Plan of Delhi, 2021 was assumed to be the land use for 2020.



Map 5: Land Use of NCT Delhi

Source: Compiled by SPA Delhi using MPD 2021

4.7. Transportation

Delhi relies heavily on its transport infrastructure. The city has developed a highly efficient public transport system—the Delhi Metro—which is undergoing rapid modernization and expansion. There are 1,18,33,121 number of registered vehicles in the city as of 31.12.2019 (Transport Department, Delhi). Therefore, serious efforts, including a number of transport infrastructure projects, are underway to encourage the usage of public transport in the city. As per the TERI source apportionment report-2018, the share of the transport sector is significant (39%) in $PM_{2.5}$ emissions. This reduces to 19% in PM_{10} emissions in Delhi, due to the presence of other major sources, such as road dust and construction, which emit more particles in the coarser range of PM. With the closure of some of the coal-based power generating units, Transport now has a dominant share (81%) in the NOx emissions amongst the sources within Delhi. The modal split data of registered vehicles over the last decade has been shown in the table 14 below:

Table 14: Year-wise registration of vehicles in Delhi

Category	Year-wise					Financial year
	2015	2016	2017	2018	2019	2018-2019
Bus	821	891	730	385	975	613
e-Rickshaw (P)	3488	21380	16989	19271	19664	1061
Goods Carrier	16312	11536	13718	19637	19390	20219
Luxury Cab	461	146	0	1	0	0
Maxi Cab	2154	1073	479	418	146	117
M-Cycle/Scooter	418500	442423	472308	487191	420197	472662
Moped	4711	5065	4994	3887	2563	3539
Motor Cab	19285	29131	12259	10468	7506	10055
Motor Car	175916	156211	180156	163633	147221	160067
3- Wheeler (Goods)	2555	3527	2530	1853	2633	2143
3- Wheeler (Passenger)	17529	11027	8763	12720	5766	8236
Others	423	348	769	1186	2242	19385
TOTAL	6,62,155	6,82,758	7,13,695	7,20,650	6,28,303	6,98,097

Source: Transport Department, Govt. of NCT Delhi

The total number of diesel vehicles registered between 1st Jan 2010 to 31st Dec 2019 (10 years), excluding NOC, Scrapped and Surrendered Vehicles are 5,00,907.

Table 15: Registered Diesel Vehicles in Delhi

Vehicle Description	Diesel	Diesel/ Hybrid	Grand Total
Agricultural Tractor	253		253
Ambulance	302		302
Bus	1174		1174
Cash Van	46		46
Construction Equipment Vehicle	2		2
Crane Mounted Vehicle	163		163
e-Rickshaw (P)	1	3	4
Fire Fighting Vehicle	74		74
Goods Carriage	29361		29361
Invalid Carriage	48	1	49
Luxury Cab	529		529
Maxi Cab	2959		2959
M-cycle/Scooter	36		36
Mobile Workshop	14		14
Motor Cab	16932	503	17435
Motor Car	429980		447479
Omni Bus	6		6
Private Service vehicle	3		3
Recovery Vehicle	3		3
Tractor (Commercial)	1015		1015
Grand Total	482901		500907

Table 16: Registered Petrol & Other Vehicles

Vehicle Description	CNG only	Electric (BOV)	LPG only	Petrol	Petrol/ CNG	Petrol/ Hybrid	Petrol/ LPG	Grand Total
Ambulance	10		3	936	9			958
Bus	16670	1	1		35			16707
Cash Van	87				3			90
Crane Mouted Vehicle	6							6
Educational Institution Bus	5							5
e-Rickshaw with Cart (G)		3184						3184
e-Rickshaw (P)	1	79680		4				79685
Goods Carrier	101090	22	3363	223	12102		130	116930
Invalid Carriage		6		634	70	6		716
Luxury Cab	14			41	94			149
Maxi Cab	2295	1		21	1208	1		3526
M-cycle/Scooter		3987		5025575	45			5029608
M-cycle/ Scooter side car		15		1077				1092
Mobile Workshop	2				3			5
Moped		243		56335				56578
Motor Cab	12964	528	1	4509	63675	53	26	81756
Motor Car	2862	889	1004	1248997	387028	11707	6036	1658523
Motorized Cycle		3		24				27
Omni Bus	22	1			1			24
Omni Bus (Private Use)				2	1			3
Private Service Vehicle				2				2
Recovery Vehicle	167							167
3-wheeler (goods)	54701				13346		2	68049
3-wheeler (Passenger)	9989		1		82649		2	92641
3-wheeler (personal)	4			4	45			53
Grand TOTAL	200889	88560	4373	6338384	560314	11767	6197	7210484

Source: Transport Department, Govt of NCT Delhi

The total number of petrol and other vehicles registered between 1st Jan 2005 to 31st Dec 2019 (15 years), excluding NOC, Scrapped and Surrendered Vehicles are 5,00,907.

4.8. Industries

There are total 50 clusters of which 29 are industrial areas and 21 are redevelopment areas in Delhi with more than 30,000 industries. Table 17 shows the industries falling into red, orange, green and white categories in each industrial cluster whereas Table 18 shows the redevelopment area industries.

Table 17: Industries in different categories

S. NO.	NAME OF INDUSTRIAL AREA	RED	ORANGE	GREEN	WHITE	TOTAL
1	Badli Industrial Area	27	182	255	138	602
2	Bawana Industrial Area	88	878	3443	894	5303
3	Friends Colony Industrial Area	17	352	535	72	976
4	GT Karnal Road Industrial Area	18	193	225	207	643
5	Jhandewalan FFC Industrial Area	0	9	9	411	429
6	Jhilmil Industrial Area	22	328	473	219	1042
7	Keshopur Industrial Area	1	11	3	24	39
8	Kirti Nagar Industrial Area	22	198	223	234	677
9	Lawrence Road Industrial Area	18	121	688	48	875
10	Mangolpuri Industrial Area	18	93	685	334	1130
11	Mayapuri Industrial Area	90	451	656	1004	2201
12	Mohan Co-operative Industrial Area	7	88	27	93	215
13	Moti Nagar DLF Industrial Area	5	46	75	50	176
14	Najafgarh Road Industrial Area	21	274	281	182	758
15	Nangloi Industrial Area	12	103	250	117	482
16	Naraina Phase-I Industrial Area	33	196	205	261	695
17	Naraina Phase-II Industrial Area	14	164	47	93	318
18	Narela Industrial Area	127	1031	2199	172	3529
19	Okhla FFC Industrial Area	0	13	5	172	190
20	Okhla Industrial Area	72	770	346	1341	2529
21	Okhla Estate Industrial Area	11	29	41	105	186
22	Patparganj Industrial Area	18	323	267	206	814
23	Rajasthan Udhyog Nagar Industrial Area	3	46	56	15	120
24	SMA Industrial Area	11	63	85	39	198
25	SSI Industrial Area	7	54	63	23	147
26	Shahzada Bagh Industrial Area	12	80	827	185	1104
27	Tilak Nagar Industrial Area	0	42	17	13	72
28	Udyog Nagar Industrial Area	15	139	427	120	701
29	Wazirpur Industrial Area	46	179	827	780	1832
	Total	735	6456	13240	7552	27983

Source: DPCC

Table 18: Redevelopment Area Industries in different categories

S. NO.	NAME OF INDUSTRIAL AREA	RED	ORANGE	GREEN	WHITE	TOTAL
1	ANAND PARBAT	41	41	87	190	359
2	Dabri	0	0	3	18	21
3	HAIDERPUR	0	3	11	13	27
4	HASTAL POCKET- A and B	0	1	2	27	30
5	HASTAL POCKET-D	0	2	11	9	22
6	JAWAHAR NAGAR	1	21	43	14	79
7	KARAWAL NAGAR	2	19	115	18	154
8	KHYALA	1	7	16	125	149
9	LIBASPUR	0	27	89	38	154
10	MUNDKA AND MUNDKA UDYOG NAGAR	0	8	37	99	144
11	NARESH PARK EXTENSION	0	0	8	1	9
12	NAWADA	0	1	0	11	12
13	NEW MANDOLI	0	84	64	31	179
14	PEERAGARHI VILLAGE	0	1	4	8	13
15	Prahladpur Banger 1	0	7	39	9	55
16	RITHALA	0	4	8	8	20
17	SAMAI PUR BADLI	10	125	194	110	439
18	SAHADARA	2	41	192	69	304
19	SHALAMAR VILLAGE	0	5	79	5	89
20	SULTANPUR MAZRA	0	16	19	4	39
21	SWARN PARK MUNDKA	0	6	25	45	76
	Total	57	419	1046	852	2374

Source: DPCC

4.9. Tourism

INTRODUCTION

Delhi city is sprinkled with dazzling gems: captivating ancient monuments, fascinating museums and art galleries, architectural wonders, a vivacious performing-arts scene, fabulous eating places and bustling markets. With its rich and diverse cultural heritage, Delhi is also used as a gateway for travelling to cities of India. The city is significant for the role it has played throughout history, having been the centre of an empire for the majority of this millennium. It is an important city in the Indian subcontinent and comparisons have often been made to other great cities of the world. However, very few cities carry with them, to such an extent, the weight of several layers of continuous history.

One can have a fascinating glimpse into the past in Old Delhi, with its labyrinth of narrow lanes, old havelis, and colourful bazaars. Rickshaws wind their way through this crowded, bustling capital of the Mughals, where life continues, much as it did hundreds of years ago. Modern Delhi has a lot more to offer. Delhi has a modern, well-planned and extensive Metro network that connects all corners of Delhi; this network is still growing. New roadways and flyovers have improved connectivity, the latest of which is the Signature Bridge, an ambitious project of Delhi Tourism. Delhi Tourism is on a mission to change status quo and ensure that Delhi becomes a world-class tourist destination and the leader in art, culture, music, theatre, film and entertainment.

PROFILE OF DELHI TOURISM

The capital of India is one of the key arrival destinations for both foreign and domestic tourists. The state is among the top tourist destinations in the country. The number of domestic tourists visiting the state had been rising continuously. It grew from 18.49 million in 2012-13 to 22.62 million in 2014-15. The latest survey conducted by NSSO (72nd round, 2014-15) on tourism illustrated that the majority of tourists (95 per cent) visited Delhi during the year for 'holidaying, leisure and recreation'. These tourists mostly stayed in hotel & guest houses followed by friends & relative's home. This clearly reveals that tourism has a huge potential for employment generation and becoming a growth driver of the state.

The capital boasts of some great heritage sites within and near the city. Delhi also generates income from the tourism sector. The tourists from all over the world come to Delhi not only to visit the capital but the areas surrounding it. There is an increasing number of medical tourists also to take advantage of its world-class hospitals in Delhi.

The schemes of Tourism Department, Government of NCT of Delhi have been implemented by the Delhi Tourism and Transportation Development Corporation (DTTDC), an undertaking of the GNCTD incorporated in 1975 to promote tourism in Delhi. Delhi being National Capital Territory, received a large number of foreign travellers and NRIs visiting India.

VISION OF DELHI TOURISM

To expose rich cultural heritage of the city, develop recreational facilities to the tourist, promote Delhi as one of the most popular and preferred tourist destinations and to increase the number of foreign tourist arrivals which will contribute to the economy of the city and generate additional employment opportunities. To make Delhi environmental & eco-friendly tourism and cultural & heritage destination, there is a need to spread awareness among tourists as well as its citizens regarding Delhi's glorious past.

TOURISM ACTIVITIES

DTTDC is running Information Counters at embarkation and disembarkation points in Delhi and in other cities such as- Kolkata and Chennai. At these information counters, the following activities are performed: -

- Information regarding places of tourist interest in and around Delhi e.g. Monuments, Museums, Shopping Markets, Places of Entertainments and forthcoming cultural events, fairs & festivals, exhibitions, food and cuisine etc. is provided to the tourists.
- Reservation of Hotel Accommodation, transport facility (DLY, DLZ, cars, Coaches, AC & Non-AC), regular and seasonal tours as per the demand of the tourists.

• DTTDC also operate regular tours by cars and coaches. These can be booked from DTTDC Information offices and from the website also.
• DTTDC also produces, distributes free tourist literature for the purpose of creating publicity for and developing tourism in Delhi.

Delhi Tourism is running Tourist Information Centers at all the main embarkation points in Delhi besides information offices in Kolkata and Chennai. Delhi Tourism disseminates information and distributes literature to the tourists from these offices and a large number of foreign and domestic tourists avail these facilities. The information centers are at the following places in and outside Delhi:
- Domestic Airport- Terminal-I
- Nizammudin Railway Station
- Travel office at Delhi Emporium, Baba Kharak Singh Marg
- Coffee Home, Baba Kharak Singh Marg
- I Center, Baba Kharak Singh Marg
- Govt of India Tourist Office, Janpath
- Dilli Haat, INA
- Kolkatta
- Chennai

Against the target of facilitation to 22000 visitors during the year 2018-19, 4665 tourists visited the information center until December 2018. In addition, a number of tourists were facilitated over the phone and through the DTTDC website.

Delhi Tourism organizes a number of fairs and festivals in Delhi. Delhi Tourism also runs Dilli Haat – INA, Dilli Haat – Pitampura and Dilli Haat – Janakpuri (Food & Craft bazaar) and Coffee Home's. Delhi Tourism also has a Garden by the name of Garden of Five Senses.

WATER SPORTS ACTIVITIES

The idea of providing leisure boating to the people of Delhi was conceived in the year 1991. By identifying the potential water bodies in Delhi, DTTDC approached the land-owning agencies and in due course of time, various lakes were allotted to DTTDC purely with boating rights. As per the agreement DTTDC is paying 12.5% of its sale to the land-owning agencies as their share. At present, DTTDC is providing Boating facility at 03 lakes in Delhi i.e. Krishi Bhawan Boat Club near President House; Boat Club, Maan Singh Road, India Gate and Bhalaswa Lake.

GROUP TOUR

The DTTDC also deals in Group Tours, customized tours as per the needs of the clients. These programs are tailor-made and planned as per the requirements and budget of the client.

BRANDING DELHI

Delhi, the capital of India, has its origin in 1450 B.C. and has been in continuous existence for over a thousand years now. It is a site of many historic capital cities, traces of ten of which survive even today. The city is significant for the role it has played throughout history, having been the center of an empire for the majority of this millennium. It is an important city in the

Indian sub-continent and comparisons have often been made to other great cities of the world. However, very few cities carry with them, to such an extent, the weight of several layers of continuous history. Inspite of this rich and diverse cultural heritage, Delhi is used only as a gateway for travellers to other cities of tourist interest.
Delhi has a lot to boast about and hence arises the dire need to promote Delhi as one of the most sought-after tourist destinations not only in the domestic but also in the international arena.
Undoubtedly, tourism requires careful planning and management and in the absence of a concrete Tourism Policy, there is no set plan drawn to market the city in the International market so as to showcase the potential of the city as a Tourist Friendly destination. There is a need to initiate steps to market Delhi more effectively and in a strategic manner on the lines of other State Tourism Boards.
In the current scenario, Delhi not only faces competition from the neighbouring cities/states but also from neighbouring international destination – like Singapore, Malaysia, Dubai etc. Further, Delhi is suffering from image problem i.e. Delhi being projected as an unsafe destination especially for woman tourists, in international media which is adversely affecting the inflow of foreign tourists especially women to Delhi.

With an objective to promote tourism in and around the capital city, DTTDC has been playing a role of catalyst and been taking following proactive steps in making the city a Tourist Friendly destination under Branding Delhi.
a) Promotion through TVCs, Radio, Social Media, Outdoor, Print Media, Production of Film etc.
b) Production of Publicity Literature
c) Promotion of Delhi as a Film Shooting Destination

PARTICIPATION IN NATIONAL & INTERNATIONAL TOURISM EVENTS

National & International Events are an integral part of Tourism promotion exercise for any state Tourism organization. In line with the above, Ministry of Tourism, Govt. of India, State Tourism Boards & leading Travel Trade associations organizes Travel Marts/conventions within and outside the country, throughout the year, which is actively participated by most of the State Tourism corporations, Tourism Boards of different countries, Hoteliers, Airlines, Travel Agents, Tour operators, Ministries of Railways, Civil Aviation, Adventure Tourism bodies etc. to showcase their products to promote the destination on Business platforms.

DTTDC also participates in such leading Travel Events of the Industry with the sole objective to Brand Delhi and promote the capital – as a Tourist Friendly Destination.

BED & BREAKFAST SCHEME

This scheme started in the month of October 2007 and to be continued during the year 2018-19 to provide budget accommodation to tourists coming to Delhi and enjoy the traditional Indian Home & Culture and also have the confidence of the families support and protection and go back with pleasant memories. In the Bed & Breakfast accommodation in Delhi, there are two categories facilities i.e. Silver and Gold.
17,800 Tourists stayed in Gold category rooms and 82,600 tourists stayed in Silver category rooms under the scheme "Bed & Breakfast" during 2017-18. 15936 Tourists stayed in Gold

category rooms and 72,542 tourists stayed in Silver category rooms up to December 2018 during 2018-19.

GARDEN OF FIVE SENSES

The Garden of Five Senses is a park in Delhi. Spread over 20 acres, the park is located in Said-ul-Ajaib village, opposite Saket, near the Mehrauli heritage area. The park was developed by Delhi Tourism and Transportation Development Corporation, Delhi over a period of three years and opened in February 2003. Partly built over rocky terrain, the garden has various theme areas, including a section on the lines of Mughal Gardens, plus pools of water lilies, bamboo courts, herb gardens and solar energy park. The garden is designed to stimulate our five senses with its beauty and attractions and give us a chance to touch, smell, hear and see our natural surroundings. The garden serves as one of the prominent cultural venues of the capital, as programmes are organized here round the year. The Garden tourism festival (February), food festivals, different melas, Dandiya festivals and other cultural programmes are held here at different times.

GURU TEGH BAHADUR MEMORIAL AT NH-I

DTTDC has constructed Guru Tegh Bahadur Memorial at Singhu Border (NH-1), G.T. Karnal Road, spread over land measuring 11.87 acres. The project was set-up under the scheme of beautification of entry points of Delhi. In the landscaped tranquil background, the 24 metres high central pylon with petals at the base represents the Guru and his strength. The C arches denote his three followers and the monoliths represent the 10 Sikh Gurus with their sayings inscribed on them.

HOP-ON HOP-OFF (HO-HO) BUS DELHI SIGHTSEEING TOUR

HOHO Bus Delhi Sightseeing tour brings upfront to the rich heritage of Delhi comprising ASI Monuments and Museums. Delhi Tourism brings the most exciting way to see Delhi with HOHO bus.

The tour features 20+ tourist places including heritage monuments like Qutab Minar, Red Fort, Humayun's Tomb etc. One can enjoy popular museums like the National Rail Museum, the National Gallery of Modern Art and much more.

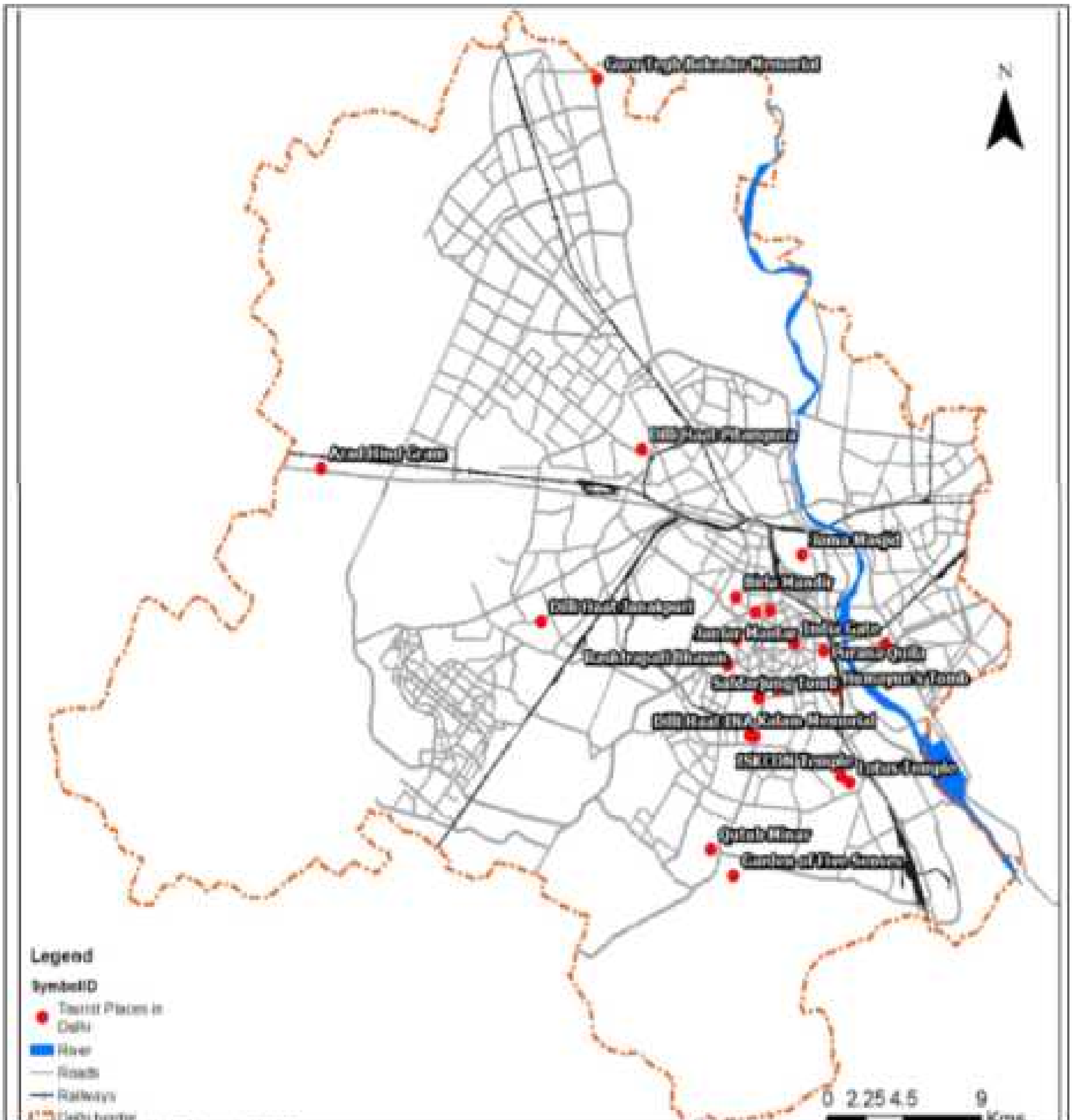
The Hop On Hop Off Bus service is operated by multiple buses instead of a single one. Buses are available every 40 minutes at each HOHO Bus Stop.

Each bus follows the same route covering 20+ tourist destinations and the guest is free to get down at any tourist attraction of his/her choice. After sightseeing, simply come to the same point and take the next bus to go to the next destination.

Table 19: List of Tourists Places in Delhi

Akshardham Temple	**Jama Masjid**
Azad Hind Gram	**Jantar Mantar**
Birla Mandir	**Lodhi Tomb/ Lodhi Garden**
Kalam Memorial	**Parliament House**
Dilli Haat INA	**Purana Quila**
Dilli Haat Pitampura	**Qutub Minar**

Dilli Haat Janakpuri	Rashtrapati Bhavan
Garden of Five Senses	Safdarjung Tomb
Humayun's Tomb	Gurudwara Bangla Sahib
India Gate	Guru Tegh Bahadur Memorial
ISKCON Temple	National Police Memorial
Lotus Temple	



Map 6: Major Tourists Places in Delhi

4.10. Emission loads in Delhi city

4.10.1. Solid waste management

The problem of solid waste management in Delhi is assuming serious proportions due to increasing population, urbanization, changing lifestyles and consumption patterns. The garbage from unauthorized developments, slums, JJ settlements, etc., is not collected which further adds to the environmental degradation. The total garbage generation in the year 2020 is 10470.57 tons/day as given in Table 20.

Table 20: Total Solid Waste Generation and its processing & disposal

S.No.	Particulars	North DMC	SDMC	EDMC	NDMC	DCB	Total
1.	Area (in Sq Kilometer)	636	656.91	105.98	42.67	42.8	1484.36
2.	Population (in Lakh)	90	70	50	2.57	1.332	213.90
3.	No. of Wards	104	104	64	14 (Circles)	8	294
4.	No. of House Holds (in Lakhs)	16.5	1.61	10.5	0.47	0.10	29.19
5.	Solid Waste Generation (in TPD)	4013	3500	2700	185.57	72	10470.57
6.	Collection of Solid Waste in TPD (in %)	4013 (100%)	3500 (100%)	2700 (100%)	185.57 (100%)	68 (94 %)	10466.57 (99.96%)
7.	Premises Segregating the waste at Source	80 % (in Model Wards)	10%	10%	90%	90% in Civil Area & 60% in Army Area	-
8.	Processing / Treatment of Solid Waste in TPD (in %)	2013 (50.2%)	1700 (48.6%)	1250 (46.3%)	185.57 (100%)	42 (58.3%)	5193.57 (49.6 %)
9.	Disposal of Solid Waste in Landfill/ Dumpsite Sites (at Bhalaswa, Ghazipur & Okhla)	2000* (49.8%) (at Bhalaswa)	1800 (51.4%) (at Okhla)	1450 (53.7%) (at Ghazipur)	Nil	26 (36.1%)(at Okhla)	5276 (50.4 %)
10.	Engineered Sanitary Land Fill(SLF)	One (Operational at Bawana)	(Proposed at Tehkhand)				One
11.	Operational Waste to Energy Plant	One (at Bawana – 2000 TPD)	One (at Okhla- 1950 TPD)	One(at Ghazipur – 1300 TPD)			3 (5250 TPD)
12.	Operational Centralised Compost Plants	One (at Bawana)	One (at Okhla)				2
13.	Operational Bio-methanation/ Composter Plants	4	6	10	1	8	29

Source: DPCC

Table 21: Estimated Waste generation in Delhi as per standards

Local Body Area	Population 2019 (in lakh)	Generation in 2020 (tons/day) Source: DPCC	Estimated Generation @0.68kg/ per capita (in tons/day)
MCD	221	10213	15028
NDMC	2.57	185.57	174.76
Cantonment	1.3	72	88.4
Total	224.87	10470.57	15291.16

(a) Collection, Segregation & Transportation of Municipal Solid Waste:

There are 5 Local Bodies in Delhi responsible for implementation of the Solid Waste Management Rules, 2016. Total Municipal Solid Waste generation in Delhi is 10470.57 Tonnes per day (TPD). Local Bodies are implementing waste segregation at source, door to door collection, intermediate storage and transport facility with GPS for the transportation of the collected solid waste to the operational Solid Waste Processing / Treatment Facilities or at the 3 existing Landfill / Dumpsites at Bhalaswa, Ghazipur & Okhla in Delhi.

New Delhi Municipal Council (NDMC) & Delhi Cantonment Board (DCB) are implementing the provisions of the SWM Rules, 2016 in their areas in a better way . However other Local Bodies (North DMC, SDMC, EDMC) are also making all efforts and taking measures to implement the provisions of the SWM Rules, 2016 in their areas.

About 100 % collection of Solid Waste, Door to Door collection and Transportation of Solid Waste in covered vehicles have been reported by the Local Bodies in their Annual Reports.

NDMC has reported that 90% Premises in the area are segregating the waste at source.

Delhi Cantonment Board (DCB) has reported that 90% Premises in Civil Area & 60% Premises in Army Area are segregating the waste at source.

SDMC & EDMC have reported that 10% Premises in their areas are segregating the waste at source.

North DMC has reported that 80% Premises in their 3 Model Wards are segregating the waste at source however information not provided for other wards in their areas.

Management of solid waste involves waste generation, segregation and storage; waste collection; waste transfer/ transportation; treatment, recycle, reuse, recovery; and disposal. For effective waste management, its segregation at the community and neighbourhood level is imperative. The waste shall be segregated and collected, in separate chambers at dhalaos. For this, involvement of rag pickers with RWAs, CBOs and NGOs are to be encouraged.

Landfills

There are 3 Dumpsites at Ghazipur, Bhalaswa and Okhla in Delhi where Municipal Solid Waste have been dumped and there is legacy waste of 28 Million Tons.

Table 22: Landfill sites in Delhi city

Sno.	Name of Landfill / Dump Site	Location	Area (in Acres)	Concerned Local Body	Height of Dump Site (Appx.) (in Meters)	Legacy Waste (in Million Tons)
1	Bhalaswa	North Delhi	36	North DMC	62	8
2	Ghazipur	East Delhi	70	EDMC	65	14
3	Okhla	South East Delhi	46	SDMC	40	6
	Total		152			28

Source: SWM Annual Report, DPCC

The population of Delhi in year 2020 is around 224.87 lacs.

Total solid waste generation in Delhi for 2020 is 1,04,70,570 kgs per capita per day or 10470.5 tonnes per capita per day.

The emission factors for Solid Waste Burning is given below:

- $PM_{2.5}$: 5.44 kg/ton
- PM_{10}: 8 kg/ton

Table 23: Emissions from landfill sites

Sl.No.	Location	Area (in ha.)	%age share	Waste Collected in tcpd	Waste Burned = 3% of total waste (tcpd)	$PM_{2.5}$ Emission load (kg/day)	PM_{10} Emission load (Kg/day)
				A	B = 0.03 x A	C = Bx 5.44	D = B x 8
1	Site near Ghazipur Dairy Farm	70	46.2	1450	43.5	236.64	348
2	Site near Jhangipur / Bhalswa	36	23.6	2000	60	326.4	480
3	Okhla Phase I	46	30.2	1826	54.78	298	438.24
	Total	152		5276	158.28	861.04	1266.24

The $PM_{2.5}$ emission per day is around 861.04 Kgs/day and the PM_{10} emissions per day is around 1266.24 Kgs/day.

Garbage burning is one of the major contributors to pollution in Delhi. The city produces nearly 10,470 metric tonnes of municipal solid waste daily, 50% of which directly lands at already exhausted landfills. In 2015, the NGT had directed authorities to levy a fine of 5,000 on anyone found burning garbage in the open.

Figure 30: Ragpickers sort through the mountain of garbage at Bhalswa for usable material. (Photo credit: Sajjad Hussain/AFP).

Hon'ble NGT has directed the Municipal Corporations to go for bio mining using trommels instead of capping of the dump sites at Bhalswa, Ghazipur and Okhla. SDMC on behalf of all the three DMCs has moved an application to Forest Department for procurement of space in four empty pits of Bhatti mines for temporarily dumping inert materials generated due to bio-mining. The details of processing of legacy waste by each DMC is given in following Table no. 24.

Table 24: Bio-Mining of Legacy Waste at 3 Dumpsites in Delhi (As on 12.03.2020)

S.No.	Name of Local Body (Dumpsite)	No. of Trommels Installed	No. of Trommels under installation	Quantity of Legacy Waste Processed (MT)	% of Inert Material by weight
1	SDMC (Okhla Dumpsite)	3	3	31,000	60-70%
2	EDMC (Ghazipur Dumpsite)	3	8	80,000	60-70%
3	North DMC (Bhalaswa Dumpsite)	13	17	1,47,000	60-70%
		19	28	2,58,000	

Source: SWM Annual Report, DPCC

Waste to Energy Plant

Delhi has 3 Waste to Energy Plants (WTE Plants) of capacity 5250 TPD at 3 different locations in Delhi namely Okhla, Ghazipur and Bawana. One New Waste to Energy Plant of capacity about 2000 TPD is proposed at Tehkhand and another in the Integrated Waste Complex at Ghonda Gujran. After commissioning of these 2 proposed WTEs capacity of WTE Plants will increase from 5250 TPD to about 9000 TPD by June, 2022.

Table 25: Operational Waste to Energy Plants in Delhi

S. No	Name of Waste to Energy Plant	Existing Capacity (in TPD)
1	Timarpur Okhla Waste Management Company Ltd., Old NDMC Compost Site, Okhla.	1950
2	East Delhi Waste Processing Company Ltd., Ghazipur	1300
3	Delhi MSW Solutions Ltd, Narela Bawana Road, Bawana	2000
	Total	5250

Source: SWM Annual Report, DPCC

Waste Handling Concepts in WTE Plants in Delhi :

1. Okhla WTE Plant : SDMC provides waste at its door step. Processes waste for production of RDF for electricity production

2. Bawana WTE Plant :The plant has provision for Collection, transportation, processing, composting, WTE plant and engineered landfill facility.

3. Ghazipur WTE Plant : EDMC provides waste at its door step. Processes waste for production of RDF for electricity production. Composting plant at their other facility.

(a) Waste to Energy Plant at Okhla

(A). Waste-to-Energy Plant at Okhla receives approx. 1950 MTD of Mixed Municipal Waste from South DMC, New Delhi Municipal Council and Delhi Cantonment Board (DCB). The waste is transferred through tippers and is dumped in a storage pit where microbial culture (solid and/or aqueous form) is mixed with MSW and kept for nearly 5 days. The storage pit is equipped with 02 grab cranes and keeps on mixing the waste for homogenization. After 5 days MSW is sent to pre-processing section (covered under shed), which consist of two segregation channels.

Each segregation channel has the following system :
- Manual segregation on moving belt conveyor – to sort out large size recognizable wastes such as Construction & Demolition waste, sanitary hardware, fibre, plastic materials, etc.

- Ballistic Separator, Shredder and Vibratory screen – A two deck density separation system where heavier and lighter fractions are separated. The heavier fractions are disposed into Okhla Landfill. The lighter fractions are separated into three sizes viz., (+) 100mm; (-) 100 mm to (+)10mm and (-) 10mm. (+) 100mm size is passed through a shredder and shredded material directly goes to storage pit for feed into the Boilers. (-) 100 mm to (+) 10mm size material from the Ballistic Separator directly goes to storage pit for feed into the Boilers. 10mm size from both the Ballistic Separator are being send to sieve of 6mm size, (+) 6mm is sent to RDF storage and (-) 6mm is sent to the compost section.

- Magnetic Separator – An electromagnet with moving belt to trap ferrous metals is installed on the line transporting -100 mm material and +10 mm material to RDF storage Pit. Two magnetic separators have been installed on the conveyer belt carrying the bottom ash.

- Plant has constructed a pit (50 meters' x 28 meters) under a covered shed for storage of RDF equipped with Grab Cranes. The pre-processed waste from the RDF storage pit is fed into the Boilers (three Nos.) using grab crane to run turbine to generate electricity of upto 23 MW.
- The temperature in the boilers are maintained above 950°C as per Solid Waste Management Rules, 2016. Bottom ash along with inerts from pre-processing section is sent to landfill.
There are 03 flue gas cleaning units 01 for every boiler consisting of Lime spray reactor (lime slurry is added by atomizing), Activated Carbon Injection, Bag House filter followed by dispersion into the atmosphere through a common stack of height about 60 meters from the ground. Unit has installed brick manufacturing unit for utilization of fly ash.

The (-) 6mm material from pre-processing section is stacked and composted for 30-35 days as windrow. After completion of 30-35 days the decomposed material is passed through 4mm trammel (+)4mm is sent to RDF storage and (-)4mm is sent to another sieve of 2mm. (+)2mm is sent to RDF storage and (-)2mm is the composted material which is being used for in house horticulture process.
The leachate generated in the storage pits is treated in Multi Effect Evaporator (MEE). The wet sludge from MEE is incinerated along with RDF in the boilers and treated water is reused.

(b) Waste to Energy Plant at Ghazipur

Waste-to-Energy plant at Ghazipur is having capacity of 12 MW electricity generation from burning of waste being run by IL&FS. The facility receives mixed Municipal Solid Waste (MSW) in a covered pit (Size 62 meter X 20 meters and 13 meters high). The waste from the pit is subjected to pre-processing in two lines and each line has provision of manual segregation on moving conveyor belts, two trommels for segregation of various sized viz. (+) 200mm, (-) 200mm to (+) 50 mm and (-50) mm, magnetic separator and Shredder (100mm Size). The flue gases are diluted with atmospheric air to bring down the temperature to the level of about 200-300 Deg C. The flue gas is subjected to air pollution control devices viz. Multicyclone, Venturi Scrubber with lime injection, demister (to remove moisture), and Activated Carbon Bed followed by dispersion into the atmosphere through a stack of > 950 oC .

The flue gas from the boiler passes through air pollution control devices viz. Selective Non-catalytic reactor where urea is injected (for NOX reduction), Semi-wet reactor where lime slurry is atomised, Activated Carbon Injection, Bag House (8 chamber and each having 14*14 bags) followed by dispersion into the atmosphere through a stack of height about 60 meters from ground.
Manual segregation on moving belt conveyor – to sort out large size recognizable wastes such as Construction & Demolition waste, sanitary hardware, fibre, plastic materials, etc. For the treatment of leachate an Effluent Treatment Plant (ETP) has been installed at Ghazipur site. It has provision to collect leachate generated from the mixed MSW and the leachate collected is thereafter treated at Effluent Treatment Plant.

(c) Waste to Energy Plant at Bawana

The Waste-to-Energy Plant at Bawana is being operated by M/s Delhi MSW Solutions Ltd, having capacity of 2000 TPD & Electricity generation capacity is 24 MW. The WTE Plant receives mixed Municipal Solid Waste (MSW) on covered tipping floor (of size 150 meters x 25 meters and 7.5 meters high), which is made of RCC and covered under shed. The tipping floor has provision to collect leachate generated from the mixed Solid Waste into storage tank.. The pre-processing system has five trommels (cylindrical rotary equipment with a screen) to sort out (+)50 mm size material which is stored separately in the said tipping floor and is used as Refuse Derived Fuel (RDF) and is conveyed to a storage pit to feed into Boilers.

Segregation on moving belt conveyor is carried out to sort out large sized recognizable wastes such as Construction & Demolition waste, sanitary hardware, fibre, plastic materials, etc. The waste is then processed and disposed into composting facility, RDF for Waste-to-Energy facility and rejects are sent to Secured Landfill Site. The temperature in the boilers are maintained above 950°C as per Solid Waste Management Rules, 2016. Bottom ash along with inerts from pre-processing section is sent to Engineered landfill existing in the plant site at Bawana.

There are flue gas cleaning units for boilers consisting of Lime spray reactor (lime slurry is added by atomizing), Activated Carbon Injection, Bag House filter followed by dispersion into the atmosphere through a common stack of height about 60 meters from the ground.

The leachate collected is treated in Leachate Treatment Plant (LTP) within the WTE plant. It has provision to collect leachate generated from the mixed MSW and the collected leachate is thereafter treated in the Leachate Treatment Plant.

The plant uses about 1300 ton/day of refuse each to derive fuel to generate energy. The plant at Okhla equipped with bag house filter, so the controlled emission factor of AP-42 (USEPA, 2000) was used to calculate the controlled emissions. The other two plants at Bawana and Ghazipur were also assumed to be using spray dryer and fabric filter (bag house filter) for emissions control. The emission factor for SD/FF for burning municipal solid waste is 3.11E-02 kg/Mg. The plant emissions are approx. 40 kg/day of total particulate matter each.

Table 26: Emissions from WTE plants

Sno.	Name	PM Emissions (kg per day)
1	WTE, Okhla	38.87
2	WTE, Bawana	40.43
3	WTE, Ghazipur	40.43
TOTAL		119.73

4.10.2 Transport

Apart from the issue of pollution on account of industries, the major area of planning and intervention would relate to transportation planning. With the phenomenal growth in the number of vehicles, almost 8-10 times in the last two decades in absolute terms, the most significant aspect in the context of congestion and pollution, relates to the growth in personalized transport as compared to the availability of public transport. It has been estimated that buses, which constitute barely 1.2 percent of the total number of vehicles, cater to around 60 percent of the total transport load, while personal vehicles –cars and scooters, though almost 93 percent of the total number of vehicles, cater to around only 30 percent of the travel demand. Such a huge share of private vehicles in Delhi, while serving a relatively limited purpose in terms of the transportation modal split, obviously creates tremendous pressure on road space, parking, and pollution directly and through congestion.

Public transportation planning must, therefore, drive the future policy. So far public transport is largely seen as the transport mode for the not so well off and poorer sections of the community, who cannot afford to own/use personal transport. An important element of policy would now also have to aim to make public transport a mode for personal vehicle owners and users through a mix of incentives and disincentives. Apart from aspects like frequency, inter-modal integration, a possible single ticketing system, use of parking policy as a means to influence vehicle use, etc., the quality of public transport, particularly buses, would need to be significantly upgraded, inter-alia, keeping the element of clean transport in view. Another issue which has been raised in the context of vehicular congestion and pollution relates to the policy of mixed land use, which will also have to be carefully considered.

The period between 1981 and 2001 and subsequently 2011 has seen a phenomenal increase in the growth of vehicles and traffic in Delhi. There has been a rise in per capita trip rate (excluding walk trips) from 0.72 in 1981 to 0.87 in 2001 and exponentially more in 2011.

Keeping in view the population growth, this translates into an increase from 45 lakh trips to around 118 lakh trips in 2001 and 144 lakh trips till 2008. As per the Transport Demand Forecast Study (TDFS) undertaken by GNCTD and approved by the UTTIPEC in 2011, it is seen that between 2001 and 2008, the private motor vehicle trips have increased from 28% to 35% and non-motorized vehicle trips from 9% to 15%, however bus trips have unfortunately decreased from 60% to 42% of the total number of trips.

Despite measures by way of increasing the length of the road network and road surface space through widening, construction of a number of flyovers / grade separators and, launching of the Metro, the traffic congestion has continued to increase unabated. This has its inevitable consequences in terms of accidents, pollution, commuting time, and wasteful energy / fuel consumption.

Based on the rate of increase in the number of trips between 1981 and 2001/2011, it is estimated that the total trips would rise to 280 lakh by the year 2021, including 257 lakh motorized trips and 23 lakh non-motorized trips. In this context, it needs to be noted that roads already occupy approx. 21 percent of the total area of the city, which clearly limits the potential for increase in road space.

Table 27: Number of different types of registered vehicles in Delhi

Category	2015	2016	2017	2018	2019
Bus	821	891	730	385	975
e-Rickshaw (P)	3488	21380	16989	19271	19664
Goods Carrier	16312	11536	13718	19637	19390
Luxury Cab	461	146	0	1	0
Maxi Cab	2154	1073	479	418	146
M-Cycle/Scooter	418500	442423	472308	487191	420197
Moped	4711	5065	4994	3887	2563
Motor Cab	19285	29131	12259	10468	7506
Motor Car	175916	156211	180156	163633	147221
3-Wheeler (Goods)	2555	3527	2530	1853	2633
3-Wheeler (Passenger)	17529	11027	8763	12720	5766
Others	423	348	769	1186	2242
Total	662155	682758	713695	720650	628303

Source: Transport Department

Table 28: Number of registered vehicles (based on vehicular types) in Delhi

Category	2015	2016	2017	2018	2019
Truck	16312	11536	13718	19637	19390
Tractor	423	348	769	1186	2242
Bus	821	891	730	385	975
Cars	197816	186561	192894	174520	154873
2 Wheelers	423211	447488	477302	491078	422760
3 Wheelers (Auto-CNG)	17529	11027	8763	12720	5766
LCVs	2555	3527	2530	1853	2633
Total	658667	661378	696706	701379	608639

Source: Compiled from data provided byTransport department

The emission factors considered for the emission load calculations are as follows:

Table 29: Emission factor used for calculating $PM_{2.5}$ emission loads from vehicles

Fuel Type	Emission Factors (g/Km)
	$PM_{2.5}$
2W	0.013
3W	0.015
Buses (CNG)	NA
Cars (Petrol)	0.002
Cars (Diesel)	0.015
Commercial Cars (CNG)	0.002
Commercial Cars (Diesel)	0.015
HCV	0.42
LCV	0.475

Source: Apportionment Study, Mumbai; Source Apportionment Study, Pune; Source Apportionment Study, Delhi, TERI; Emission Inventory of Delhi – SAFAR, 2018.

Assumptions: 65% share in cars running petrol and 35% share in cars running diesel. Based on the fact that people rely more on petrol driven cars these days owing to better fuel efficiency and pollution norms.

Table 30: Vehicle-kilometers of travel (VKT) generated during random survey

Vehicle Type	VKT (Km/day)
2W	60
3W	120
Buses (CNG)	210
Cars (Petrol)	55
Cars (Diesel)	55
Commercial Cars (CNG)	400
Commercial Cars (Diesel)	210
HCV	75
LCV	140

Source: SAFAR, 2018

Based on the above given data in tables 27, 28 and 29, total emissions were calculated for each year from 2105 to 2019.

Table 31: Cumulative Emissions from vehicles during 2015

Category	2015	VKT (Km/day)	PM 2.5 EF	$PM_{2.5}$ Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Truck (Diesel)	16312	75	0.42	513.83	21.41
Tractor (Diesel)	423	45	0.42	7.99	0.33
Bus (CNG)	821	210	0	0.00	0.00
Cars (Petrol) - 65%	128580.4	55	0.002	14.14	0.59
Cars (Diesel) - 35%	69235.6	55	0.015	57.12	2.38
2 Wheelers (Petrol)	423211	60	0.013	330.10	13.75
3 Wheelers (Auto-CNG)	17529	120	0.015	31.55	1.31
LCVs (Diesel)	2555	140	0.475	169.91	7.08
Total	658667			1124.65	46.86

Source: Compiled by SPA Delhi

Table 32: Cumulative Emissions from vehicles during 2016

Category	2016	VKT (Km/day)	$PM_{2.5}$ EF	Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Truck (Diesel)	11536	75	0.42	363.38	15.14
Tractor (Diesel)	348	45	0.42	6.58	0.27
Bus (CNG)	891	210	0	0.00	0.00
Cars (Petrol) - 65%	121264.65	55	0.002	13.34	0.56
Cars (Diesel) - 35%	65296.35	55	0.015	369.18	15.38
2 Wheelers (Petrol)	447488	60	0.013	8.60	0.36
3 Wheelers (Auto-CNG)	11027	120	0.015	6.35	0.26
LCVs (Diesel)	3527	140	0.475	43981.64	1832.57
Total	661378			44749.06	1864.54

Source: Compiled by SPA Delhi

Table 33: Cumulative Emissions from vehicles during 2017

Category	2017	VKT (Km/day)	$PM_{2.5}$ EF	$PM_{2.5}$ Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Truck (Diesel)	11536	75	0.42	363.38	15.14
Tractor (Diesel)	348	45	0.42	6.58	0.27
Bus (CNG)	891	210	0	0.00	0.00
Cars (Petrol) - 65%	121264.65	55	0.002	13.34	0.56
Cars (Diesel) - 35%	65296.35	55	0.015	369.18	15.38
2 Wheelers (Petrol)	447488	60	0.013	8.60	0.36
3 Wheelers (Auto-CNG)	11027	120	0.015	6.35	0.26
LCVs (Diesel)	3527	140	0.475	43981.64	1832.57
Total	661378			44749.07	1864.54

Source: Compiled by SPA Delhi

Table 34: Cumulative Emissions from vehicles during 2018

Category	2018	VKT (Km/day)	$PM_{2.5}$ EF	$PM_{2.5}$ Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Truck (Diesel)	19637	75	0.42	618.57	25.77
Tractor (Diesel)	1186	45	0.42	22.42	0.93
Bus (CNG)	385	210	0	0.00	0.00
Cars (Petrol) - 65%	113438	55	0.002	12.48	0.52
Cars (Diesel) - 35%	61082	55	0.015	405.14	16.88
2 Wheelers (Petrol)	491078	60	0.013	9.92	0.41
3 Wheelers (Auto-CNG)	12720	120	0.015	3.34	0.14
LCVs (Diesel)	1853	140	0.475	46641.70	1943.40
Total	701379			47713.56	1988.06

Source: Compiled by SPA Delhi

Table 35: Cumulative Emissions from vehicles during 2019

Category	2019	VKT (Km/day)	$PM_{2.5}$ EF	$PM_{2.5}$ Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Truck (Diesel)	19390	75	0.42	610.79	25.45
Tractor (Diesel)	2242	45	0.42	42.37	1.77

Category	2019	VKT (Km/day)	$PM_{2.5}$ EF	$PM_{2.5}$ Emissions (Kg/day)	$PM_{2.5}$ Emissions (Kg/hr)
Bus (CNG)	975	210	0	0.00	0.00
Cars (Petrol) - 65%	100667	55	0.002	11.07	0.46
Cars (Diesel) - 35%	54206	55	0.015	44.72	1.86
2 Wheelers (Petrol)	422760	60	0.013	329.75	13.74
3 Wheelers (Auto-CNG)	5766	120	0.015	10.38	0.43
LCVs (Diesel)	2633	140	0.475	175.09	7.30
Total	608639			1224.18	51.01

Source: Compiled by SPA Delhi

4.10.3 Surface infrastructure

The city of Delhi has one of the largest road networks in India. The road network already occupies 21% of the total city area, limiting the potential for future increase; Nonetheless, the modal share of Delhi is much better than any developed country as only 25% of the population is using private vehicles while the rest are using public or non-motorized transport (NMT) (Figure 31).

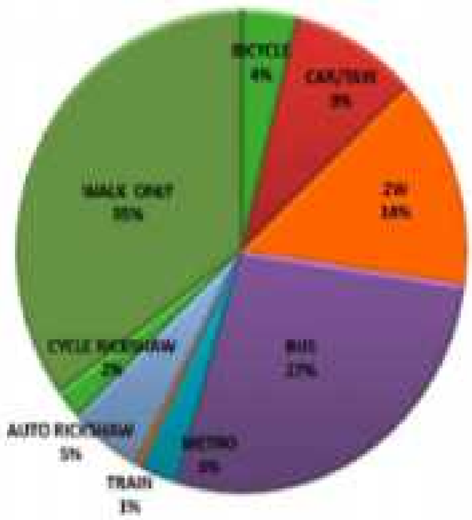


Figure 31: Modal share of Delhi as of 2014

Source: Report of High-Powered Committee on How to Decongest Delhi, 2014

Nonetheless, the priority given to construction of new road and flyover infrastructure to ease traffic congestion has spurred growth of private vehicles. Adding to this is the middle-class aspiration of owning a car. However, the level of ownership of vehicles is still low when compared with developed countries – for instance, Delhi has 85 vehicles per 1000 persons whereas in UK, it is 760 vehicles per 1000 persons.

In this setting, the attractiveness of buses has fallen over the years, as is also shown in Figure 32. The future looks bleak as a Bus Rapid Transit System (BRTS) commissioned in 2008 was taken down this year due to massive protest from the neighbouring areas. Thus, it is critical to identify areas for dedicated bus corridors and make bus services more reliable, convenient, attractive and efficient by reforming the bus system. Bus route rationalization, use of IT can help fulfil this purpose to a great extent.

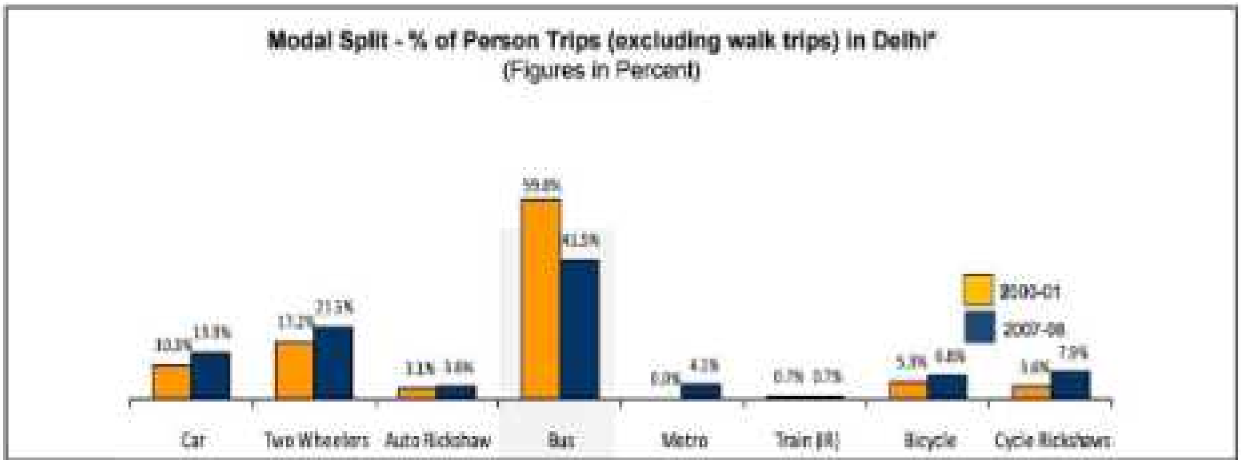


Figure 32: Comparison of Modal split in 2000 and 2007 in Delhi

Source: Tiwari, 2011

The bus service faces multiple challenges:

Competition among different bus operators: DMRC feeder buses and Delhi government buses are often seen competing for passengers on overlapping routes. They indulge in rash driving and sometimes skip bus stops as well, causing inconvenience to the passengers.
No coordinating authority: The transport system in the city is highly fragmented. Presence of multiple bus operators, including many contractors, which are only concerned about their own routes and profitability has led to underservicing of lower-income group areas.

Increasing modal competition: Fall in attractiveness of the bus service due to its poor quality, slow speed and poor last-mile connectivity has led to some of the affluent passengers to transition to the metro even for short trips. The modal share of the bus has fallen from 59.8% in 2001 to 41.5% in 2008 whereas the share of metro stood at 4.1% in 2008 (Figure 32). A further fall needs to be averted such that people transition from their private vehicles to the metro and not from buses to metro.

Opposition to BRTS: The 5.8km dedicated BRTS, from the very beginning, faced a lot of opposition from the car lobby as it was seen as taking away their road space. The corridor was carrying more people per hour than all the vehicles put together, but the efficiency of this network was not considered before deciding to scrap it. That a social challenge, coming from those upper-middle-income groups living adjacent to the corridor, could lead to scrapping of the entire project must not have been anticipated during the initial stages of the project. This submission of the government to the private vehicle lobby without attempting to discuss the benefits of a BRTS have clouded the future of any other BRTS network. This will prove to be highly detrimental to the public transport system in Delhi.

Other challenges and opportunities
Urban sprawl and mobility needs. The extension of NCT of Delhi into the National Capital Region (NCR) displays the sprawl tendencies of urban growth in Delhi. Sprawled over 34,000 sq. km area, NCR is the country's largest planning region with a population of 46 million. As can be seen from Figure 33, Delhi has expanded geographically to a large extent.

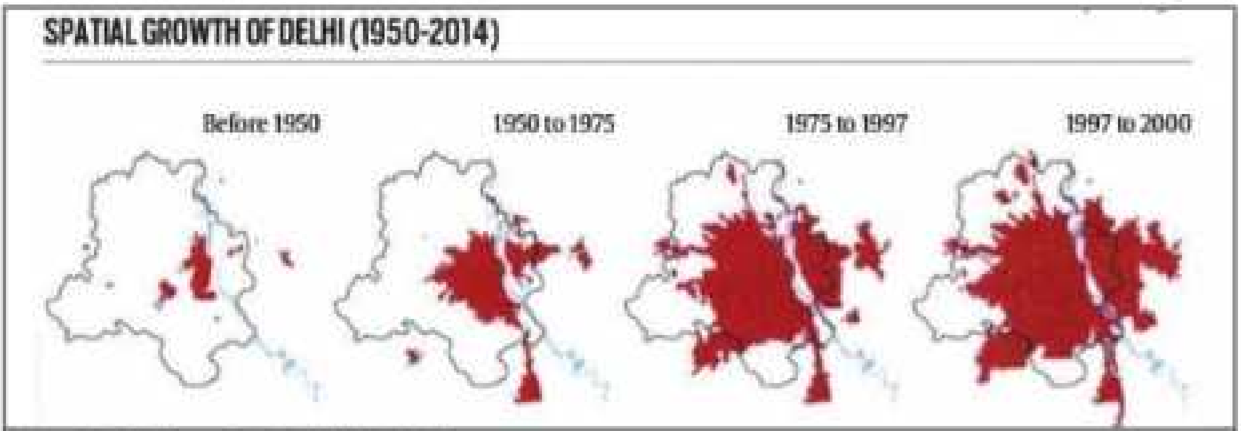


Figure 33: Spatial growth of Delhi (1950 – 2014)

Source: Nair, 2015

Delhi is faced with rising challenge of traffic congestion. The number of private vehicles (both two-wheelers and cars) is continuously rising in the city. As of 31 March 2015, Delhi had 8.83 million vehicles, up from 0.56 million in 1981, and this is only expected to rise. Frequent traffic jams across Delhi due to increase in number of personal vehicles further reduce the attractiveness of buses as the time taken by them increases due to absence to dedicated bus corridors. This in turn makes people shift to private modes of transport, further adding to congestion.

Influx of Intermediary Public Transport (IPT) like auto rickshaws, e-ricks, cycle rickshaws have added to the congestion on the roads as some of them are non-registered and flout a lot of traffic and parking norms.

Poor infrastructure for pedestrians and cycling is a major challenge that needs to be addressed to aid 35% of commuters walking to their destinations and 4% of those cycling in the city. Unsafe and inadequate cycling-friendly infrastructure has led to many short trips being made on private vehicles. To keep the modal share favourable to NMT, it is crucial to invest in dedicated cycling lanes and pedestrian pathways.

Environmental challenge

Last year, Delhi received the title of the 'world's most polluted city'. Although burning of agricultural waste in the neighbouring state of Punjab played a big role, the increasing number of diesel vehicles on the streets were also to be blamed. This is not the first time that Delhi's pollution hit an all-time high. In late 1990s and early 2000s, industrial emissions and effluents from vehicles often left Delhi skies clouded with smog. So, in 2002, a benchmark decision was taken to shift the entire public road transport system on CNG Fuel System. Now all auto-rickshaws, buses and even some cars are run on CNG. This had a tangible effect on Delhi's air pollution level.

However, the ever-increasing number of diesel vehicles due to subsidies on diesel has again led to high levels of air pollution in recent times. Both particulate matter (PM_{10} and $PM_{2.5}$) as well as nitrogen oxides are increasing steadily. In fact, $PM_{2.5}$ levels are normally 3 to 4 times the standards during winter times and are as high as 7 to 8 times the standards during smog. Ozone levels have also been rising. This has serious consequences for public health.

Information and Communication Technology

Integration of IT solutions with public transport system is missing across the city. The BRTS had limited success with LCD screens that displayed time for the next bus. Attempt was also made to link the bus system and the metro with a single smart card, but it hasn't been operationalized. Much can be done with CCTV cameras installed on some of the streets and if their coverage is expanded, a robust control room can help in streamlining the transportation system of Delhi.

Figure 34: The metropolis has progressed to building a Smart City, but the basic foundation of inclusiveness in public spaces seems to have withered away. (Arun Sharma/HT FILE)

Uncontrolled traffic at a typical road crossing

Typical situation along a major arterial road passing through Govindpuri with cars parked on both sides of the road reducing vehicular traffic lanes. All footpaths have disappeared forcing pedestrians to mix with the traffic

A wide road in one of the Delhi's urban villages with limited space for traffic and pedestrians, banners and overhead electric wires add to the chaos.

The Inner Ring road as it passes through South Extension flanked by high end retail structures on both sides.

Another view of the Inner Ring road in South Extension where restricted space for vehicular traffic movement has been further narrowed by ongoing metro construction works.

Table 36: Total number of vehicles in different areas

Locations	Total no. of vehicles plying (Approximate Values)
Vishwa Vidyalaya	18000
Vasant Kunj	30000
Uttam Nagar	42000
Tilak Nagar	86000
Tegras Garden	85000
Suraj Dharamkanta	38000
Sunder Nagar	50000
South Extension	140000
SI Hospital	122000
Shivaji Marg	17000
Shershah Road	23000
Shantipath	41000
Sewak Park, Dwarka Mor	17000
Satyaniketan	139000
Sardar Patel Marg	62000
Saket Metro Station	123000
Sai Baba Mandir Road	73000
Sagarun Panka Road	31000
Root Rouz Genj	78000
Rohtak Road	80000
RML Hospital Road	40000
Rangpuri Airport	8000
Rajopuri Garden	122000
Rajdhani Park	111000
Rajawi Marble Market	125000
RK Puram	3000

Locations	Total no. of vehicles plying (Approximate Values)
PWD Office	70000
Purani Delhi Railway Station	16000
Post office, Civil Lines	14000
Pitampura	57000
Peeragarhi	64000
Paharganj	81000
Northern Access Road	38000
Noida Sector 62	25000
New Moti Nagar	112000
New Friends Colony	70000
Najafgarh	116000
Moti Nagar	41000
Mother Teresa Cres	83000
Mehram Nagar	11000
Mayapuri	41000
Mathura Road	14000
Main Patel Road	82000
Mahatma Gandhi Marg	80000
Maharaja Agrasen	26000
Loni Road	3000
Laxmi Nagar	50000
Lajpat Nagar	106000
Kirti Nagar	69000
Kirki Place	42000
Khan Market	15000
Kausambhi	37000
Kashmere Gate	160000
Karol Bagh	70000
Karampura Flyover	16000
Kanjhawala Road	25000
Kamla Nagar	52000
Jarak Cinema	37000
Janakpuri	48000
Jama Masjid	20000
Jahangipuri	50000
ITO	60000
India Gate	82000
Harijan Basti	50000
Hapur	100000
GT Karnal Road	57000
Greater Noida Expressway	79000
Ghaziabad	94000
Feroz Shah Marg	39000
Fateh Nagar	30000
Dwarka	38000

Locations	Total no. of vehicles plying (Approximate Values)
Dhuala Kuan	136000
Delhi Meerut Expressway	167000
Delhi Cantontment	115000
DBG Road, Pahar Ganj	40000
Civil Line	15000
Chandni Chowk	11000
Chankyapuri	56000
Cariappa Marg Ashram	67000
Connaught Place	10000
Bapudham	62000
Baba Kharak Singh Marg	22000
Ashram Road	81000
Anand Vihar	83000
Airport	43000
AIIMS	63000
Aadarsh Nagar	50000

Source: SAFAR Emission Inventory of Delhi, 2018

4.10.4 Road Dust

Road dust consists of solid particles that are generated by any mechanical processing of materials, including crushing, grinding, rapid impact, handling, detonation, and decrepitation of organic and inorganic materials such as rock, ore, and metal.[2] When this dust becomes airborne, primarily by the friction of tires moving on unpaved dirt roads and dust-covered paved roads, it is referred to as road dust.

Table 37: Emission factors used in SAFAR & IIT Kanpur study

	SAFAR	IIT Kanpur
Paved Road Dust	E = [k (sL/2)0.91 (W)1.02](1-P/4N) E = particulate emission factor (having units matching the units of k) k = particle size multiplier for particle size range and units of interest sL = road surface silt loading (grams per square meter) (g/m²) W = average weight (tons) of the vehicles traveling on the road P=No. of wet days with at least 0.254 mm (0.01 in) of precipitation during avg. period N = No. of days in averaging period (365 for annual, 30 for monthly, 91 for seasonal)	E = k (sL/2)0.65 (w/3)1.5 ...... (Eq 1) where E is the emission rate of size specific PM (same units as 'k'), sL is the silt load (g/m²), W is the mean weight of the vehicle fleet (tons), and k is the constant (function of particle size) in g/ VKT (vehicle kilometre traveled) (e.g., k = 4.6 for PM_{10})
	k - 0.62 for PM_{10} as per IIT Kanpur SA Study Report	The equation is based on regression analysis of numerous emission tests. Sources tested include public paved roads and controlled and uncontrolled industrial paved roads. The conditions for which it is applicable are for: a silt loading of 0.02–400 g/m², a mean vehicle weight of 1.8–38 (tons) and a mean vehicle speed of 16–88 km/h.

2 Environmental Protection Agency Alaska native village air quality fact sheet series: road dust. 2010 [cited 2018 Apr 23]. Available from: https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008ELK.PDF?Dockey=P1008ELK.PDF

Table 38: Assessment of fugitive road dust emissions in Kanpur, India

	Study	Silt Load (g/m²)	PM_{10} emission rate (g/VKT)	Method
Comparison of Fugitive Road Dust (FRD) emissions (PM_{10})	Long Beach California	0.0016-0.05	0.15-2.6	Eq.1
	California	0.004-0.2	0.2-3	Upwind and downwind measurement
	Washington	1.2-3.2	0.4-1.7	Tracer Technique
	Bangkok	1.37-27	0.5-25	Eq.1
	IIT Kanpur, V.S. Bhasker and M. Sharma, 2008	18-84	9.2-42.5	Eq.1

Source: V. Sai Bhaskar, Mukesh Sharma, Transportation Research Part D 13 (2008) 400–403

The transportation of excavations and other construction materials as well as other works involve the transit of vehicles on unpaved roads, where the friction of the wheels on the road surface determines the pulverization of the surface material and the subsequent volatilization and dispersion in the atmosphere.

UNPAVED ROADS

For vehicles traveling on unpaved surfaces at industrial sites, emissions are estimated from the following equation:

E = k * (s/12)"a" * (W/3)b .... (Equation 1a)

and, for vehicles traveling on publicly accessible roads, dominated by light duty vehicles, emissions may be estimated from the following:

E = (k (s/12)"a" *(S/30)"d")/((M/0.5)"c") – C .... (Equation 1b)

where k, a, b, c and d are empirical constants (Reference 6) given below and

E = size-specific emission factor (g/VKT)

s = surface material silt content (%)

W = mean vehicle weight (tons)

S = mean vehicle speed (mph)

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

Constant Values

Table 39: Value of constants for Industrial & Public roads

Constant	Industrial Roads (Equation 1a)			Public Roads (Equation 1b)		
	$PM_{2.5}$	PM_{10}	PM_{30}	$PM_{2.5}$	PM_{10}	PM_{30}
K (g/VKT)	42.285	422.85	1381.31	50.742	507.42	1691.4
a	0.9	0.9	0.7	1	1	1
b	0.45	0.45	0.45	-	-	-
c	-	-	-	0.2	0.2	0.3
d	-	-	-	0.5	0.5	0.3

Source: US EPA

*Assumed equivalent to total suspended particulate matter (TSP)

"-"= not used in the emission factor equation

Table 40: Characteristics influencing the emission factors

Emission Factor	Surface Silt Content (%)	Mean Vehicle Weight (tonnes)	Mean Vehicle Speed (Km/ hr)	Mean No. of Wheels	Surface Moisture Content (%)
Industrial Roads (Eq.1a)	1.8-25.2	2-290	8-69	4-17	0.03-13
Public Roads (Eq.1b)	1.8-35	1.5-3	16-88	4-48	0.03-13

Source: US EPA

All roads are subject to some natural mitigation because of rainfall and other precipitation. The Equation 1a and 1b emission factors can be extrapolated to annual average uncontrolled conditions (but including natural mitigation) under the simplifying assumption that annual average emissions are inversely proportional to the number of days with measurable (more than 0.254 mm [0.01 inch]) precipitation:

Eext = E [(365-P)/365] .... (2)

where:

Eext = annual size-specific emission factor extrapolated for natural mitigation, lb/VMT

E = emission factor from Equation 1a or 1b

P = number of days in a year with at least 0.254 mm (0.01 in) of precipitation

Controls

A wide variety of options exist to control emissions from unpaved roads. Options fall into the following three groupings:

1. Vehicle restrictions that limit the speed, weight or number of vehicles on the road;
2. Surface improvement, by measures such as (a) paving or (b) adding gravel or slag to a dirt road; and
3. Surface treatment, such as watering or treatment with chemical dust suppressants.

Available control options span broad ranges in terms of cost, efficiency, and applicability. For example, traffic controls provide moderate emission reductions (often at little cost) but are difficult to enforce.

Although paving is highly effective, its high initial cost is often prohibitive. Furthermore, paving is not feasible for industrial roads subject to very heavy vehicles and/or spillage of material in transport. Watering and chemical suppressants, on the other hand, are potentially applicable to most industrial roads at moderate to low costs. However, these require frequent reapplication to maintain an acceptable level of control. Chemical suppressants are generally more cost-effective than water but not in cases of temporary roads (which are common at mines, landfills, and construction sites). In summary, then, one needs to consider not only the type and volume of traffic on the road but also how long the road will be in service when developing control plans.

Vehicle restrictions.

These measures seek to limit the amount and type of traffic present on the road or to lower the mean vehicle speed. For example, many industrial plants have restricted employees from driving on plant property and have instead instituted busing programs. This eliminates emissions due to employees traveling to/from their worksites. Although the heavier average vehicle weight of the buses increases the base emission factor, the decrease in vehicle-miles-traveled results in a lower overall emission rate.

Surface improvements

Control options in this category alter the road surface. As opposed to the "surface treatments" discussed below, improvements are relatively "permanent" and do not require periodic retreatment.

The most obvious surface improvement is paving an unpaved road. This option is quite expensive and is probably most applicable to relatively short stretches of unpaved road with at least several hundred vehicle passes per day. Furthermore, if the newly paved road is located near unpaved areas or is used to transport material, it is essential that the control plan address routine cleaning of the newly paved road surface.

The control efficiencies achievable by paving can be estimated by comparing emission factors for unpaved and paved road conditions. The predictive emission factor equation for paved roads, requires estimation of the silt loading on the traveled portion of the paved surface, which in turn depends on whether the pavement is periodically cleaned. Unless curbing is to be installed, the effects of vehicle excursion onto unpaved shoulders (berms) also must be taken into account in estimating the control efficiency of paving.

Other improvement methods cover the road surface with another material that has a lower silt content. Examples include placing gravel or slag on a dirt road. Control efficiency can be estimated by comparing the emission factors obtained using the silt contents before and after improvement. The silt content of the road surface should be determined after 3 to 6 months rather than immediately following placement. Control plans should address regular maintenance practices, such as grading, to retain larger aggregate on the traveled portion of the road.

Surface treatments refer to control options which require periodic reapplication. Treatments fall into the two main categories of **(a) "wet suppression" (i. e., watering, possibly with surfactants or other additives), which keeps the road surface wet to control emissions and (b) "chemical stabilization/treatment"**, which attempts to change the physical characteristics of the surface. The necessary reapplication frequency varies from several minutes for plain water under summertime conditions to several weeks or months for chemical dust suppressants.

Watering increases the moisture content, which conglomerates particles and reduces their likelihood to become suspended when vehicles pass over the surface. The control efficiency depends on how fast the road dries after water is added. This in turn depends on (a) the amount (per unit road surface area) of water added during each application; (b) the period of time between applications; (c) the weight, speed and number of vehicles traveling over the watered road during the period between applications; and (d) meteorological conditions (temperature, wind speed, cloud cover, etc.) that affect evaporation during the period.

The control effectiveness of **chemical dust suppressants** appears to depend on (a) the dilution rate used in the mixture; (b) the application rate (volume of solution per unit road surface area); (c) the time between applications; (d) the size, speed and amount of traffic during the period between applications; and (e) meteorological conditions (rainfall, freeze/thaw cycles, etc.)

during the period. Other factors that affect the performance of dust suppressants include other traffic characteristics (e. g., cornering, track-on from unpaved areas) and road characteristics (e. g., bearing strength, grade). The variabilities in the above factors and differences between individual dust control products make the control efficiencies of chemical dust suppressants difficult to estimate. Past field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a PM_{10} control efficiency of about 80 percent when applied at regular intervals of 2 weeks to 1 month.

PAVED ROADS

The revised emissions factor equation published in the January 1995 update of the paved road section included silt loading, average vehicle weight and a particle size multiplier as independent variables. The resulting equation was:

E = k * (sL/2)0.65 * (W/3)1.5 .... (3)

where: E = particulate emission factor (having units matching the units of k)

k = particle size multiplier for particle size range and units of interest (see below),

sL = road surface silt loading (grams per square meter) (g/m²), and

W = average weight (tons) of the vehicles traveling the road.

Table 41: Value of Multiplier k

Size Range	Multiplier k
	g/VKT
$PM_{2.5}$	1.1
PM_{10}	4.6 (0.62 as per IIT K SA Study for Delhi)
PM_{15}	5.5
PM_{30}	24

Source: Emission Factor Documentation for AP-42, Section 13.2.1, Paved Roads, January 2011

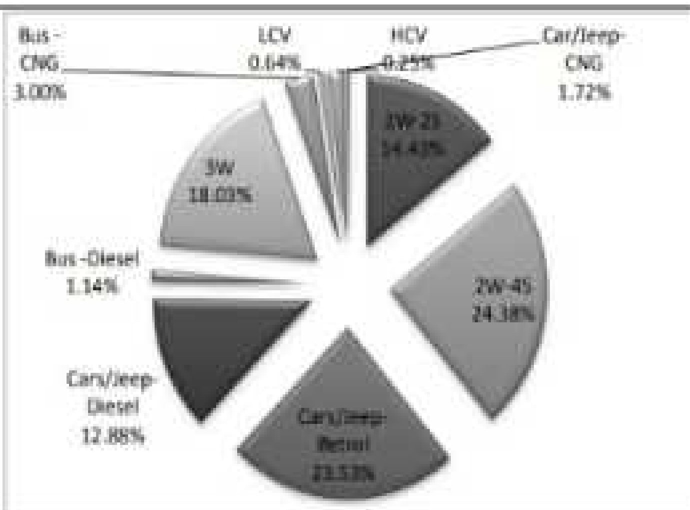


Figure 35: Traffic fleet characteristic of the ITO intersection

Source: Performance evaluation of air quality dispersion models at urban intersection of an Indian city: a case study of Delhi city, M. Khare & S. Gulia, WIT Transactions on Ecology and The Environment, Vol 1, ©2012 WIT Press

Emission Derivation for Dust Emission for Paved Roads in Delhi:

Table 42: On road vehicular weight by percentage

Category	Year 2019	% count Vehicle (A)	Weight in tonnes (fully loaded) (B)	Veh. Weight by % (A*B)
HCVs (Truck)	19390	0.03	28	0.89
Bus	975	0.002	9.86	0.01
Cars	154873	0.25	1.57	0.40
2 Wheelers	422760	0.69	0.27	0.19
3 Wheelers (Auto-CNG)	5766	0.01	0.64	0.006
LCVs	2633	0.004	6.02	0.02
Total	606397			1.54

Source: Compiled by SPA Delhi

A - Modal Share in %age (Delhi High Comm. Report, 2014)

B - Modal Split (% of person trips excluding walk trips) 2000-01

C - Modal Split (% of person trips excluding walk trips) 2007-08

D - On Road Traffic Composition

E - Avg. Kerb Weight in Kgs

F - Avg Weight in Kgs (max pay load)

Table 43: Typical silt content and Loading values for Paved roads at industrial facilities

Industry	No. Of Sites	No. Of Samples	Silt Content (%)		No. Of Travel Lanes	Total Loading x 10^{-3}			Silt Loading (g/m²)	
			Range	Mean		Range	Mean	Units[b]	Range	Mean
Copper smelting	1	3	15.4-21.7	19.0	2	12.9-19.5 45.8-69.2	15.9 55.4	kg/km lb/mi	188-400	292
Iron and steel production	9	48	1.1-35.7	12.5	2	0.006-4.77 0.020-16.9	0.495 1.75	kg/km lb/mi	0.09-79	9.7
Asphalt batching	1	3	2.6-4.6	3.3	1	12.1-18.0 43.0-64.0	14.9 52.8	kg/km lb/mi	76-193	120
Concrete batching	1	3	5.2-6.0	5.5	2	1.4-1.8 5.0-6.4	1.7 5.9	kg/km lb/mi	11-12	12
Sand and gravel processing	1	3	6.4-7.9	7.1	1	2.8-5.5 9.9-19.4	3.8 13.3	kg/km lb/mi	53-95	70
Municipal solid waste landfill	2	7	—	—	2	—	—	—	1.1-32.0	7.4
Quarry	1	6	—	—	2	—	—	—	2.4-14	8.2

[a] References 1-2,5-6,10-12. Values represent samples collected from *industrial* roads. Public road silt loading values are presented in Figure 13.2.1-2, Figure 13.2.1-3, Figure 13.2.1-4, Figure 13.2.1-5, Figure 13.2.1-6, and Figure 13.2.1-7, and Tables 13.2.1-2 and 13.2.1-3. Dashes indicate information not available.

[b] Multiply entries by 1000 to obtain stated units; kilograms per kilometer (kg/km) and pounds per mile (lb/mi).

Silt Content is assumed to be 0.531 g/m² in all the roads of Delhi. (The actual silt collection process for each road should be carried out in order to estimate the actual emission factor).

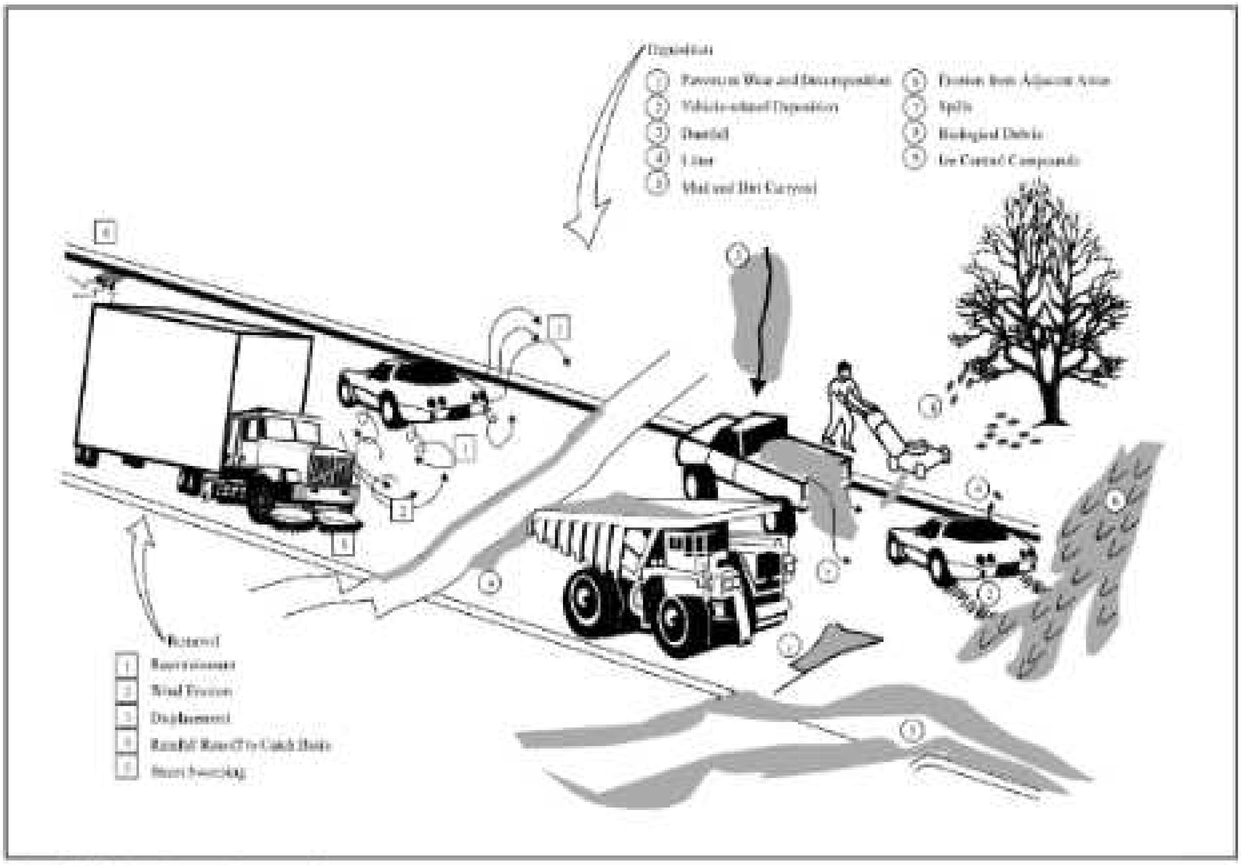


Figure 36: Deposition and removal processes

The silt loads vary with seasons and management efforts such as road cleaning, etc. The figures may be calculated based on that to estimate the dust emission season wise. (Equation 2)

Table 44: Vehicular modal split, 2019

Category	2019
Truck	19390
Tractor	2242
Bus	975
Cars	154873
2 Wheelers	422760
3 Wheelers (Auto-CNG)	5766
LCVs	2633
Total	608639

Source: Transport Department

Annual /Long Term Avg. E. Factor E = (k (sL/2)0.65 (W/3)1.5-C) (1-P/4N).

E = particulate emission factor (having units matching the units of k)

k = particle size multiplier for particle size range and units of interest

sL = road surface silt loading (grams per square meter) (g/m^2)

W = average weight (tons) of the vehicles traveling on the road

P = No. of wet days with at least 0.254 mm of precipitation during avg. period

C = Break and tire wear correction ($PM_{2.5}$=0.1005, PM_{10}=0.1317)

N = No. of days in averaging period (365 /year, 30/monthly, 91/seasonal);

Values of k (g/vkt) = $PM_{2.5}$ -1.1, PM_{10}-4.6

EF (PM_{10}) = (k (sL/2)0.65 (W/3)1.5-C) (1-P/4N)

= (4.6*((0.531/2) ^0.65) *((1.54/3) ^1.5)-0.1317) *((1-120/ (4*365))) = 0.622

EF ($PM_{2.5}$) = (k (sL/2)0.65 (W/3)1.5-C) (1-P/4N)

= (1.1*((0.531/2) ^0.65) *((1.54/3) ^1.5)-0.1005) *((1-120/ (4*365))) = 0.078

The value of silt loading is 0.531 g/m² considered similar to the case of Mumbai Case Study.

Table 45: Estimated Emissions from road dust

Vehicles	Count	VKT	$PM_{2.5}$ Emission (g)	PM_{10} Emission (g)
2W	422760	60	1989964.15	15766219.15
3W	5766	120	54282.02	430069.16
4W	154873	55	668249.30	5294449.62
Bus	975	210	16062.90	127264.22
LCV	2633	140	28918.72	229119.11
HCV	19390	75	114087.79	903902.30
Total (in g)			2871564.88	22751023.57
Total (in Kg)			2871.56	22751.02

Source: Compiled by SPA Delhi

Therefore, the total $PM_{2.5}$ emission from road dust is 2871.56 kgs per day and the total PM_{10} emission from road dust is 22751.02 kgs per day. Since 2014, different projects and policies have been introduced by the government to tackle the road dust and paving of the unpaved surfaces and greening along road sides. Some of them are mentioned below:

Control of dust emissions by carpeting unpaved roads, filling up of potholes, greening & paving of road sides:

In compliance of the orders of this Hon'ble Court dated 06.11.2019 regarding taking care of the various Hotspots of Delhi particularly w.r.t unpaved roads/pits in these identified hotspots, action plans have been prepared and action taken thereof has been submitted by way of affidavit submitted on 22.11.2019. That the Government is committed to improve the condition of the roads and uncovered stretches of land as they also contribute to the air pollution and dust. Further in addition to the action taken with regard to hotspots and in reference to the orders of this Hon'ble Court dated 06.11.2019, it is submitted that concrete action plans in collaboration with the various Municipal Corporations and Public Works Department (PWD) regarding surfacing/paving of unpaved roads and filling up of potholes have been prepared, notwithstanding the colonies are legal or not and the same are being executed.

A. Development works in unauthorized colonies:

The Government has planned and is in the process of carrying out development works i.e. construction/paving of roads and storm water drains in the unauthorized colonies of Delhi for which a plan scheme "Provision of Essential Services in Unauthorized Colonies" is being implemented. Under the Scheme, 1233 unauthorized colonies have been taken up for complete surfacing of roads and construction of storm water drains. Out of the 1233 colonies, work on surfacing of roads and construction of storm water drains have been completed in 395 colonies and in rest of the 838 colonies, works are at different stages of execution.

Under the aforesaid major plan scheme, construction of 956.79 kms of roads and storm water drain of 1743.5 kms have already been completed by December 2019. With the completion of the scheme, about 50 Lakhs people residing in these colonies will be provided with dust free environment.

In addition, the following action plans have been got prepared through the Municipal Corporations:

B). South Delhi Municipal Corporation:

Paving of Road sides: South DMC has prepared a detailed action plan on paving of roadside berms of total 4,42,230 square meters of area, the summary of the plan with the time lines is mentioned in table 46 .

Table 46: Plans and deadlines for completion of paving

Sl. No.	Paving area in Sqm	Time line/Target of completion
1	72890	Already completed by 31.12.2019
2	36934	31.01.2020
3	73865	29.02.2020
4	110799	31.03.2020
5	147742	30.04.2020
	Total	442230

Source: DPCC

The aforesaid action plan on paving envisages expenditure of Rs. 45 crores out of which Rs. 30 crores is being arranged from in-house sources and for the rest Rs. 15 crores, request has been forwarded to Ministry of Housing and Urban Affairs, Govt. of India for assistance through Urban Development Fund (UDF).

Action plan on Greening:

- SDMC has planted 763 trees on road side pavements and 2089 more trees will be planted by 31.03.2020.
- SDMC has proposed to develop parks on 19 Gram Sabha lands covering 31.5 acre area. Parks on 16 Gram Sabha land have been developed and remaining 3 will be completed by 31.03.2020.
- SDMC has developed the vertical gardens on 150 pillars of 11 numbers of flyovers with an area of 4270.5 Sqm.
- The SDMC has planted 1.5 lakhs shrubs and 80000 trees in various parks and 20000 more trees will be planted by 31.03.2020.
- SDMC has a plan to develop 163 MCD parks for greening of 123 acres of the area. Proposal has been submitted to MOHUA.

Resurfacing of Road and filling up of potholes - SDMC has prepared a plan for resurfacing of 132 km of roads (12 feet width) by 15.09.2020 at a cost of Rs. 20 Crores for which assistance has been soughtunder Urban Development Fund (UDF).SDMC has already completed the action for filling the potholes in 1298 Sqm areas around the hotspots.

C). North Delhi Municipal Corporation:

- In the areas under jurisdiction of North Delhi Municipal Corporation 4812 Sqm area of potholes have been filled up mainly in the areas around hotspots.

- Scheme for paving on the road sides berms in Karol Bagh zone, Keshav Puram zone and City- S.P zone to mitigate air pollution for total amounting Rs. 130.63 Crores have been prepared and submitted to DDA seeking sufficient funds under UDF.
- A detailed scheme along with project report for greening and paving in different parks of North DMC amounting to Rs. 17.84 Crores submitted to DDA seeking assistance for its implementation.
- Greening and Road side/ Central verge plantation:
  - o During 2018-2019, about 50000 number of trees and 10000 shrubs have been planted.
  - o In 2019-2020, 21360 trees out of the target of 25000 trees and
  - o And 38477 shrubs out of the target of 50000 shrubs have already been planted.
  - o Greening of 109.88 acre area in 167 Municipal Schools has been completed.
  - o Greening on 43 roads totaling 69.11 km completed.
  - o 54 vertical gardens have been completed by planting creepers.

D). East Delhi Municipal Corporation

- Greening and Paving –10000 Sqm of area has been paved with green carpet at 20 locations in east Delhi. Apart from this, the Municipal Corporation has developed vertical gardens at 14 locations by installation of 173 panels.
- Further the agency has planned for greening 14500 Sqm area and for paving 14500 Sqm area by the end of September 2020 by utilizing Urban Development Fund (UDF).
- Rs. 10.95 crores has been estimated to complete greening of various locations in its jurisdiction.

E). Public Works Department:

- Subsequent to digital survey carried out by PWD, 383 potholes were identified and all potholes have been filled and repaired.
- PWD has proposed the paving of roadside and other vacant patches to the tune of 15400 sqm by end of March 2020 in the areas under its jurisdiction at hotspots.
- In its long term plan for greening of road sides and other vacant patches, PWD has awarded the work for planting 6358 numbers of trees, 102368 numbers of shrubs, 17490 numbers of shade loving and 16080 numbers of creepers to be planted on hotspots upto 30.09.2020. the timeline for the aforesaid work is as follows:
  - o Administrative approval and expenditure sanction: 15.01.2020
  - o Award of work: 29.02.2020
  - o Plantation: 01.03.2020 to 31.05.2020
  - o Compensatory plantation and maintenance: 01.06.2020 to 30.08.2020

F. Implementation of plan scheme "Financial Assistance to local bodies under Mukhya mantra Sadak PunarnirmanYojna":

That the aforesaid scheme is being implemented for construction, repair and maintenance of

- Roads/Streets under any Urban local Body.
- Roads/Streets in Group Housing Societies.
- Roads/Streets of Housing Building Societies.
- Roads/Streets in unauthorized regularized colonies.

The Government has earmarked Rs. 1000 Crores for renovation of dilapidated internal roads and lanes throughout Delhi, out of which utilisation of Rs. 200 Crores was achieved in the year 2018-19 and Rs. 800 Crores is being utilized in the current year of 2019-20. The entire outlay of Rs. 1000 Crores has been made available from the budget of Government of NCT of Delhi.

4.10.5. Commercial – Hotels and Restaurants

The upscale segment of the hotel industry in India is highly organized and concentrated in few key cities. The total number of 'keys' (rooms) in the top 11 key cities covered by CARE Ratings is estimated at 92,537 as at the end of FY18. Of this, about 53% of the room inventory is concentrated in Mumbai, NCR and Bengaluru.[3] (see table no.47)

The primary survey of Hotels and Restaurants gave an average LPG consumption of 3 Cylinders (19 Kg capacity) and coal consumption of 8 Kg per hotel/restaurant as per the survey.[4]

Assuming 60% of Hotels are in Delhi City i.e., 0.6 *22159 = 13295

Emission Estimations

• Emission Load from LPG

Since LPG burning doesn't comprise of coarse particles, an assumption that only $PM_{2.5}$ particles are present in the LPG emissions is made.

Total emissions ($PM_{2.5}$) due to LPG burning in Hotels

= Number of Hotels x LPG consumption (Tons/day) x Emission Factor (Kg/MT)

Total $PM_{2.5}$ emissions due to LPG burning in Hotels

= 13295 x (3x19/1000 Tons/day) x 2.1 Kg/MT = 1591.4115 Kg/Day

Table 47: Ranking of Total number of rooms in major cities of India

		2012-13	2016-17	2017-18	Growth	
1	New Delhi*	16,738	20,981	22,159	5.6%	5.8%
2	Mumbai	12,807	13,494	13,726	1.7%	1.4%
3	Bengaluru	8,536	11,995	12,659	5.5%	8.2%
4	Chennai	6,330	8,332	9,211	10.5%	7.8%
5	Hyderabad	5,411	6,254	6,772	8.3%	4.6%
6	Goa	4,406	6,400	6,741	5.3%	8.9%
7	Pune	5,317	6,445	6,330	-1.8%	3.5%
8	Jaipur	4,129	5,058	5,426	7.3%	5.6%
9	Kolkata	2,163	3,199	3,860	20.7%	12.3%
10	Ahmedabad	2,477	3,117	3,393	8.9%	6.5%
11	Agra	1,299	2,092	2,260	8.0%	11.7%
	Total	**69,613**	**87,367**	**92,537**	**5.9%**	**5.9%**
12	Other Cities**	24,642	31,852	35,626	11.8%	7.7%
	Total	**94,255**	**119,219**	**128,163**	**7.5%**	**6.3%**

Note: *NCR includes New Delhi, Noida and Gurugram

** Other cities includes all other hotel markets across India

Source: Hotelivate

3 Hotel Industry – Review & Prospects, January 2019

4 Mumbai Source Apportionment Study

Delhi is one of the richest states in the country. The average per capita income of Delhi at 0.2 million is three times the estimate for all of India on average. In contrast to this are the nearly 1.7 million people in Delhi that are living below the poverty line, the 15 per cent of the Delhi population that lives in slums, and the 86 per cent of total workers who work in the informal economy (Delhi Human Development Report 2013). 10 million vendors in India contribute to 50 per cent of the country's savings. 63 per cent of the Gross Domestic Product comes from vendors.

Figure 37: Image of an operational street vendor in Delhi
Source: Showkat Shafi/AL Jazeera

According to various estimates and studies, there is anywhere from 300,000 to 500,000 street vendors in Delhi, but the Municipal Corporation of Delhi official figure of "legal" vendors is roughly around 125,000. Eighty-two per cent of vendors in Delhi are stationary vendors who sell perishable goods. More than half of the vendors in Delhi are in the older age group (i.e., 31-50 years). At 40 per cent, illiteracy is high among vendors.[5] Average operating hours of street vendors is 12 hours. Usage of kerosene and coal are banned in Delhi, so estimation of emissions are only done for LPG.

Emission Estimates

82% of street vendors in Delhi sell perishable goods i.e., 4,10,000.

Per capita consumption for each type of fuel is taken as

For LPG – 4 Kg /day

Total emissions = LPG burning

Emission from LPG burning (PM) per day

= Number of street vendors operating on LPG x fuel consumption per day x emission factor

PM_{10} emission from LPG = (0.2 x 410000) x 4 / 1000 x 2.10 = 688.8 Kg/d

$PM_{2.5}$ emission from LPG = (0.2 x 410000) x 4 / 1000 x 0.33 = 108.24 Kg/d

5 SEWA Bharat and Street Vendors in Delhi, Inclusive Cities Project, August 2015

4.10.7. Domestic

Table 48: Total numbers of cylinder: LPG consumption, 2015

(in Number)

State / UT	As on 31st March 2016				Total as on 31.03.2015
	IOCL	HPCL	BPCL	TOTAL	
(1)	(2)	(3)	(4)	(5)	(6)
STATES					
Andhra Pradesh	4992689	5878895	2575417	13447001	11015440
Arunachal Pradesh	257976	0	5049	263025	244245
Assam	3490797	105795	339624	3936216	3497667
Bihar	4330870	1693448	1558006	7582324	6380454
Chhattisgarh	1254511	781791	327964	2364266	2008339
Delhi	4079083	862051	1392850	6333984	6146480
Goa	15400	365498	190854	571752	559013
Gujarat	4583094	1874795	2116827	8574716	8100759
Haryana	2687576	1191764	1910959	5790299	5310990
Himachal Pradesh	1651026	221271	141435	2013732	1916380
Jammu & Kashmir	665769	1424617	241098	2331484	2174536
Jharkhand	1501722	510994	330561	2343277	2047293
Karnataka	5120967	4058005	2930191	12109163	10829277
Kerala	4619029	1591317	2599798	8810144	8487215
Madhya Pradesh	4286935	2379952	1910767	8577654	7734329
Maharashtra	3085505	10028005	10345196	23458706	21793042
Manipur	419321	0	0	419321	390028
Meghalaya	194268	0	4572	198840	188993
Mizoram	307884	0	0	307884	293261
Nagaland	241230	225	2670	244125	232823
Orissa	1540519	1465037	910129	3915685	3117055
Punjab	4656626	1537598	1919714	8113938	7548988
Rajasthan	4379477	2823173	2744724	9947374	8813142
Sikkim	168589	0	0	168589	157559
Tamil Nadu	10765323	2860711	4684011	18310045	17044036
Telangana	4353355	3606191	2508177	10467723	9271617
Tripura	512023	0	0	512023	450570
Uttar Pradesh	14620127	4060613	6158554	24839294	21447880
Uttarakhand	2017751	178529	421164	2617444	2432775
West Bengal	7495936	2514819	2156598	12167353	10454283
UNION TERRITORIES					
Andaman & Nicobar	94100	0	0	94100	86026
Chandigarh	274563	84833	58120	417516	408309
Dadra & Nagar Haveli	0	75769	0	75769	72139
Daman & Diu	0	45132	26954	72086	68800
Lakshadweep	4756	0	0	4756	4512
Puducherry	142488	150123	94438	387049	374211
GRAND TOTAL	98811285	52370951	50606421	201788657	181902266

Source: Central Public Sector Enterprises

Source: Indian Petroleum & Natural Gas Statistics, 2015-16

The total numbers of cylinder LPG consumption during the year 2015 in domestic sector is estimated to be 633984 = of 14.6 Kg each.

Households Fuel Consumption in Delhi:

Table 49: Fuel usage distribution in 2011 in Delhi

	HOUSEHOLDS					
TYPE	TOTAL	%AGE	RURAL	%AGE	URBAN	%AGE
LPG/PNG	3003996	89.92	59510	75.22	2944486	90.28
KEROSENE	175443	5.25	6123	7.74	169320	5.19
COW DUNG CAKE	19487	0.58	2907	3.67	16580	0.51
WOOD	112291	3.36	8927	11.28	103364	3.17
COAL/COKE/LIGNITE	4476	0.13	102	0.13	4374	0.13
BIO-GAS	3017	0.09	65	0.08	2952	0.09
CROP RESIDUE	9094	0.27	1241	1.57	7853	0.24
ELECTRICITY	1335	0.03	56	0.07	1279	0.04
OTHERS	1866	0.05	27	0.03	1839	0.06
NO COOLING	9533	0.28	157	0.20	9376	0.29
TOTAL	3340538	100	79115	100	3261423	100

Source: Census 2011

Since 2011, many programmes and policies have been initiated to ban usage of fuels like kerosene and coke, so the emissions from these are negligible and have not been accounted for carrying out the emission estimations.

Emission Estimation

• Emission Load from LPG

LPG consumption per household = 1 cylinder/month = 14.2 kg/month

Total emissions (PM) from LPG burning for domestic cooking

PM emission= Number of LPG cylinders consumed x Capacity of the cylinder (14.2 Kg) x Emission Factor (Kg/ton)

PM_{10} emission = 633984 x 14.2/30 x 2.1/1000 Kg/d= 6295.98 Kg/day

$PM_{2.5}$ emission = 633984 x 14.2/30 x 0.33/1000 kg/day = 989.36 Kg/d ay

4.10.8. Building construction

There were 29 major construction projects that were completed.

Table 50: List of completed projects

S.no.	Name & address of the Project
1	"Addition/Alteration in Existing National Institute of Fashion Technology(NIFT)" at Hauz Khas, New Delhi-16
2	Proposed 'Gujarat Bhawan' at 25-B, Akbar Road, New Delhi
3	Construction of Proposed District Court, Opposite Mata Sundri College & FDA Bhawan, New Delhi.
4	Proposed building "MDBP Project" with in the complex of National Small Industries Corporation Ltd., Okhla Industrial Estate., New Delhi-20
5	Hotel with General Commercial including Multiplex, Sector-14, Dwarka, New Delhi-78
6	Construction of 240 Dwelling Units Multi-storey Housing Pocket at Pocket E, Bakkarwala, New Delhi-110041.

S.no.	Name & address of the Project
7	Construction of Group Housing Complex at 850 (mass housing), near Sultan Garhi Tomb at Vasant Kunj, New Delhi.
8	Construction of HIG (Multistorved House at Sector 19 B, Phase-II, Dwarka, New Delhi
9	Construction of EWS & Category - II at Pocket 1C, Sector A1-A4, Narela New Delhi-40
10	Proposed Construction of Multistoried 2 bedroom housing at Pocket 2, Sector 16(B), Dwarka, New Delhi
11	Prefab LIG & EWS Housing for DDA at Pocket-III, Sector-G2G6, Narela, Delhi-40
12	Prefab LIG & EWS Housing for DDA at Pocket-V, sector G2-G6, Narela, Delhi-40
13	Prefab LIG & EWS Housing for DDA at Pocket-IV, sector G8, Narela, Delhi-40
14	Prefab LIG & EWS Housing for DDA at Pocket-V, sector G8, Narela, Delhi-40
15	Construction of Group Housing Complex at 852 & 362 (cluster project), near Sultan Garhi Tomb at Vasant Kunj, New Delhi-70
16	Modernization 181 Nos. of M.S. Flats (Group Housing Complex) at Plot No. B-4, Vasant Kunj, New Delhi-70
17	Expansion of the Group Housing Park "Metro Park" at Dwarka Morh, Delhi
18	Expansion of Group Housing at W-Block, Greater Kailash-II, New Delhi.
19	Group Housing Project,Pocket 9B,Jasola ,New Delhi
20	In situ Rehabilition Project - Multistored Housing at Kalkaji Extension Pocket A-14, Delhi.
21	Residential Complex " A.P. Wonders , MRTS Ritala, Near Rithala Metro Station, Delhi
22	Construction of residential flats for Delhi Armed Police Line(DAP) at Dwarka, Sector 9, New Delhi-75
23	Extension of G. B. Pant Polytechnic (Phase–I) at Okhla-III, New Delhi-20
24	Proposed Additional Building Complex for the Supreme Court of India adjoining Pragati Maidan, New Delhi
25	Construction of Indian Aviation Academy & Hostel Block at Rangpuri, VasantKunj, New Delhi-70
26	"Prefab Cat-II & EWS Housing" at Pocket 1A, Sector-A-1-A4 , Narela , New Delhi -40
27	"Prefab Cat-II & EWS Housing" at Pocket 1B, Sector-A-1-A4 , Narela , New Delhi-40 By M/s Delhi Development Authority
28	Proposed "Office & Data Centre Complex for National Intelligence Grid" , Andheria Mod , New Delhi
29	Construction of 352 Multistoried 2-Bedroom Apartments" adjoining Pocket 3, Sector 19B, Dwarka , New Delhi

Source: DPCC

For the purpose of estimating emissions, it is assumed that the fugitive dust emission is related to the acreage affected by construction

Step 1 –Total No. of construction activities in each region. This was obtained from PWD.

Step 2 – Acres disturbed

For new buildings, = 0.5 acres are disturbed per activity

For addition / alteration = 0.2 acres per activity are disturbed

Step 3 – Months of activity

New buildings = 18 months, Addition / alteration = 6 months

Step 4 – Acre –months of activity

For new building = 18 x total number of acres disturbed

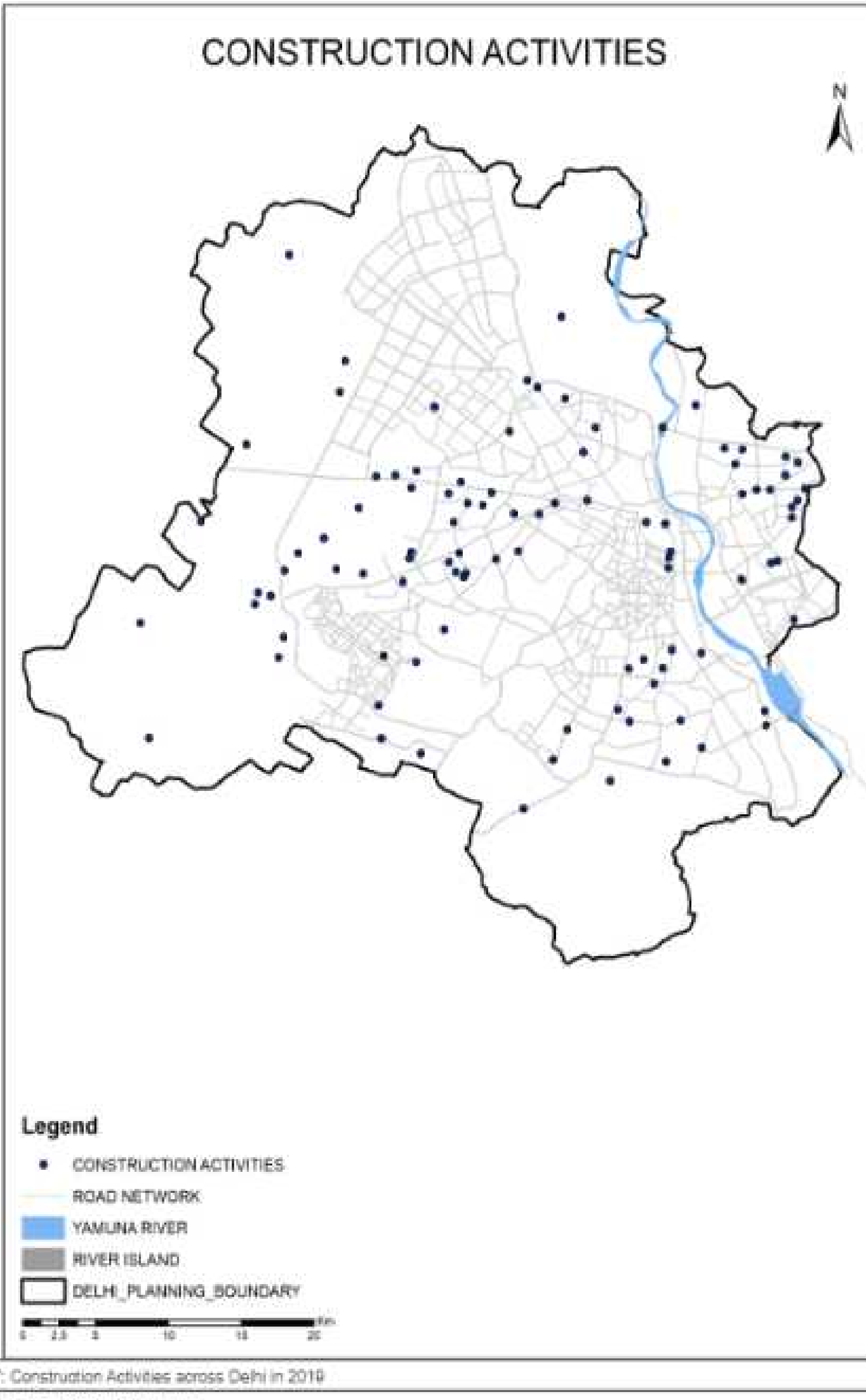
For addition / alteration = 6 x total number of acres disturbed

Step 5 – PM_{10} Tons /years = 1.2 x total number of acres – months

(AP42, Section 13.2.3.3– PM_{10} - 1.2 tones/ acres months)

Issues

• The current methodology assumes that all construction operations emit the same levels of PM on per acre basis.



Map 7: Construction Activities across Delhi in 2019

Source: Public Works Department

- The methodology assumes that construction dust emissions are directly proportional to the number of acres disturbed during construction. The estimates of acreage disturbed are limited in their accuracy, as explained above
- Emission due to vehicle movement during construction activity is not calculated

Management of Construction and Demolition (C&D) Waste :

There are 5 Local Bodies / Municipal Corporations [3 Municipal Corporations (North DMC, EDMC & SDMC), New Delhi Municipal Council (NDMC) & Delhi Cantonment Board (DCB) in Delhi. Approximately 3900 TPD of Construction and Demolition Waste (C&D Waste) is generated in Delhi. Separate collection and transport infrastructure of C&D Waste has been set up under which the C&D Waste is collected at ear marked sites identified by the 3 Municipal Corporations (North DMC, EDMC & SDMC), NDMC & DCB and the same is transported to the 4 existing Construction and Demolition Waste Processing / Recycling Facilities / Plants functioning in Delhi. The existing capacity of the 4 operational Construction and Demolition Waste Processing / Recycling Facilities is 3650 TPD.

The existing Construction and Demolition Waste Processing Facilities & Proposed Expansion is briefed in following Table

Table 51: C&D Waste Processing Facility

S.No.	C& D Waste Processing Facility	Existing Capacity (in TPD)	Proposed Expansion for Additional Waste Processing Capacity (in TPD)
1	North DMC: C & D Waste Processing Facility at Jahangir Puri (Being operated by IL&FS)	2000	
2	East DMC: C & D Waste Processing Facility at Shastri Park (Being operated by IL&FS)	500	500 (By March, 2021)
3	DMRC: C & D Waste Processing Facility at DMRC Site Rani Khera (Being operated by IL&FS)	150	
4	C & D Waste Processing Facility at Bakkarwala (South DMC) (New Facility started operation in March, 2020)	1000	
	Total	3650	500

Source: DPCC

In these processing facilities, Paver Blocks, Kerb Stones, Bricks, Aggregates, Sand and Soil of BIS standards are being produced out of the C&D waste which is further used in the infrastructure projects, thus fresh requirement of natural resources is minimized. With the existing and proposed processing facilities, it is expected that the entire C&D waste generated in Delhi will be managed properly in a scientific manner.

Table 52: Proposed Sites of C&D Waste Processing

S.No	Proposed Site of C& D Waste:Processing Facility	Proposed Waste Processing Capacity (in TPD)
1	Maidangarhi (South DMC)	1000
2	Ranikhera (North DMC)	1000
3	Libaspur(PWD)	500
	Total	2500

Source: DPCC

Consent to Establish under the Air & Water Acts granted to M/s IL&FS Environmental Infrastructure and Services Ltd. for its new Construction and Demolition Waste Processing Facility of 1000 TPD at Rani Khera on 14.02.2020.

Consent to Operate under the Air & Water Acts and Authorization under the Construction and

Demolition Waste Management Rules, 2016, were granted to M/s Garg & Company for its new Construction and Demolition Waste Processing Facility of 1000 TPD at Bakkarwala on 27.02.2020 and 18.03.2020 respectively. This Facility has started its operation in March, 2020. Consent to Establish under the Air & Water Acts was granted to M/s IL&FS Environmental Infrastructure and Services Ltd. for expansion of its Construction and Demolition Waste Processing Facility at Shastri Park from 500 TPD to 1000 TPD on 23.10.2019. Consent to Operate under the Air & Water Acts and Authorization under the Construction and Demolition Waste Management Rules, 2016, have also been issued in respect of this plant on 17.03.2020. Consent to Operate (Renewal) under the Air & Water Acts and Authorization (Renewal) under the Construction and Demolition Waste Management Rules, 2016, were granted to M/s IL&FS Environmental Infrastructure and Services Ltd. for its Construction and Demolition Waste Processing Facility at Jhangirpuri (Burari) on 25.02.2020.

Department of Urban Development, Govt. of NCT of Delhi has already issued Order Dated 06.07.2019 (Copy of Letter enclosed) regarding use of Recycled Products from C&D Waste including following measures to be taken for compliance by all Municipal / Local Govt. Bodies in Delhi, Public Works Department, Irrigation & Flood Control, DSIIDC, DJB & Departments and Organisations of GNCTD involved in Construction/Maintenance of Civil Works:

(i) A minimum of 2% of C&D Recycled Products shall be used for building works.

(ii) 10% of C&D Products shall be used for Road works.

(iii) Urban Local Bodies (ULBs) in Delhi shall mandate 5% use of C&D recycled products for nonstructural application by all, including private individuals. This condition shall be introduced by modifications in byelaws if necessary, & by including the same condition in the building plan approval.

(iv) Compliance of these conditions shall be verified and certified by the concerned Executive Engineer before verifying and certifying the bills for payments in any such contract.

(v) Intimation of the action taken/compliance report.

Ministry of Housing and Urban Affairs, Govt. of India , (MoHUA) had fixed the target of 16,07,000 MT for use of Construction and Demolition recycled materials by various Departments in the Financial Year 2019-20.

Directions u/s 5 of the EP Act were issued on 14.01.2020 to various Govt. Departments / Agencies for expediting & maximizing the utilization of C&D Waste Recycled Materials / Products of the 3 C & D Waste Processing Facilities in Delhi in their projects to meet the targets fixed by MoHUA.

In the Financial Year 2019 -2020 in respect of existing 3 C & D Waste Processing Facilities [at Jahangirpuri (Burari), Shastri Park & Mundka], Total C&D Waste Intake was 9.2 Lakh MT , Total C&D Waste Processed was 8.8 Lakh MT and Total Off-take of C & D Recycled Materials by Govt. Departments & Private Parties was 8.8 Lakh MT.

Off- take of C&D Recycled Materials by the Govt. Departments for Financial Year 2019-20 is enclosed.

Above action taken and meetings taken by the Chairman, DPCC from time to time resulted in improvement in the off take / lifting of C & D Recycled Materials from the existing C & D Waste Processing Facilities in Delhi. Over the last 10 years, it is the first time when C & D waste

Intake Quantity, Processed Quantity and Off-take Quantity are more or less same during the financial year 2019-20.

4.10.9. Crematorium

There are 53 cremation sites in the city of Delhi, which operates in various zones of Municipal Corporation of Delhi. Specific information on number of dead bodies cremated in each cremation site was not available. The information pertaining to total number of deaths in Delhi was obtained from Directorate of Economics and Statistics handbook for the year 2014. The total number of registered deaths in 2014 for Hindus was 105336. The wood required for per body for the cremation is taken as 216 kg (Sharma, 2010).

Table 53: Emission factors

	Usage (Pune SA Study)	Usage (Mumbai SA Study)	Usage (IIT K SA Study)	PM_{10}	Remarks
Fuel Wood	200Kg per body	300 kg per body	216 kg per body	15.3 g/kg	Fuel wood is used along with PNG
Electrical Cremation	60% of bodies				
Diesel (litres)	25 litres per day			0.83 g/litre	Kerosene, diesel and dung cake are no longer used for cremation activities and have been replaced by PNG and electrical cremation.
Kerosene		3 litres (2.43 kg) per body			
Dung Cake	60 Kg per body				

Source: Source Apportionment studies of Mumbai & Pune and Source Apportionment study done for Delhi by IIT Kanpur

Table 54: Birth & Death rate, Delhi

	2013	2014	2015	2016
Live Birth	370000	373693	374012	379161
Still Birth	3517	3102	3175	2977
Death	97185	121286	124516	141632

Source: Delhi Statistical Handbook, 2017

Assuming the similar figure of 373 deaths per day, the deaths in 2019 is estimated to be 136145.

Emission Estimations:

Emission (PM) =No. of Hindu Death /yr (0.7) * wood required per body (Kg) * emission factor

Number of deaths in Delhi for 2019 = 136145

Taking 70% of total dead bodies in fire wood crematoria = 95302

PM_{10} Emission from wood burning = 136145 (deaths) * 216 (kg) * 15.3 (Kg/ton) = 449931.99Kg in year 2019.

$PM_{2.5}$ Emission from wood burning = 136145 (deaths) * 216 (kg) * 1.5 (Kg/t) = 44110.98 Kg in year 2019.

SELECTED VITAL RATES OF DELHI

Year	Birth Rate* (CRS)	Death* Rate(CRS)	Average no. of events per day		Infant Mortality Rate				
			Births	Deaths	Neonatal Mortality Rate (CRS)	Neonatal Mortality Rate (SRS)	Postnatal Mortality Rate (CRS)	Infant Mortality Rate (CRS)	Infant Mortality Rate (SRS)
2010	21.66	7.48	985	341	15	19	7	22	30
2011	20.89	6.63	969	307	15	18	7	22	28
2012	20.90	6.10	988	287	14	16	10	24	25
2013	21.07	5.52	1014	266	15	16	7	22	24
2014	20.88	6.77	1024	332	14	14	8	22	20
2015	20.50	6.82	1025	341	16	14	7	23	18
2016	20.38	7.61	1036	387	13	12	8	21	18
2017	19.36	7.18	1006	373	NA	NA	NA	NA	NA

Source – O/o RGI, Govt of India & DES, Delhi

Source: Economic Survey of Delhi, 2018-19

Emission Factor Electric crematoria = 0.000025 (Kg/body) [6]

Taking 30% of total dead bodies in electric crematoria = 40844

PM_{10} Emission from cremetorium = 40844 (deaths) * 0.000025 (Kg/body) = 1.02 Kg in year 2019.

4.10.10. Waste Incinerators

At present there are 2 CBWTFs i.e, M/s SMS Water Grace BMW Pvt. Ltd, Nilothi, Near DJB STP Plant, New Delhi-110041and M/s Biotic Waste Sol. Pvt Ltd 46,47 SSI Industrial Area, G.T Karnal Road, New Delhi-110043.

The Details of both the CBWTF are as under :-

Installed capacity of both CBWTFs at present is 62 Tonnes/ Day with breakup of the capacities as follows:

M/s SMS Water Grace (P) Ltd.

1. Capacity = 28.8 Tonnes/ Day
2. Incinerators = 2 Nos (250 kg/ hr each)
3. Autoclave = 2 Nos (300 Kg / batch + 400 Kg/ batch)
4. Shredder = 3 Nos (250 kg/ hr + 350 kg/hr + 150 kg/hr)
5. Status of CEMS installed.

M/s Biotic Waste Sol. Pvt. Ltd.

1. Capacity = 34 Tonnes/ Day
2. Incinerators = 3 Nos (750 kg/ hr + 300 Kg/ hr + 200 Kg/ hr)
3. Autoclave = 1 Nos (450 Kg / batch)
4. Shredder = 2 Nos (350 kg/ hr + 100 kg/hr)
5. Status of CEMS installed.

6 Air Quality Assessment, Emission Inventory & Source Apportionment Study for Mumbai City

Table 55: Details of Bio-medical waste processed in SMS Watergrace BMW PVT. LTD

1	Name of the Organization	SMS WATERGRACE BMW PVT.LTD
2	Total no. of Health Care Facilities / Occupiers	5613
3	Bedded Hospitals and Nursing Homes (bedded)	658
4	Clinics, dispensaries	564
5	Veterinary institutions	64
6	Pathological laboratories	832
7	Blood banks	4
8	Clinical establishment	3456
9	Research Institutions	35
10	Total no. of beds	32924
11	Quantity of Bio-medical Waste Generation (in kg/day)	14243
12	Bio-medical waste generation by bedded hospitals(in kg/day)	12200

Table 56: Details of Bio-medical waste processed in Biotic waste solutions PVT. LTD

1	Name of the Organization	Biotic Waste Solutions Pvt. Ltd
2	Total no. of Health Care Facilities / Occupiers	4664
3	Bedded Hospitals and Nursing Homes (bedded)	567
4	Clinics, dispensaries	454
5	Veterinary institutions	89
6	Pathological laboratories	700
7	Blood banks	5
8	Clinical establishment	2789
9	Research Institutions	50
10	Animal houses	6
11	AYUSH	4
12	Total no. of beds	24729
13	Quantity of Bio-medical Waste Generation (in kg/day)	14,240
14	Bio-medical waste generation by bedded hospitals(in kg/day)	12,100

Table 57: Details of Bio-medical waste generated in Kg/day

	Name of the District	Bio-medical Waste Generation (in Kg/day)				
		Yellow	Red	Blue	White	Total
1	Central	1982	1974	373	107	4436
2	West	1053	1314	296	102	2765
3	South West	1591	1396	291	55	3333
4	East	587	871	179	51	1688
5	North east	129	63	17	2	211
6	Shahdara	884	741	155	30	1810
7	North	410	241	40	28	719
8	North West	1360	670	168	29	2227
9	New Delhi	2217	2890	1396	61	6564
10	South	814	710	261	38	1823
11	South East	1446	1027	359	75	2907

Source: DPCC

4.10.11. Soil Dust

Area of Barren Open soil in Delhi (as per LULC, 2019) = 748.446 sq. km or 184944.8498 acres.

Table 58: Land-cover across Delhi NCT

CLASS_NAME	Area (sq.km)	Area (acres)
BARREN (open soil)	748.44	184944.84
BUILT UP	449.48	111070.43
VEGETATION	154.68	38222.79
AGRICULTURAL - NO COVER	103.97	25692.33
AGRICULTURAL - COVER	19.81	4897.22
WATER BODY	9.98	2467.48
TOTAL	1486.39	367295.12

Source: SPA Delhi

Soil Dust Emission factor:

$PM_{2.5}$ – 0.263 Kg/acre/year; PM_{10} – 0.1315 Kg/acre/year

PM_{10} Emission from soil dust = 184944.8498 * 0.1315 (Kg/acre/year) = 24320.136 kg/year

$PM_{2.5}$ Emission from soil dust = 184944.8498 * 0.263 (Kg/acre/year) = 48640.4953 kg/year

4.10.12. Airport

Emission estimates from aircrafts have been made for the domestic and international airports. These two airport terminals are spread over two different locations about 2 kms apart in the south-west of Delhi. Terminal 1 is meant for domestic flights only. Terminal 2 is for international flights. Emissions from aircraft originate from fuel burned in aircraft engines. Emissions from aircrafts are calculated from the aircraft movements in an LTO cycle. 1 LTO = 2 aircraft movement. The aircraft movement details were obtained from the report given at the Airport Authority of India website.

Emission Estimation

Total emissions from aircrafts = Number of LTO cycles x Emission Factor

Total annual emissions (PM_{10}) from aircrafts = Number of LTO cycles x Emission factor (Kg/LTO)

= (Total Aircraft Movement/2) x 0.99 Kg/LTO

Table 59: Emission estimations from aircrafts

Aircraft Movement (in '000) 2019-20					Grand Total (including General Aviation)	LTO	PM_{10} Emission (Kg)	PM_{10} Emission (tonnes)
Month	Inter-national	Domestic	Total	General Aviation				
January	40.07	195.21	235.28	19.2	254480	127240	125967.6	125.9676
February	36.55	185.93	222.48	24.45	246930	123465	122230.35	122.23035
March	22	142.07	164.07	16.81	180880	90440	89535.6	89.5356
April	34.32	166.84	201.16	25.46	226620	113310	112176.9	112.1769
May	35	177.94	212.94	25.72	238660	119330	118136.7	118.1367
June	34.59	176.25	210.84	19.63	230470	115235	114082.65	114.08265
July	37.62	179.22	216.84	20.77	236610	118305	117121.95	117.12195
August	37.62	179.5	217.12	23.09	240210	120105	118903.95	118.90395
September	37.2	176.02	213.22	21.3	234520	117260	116087.4	116.0874
October	38.67	192.25	230.92	21.16	252080	126040	124779.6	124.7796

Aircraft Movement (in '000) 2019-20					Grand Total (including General Aviation)	LTO	PM_{10} Emission (Kg)	PM_{10} Emission (tonnes)
Month	Inter-national	Domestic	Total	General Aviation				
November	38.71	189.22	227.93	22.97	250900	125450	124195.5	124.1955
December	40.35	194.2	234.55	22.22	256770	128385	127101.15	127.10115
Total	421.7	2154.65	2588.35	262.78	2849130	1424565	1410319.35	1410.31935

Source: https://www.aai.aero/en/business-opportunities/aai-traffic-news

4.10.13. Diesel Generator Sets

It is learnt from survey that power failure in Delhi occurs approximately 100 hours per month during summer season and occasionally during rest of the year. The generators of capacity less than 2.5 KVA are not used anymore in Delhi, as housing societies have shifted towards invertors as per DPCC.

Table 60: DG Sets Supplied by Different Suppliers (Total for 10 Years)

Capacity (KVA)	Honda Seil	Total
2.5	14765	14765

Source: Generators sets suppliers: Air Quality Monitoring, Emission Inventory & Source Apportionment Studies- Delhi

Usage of diesel sets are banned for around 6 months throughout the year. It is suggested that if they are restricted for 6 months and are operating the remaining months, then it shoud be completely restricted. Subsidies should be provided for shifting to PNG fuels.

Diesel Generators have a power factor of 0.8. Electrical efficiency is usually expressed as a power factor in between 0 & 1, therefore the closer the power factor is to 1, then the more efficiently the kVA is being converted into actual kilowatts.

Assuming 2 hrs of usage per day:

Table 61: Emissions from DG sets 2.5KVA

Capacity (KVA)	Honda Seil	Birla Yamaha	Total	Power (Kwh) @2hr usage	PM_{10} Emission (g/day)	PM_{10} Emission (Kg/day)
2.5	14765		14765	40	785498.00	785.50

Source: Compiled by SPA Delhi

4.10.14. Biogenic Emissions

A good deal of research has been done to estimate emissions of nitrogen oxides (NOx) from soils. Although numerous measurements have been made, emissions from soils show variability based on a number of factors. Differences in soil type, moisture, temperature, season, crop type, fertilization, and other agricultural practices apparently all play a part in emissions from soils.

Soils emit NOx through biological and a biological pathway, and emission rates can be categorized either by fertilizer application or land use. Agricultural lands and grasslands are the most significant emission sources within this category. The quantity of NOx emitted from agricultural land is dependent on fertilizer application and the subsequent microbial denitrification of the soil.

Microbial denitrification is a natural process in soil, but denitrification is higher when soil has been fertilized with chemical fertilizers. Both nitrous oxide (N2O) and nitric oxide (NO) are emitted from this source.

Agricultural Soils

Various agricultural soil management practices contribute to greenhouse gas emissions. The use of synthetic and organic fertilizers adds nitrogen to soils, thereby increasing natural emissions of N2O. Other agricultural soil management practices such as irrigation, tillage, or the fallowing of land can also affect trace gas fluxes to and from the soil since soils are both a source and a sink for carbon dioxide (CO2) and carbon monoxide (CO), a sink for methane (CH4), and a source of N2O. However, there is much uncertainty about the direction and magnitude of the effects of these other practices, so only the emissions from fertilizer use are included in the method presented here.

Nitrous oxide emissions from commercial fertilizer use can be estimated using the following equation:

N2O Emissions = (FC * EC * 44/28)

where:

FC = Fertilizer Consumption (tons N-applied);

EC = Emission Coefficient = 0.0117 tons N2O-N/ton N applied; and

44/28 = The molecular weight ratio of N2O to N2O as N (N2O/N2O-N).

The emission coefficient of 0.0117 tons N/ton N-applied represents the percent of nitrogen applied as fertilizer that is released into the atmosphere as nitrous oxide. This emission coefficient was obtained from the Agricultural Research Service of the U.S. Department of Agriculture (USDA), which estimated that 1.84 kg N2O was emitted per 100 kg of nitrogen applied as fertilizer. After applying the appropriate conversion, this is equivalent to 0.0117 tons N2O-N/ton N-applied.

Other Soils

The amount of N2O emitted from non-agricultural soils is dependent on the soil's nutrient level and moisture content.5 It is believed therefore that soils in tropical regions emit far more N2O than soils in other terrestrial ecosystems. Because of the variability of soil types and soil moisture levels, some tropical soils emit more N2O than others.

Table 62: Distribution of Fertilizer in Delhi (in M. Tons)

Fertilizer	2013	2014	2015	2016	2017
Nitrogenous	1862	1862	4180	5641	7566
Phosphatic	1052	1052	1870	2502	316
Potassic	358	358	1220	1220	NA
Total	3272	3272	7270	9363	7882

Source: Joint Director (Agriculture), Govt. of NCT of Delhi, Delhi Statistical Handbook, 2017

Table 63: Nitrogen Content of Principal Fertilizer Materials

MATERIAL	% NITROGEN (by wt)
Nitrogen	
Ammonia, Anhydrous	82
Ammonia, Aqua	16-25
Ammonium nitrate	33.5
Ammonium nitrate-limestone mixtures	20.5
Ammonium sulfate	21
Ammonium sulfate-nitrate	26
Calcium cyanamide	21
Calcium nitrate	15
Nitrogen solutions	21-49
Sodium nitrate	16
Urea	46
Urea-form	38
Phosphate	
Basic slag, Open hearth	—[b]
Bone meal	2-4.5
Phosphoric acid	—[b]
Rock phosphate	—[b]
Superphosphate, Normal	—[b]
Superphosphate, Concentrated	—[b]
Superphosphoric acid	—[b]
Potash	—[b]
Potassium chloride (muriate)	—[b]
Potassium magnesium sulfate	—[b]
Potassium sulfate	—[b]
Multiple Nutrient	
Ammoniated superphosphate	3-6
Ammonium phosphate-nitrate	27
Ammonium phosphate-sulfate	13-16
Diammonium phosphate	16-21
Monoammonium phosphate	11
Nitric phosphates	14-22
Nitrate of soda-potash	15
Potassium nitrate	13
Wood ashes	—[b]
Blast furnace slag	—[b]
Dolomite	—[b]
Gypsum	—[b]
Kieserite (emjeo)	—[b]
Limestone	—[b]
Lime-sulfur solution	—[b]
Magnesium sulfate (Epsom salt)	—[b]
Sulfur	—[b]

[a] Reference 3.
[b] No, or a negligible amount of, nitrogen present.

Source: Emissions from Soils—Greenhouse Gases, EPA, https://www3.epa.gov/ttn/chief/ap42/ch14/final/c14s01.pdf

Famers in India uses Nitrogen solutions containing 21-49% of nitrogen (by wt) and Potassium Nitrate containing 13% of nitrogen (by wt). The Phosphate fertilizers used contains no or a negligible amount of nitrogen.

Emissions from agricultural land (as per 2017):

FC, Fertilizer Consumption (tons N-applied) = [7566 M.tons of Nitrogen fertilizer * 21% N/ton fertilizer] = 1588.86 x 106 tons N

Emissions are calculated by:

N_2O emissions = (1588.86 x 106 tons N applied) x (0.0117 tons N_2O) x 44/28

N_2O emissions = 29.212 x 106 tons N_2O (in year 2017)

Emission Factors for N_2O from Non-Agricultural Soils

Table 84: Emission Factors

Ecosystem	Emission Factors (lbs N2O/acre/yr)
Tropical Forest	3.692
Savanna	2.521
Temperate Forests (coniferous)	1.404
Temperate Forests (deciduous)	0.563
Grassland	1.503
Shrubs/Woodlands	2.456

To convert lb N_2O/acre/yr to g N_2O/m^2/yr, multiply by 0.11208

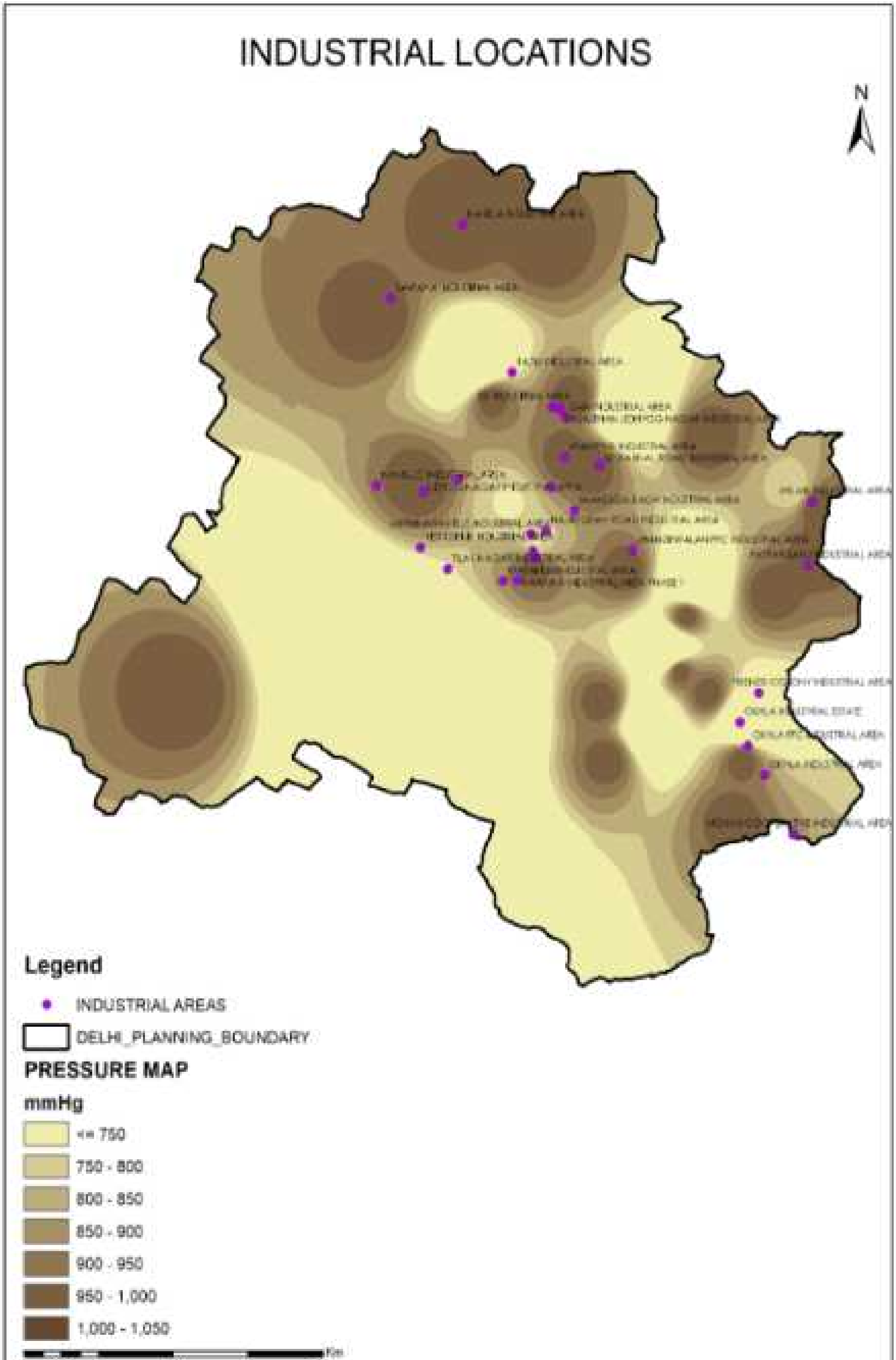
Table 85: Emission Calculation for Non-Agricultural Soils

CLASS	Area (sq.m)	Emission Factor (lbs N2O/acre/yr)	Emission Factor (g N2O/m² /yr)	Emission (g N2O/yr)	Emission (Kg N2O/yr)
BARREN	748446408.5	2.456	0.27526848	206023705.2	206023.7052
BUILT UP	449486780.5	0	0	0	0
VEGETATION	154682419.7	0.563	0.06310104	9760621.554	9760.621554
AGRICULTURAL-NO COVER	103973345.1	0	0	0	0
AGRICULTURAL - COVER	19818412.63	0	0	0	0
WATER BODY	9985576.308	0	0	0	0
TOTAL				215784326.8	215784.3268

Source: Compiled by SPA Delhi

4.10.15. Industries

The emissions from the industries are calculated based on their fuel usage. The data of 31 industrial areas was made available with 1445 industries in it, out of total 28000 industries in these clusters. For diesel fuel usage, it was given that BS-VI norms are being followed, so as per the BS-VI the emissions for diesel operations were calculated. The emission factor used was 0.34 g/kg of $PM_{2.5}$ on combustion of natural gas and 0.31g/kg of $PM_{2.5}$ on combustion of LPG (Reddy & Venkataraman,2002). For calculating the daily emissions, it was further assumed that industries are operational only 25 days per month.



Map 8: Industrial Locations and Pressure Map of Delhi

Table 66: Emissions from industries

Sno.	Industrial Cluster	Total industries in cluster	Given Emission Data (no.s of industries)	PNG/CNG	DIESEL	LPG
				PM EMISSIONS (kg/day)		
1	Badli	602	56	3339.48	0	0
2	Mohan Cooperative	215	8	610.8	0.0000165	0
3	GTK raod	643	14	920.35	0	0
4	Lawrence	875	52	3839.08	0.00003	0
5	Mangolpuri	1130	51	1362.41	0.00001	0
6	Mayapuri	2181	74	4061.73	0	0.01
7	Narayana	986	20	724.55	0	0
8	Narela	3528	236	8133.3	0	0
9	Okhla	2902	66	1600.7	0.0001	0
10	Prahladpur	55	2	53.72	0	0
11	Run	119	13	786.4	0	0
12	SMA	198	23	2067.9	0	0
13	SSI	147	14	2103.8	0	0
14	Wazirpur	1832	68	2935.96	0.00005	0
15	Bawana	5303	337	8908.68	0	0
16	Jawahr Nagar	79	14	0	0.0002	2.15
17	Karawal Nagar	154	6	0	0	6.04
18	Samaypur	439	73	3002.02	0	0
19	Jhilmil	1042	40	2979.40	0	0
20	Friends colony	975	5	1474.2	0	0
21	Mandoli	179	94	5641.58	0	0
22	Shahadra	304	8	20.04	0	0.22
23	Pratapganj	814	44	1809.5	0	0
24	Kirti Nagar	677	19	454.78	0	0
25	Moti Nagar	176	10	619.04	0	0
26	Tilak Nagar	72	2	8.1	0	0
27	Najafgarh Road	757	22	801.11	0	0
28	Nangloi	482	12	591.08	0	0
29	Udyog Nagar	701	27	1733.5	0	0
30	Mundka	144	14	734.91	0	0
31	Swarn Park	76	21	1174.06	0	0
	Total	**27787**	**1445**	**62492.75**	**0.0004**	**8.44**

Source: Compiled by SPA Delhi

4.10.16. Power plants

There are 3 power plants operating in the city which uses fuel mainly PNG/CNG and some operate using diesel and LPG.

Table 67: List of operational thermal powerplants in Delhi

S. No.	Name and Address of the Power Plant	Electricity Generation Capacity	Type of Fuel & Quantity per day	Current Electricity Generation
1	Pragati Power Corporation Limited, Sector V, DSIIDC, Bawana Industrial Area, New Delhi – 110039	1500 MW	Natural Gas & 1.4 MMSCM	320 MW
2	Pragati Power Corporation Limited, Ring Road I.P Estate , Delhi – 110002	330 MW	Natural Gas & 1.4 MMSCM	105 MW
3	I.P. Gas Turbine Power Station (I.P. Power Generation Co. LTD.), I.P. Estate, Ring Road, Delhi - 110002	270 MW	Natural Gas & 0.48MMSCM	68 MW

Source: DPCC

Based on the emission factors of fuel combustion of natural gas, LPG the emissions were calculated for all the power plants in kg/day. For diesel fuel usage, it was given that BS-VI norms are being followed, so as per the BS-VI the emissions for diesel operations were calculated. It is assumed that power plants are operational 30 days a month and 24 hours per day. Although during the secondary survey it was collected that there are negligible emissions from powerplants, which might be possible by using better quality filters for emissions of $PM_{2.5}$ particles.

Table 68: Estimated Emissions

Sno.	Name	PM Emissions (kg per day)			
		PNG/CNG	Diesel	LPG	Sub Total
1	I.P. Gas Turbine Power Station	417.85	0	0	417.85
2	Pragati Power Corporation Limited	2548	0	0	2548
3	Pragati Power Corporation Limited, Sector V, DSIIDC, Bawana Industrial Area,	43850.8	0	0	43850.8
	TOTAL				46816.6

Source: Compiled by SPA Delhi

4.10.17 Emission Factors Used in the Calculation

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

Table 59: Emission factors used for calculating emissions

Category	Fuel Type	Emission Factors	
		$PM_{2.5}$	PM_{10}
Transport (g/Vehicular Kilometre Traveled)	2W	0.013	
	3W	0.015	
	Buses	NA	
	Cars (Petrol)	0.002	
	Cars (Diesel)	0.015	
	Commercial Cars (CNG)	0.002	
	Commercial Cars (Diesel)	0.015	
	HCV	0.42	
	LCV	0.475	
Thermal Power Plants (kg/MG)	Coal	0.6	2.3
	Natural Gas	121.6	
DG Sets (g/Kwh)			1.33
Industrial Sector ($PM_{2.5}$ - g/Kg & PM_{10} - g/unit)	CNG/NG	0.34	0
	LPG	0.31	0
	Diesel	0.97	0.0009
Residential Sector	LPG (g/Kg)	0.33	2.1
Agricultural Waste Burning (g/ton)		11	11
Medical Waste Incineration (g/ton)			2.33
Solid Waste Burning (g/ton)		5.44	8
Municipal Solid Waste Landfill (g/ton)		5.44	8
Construction (Buildings)			
(tons/acre/month of activity)			1.2
Construction roads (tons/acre/month of activity)			1.2
Soil Dust (Wind Erosion) (Kg/acre/year)		0.263	0.1315
Paved Roads	Given equation has to be used and respective parameters shall vary for each city and/or grid		

Source: Air Quality Assessment, Emission Inventory & Source Apportionment Study for Mumbai City; SA Study Pune; Source Apportionment Study at Kanpur; Air Quality Monitoring, Emission Inventory & Source Apportionment Studies- Delhi; Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi & Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources.

4.10.18. Total Emission Estimation

Emission factors are translated into emissions by multiplication with an activity rate as follows:

Ex= EFx * Q , where:

Ex=Emissions of pollutant x

EFx=Emission factor of pollutant x

Q=Activity or production rate.

The $PM_{2.5}$ emissions are estimated to be around 82.1 tonnes per day whereas PM_{10} emissions are 49.9 tonnes per day.

Table 70: Total emission estimation

SECTOR	Emissions (kg/day)	
	$PM_{2.5}$	PM_{10}
TRANSPORT	1224.18	-
INDUSTRIES	62501.2	0
POWER PLANTS	-	-
RESIDENTIAL	989.36	6295.98
AGRICULTURAL BURNING	1041.09	1301.36
ROAD DUST	2871.56	22751.02
CONSTRUCTION	-	1074.9
DG SETS	-	785.5
REFUSE BURNING	861.04	1266.24
CREMATORIUM	120.8	1232.69
RESTAURANT	11545.8	10023.25
AIRPORT	-	3863.88
SOIL DUST	133.26	66.63
WASTE INCINERATORS	-	14.37
LANDFILL FIRES	861.04	1266.24
TOTAL	82149.33	49942.06

Source: Compiled by SPA Delhi

The updated values of PM_{10} emission factors are not available in CPCB database and online published reports, so the emissions values of transportation and industries couldn't be estimated. But in general the PM_{10} would exceed approximately twice the $PM_{2.5}$ emission load.

5. PROJECTIONS

INTRODUCTION

The projections of various sectors have been carried out and categorized as:

- Short Term (2025)
- Medium Term (2030)
- Long Term (2040)

5.1. Sector Wise Projections:

The Master Plan envisages vision and policy guidelines for the perspective period up-to 2021. It is proposed that the Plan be reviewed at five yearly intervals to keep pace with the fast-changing requirements of the society.

5.1.1. Land Use & Land Policy

Delhi as the National Capital has a distinct and unique character. It is a growing and expanding magnet of attraction for people from across the country and a hub for the region surrounding it. Delhi has focused on balanced regional development.

The Regional Plan 2021 has been drawn up with reference to the following four Policy Zones:

i. NCT of Delhi.

ii. Central National Capital Region - Central NCR

iii. Highway Corridor Zone

iv. Rest of NCR.

The physical potential for further urbanization within the NCT is reducing although there is a virtual urban continuum between Delhi and the surrounding areas, which lie in the States of Uttar Pradesh and Haryana. With the imperatives of growth and development, the problems of Delhi have become complex, which have to be viewed both as a challenge in terms of the pressures of regular and floating in-migration, as well as an opportunity in terms of planning and development in a regional context.

Table 71: Landuse Distribution

Land Use	Percentage
Residential	45-55
Commercial	4-5
Industrial	4-5
Green/Recreational	15-20
PSP Facilities	8-10
Circulation	10-12

Source: Master Plan 2021

On an average the space required per person would be 40 Sq.m., covering about 920 sq.km. of urban area for the projected population of 230 lakh in year 2021.

Table 72: Zone wise Estimated Holding Capacity of Existing Urban Area

Zone	Holding Capacity MPD 2001	Population 2001	Holding Capacity 2021
A	420	570	570
B	630	624	630
C	751	679	788
D	755	587	813
E	1789	2798	2800
F	1278	1717	1975
G	1490	1629	1955
H	1865	1226	1865
Sub Total	8978	9830	11400
Dwarka		597	1300
Rohini III		96	160
Rohini IV and V		198	820
Narela		179	1620
Sub Total	3222		3900
Grand Total	122 Lakh	109 Lakh	153 Lakh

Source: Master Plan of Delhi, 2021

Development and construction activities can be directly related to the degree of accommodating additional population within the zones.
Major development and construction activities will be proliferating in Dwarka, Rohini, Narela to accommodate additional population.

There are multiple factors of urban environmental change, but the two most prominent factors that have shaped and reconstructed the Indian urban environment are: (1) population and (2) vehicular growth.

Population growth induces vehicular growth to meet the demands of movement of people, goods and services. Vehicles discharge gases that harm the environment and human health.
The Master Plan of Delhi 2041 is being prepared by Delhi Development Authority at present and will be soon publicly available. The proposed land uses in the upcoming master plan of Delhi will help in determining the focal areas of air quality concerns. The strategies to be mentioned in the upcoming plan will draft the vision plan for maintaining air quality standards of Delhi.
The development of short-term, medium-term and long-term projections for Landuse shall be governed by upcoming Master Plan of Delhi. The strategies would require area-based interventions and the Zonal Development Plans will serve as a guide in implementation of Air Quality Improvement Strategies in phase manner.

5.1.2. Demography

Delhi accounts for 1.38% of the total country's population and its annual growth rate is 1.92% (Census of India 2011). The population trend of Delhi indicates steep rise from 0.4 million in

1901 to 13.85 million in 2001 and to 16.75 million in 2011.

Population density is an indicator of population concentration and resultant pressure on land resources.

The spatial pattern of population density is uneven with maximum densities found in the North-East district followed by Central and East Delhi district. While the average density was 274 persons per km² in 1901, it increased to 4,194 (1981), 6,352 (1991), 9,340 persons per km² in 2001 and 11,297 in 2011 (Directorate of Economics and Statistics 2014).

As per the Best Fit Curve model, the population of Delhi in 2019 is around 19.5 million and is likely to increase to around 23 million in 2025, 26 million by 2030 and 31 million by 2040.

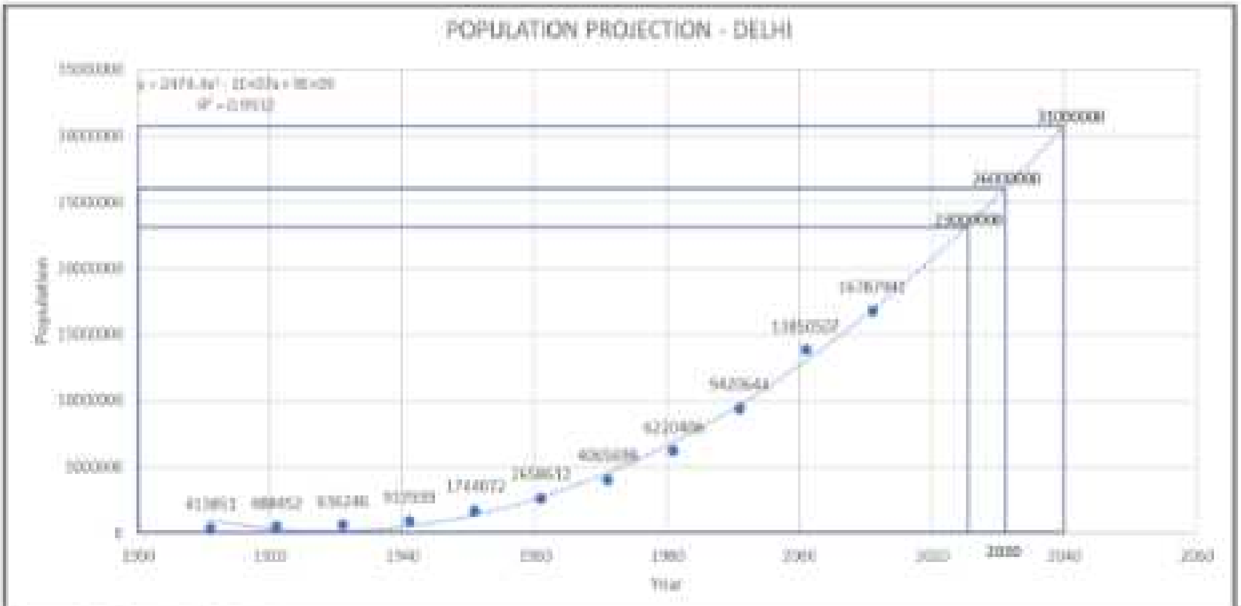


Figure 38: Population Projection

Source: Compiled by SPA Delhi

5.1.3. Transport

The number of vehicles in Delhi shows a steady growth. The year 2017 showed a slight increase from previous years in cars and two wheelers. With Delhi's air quality turning "severe" in 2019, the Transport Department of Delhi UT issued a notice warning that 15-year-old petrol and 10-year-old diesel vehicles plying on the city roads in violation of Supreme Court and National Green Tribunal (NGT) orders will be impounded. In its 2015 order, the National Green Tribunal (NGT) had banned the plying of petrol vehicles older than 15 years and diesel vehicles older than 10 years in the national capital region (NCR). It also banned the parking of 15-year-old vehicles in any public area. It is assumed that after the year 2019 the transport sector resumes its normal growth pattern @0.007% per year. The following projection and emission estimates have been made following the assumptions made.

Table 73: Emission estimation from transportation

Category	VKT (Km/ day)	$PM_{2.5}$ EF	2015	2016	2017	2018	2019	2019_$PM_{2.5}$ Emissions (Kg/day)	2025	2025_$PM_{2.5}$ Emissions (Kg/day)	2030	2030_$PM_{2.5}$ Emissions (Kg/day)	2040	2040_$PM_{2.5}$ Emissions (Kg/day)
Truck (Diesel)	78	0.63	16512	11836	13718	16657	19580	610.79	20204	636.44	20583	667.82	22240	750.87
Tractor (Diesel)	45	0.42	453	348	789	1156	2242	42.37	2338	44.15	2415	45.64	2572	48.60
Bus (CNG)	210	0	621	691	736	366	576	0.00	1016	0.00	1060	0.00	1110	0.00
Cars (Petrol) - 65%	56	0.002	128880	121266	125381	113426	100667	11.07	104896	11.54	108415	11.50	115466	12.70
Cars (Diesel) - 35%	56	0.016	69236	65296	67513	61062	54206	44.72	56482	46.60	58378	48.16	62174	51.29
2 Wheelers (Petrol)	60	0.013	423211	447488	477302	491076	422790	329.79	440918	343.80	455573	355.14	484906	378.23
3 Wheelers (Auto-CNG)	120	0.016	17629	11627	8763	12720	5788	10.28	6006	10.81	6270	11.28	6614	11.20
LCVs (Diesel)	140	0.675	2665	3527	2530	1853	2633	175.09	2744	182.45	2838	188.58	3020	200.83
Total			656667	661375	698708	701379	608858	1224.19	634202	1275.56	655804	1318.44	698106	1404.13
Growth/ Reduction (%age)				0.004	0.053	0.007	-0.132		0.042		0.077		0.147	

Source: Compiled by EPA

5.2. AIR QUALITY

With the increase in population and urbanization in Delhi, the economic activity is going to increase rapidly catering to the growing needs of people. The intensity of activities will increase leading to proliferation of longer period of air pollution.
Emission Loads for Business as Usual Scenario (BUA) for 2019, 2025, 2030 & 2040.

Table 7.6: Estimation of scenario emissions

SECTOR	2019_Emissions (kg/day)		2025_Emissions (kg/day)		2030_Emissions (kg/day)		2040_Emissions (kg/day)	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
TRANSPORT	1224.18	-	1275.59	-	1318.43	-	1404.13	-
INDUSTRIES	62501.2	0	65626.28	0	68751.32	0	71876.38	0
POWER PLANTS	-	-	-	-	-	-	-	-
RESIDENTIAL	99.02	630.18	143.704	914.48	162.448	1033.76	193.588	1232.66
AGRICULTURAL WASTE BURNING	1041.10	1301.37	1041.12	1301.37	240.97	312.48	0	0
ROAD DUST	2871.66	22761.02	2902.17	23706.69	3092.69	24502.88	3293.56	26095.36
CONSTRUCTION	-	1074.9	-	1074.8	-	1074.8	-	1074.8
DG SETS	-	785.8	-	785.5	-	785.5	-	785.5
REFUSE BURNING	881.04	1256.24	1015.59	1493.51	1148.08	1888.32	1368.84	2013.00
CREMATORIUM	120.85	1232.89	120.85	1232.89	120.85	1232.89	120.85	1232.89
RESTAURANT	11545.80	10020.25	12123.09	10524.41	12729.58	11025.58	13977.87	11528.74
AIRPORT	-	3863.89	-	3863.89	-	3863.89	-	3863.89
SOIL DUST	133.28	96.63	120.03	60.21	108.86	55.40	100.79	50.36
WASTE INCINERATORS	-	14.37	-	14.37	-	14.37	-	14.37
LANDFILL FIRES	881.04	1256.24	1016.59	1493.51	1148.08	1888.32	1368.84	2013.00
TOTAL	81256.08	44276.28	85473.87	46466.25	88798.98	47276.08	93004.87	48902.42

Source: Compiled by SPA Delhi

The following assumptions were made for estimating emission loads:

- After the year 2019 the transport sector resumes its normal growth pattern i.e., vehicles will increase @0.007% per year.
- Taking year 2019 as base year, Industries will experience 0.5% growth in 2025, 1% growth in 2030 and 1.5% growth in 2040 maintaining the land use distribution.
- Power Plants, Construction, DG Sets, Crematorium, Airport and Waste Incinerators will show no change.
- The projected population using best fit curve were used for projecting emission from residential sector with consideration of factors i.e., 5 persons per household and assuming by 2025 every household in Delhi will be shifted to LPG fuel keeping in mind the recent changes in LPG pricing and relaxations.
- For estimating agricultural waste burning & soil dust, projected land use land cover has been calculated keeping in mind the development profile of Delhi. The values are shown in table below.

Table 75: Projections of Land Cover type

Land Cover Type	2019_%age	2025_%age	2030_%age	2040_%age
Barren Land	50.35	45.35	40.35	38.08
Built Up	30.24	30.24	36.24	38.24
Vegetation	10.41	15.41	20.41	23.00
Agricultural Land - No Cover	7.00	7.00	1.00	0.00
Agricultural Land - Cover	1.33	1.33	1.33	0.00
Water Body	0.67	0.67	0.67	0.67
Total	100.00	100.00	100.00	100.00

Source: Compiled by SPA Delhi

- The road dust emission has been projected based on projected figures of vehicles.
- Emission from refuse burning and landfill fires are projected based on estimated waste generation from project population (3% of total waste collected).

The PM_{10} values for transport and industries are not estimated due to absence of emission factor. Estimating the PM_{10} emission load from transport and industrial sector will ultimately increase the total emission load significantly.

6. ANALYSIS

Basic analysis of the baseline data and projections are mentioned in this chapter for carrying out for assessment for carrying capacity (Chapter 11). The projections are carried out for current year based on the latest data available for each aspect and following the same trend, it is further projected for 2021, 2025, 2030, 2040 for demographics & transportation. These projections would be further used to calculate the emissions from each sector.

6.1. Demography

The unprecedented scale and speed of urbanization in Delhi has resulted in enormous pressure on the physical environment with a severe adverse impact in terms of pollution and today Delhi is considered to be among the most polluted cities in the world. The projections are calculated using exponential growth method, finding most correlation among all other projection methods. Delhi accounts for 1.38% of the total country's population and its annual growth rate is 1.92% (Census of India 2011). The population trend of Delhi indicates steep rise from 0.4 million in 1901 to 13.85 million in 2001 and to 16.75 million in 2011.

Population density is an indicator of population concentration and resultant pressure on land resources. The spatial pattern of population density is uneven with maximum densities found in the North-East district followed by Central and East Delhi district. While the average density was 274 persons per km² in 1901, it increased to 4,194 (1981), 6,352 (1991), 9,340 persons per km² in 2001 and 11,297 in 2011 (Directorate of Economics and Statistics 2014).

The following table 76 represents the projections:

Table 76: Population Projections

Year	Population
Census 2001	13850507
Census 2011	16787941
2020 (Projected)	19795200
2021 (Projected)	20124708
2025 (Projected)	21442739
2030 (Projected)	23090279
2031 (Projected)	23419787
2040 (Projected)	26385358
2041 (Projected)	2,67,14,866

Source: Compiled by SPA Delhi

As per the Best Fit Curve model, the population of Delhi is likely to increase to around 25million by 2030 and 31 million by 2040.

For 2041, the population is projected as 2.67 crores for NCT Delhi. This would impose a huge impact on air environment as the rate of activities will also rise subsequently. It would have a direct impact on the increase in emissions from households and transportation. The NCR Plan 2021 has proposed the availability of urbanisable land in NCT-Delhi for 2021 provided in Master Plan of Delhi, 2021. It estimated a population of 2,20,02,953 i.e.,220 lakhs which can be accommodated in urbanisable area of 97790.90 ha. @ 225 PPH. The present approach of Master Plan of Delhi, 2021 in lieu of accommodation of further population i.e., 220 lakhs within the city will have an adverse impact on state of environment of Delhi. The city's environment can essentially be seen in terms of two components of urban management – the environment per se, or the habitat and service management. The former pertains to the natural features and resources including: the elements of air and noise, water and land with reference to open spaces, green areas and other surface and sub-surface conditions. The latter is related to the built environment and includes the environmental infrastructure – water supply, sewerage, solid waste disposal and transportation network.

6.2. Land use

The concentration of emissions is closely related to the land use type and type of activities involved. Studies have shown a positive correlation between the spatial patterns of air pollutants and urban built-up density.[7] However, the study on degree of land-use contribution to pollution has not been explored to such depth.

The kind of fuel usage in residential areas, commercial areas, industrial areas, etc., and the trips generated by these land uses needs to explored. Various land use types generated varying degree of trips. In contemporary transportation planning language, A Trip is defined as a one-way person movement by a mechanized mode of transport, having two trip ends. The start of the trip is called as origin and the end of trip is called as destination. Trip is classified as Production or Origin and Attraction or Destination.

Urban planners and transport engineers have long been developing different methods and models to forecast travel demand in urban areas. Usually trip attraction volumes are estimated based on land use characteristics. However, executing of land use-based trip attraction models are severely constrained by the lack of updated land use data in developing countries.[8]
For carrying out the analysis for emissions as per land-use, previously done source apportionment studies were used based on the emissions from each sector. It was also compared with the land-use suggested in the URDPFI guidelines. As the land use is for 2021 (Master plan, Delhi), so the proportion of emissions is segregated as represented in the following table:

7 Urban Air Pollution Patterns, Land Use, and Thermal Landscape: An Examination of the Linkage Using GIS, Qihao Weng & Shihong Yang, Environmental Monitoring and Assessment volume 117, pages463–489(2006)
8 Application for developing countries: Estimating trip attraction in urban zones based on centrality: Amila Jayasinghe, Kazushi Sano, Kasemsri Rattanaporn, Journal of Traffic and Transportation Engineering (English Edition) Volume 4, Issue 5, October 2017, Pages 464-478

Table 77: Sub-sectoral contribution to $PM_{2.5}$ & PM_{10} in Delhi in summers 2018

Sectors	Sub-sectors	PM_{10}	$PM_{2.5}$
Residential		**8%**	**8%**
	Biomass	8%	7%
	Kerosene	0.5%	1%
	LPG	0.1%	0.1%
Agri-Burning	Biomass	7%	7%
Industry		22%	22%
	Power-plant	7%	7%
	Bricks	5%	5%
	Stone crushers	2%	1%
	Other Industries	8%	8%
Others		7%	8%
	DG Sets	2%	2%
	Refuse Burning	4%	4%
	Crematoria	0.3%	0.2%
	Restaurant	0.5%	0.4%
	Airport	0.1%	0.2%
	Waste Incinerators	0.3%	0.3%
	Landfills	0.4%	0.5%
Dust		43%	38%
	Road Dust	10%	3%
	Construction	4%	2%
	Others	28%	33%
Transport		15%	17%
	Trucks	5%	5%
	Tractor	1%	1%
	Bus	1%	1%
	Cars	2%	2%
	2-wheelers	4%	4%
	3-wheelers	3%	3%
	LCVs	0.5%	1%

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

Table 78: Sub-sectoral contribution to $PM_{2.5}$ & PM_{10} in Delhi in winters 2018

Sectors	Sub-sectors	PM_{10}	$PM_{2.5}$
Residential		**9%**	**10%**
	Biomass	8%	9%
	Kerosene	1%	1%
	LPG	0%	0.1%
Agri-Burning	Biomass	4%	4%
Industry		27%	30%
	Power-plant	5%	6%
	Bricks	7%	8%
	Stone crushers	3%	2%

Sectors	Sub-sectors	PM_{10}	$PM_{2.5}$
	Other Industries	12%	14%
Others		10%	11%
	DG Sets	4%	5%
	Refuse Burning	4%	3%
	Crematoria	0.3%	0.2%
	Restaurant	0.6%	1%
	Airport	0.4%	1%
	Waste Incinerators	0.6%	1%
	Landfills	0.4%	0.4%
Dust		25%	17%
	Road Dust	8%	4%
	Construction	6%	1%
	Others	11%	12%
Transport		24%	28%
	Trucks	7%	8%
	Tractor	1%	1%
	Bus	2%	3%
	Cars	3%	3%
	2-wheelers	6%	7%
	3-wheelers	4%	5%
	LCVs	1%	1%

Source: Source Apportionment of $PM_{2.5}$ & PM_{10} of Delhi NCR for Identification of Major Sources

The percentage distribution of $PM_{2.5}$ & PM_{10} from different sources are taken and allocated to their respective land-use under which they fall. As DG set use was not clear with respect to land-use, it was assumed that the DG sets are used only in the commercial sector. Although airport comes under transportation land use, it is demarcated differently for generation of map. The classes of map are in terms of the percent from the source apportionment study.

It gives a generally overview of how the sources are spatially distributed on the land-use map of the city

Table 79: Land Use wise distribution of sub-sectoral contribution to $PM_{2.5}$ & PM_{10} in Delhi in 2016

Sno	MPD 2021		Land-use	SECTOR (TERI REPORT)	$PM_{2.5}$ (%)		PM_{10}(%)	
	LANDUSE	%	AS PER URDPFI		WINTERS	SUMMERS	WINTERS	SUMMERS
1	Residential	45-55	36-38	Residential (R)	10	8	9	8
2	Agriculture	Balance	Balance	Agricultural Burning (A)	4	7	4	7
3	Industrial	4-5	7-8	Industry (I)	30	22	27	22
4	Commercial	4-5	5-6	Restaurant	1	0.4	0.6	0.5
				DG sets	5	2	4	2
5	PSP	8-10	10-12					
6	Circulation	10-12	12-14	Transport	28	17	24	15
				Road Dust	4	3	8	10
				Airport	1	0.2	0.4	0.1

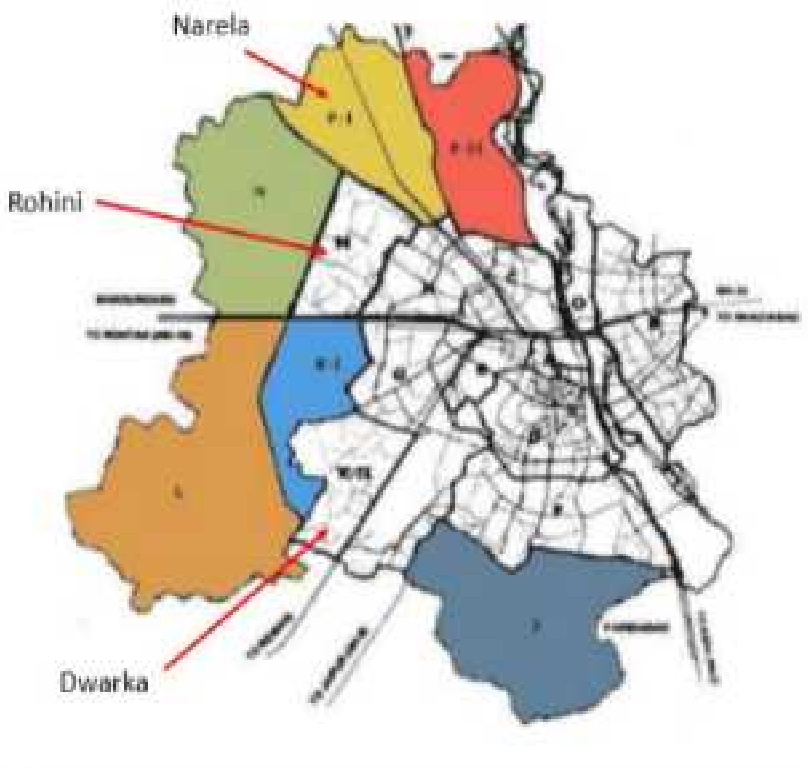
Sno	MPD 2021		Land-use	SECTOR (TERI REPORT)	$PM_{2.5}$ (%)		PM_{10}(%)	
	LANDUSE	%	AS PER URDPFI		WINTERS	SUMMERS	WINTERS	SUMMERS
7	Green / Recreational	15-20	14-16					
8	Vacant Land			Dust-Others	12	33	11	28
	TOTAL				95	92.6	88	92.6

Source: Compiled by SPA Delhi

Major development and construction activities will be proliferate in Dwarka, Rohini, Narela to accommodate additional population.

There are multiple factors of urban environmental change, but the two most prominent factors that have shaped and reconstructed the Indian urban environment are: (1) population and (2) vehicular growth.

Population growth induces vehicular growth to meet the demands of movement of people, goods and services. Vehicles discharge gases that harm the environment and human health. As per CPCB (1995), the vehicular PM load in Delhi was estimated to be 10.3 tonnes per day, while for Mumbai, it was 5.59 tonnes per day.

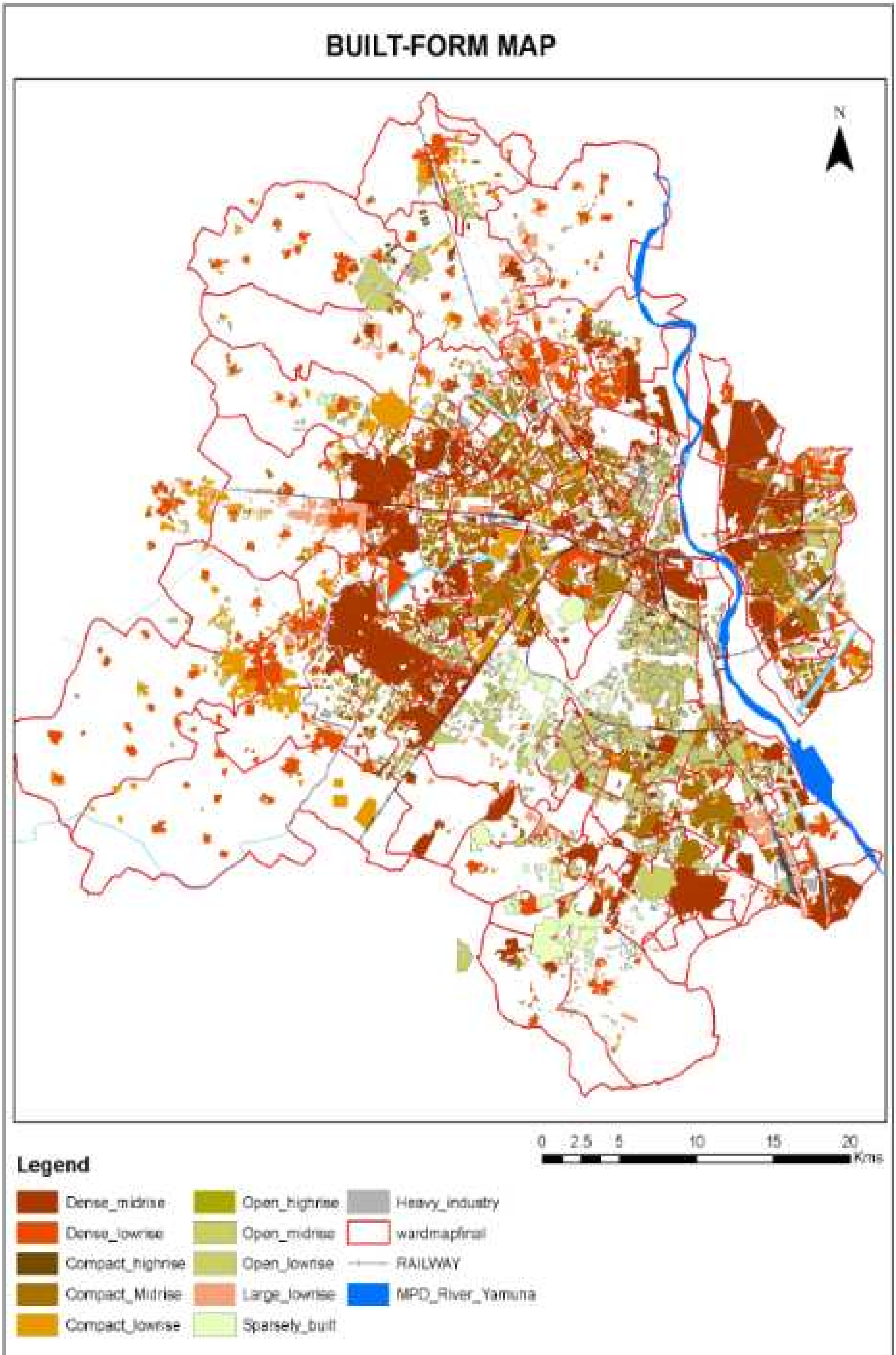


Map 9: Urbanisable land

Source: MPD 2021

6.3. Urban built-form

Although various building configurations exist in urban areas, idealized building configurations suggested by Stewart and Oke in 2012 have been considered to represent the basic configuration

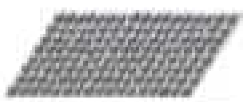
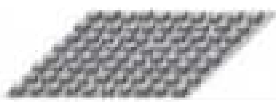
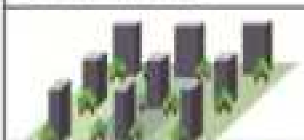
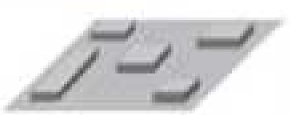
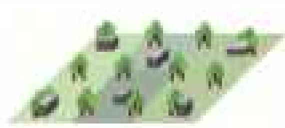


Map 10: Built form map of Delhi based on LCZ categorization

Source: Compiled by SPA Delhi

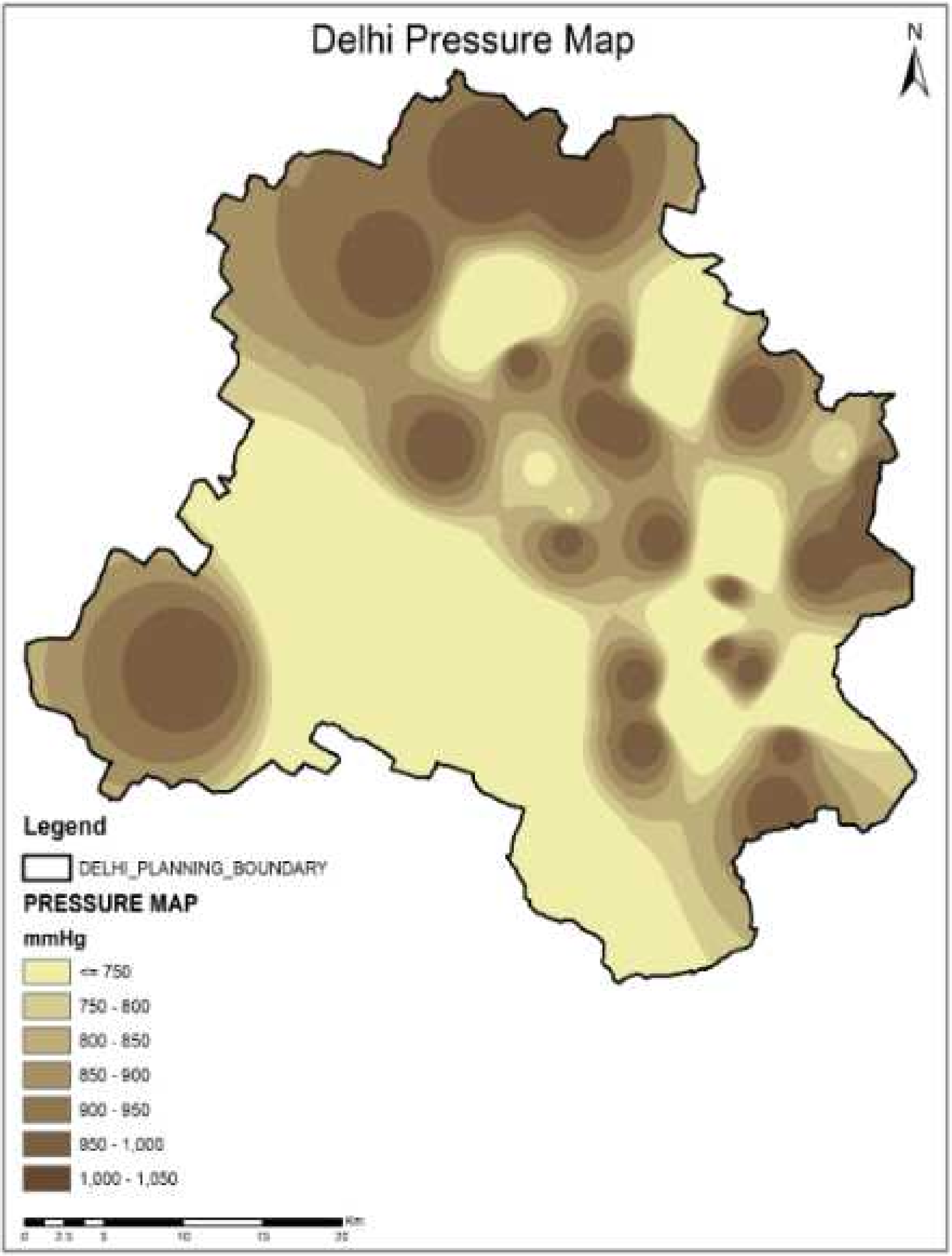
directly affecting the mechanism of dispersion processes in urban neighborhoods. The primary purpose of Local Climate Zones (LCZs) is the observation of Urban Heat Island studies by standardizing the classification of urban and rural field sites. LCZs are fundamentally composed of several elements of any settlement such as built structures, roads, vegetation, soil types and water bodies, all in varying amounts and arranged uniformly into 17 schemes. Out of 17 built types, only 9 represent configurations with features relevant to pollution dispersion studies. Looking at the context of Delhi city, 2 schemes were added of dense mid-rise and dense low-rise which basically covering the settlements with aspect ratio more than 2 under mid-rise and more than 1.5 in low-rise building typologies.

Table 80: Built-form categorization

Configuration	Classification	Aspect Ratio	Description
	Dense mid-rise LCZ 1	>2	Dense mix of mid-rise buildings (3-8 stories). No trees. and cover paved. Stone, brick, tile and concrete construction materials. Mostly includes the urban villages in the city.
	Dense low-rise LCZ 2	>1.5	Dense mix of low-rise buildings (1-3 stories). No trees. and cover paved. Stone, brick, tile and concrete construction materials. Mostly includes the slum settlements of the city.
	Compact high-rise LCZ 3	>2	Dense mix of tall buildings (more than 8 stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone and glass construction materials.
	Compact mid-rise LCZ 4	0.75- 2	Dense mix of mid-rise buildings (3-8 stories). Few or no trees. and cover mostly paved. Stone, brick, tile and concrete construction materials.
	Compact low-rise LCZ 5	0.75- 1.5	Dense mix of low-rise buildings (1-3 stories). Few or no trees. and cover mostly paved. Stone, brick, tile and concrete construction materials.
	Open high-rise LCZ 6	0.75- 1.25	Open arrangement of tall buildings (more than 8 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone and glass construction materials.
	Open mid-rise LCZ 7	0.3- 0.75	Open arrangement of mid-rise buildings (3-8 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone and glass construction materials.
	Open low-rise LCZ 8	0.3- 0.75	Open arrangement of low-rise buildings (1-3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick tile, stone and glass construction materials.
	Large low-rise LCZ 9	0.1-0.3	Open arrangement of large low-rise buildings (1-3 stories). Abundance of pervious land cover (low plants, scattered trees).Concrete, steel, stone and glass construction materials.
	Sparsely built LCZ 10	0.1-0.25	Sparse arrangements of small or medium-sized buildings in a natural setting. Abundance of pervious land-cover (low plants, scattered trees).
	Heavy Industry	0.2-0.5	Highly irregular mix of low and mid-rise industrial structures (tanks, towers, sacks). Structures openly spaces on hard packed surfaces. Few or no trees.

6.4. Wind Speed & Direction

Monthly data of wind speed and wind direction of 2019 was collated and represented on the Map of NCT Delhi to understand spatially how wind speed and direction affects the pollution concentration in the city. The wind speed and wind direction of Delhi has been shown in Table 81 and Table 82. Map 11 shows the atmospheric pressure in Delhi, which influences the wind speed and direction across the city.



Map 11: Delhi Pressure Map

Table 21: Wind speed monitored in Delhi, 2016

S.No.	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
1	Alipur, Delhi - DPCC	Delhi												
2	Shadipur, Delhi - CPCB	Delhi	0.872728	0.920286	1.117419	1.190667	1.142646	1.226667	1.112646	0.996	0.9286	0.837323	0.693667	0.916323
3	IHBAS, Dilshad Garden, Delhi - CPCB	Delhi	1.14871	1.69826	1.798773	1.180197	1.273083	1.3398	1.320936	1.820936	1.537197	0.899966	1.277333	1.562419
4	NSIT Dwarka, Delhi - CPCB	Delhi	0.894134	1.001786	1.127742	1.313	1.312742	1.468102	1.178363	1.055291	1.876	0.754677	0.757333	0.735484
5	DTU, Delhi - CPCB	Delhi	0.900645	0.807567	0.894677	0.900647	2.157333	0.966032	0.752742	0.667323	0.666333	0.619161	0.6222	0.679484
6	ITO, Delhi - CPCB	Delhi												
7	Sirifort, Delhi - CPCB	Delhi	0.421207	0.2742	0.525069	0.448551	0.475763	0.693333	0.268581	0.281111	0.586633	0.237903	0.31	0.290323
8	Mandir Marg, Delhi - DPCC	Delhi	0.890606	1.25675	1.420045	1.444633	1.491505	1.801552	1.340128	1.177742	1.194833	0.755548	0.885167	0.841774
9	Anand Vihar, Delhi - DPCC	Delhi	0.798677	1.178714	1.124266	1.080197	1.222277	1.806263	1.796032	0.846801	0.826621	0.899976	0.9576	0.883844
10	R K Puram, Delhi - DPCC	Delhi	0.968229	0.941071	0.973657	1.090172	1.085308	1.893833	1.07571	1.008774	1.019833	0.879387	0.849833	0.819774
11	Punjabi Bagh, Delhi - DPCC	Delhi	0.761774	0.296536	0.973484	0.900333	0.91455	1.187527	0.894677	0.947903	0.732667	0.473431	0.918667	0.90629
12	Aya Nagar, Delhi - IMD	Delhi	0.711111				1.224286	2.26			0.04	0.067	0.166667	0.228636
13	Lodhi Road, Delhi - IMD	Delhi	0.446								0.063333	0.061667	0.42	0.448
14	North Campus, DU, Delhi - IMD	Delhi	0.83											
15	Burari Crossing, Delhi - IMD	Delhi	0.210763				0.2					0.013222	0.088	0.158421
16	CRRI Mathura Road, Delhi - IMD	Delhi	0.3662				1.20126	4.03			0.068	0.174	0.1476	0.241354

Sl._No	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
17	Pusa, Delhi - IMD	Delhi	1.191613	1.371571	1.306342	1.078667	1.422242	1.276667	1.613333	1.314516	1.283333	2.097143	2.033667	0.85
18	IGI Airport (T3), Delhi - IMD	Delhi												
19	East Arjun Nagar, Delhi - CPCB	Delhi												
20	Anand Vihar, Delhi - DPCC	Delhi	0.889613	0.964534	0.897642	0.71611	0.833863	1.029816	1.03013	0.913866	0.867357	0.60066	0.600776	0.669891
21	Jawaharlal Nehru Stadium, Delhi - DPCC	Delhi												
22	Nehru Nagar, Delhi - DPCC	Delhi	0.659032	0.853714	0.92	1.127903	1.114232	2.353333	0.830161	0.890032	0.896271	0.463806	0.486933	0.512258
23	Dwarka-Sector 8, Delhi - DPCC	Delhi	0.907613	0.863929	1.709839	1.178333	1.279876	1.372099	1.263226	1.049968	0.897533	0.703064	0.769667	0.736946
24	Dr. Karni Singh Shooting Range, Delhi - DPCC	Delhi	1.503387	1.84	1.817742	1.837167	1.990484	1.991833	1.293197	1.152097	1.163333	0.997097	1.1606	1.064818
25	Patparganj, Delhi - DPCC	Delhi	0.937557	1.031364	0.963492	1.0366	1.012903	1.222407	1.400046	1.333332	1.212667	0.830062	0.912667	0.733333
26	Sonia Vihar, Delhi - DPCC	Delhi	1.355484	1.946571	1.799462	1.793	1.918871	2.030167	1.353118	1.454358	1.3635	1.090591	1.1533	1.390806
27	Jahangirpuri, Delhi - DPCC	Delhi	0.575161	0.75375	0.807531	0.745	0.737097	0.953167	0.830323	0.810606	0.833333	0.423484	0.483333	0.351613
28	Rohini, Delhi - DPCC	Delhi	1.434	1.712571	1.907241	2.066993	2.036233	2.192833	1.330129	1.723333	1.734633	1.26393	1.260933	1.109333
29	Najafgarh, Delhi - DPCC	Delhi	1.483419	1.767321	1.777419	1.986333	2.160161	2.016833	1.23367	1.111774	1.947091	2.784032	1.2666	1.16871
30	Vivek Vihar, Delhi - DPCC	Delhi	2.648	1.653214	1.842194	1.317938	1.983807	0.6799	2.232867	2.729355	2.190333	1.660194	1.6636	1.668065
31	Major Dhyan Chand National Stadium, Delhi - DPCC	Delhi	0.712581	0.754643	1.000065	0.585667	0.925323	1.178667	0.907135	0.880645	0.942167	0.823548	0.854833	0.632581

Sl._No	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
33	Narela, Delhi - DPCC	Delhi	1.033863	1.126536	1.320378	1.366	1.387419	1.8848	1.201542	1.117097	1.098833	0.827681	0.87333	0.740648
[illegible]	Okhla Phase-2, Delhi - DPCC	Delhi	1.126455	1.029714	1.219032	1.0666	1.120645	1.275	0.958371	0.994516	1.127734	0.961129	0.949333	0.878516
34	Wazirpur, Delhi - DPCC	Delhi	1.412226	1.624727	1.714194	1.72	1.76129	2.124276	1.299355	1.277258	1.292686	1.227097	1.272222	1.217581
[illegible]	Bawana, Delhi - DPCC	Delhi	1.032226	1.119828	1.367378	1.427667	1.365226	1.366333	1.37322	1.207742	1.152833	0.822278	0.962333	0.880968
36	Sri Aurobindo Marg, Delhi - DPCC	Delhi	5.297419	5.270357	5.299355	5.391333	5.325484	5.218333	4.752333	4.898677	4.708333	4.350806	4.7	4.925548
37	Pusa, Delhi - DPCC	Delhi	1.191613	1.271071	1.356452	1.476667	1.888889	1.913667	1.214522	1.014676	1.333333	2.297452	2.522667	2.98
38	Mundka, Delhi - DPCC	Delhi	1.277419	1.398863	1.433227	1.533333	1.72	1.892667	1.397157	1.335323	1.3198	0.997742	1.156	1.027742

Table 62: Wind Direction monitored in Delhi, 2019

Sl._No	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
1	Alipur, Delhi - DPCC	Delhi	139.1976	140.2386	128.9257	129.4854	162.3091	140.557	153.4086	105.15	75.950216	140.1397	201.7833	250.1535
2	Shadipur, Delhi - CPCB	Delhi	197.1926	200.2213	205.4601	132.6264	162.2127	171.2024	148.2821	121.88	127.492294	131.7677	191.62856	188.2244
3	IHBAS, Dilshad Garden, Delhi - CPCB	Delhi	212.3006	209.0260	192.8266	170.3733	224.173	176.0668	164.1295	144.13	134.103868	181.3209	231.03616	232.40222
4	NSIT Dwarka, Delhi - CPCB	Delhi	207.3801	217.8594	184.8339	137.4007	211.523	184.4713	177.3333	107.06	145.742709	172.1347	136.60352	202.00017
5	DTU, Delhi - CPCB	Delhi	126.2607	182.2427	128.0363	182.7702	233.4022	122.2447	100.1248	122.7	127.243323	101.7402	203.16224	288.2772
6	ITO, Delhi - CPCB	Delhi												
7	Sirifort, Delhi - CPCB	Delhi	226.7773	210.3032	239.6354	222.7197	262.1978	231.000	203.0619	223.75	237.234665	249.3660	241.19666	242.09877

Sl._No	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
8	Mandir Marg, Delhi - DPCC	Delhi	243.0884	229.04	244.6827	238.0368	240.3788	207.7342	136.4472	128.03	173.204097	246.9683	247.77733	209.02943
9	Anand Vihar, Delhi - DPCC	Delhi	218.999	189.999	229.8928	209.5818	209.0189	184.9726	160.0398	144.39	120.791087	169.1888	230.85024	227.54798
10	R K Puram, Delhi - DPCC	Delhi	136.2462	169.2712	199.1782	193.0141	197.4704	170.2124	167.7609	162.22	126.175067	203.8666	191.44716	186.22915
11	Punjabi Bagh, Delhi - DPCC	Delhi	122.1727	122.0288	110.8744	81.58237	69.6038	106.7074	116.0873	117.38	133.823968	64.01587	102.83128	116.22868
12	Aya Nagar, Delhi - IMD	Delhi												
13	Lodhi Road, Delhi - IMD	Delhi												
14	North Campus, DU, Delhi - IMD	Delhi												
15	Burari Crossing, Delhi - IMD	Delhi												
16	CRRI Mathura Road, Delhi - IMD	Delhi												
17	Pusa, Delhi - IMD	Delhi	167.4216	151.3812	184.1123	192.0869	154.9291	163.2721	132.1733	114.37	101.288806	151.2801	139.28733	217.2182
18	IGI Airport (T3), Delhi - IMD	Delhi												
19	East Arjun Nagar, Delhi - CPCB	Delhi												
20	Ashok Vihar, Delhi - DPCC	Delhi	132.118	134.799	160.1799	126.7902	141.2041	158.7647	91.03284	82.213	86.8703472	107.8427	123.88158	133.86862
21	Jawaharlal Nehru Stadium, Delhi - DPCC	Delhi	244.5481	260.7964	233.073	237.8851	269.5026	201.2788	169.2779	160.16	143.861335	247.4226	280.21737	241.77838
22	Nehru Nagar, Delhi - DPCC	Delhi	222.8327	211.5884	239.5652	226.8808	219.575	181.6865	152.178	146.66	124.479483	218.1889	238.90164	237.21938
23	Dwarka-Sector 8, Delhi - DPCC	Delhi	217.0291	205.6969	231.6007	213.2889	249.4273	196.0736	162.478	136.14	130.824678	217.7766	230.62733	237.67277
24	Dr. Karni Singh Shooting Range, Delhi - DPCC	Delhi	209.727	194.8184	209.799	214.2299	233.8839	181.9978	143.0379	161.1	159.007939	220.3403	239.83877	209.38443

Sl. No	Station	City	January	February	March	April	May	June	July	August	September	October	November	December
25	Patparganj, Delhi - DPCC	Delhi	224.1375	217.6003	214.8433	187.799	237.5226	158.4037	164.2683	162.79	127.384379	213.1337	230.86207	230.96033
26	Sonia Vihar, Delhi - DPCC	Delhi	149.4024	181.6619	152.3848	142.7029	153.7154	164.3152	159.2259	160.16	157.630863	149.5418	117.17581	127.59093
27	Jahangirpuri, Delhi - DPCC	Delhi	96.0597	107.4662	79.21074	112.3046	112.2222	141.2169	101.2242	127.42	155.029404	112.7496	162.26623	182.8707
28	Rohini, Delhi - DPCC	Delhi	233.8018	221.3313	233.3787	214.6038	233.38	162.7146	133.889	146.21	133.169738	228.6817	238.12078	237.66676
29	Najafgarh, Delhi - DPCC	Delhi	225.5948	236.7388	223.3166	178.5237	231.1587	199.3474	131.5844	130.38	163.750788	193.427	170.63028	181.0661
30	Vivek Vihar, Delhi - DPCC	Delhi	189.0236	188.3468	208.3346	137.3712	154.4603	137.378	158.2623	138.27	131.836423	155.4521	220.10363	214.22307
31	Major Dhyan Chand National Stadium, Delhi - DPCC	Delhi	207.4473	203.3103	233.4423	173.2780	208.0862	166.6661	132.0209	133.99	121.617378	183.247	203.2322	207.37098
32	Narela, Delhi - DPCC	Delhi	238.8013	242.5483	232.328	166.1037	241.1909	164.3373	125.5547	141.99	122.403373	225.761	243.63278	235.6233
33	Okhla Phase-2, Delhi - DPCC	Delhi	144.4377	142.7782	133.3372	123.7764	128.222	190.0176	220.6176	231.42	144.1142	217.2169	244.2262	244.3244
34	Wazirpur, Delhi - DPCC	Delhi	227.7720	233.326	227.6377	203.2033	233.6644	167.6343	153.3773	147.33	132.636366	233.3366	247.31763	231.37322
35	Bawana, Delhi - DPCC	Delhi												
36	Sri Aurobindo Marg, Delhi - DPCC	Delhi												
37	Pusa, Delhi - DPCC	Delhi	167.4374	161.2673	138.1123	162.0969	153.899	163.3737	139.1766	115.97	131.268838	161.2037	128.66768	277.8733
38	Mundka, Delhi - DPCC	Delhi												

6.5. Transportation

Despite various initiatives and measures taken over the past few years, like introduction of CNG and EURO II norms etc., the air quality in the city, in terms of pollution levels, has continued to be a matter of concern, and has been responsible for a number of respiratory diseases, heart ailments, eye irritation, asthma, etc. The three main sources of air pollution in Delhi are vehicular emission (around 70 percent) industrial emissions (around 20 percent) with a major element of this coming from the three thermal power plants, and from other sources such as diesel generator sets and domestic cooking, burning of biomass, etc.

Apart from the issue of pollution on account of industries, the major area of planning and intervention would relate to transportation planning. With the phenomenal growth in the number of vehicles, almost 8-10 times in the last two decades in absolute terms, the most significant aspect in the context of congestion and pollution, relates to the growth in personalized transport as compared to the availability of public transport. It has been estimated that buses, which constitute barely 1.2 percent of the total number of vehicles, cater to around 60 percent of the total transport load, while personal vehicles -cars and scooters, though almost 93 percent of the total number of vehicles, cater to around only 30 percent of the travel demand.

Such a huge share of private vehicles in Delhi, while serving a relatively limited purpose in terms of the transportation modal split, obviously creates tremendous pressure on road space, parking, and pollution directly and through congestion.

Table 83: Category-wise distribution of cars share to $PM_{2.5}$ concentrations

	Delhi					NCR				
Emission norms	Petrol	Diesel (Smaller)	Diesel-MUV	CNG	All cars	Petrol	Diesel (Smaller)	Diesel-MUV	CNG	All cars
Pre BS to BS-I	0%	0%	0%	0%	0%	5%	9%	8%	0%	22%
BS-II	4%	13%	15%	0%	31%	3%	14%	11%	0%	28%
BS-III	2%	8%	5%	4%	19%	1%	10%	7%	3%	22%
BS-IV	7%	20%	7%	16%	50%	5%	11%	4%	9%	28%
Total	13%	41%	26%	20%	100%	14%	44%	30%	13%	100%

* accounting for both primary PM and secondary nitrate contributions to PM2.5 conc. in Delhi-NCR

It may be noted that these are the shares of vehicles in 2016, and with fleet turnovers, the share of BS-IV vehicles will increase, and contribution of older vehicles will decline. Although, the absolute numbers of BS-IV vehicles will be much lower than pre-BS-IV vehicles due to improved technologies.

6.6. Emission Estimations

Emission estimations were carried out for 2019 for Delhi for both $PM_{2.5}$ and PM_{10}. It was observed that there is a emission of 82149.33 kgs of $PM_{2.5}$ particles per day and 49,942 kgs of PM_{10} particles per day. The values show the daily estimated ground concentration of $PM_{2.5}$ and PM_{10}. The values have decreased over the years due to improvement in fuel standards and shift to clean fuel in industries and also as per the emission factors from combustion of NPG, PM_{10} emissions were considered negligible.

Also, there have been significant decrease in the emissions from landfills, as solid waste management rules and regulations 2016 were incorporated and changes were made in the Delhi Bye-laws based them in 2017.

Emissions from power plants are said to be negligible as coal based Badarpur power-plant was shut down in 2018 and others moved to clean fuels for production of electricity. In crematoriums, fuel wood is being used along with PNG which is expected to further completely shift into electric crematorium or PMG based, which will reduce a the emissions from this sector.

In transportation sector, several amendments were made due to which increase in emissions from this sector have not been observed (even with the increase in vehicular registrations every year) like phasing out of 10 years old diesel vehicles and 15 year old petrol vehicles and completion of Eastern Peripheral Expressway and Western Peripheral Expressway, reducing the amount of go-though traffic from Delhi. With the further interventions like bio-mining for landfills and proposals of new waste to energy plants would reduce the emissions from solid waste burning.

6.7. Air Quality

In Mercer's 2015 annual quality-of-living survey, New Delhi ranks at number 154 out of 230 cities due to bad air quality and pollution. The World Health Organization ranked New Delhi as the world's worst polluted city in 2014 among about 1,600 cities the organization tracked around the world. In 2016, United States Environmental Protection Agency listed New Delhi as the most polluted city on Earth.

In an attempt to lessen air pollution in New Delhi, which gets worse during the winter, a temporary alternate-day travel scheme for cars using the odd- and even-numbered license plates system was announced by Delhi government in December 2015. In addition, trucks were to be allowed to enter India's capital only after 11 pm, two hours later than the existing restriction. The driving restriction scheme was planned to be implemented as a trial from 1 January 2016 for an initial period of 15 days. The restriction was in force between 8 am and 8 pm, and traffic was not restricted on Sundays. Public transportation service was increased during the restriction period.

On 16 December 2015, the Supreme Court of India mandated several restrictions on Delhi's transportation system to curb pollution. Among the measures, the court ordered to stop registrations of diesel cars and sport utility vehicles with an engine capacity of 2,000 cc and over until 31 March 2016. The court also ordered all taxis in the Delhi region to switch to compressed natural gas by 1 March 2016. Transportation vehicles that are more than 10 years old were banned from entering the capital.

On 7 November 2017, the Indian Medical Association declared a public health emergency due to high pollution levels. The highest being in the Punjabi Bagh district with an air quality index of 999 and in the RK Puram district with an index of 852. The lowest index recorded was in the Anand Vihar district with an index of 319. Levels of $PM_{2.5}$ were recorded at 710 μg/m³, more than 11 times the World Health Organization's safe limit.

In a 2018 study, New Delhi was found to be the most polluted capital out of 61 capital cities around the world. In December 2019, IIT Bombay, in partnership with the McKelvey School of Engineering of Washington University in St. Louis, launched the Aerosol and Air Quality Research Facility to study air pollution in New Delhi, among other Indian cities.

6.7.1. Monitoring Stations

For carrying out the assessment, data from 38 monitoring stations all over the Delhi was taken for Wind speed, wind direction and concentrations of $PM_{2.5}$ & PM_{10} through the year for 2019.

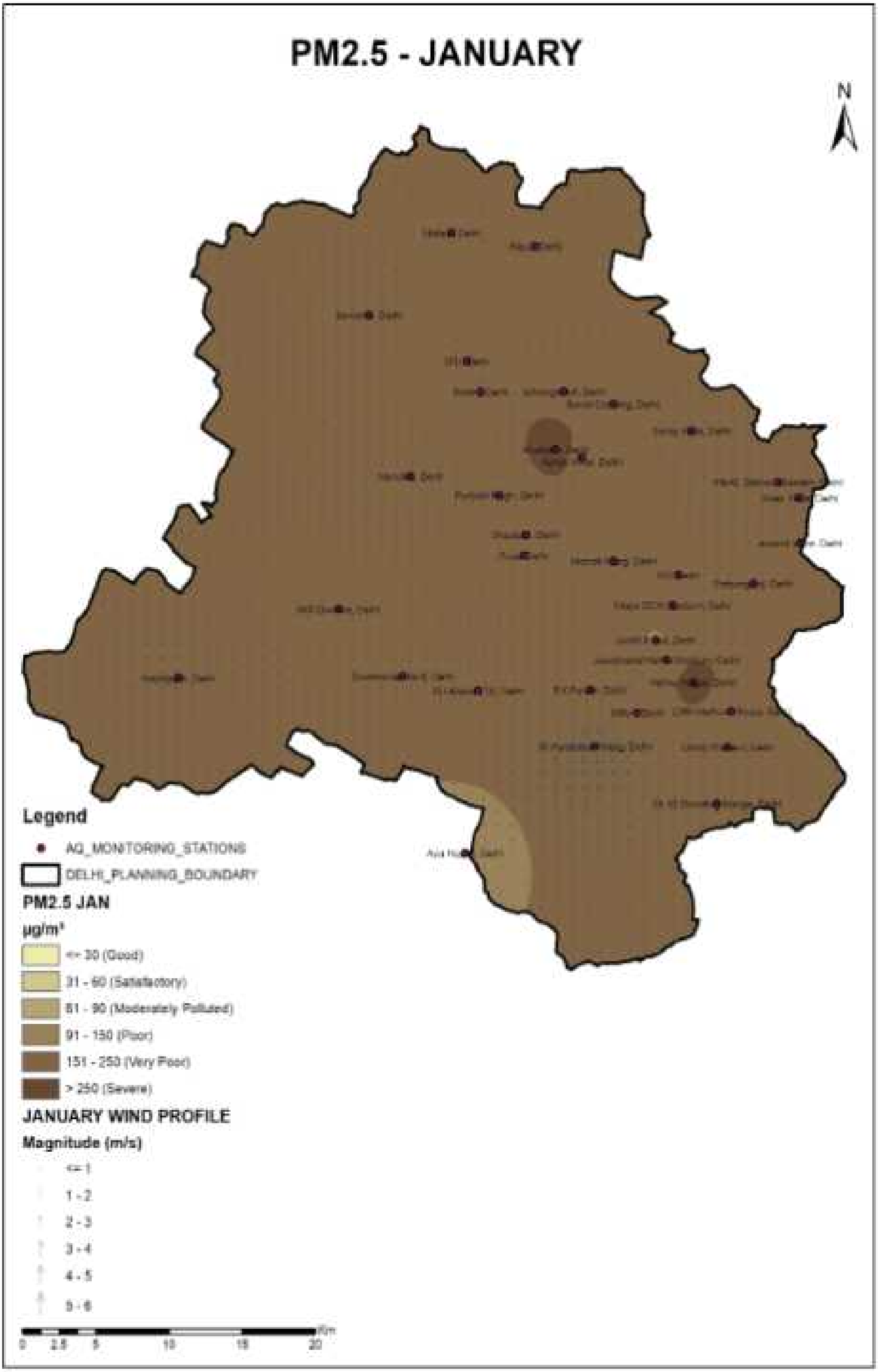
Table 84: List of Monitoring Stations

SNo	Station Name	SNo	Station Name
1	Alipur, Delhi - DPCC	21	Jawaharlal Nehru Stadium, Delhi - DPCC
2	Shadipur, Delhi - CPCB	22	Nehru Nagar, Delhi - DPCC
3	IHBAS, Dilshad Garden, Delhi - CPCB	23	Dwarka-Sector 8, Delhi - DPCC
4	NSIT Dwarka, Delhi - CPCB	24	Dr. Karni Singh Shooting Range, Delhi - DPCC
5	DTU, Delhi - CPCB	25	Patparganj, Delhi - DPCC
6	ITO, Delhi - CPCB	26	Sonia Vihar, Delhi - DPCC
7	Sirifort, Delhi - CPCB	27	Jahangirpuri, Delhi - DPCC
8	Mandir Marg, Delhi - DPCC	28	Rohini, Delhi - DPCC
9	Anand Vihar, Delhi - DPCC	29	Najafgarh, Delhi - DPCC
10	R K Puram, Delhi - DPCC	30	Vivek Vihar, Delhi - DPCC
11	Punjabi Bagh, Delhi - DPCC	31	Major Dhyan Chand National Stadium, Delhi - DPCC
12	Aya Nagar, Delhi - IMD	32	Narela, Delhi - DPCC
13	Lodhi Road, Delhi - IMD	33	Okhla Phase-2, Delhi - DPCC
14	North Campus, DU, Delhi - IMD	34	Wazirpur, Delhi - DPCC
15	Burari Crossing, Delhi - IMD	35	Bawana, Delhi - DPCC
16	CRRI Mathura Road, Delhi - IMD	36	Sri Aurobindo Marg, Delhi - DPCC
17	Pusa, Delhi - IMD	37	Pusa, Delhi - DPCC
18	IGI Airport (T3), Delhi - IMD	38	Mundka, Delhi - DPCC
19	East Arjun Nagar, Delhi - CPCB		

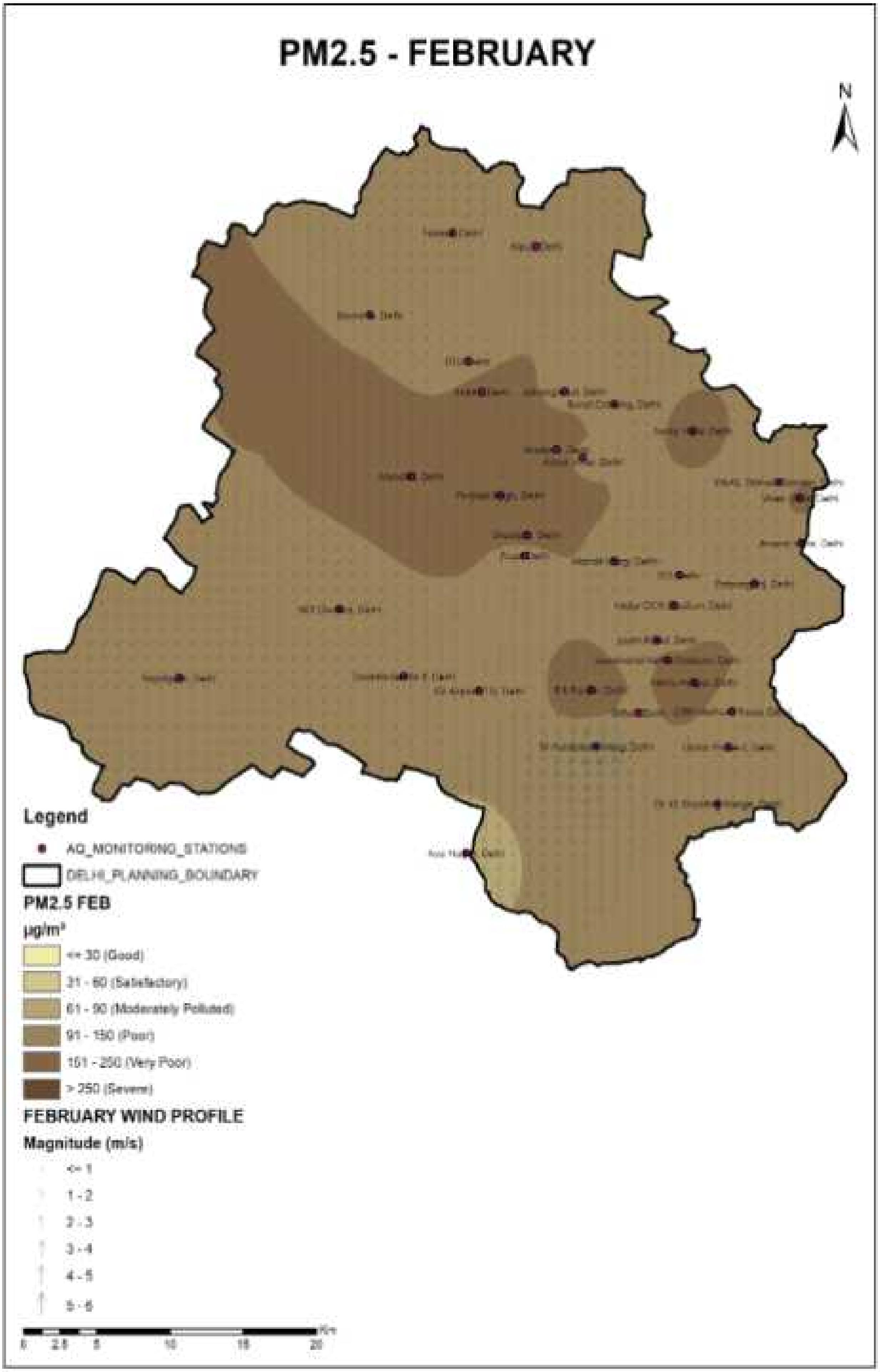
6.7.2. Mapping of $PM_{2.5}$ and PM_{10} concentration, 2019

The emission data for $PM_{2.5}$ and PM_{10} for Delhi for all the above-mentioned monitoring stations have been collected from DPCC and CAAQM-All India. The data is translated spatially using ArcGIS via interpolation techniques.

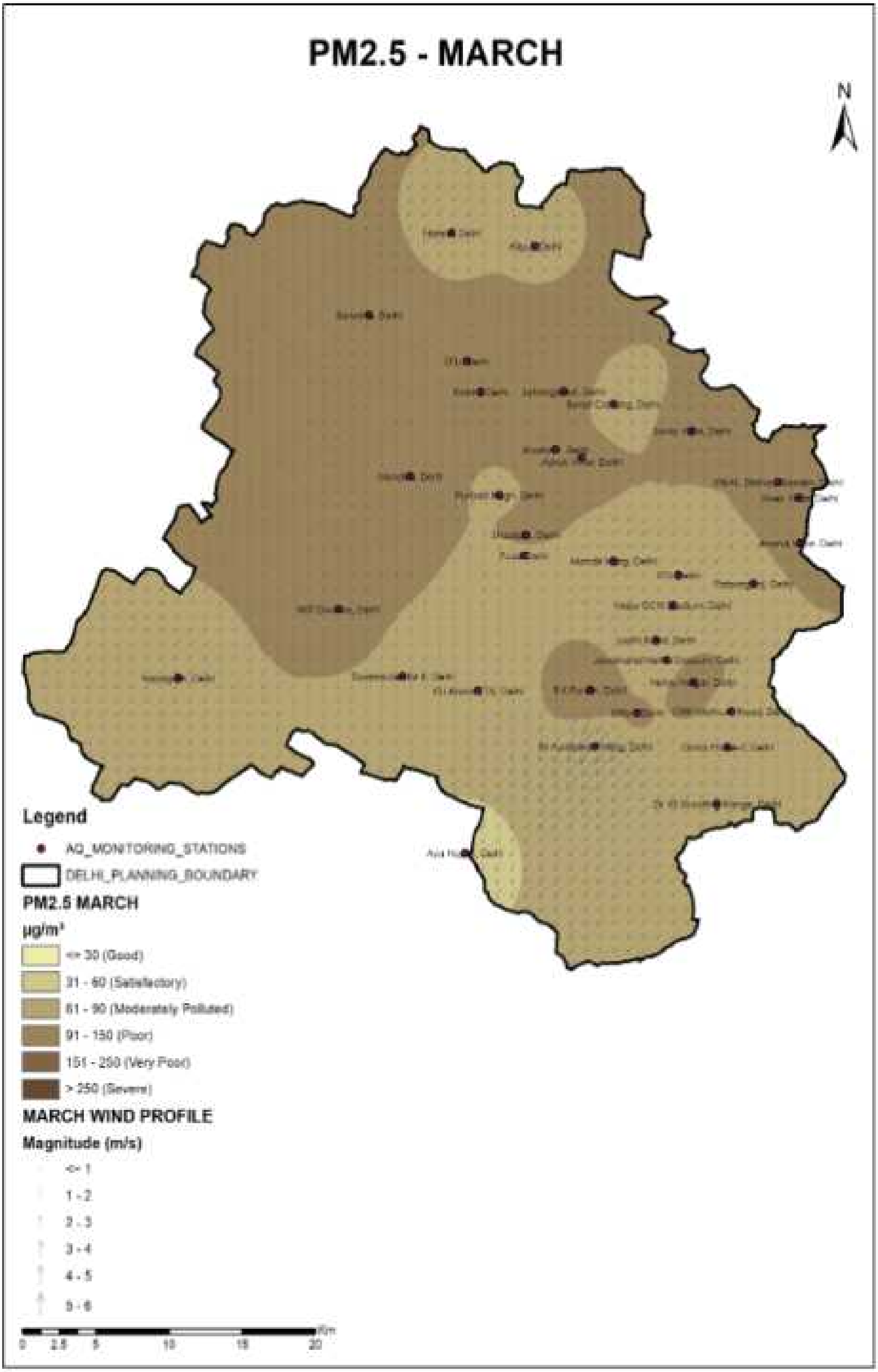
The maps show a good correlation between the activity and the pollutant concentration supplemented by wind speed and wind direction data.



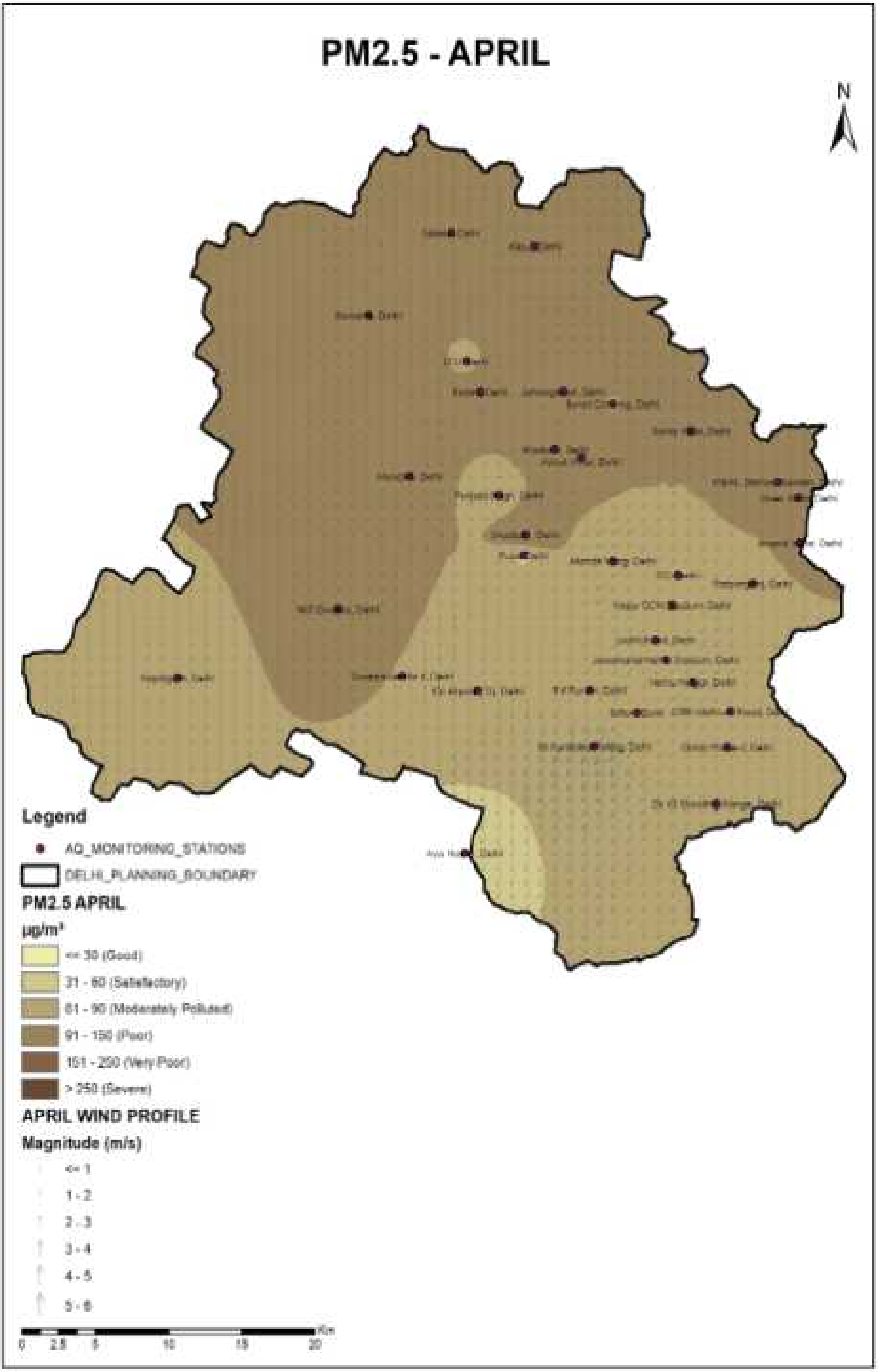
Map 12: PM 2.5 Concentration in January, 2019



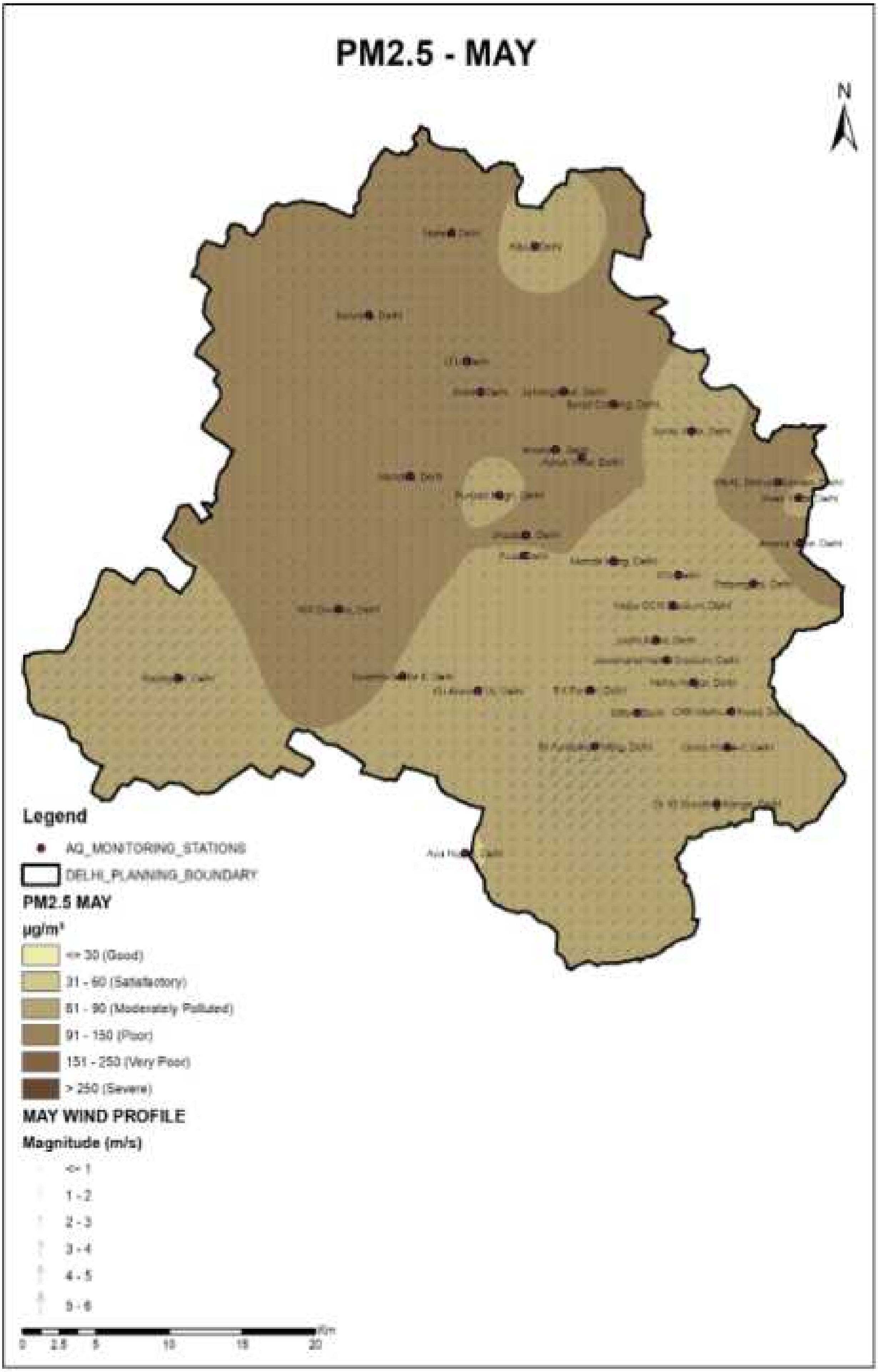
Map 13: PM 2.5 Concentration in February 2019



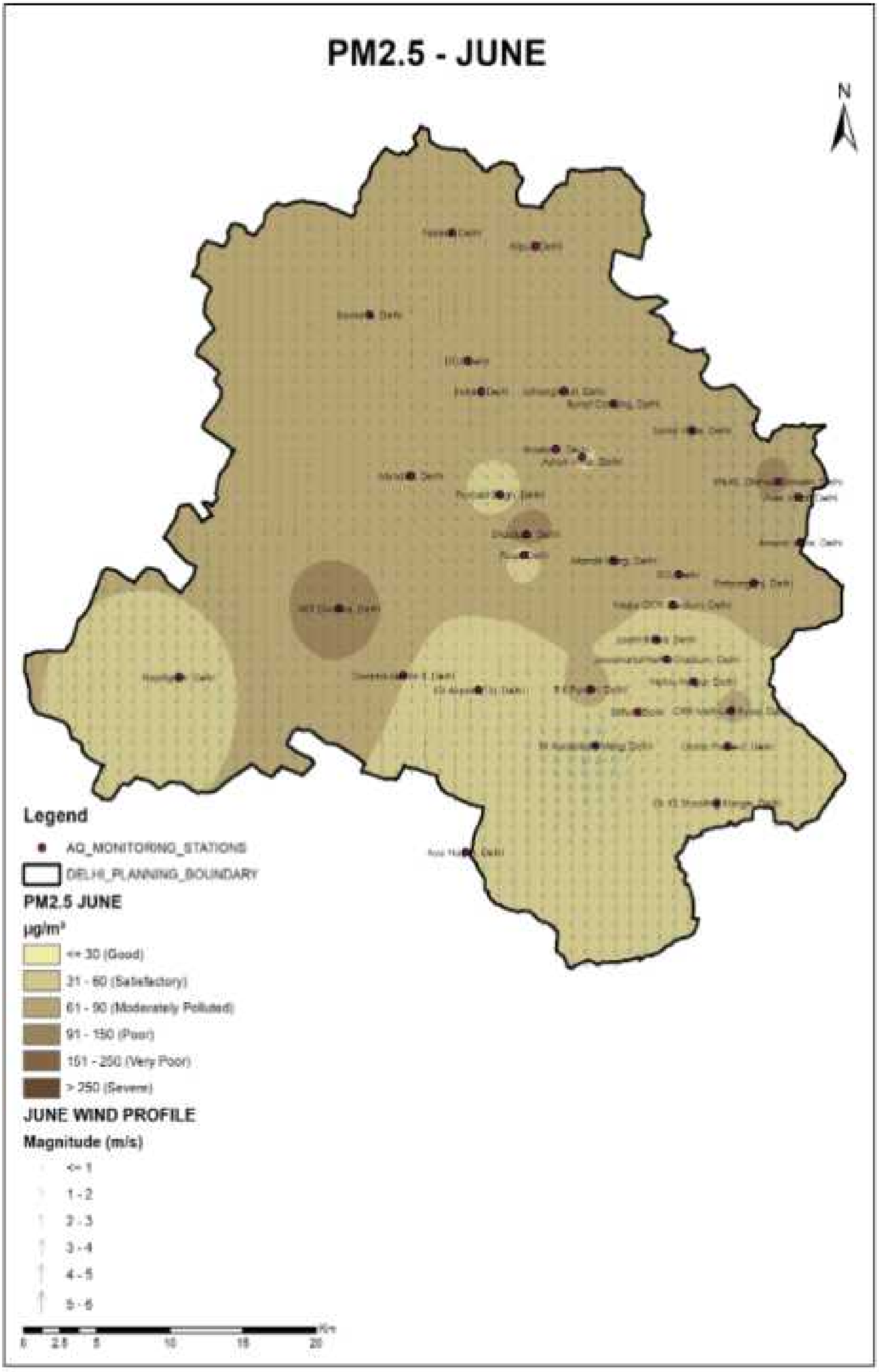
Map 14: PM 2.5 Concentration in March, 2019.



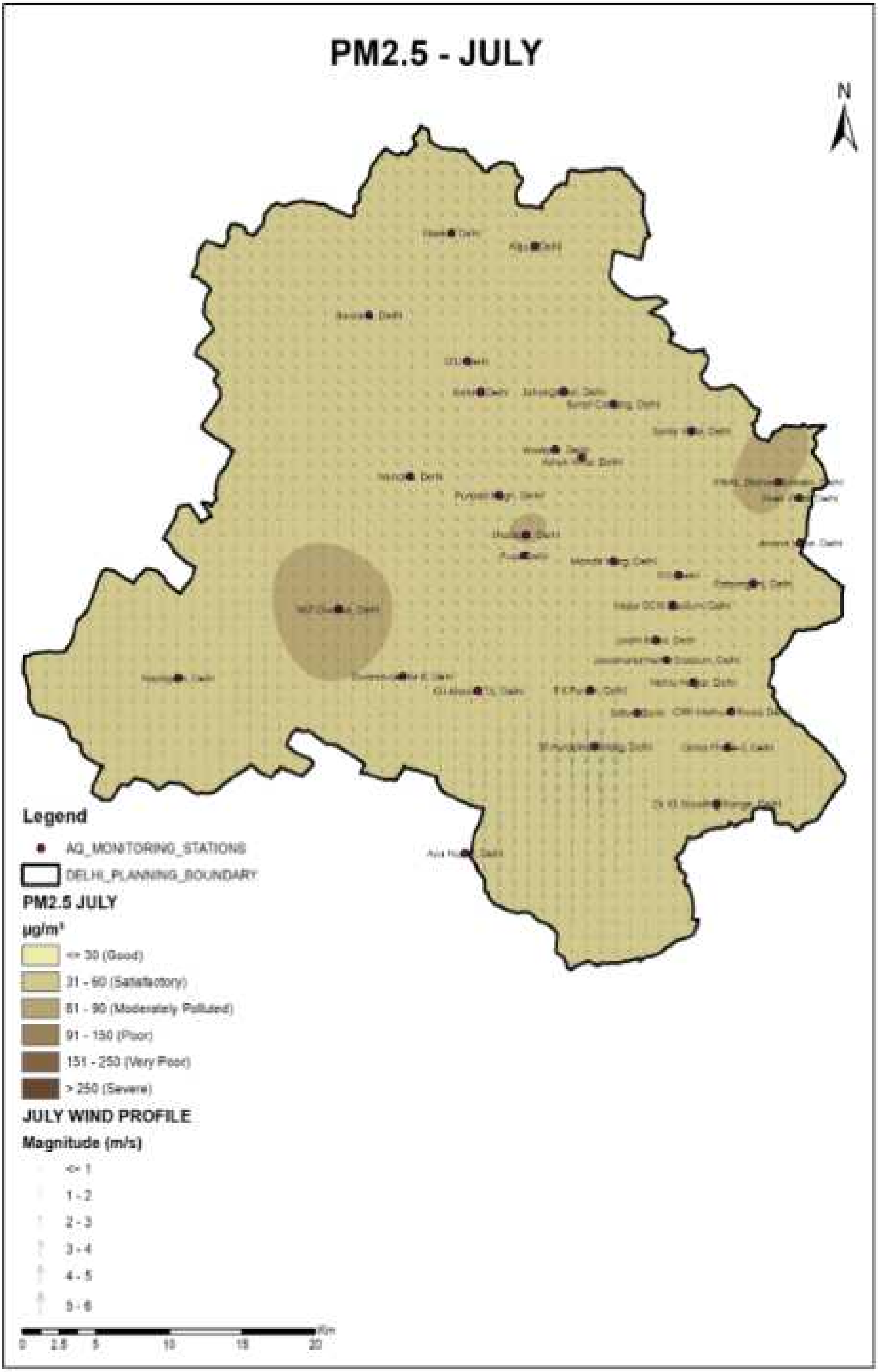
Map 15: PM 2.5 Concentration in April, 2019



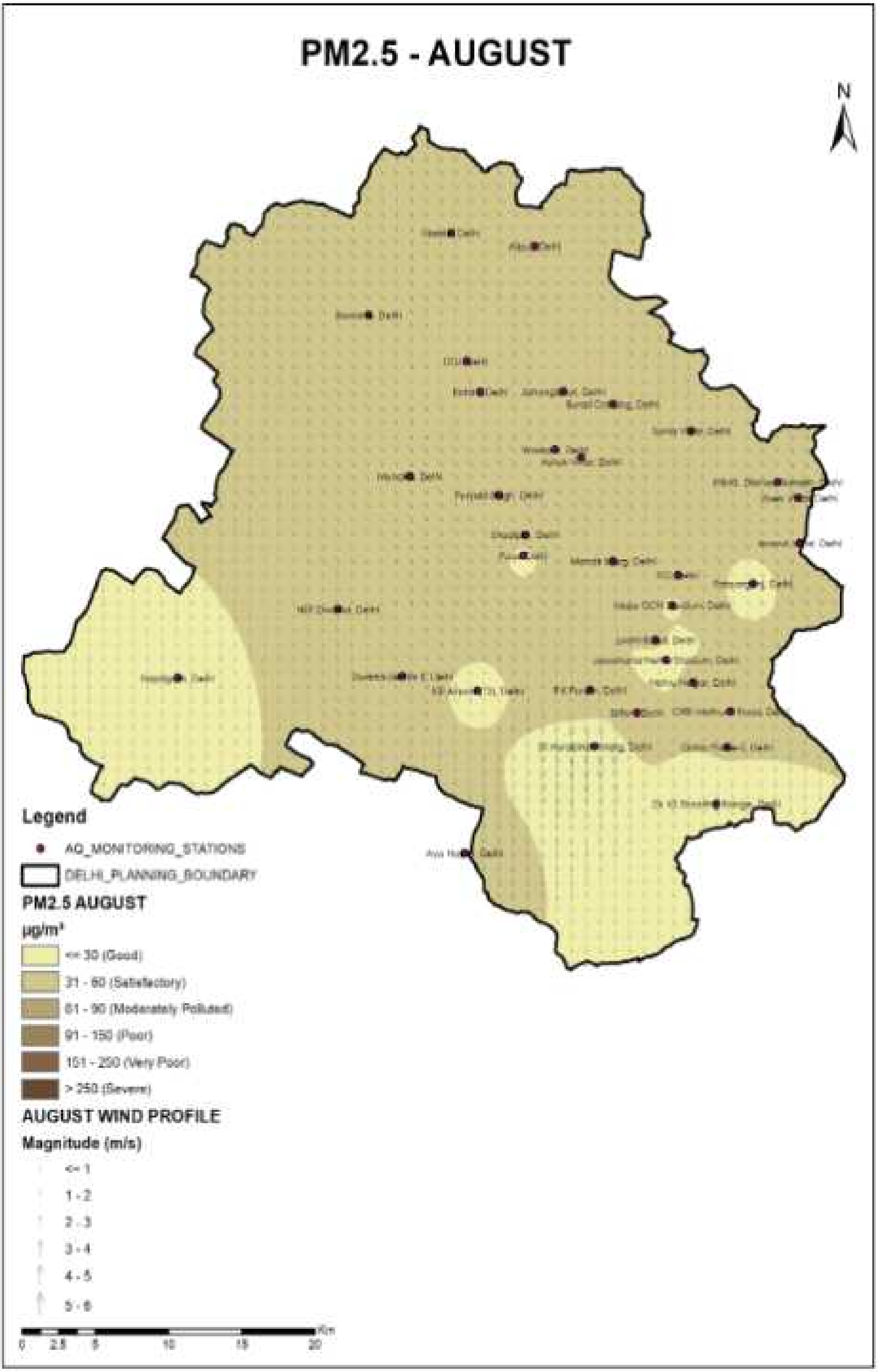
Map 16: PM 2.5 Concentration in May, 2019



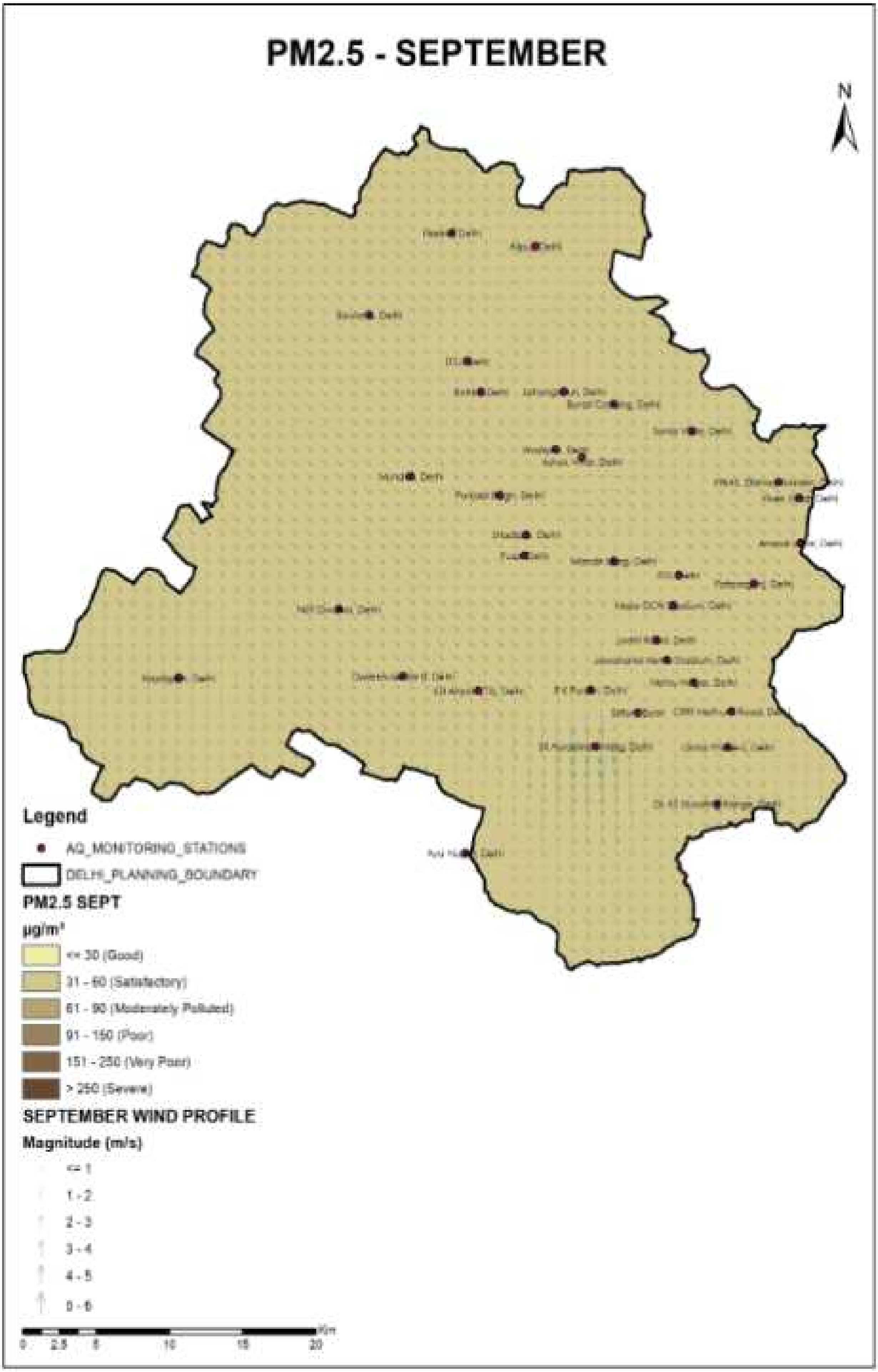
Map 17: PM 2.5 Concentration in June, 2019



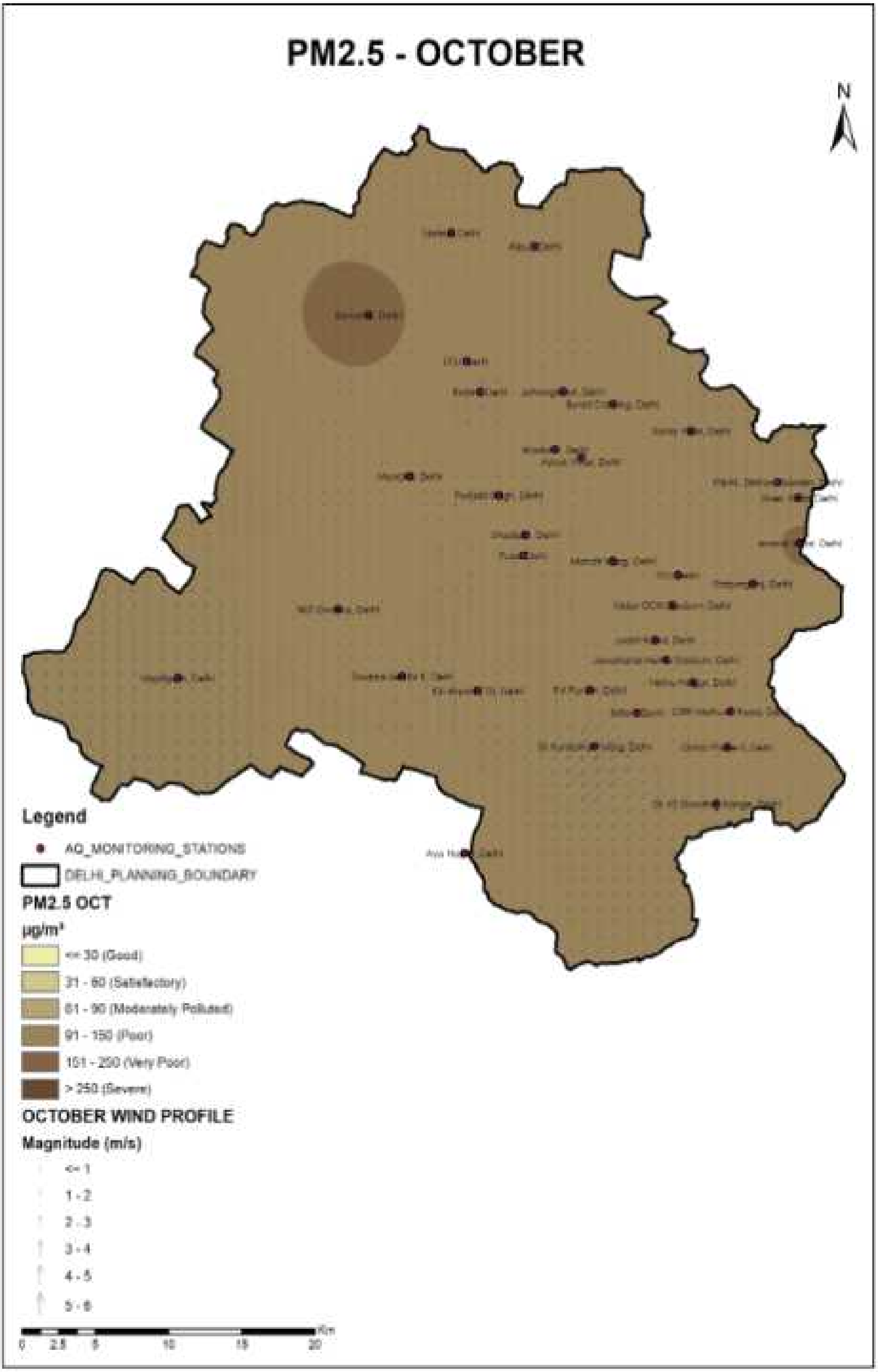
Map 18: PM 2.5 Concentration in July, 2019



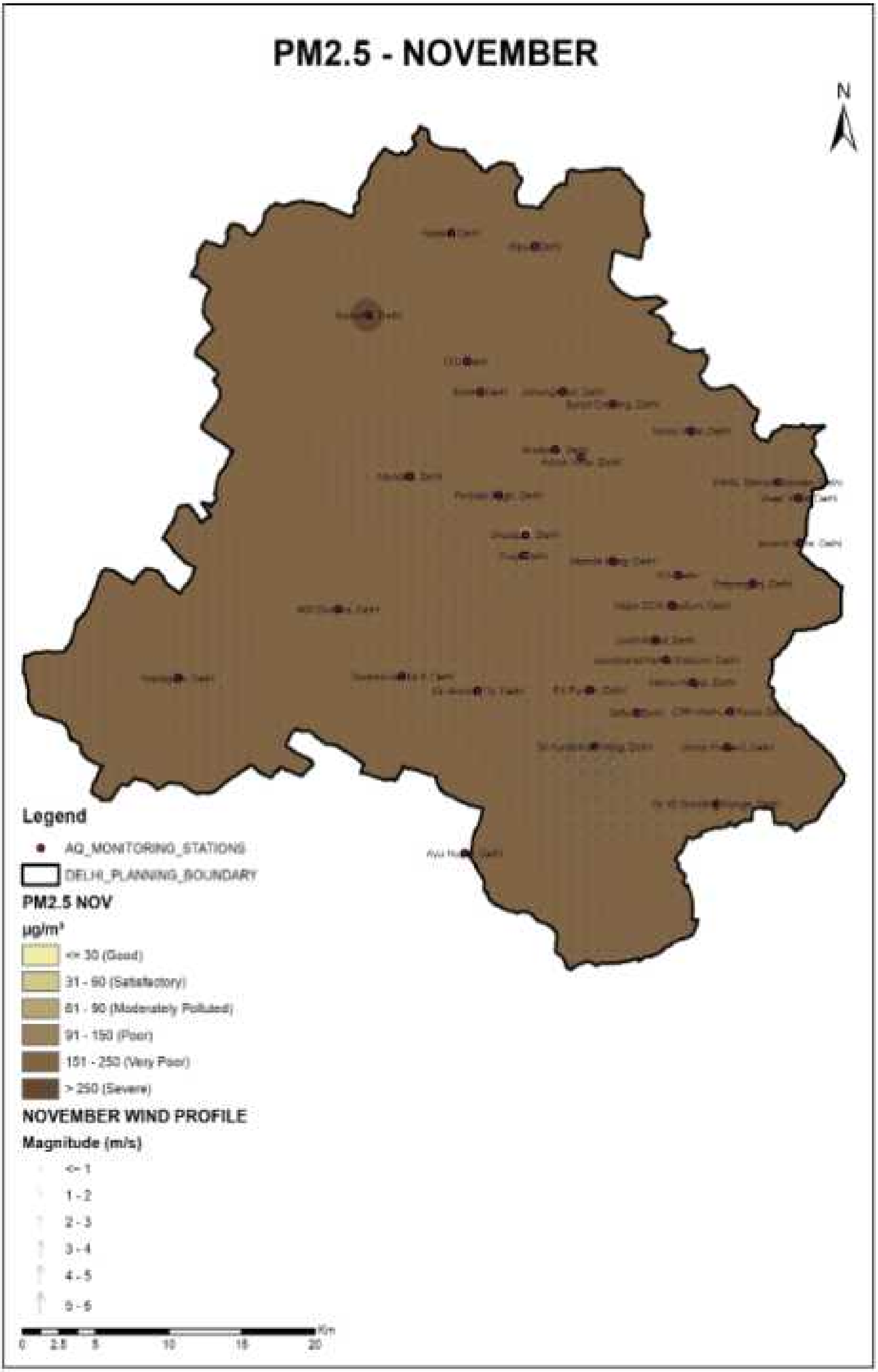
Map 19: PM 2.5 Concentration in August, 2019



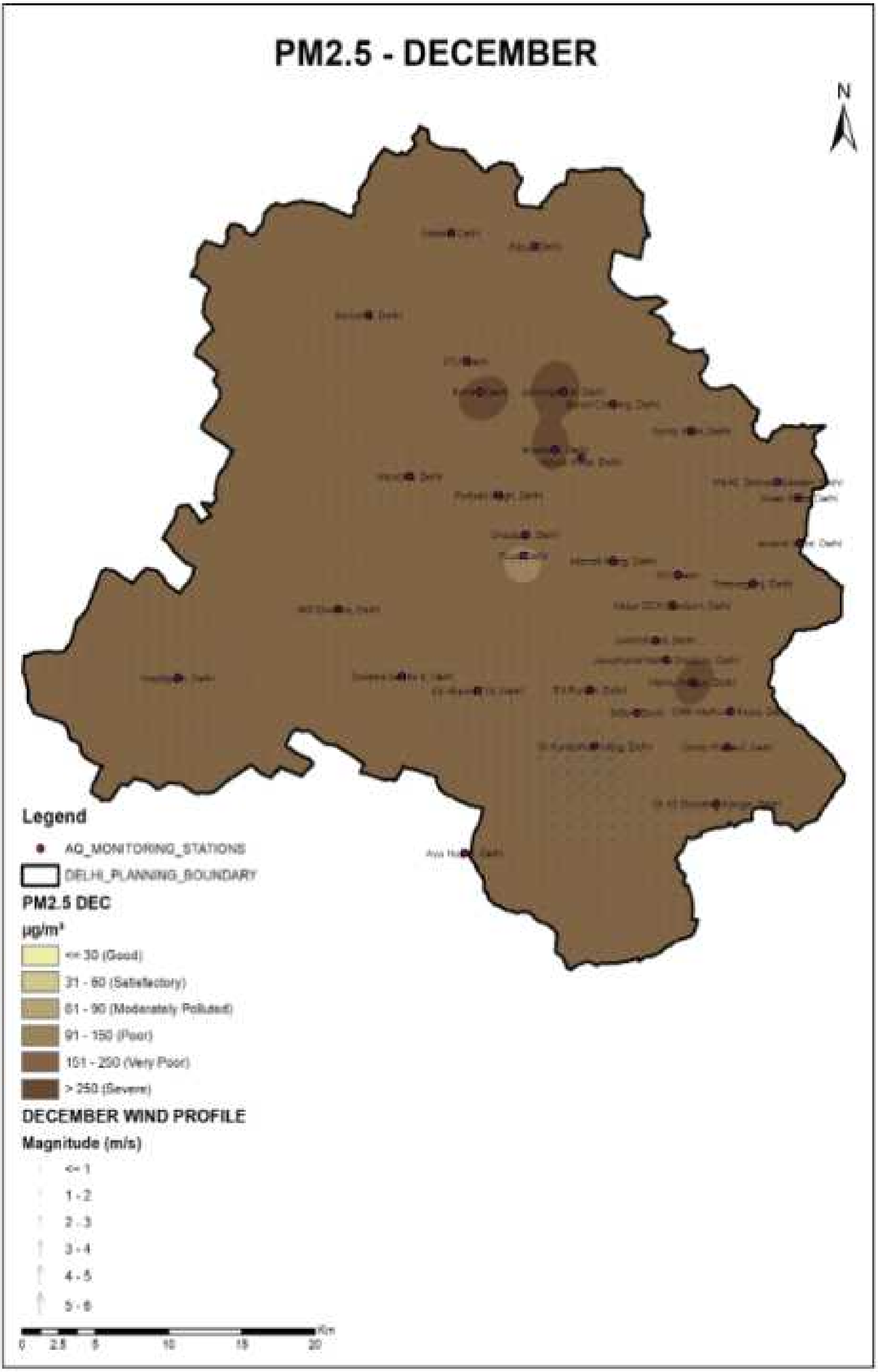
Map 20: PM 2.5 Concentration in September, 2019



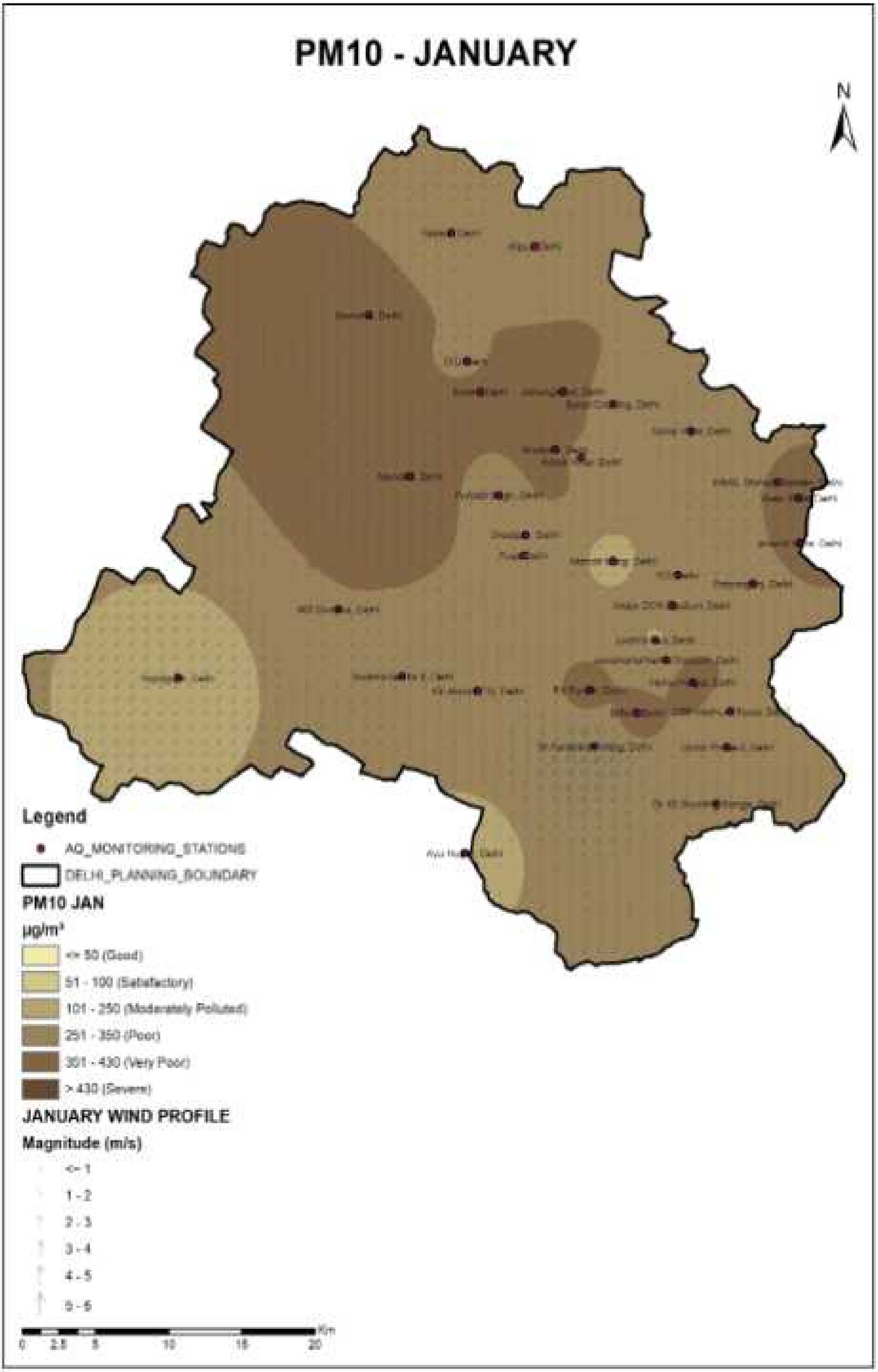
Map 21: PM 2.5 Concentration in October, 2019



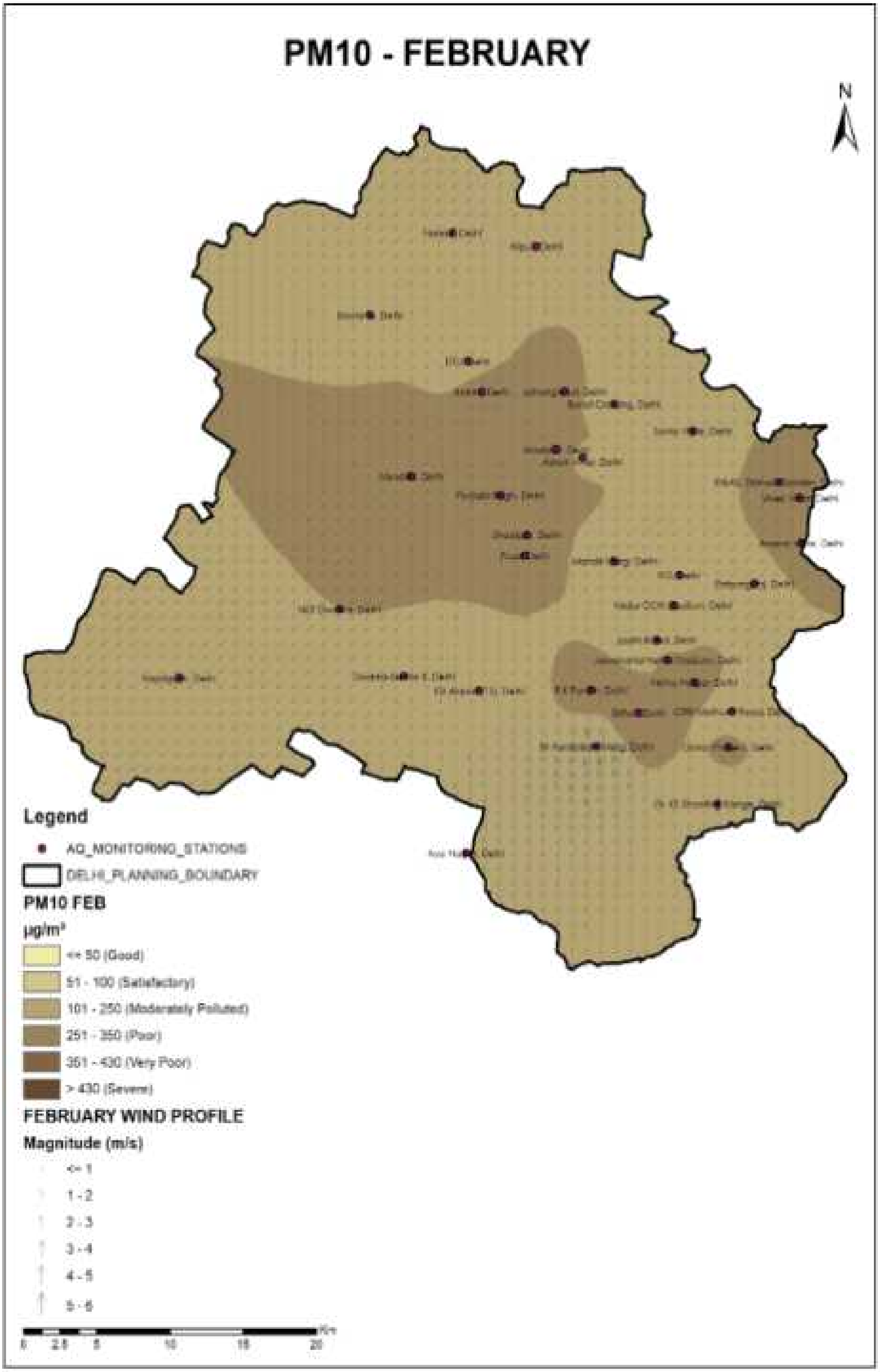
Map 22: PM 2.5 Concentration in November, 2019



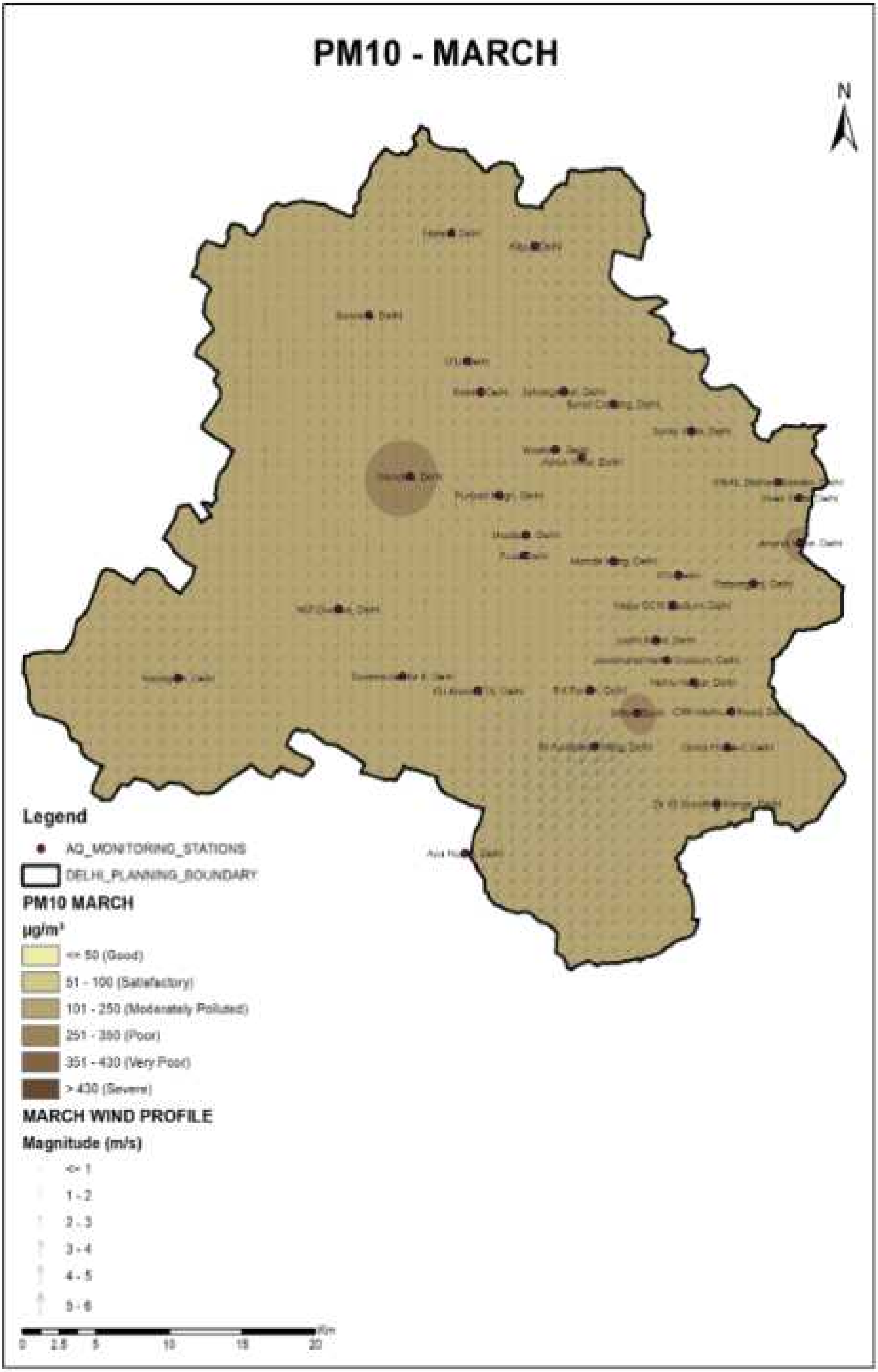
Map 23: PM 2.5 Concentration in December, 2019



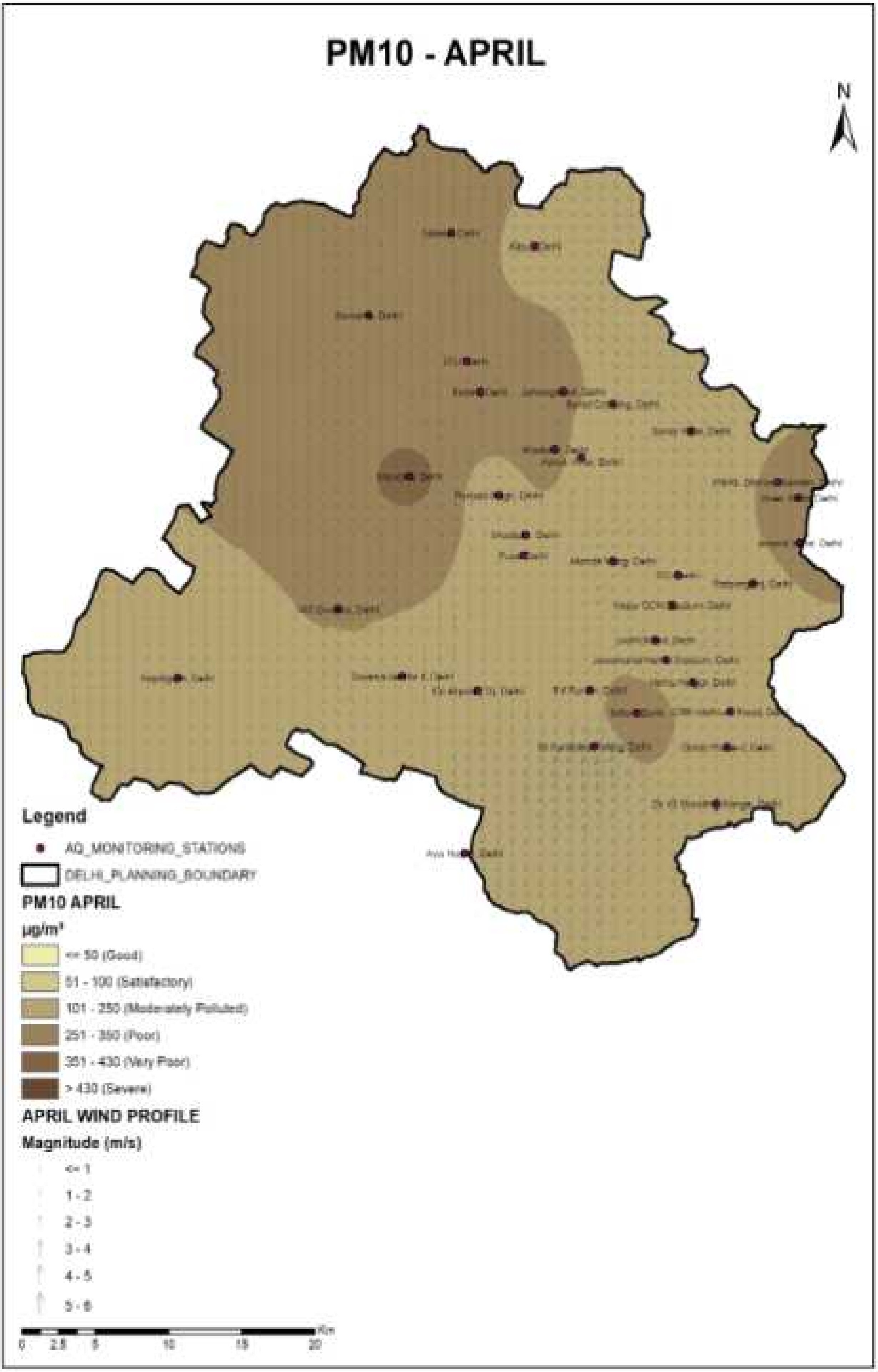
Map 24: PM 10 Concentration in January, 2019



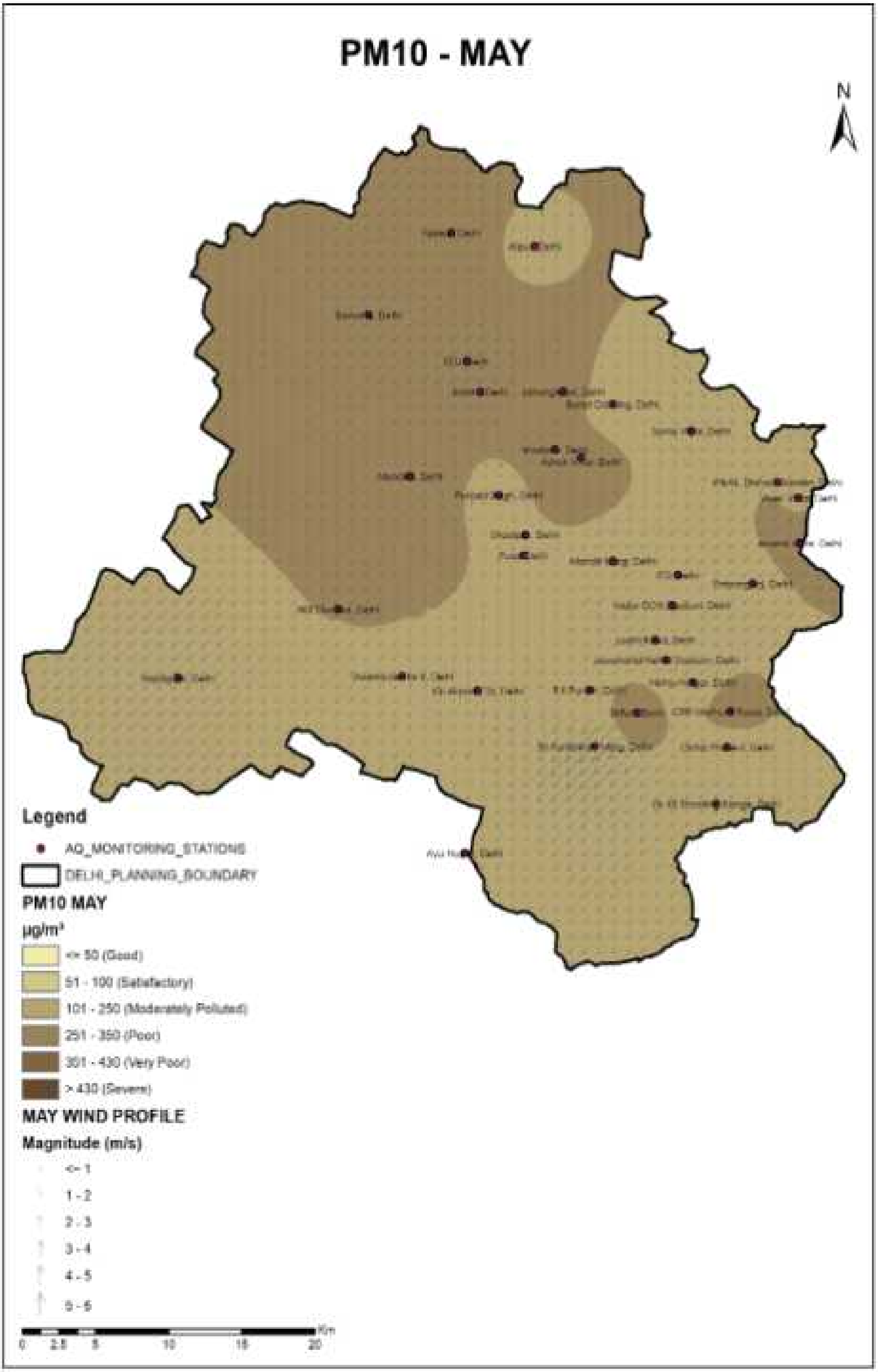
Map 25: PM 10 Concentration in February, 2019



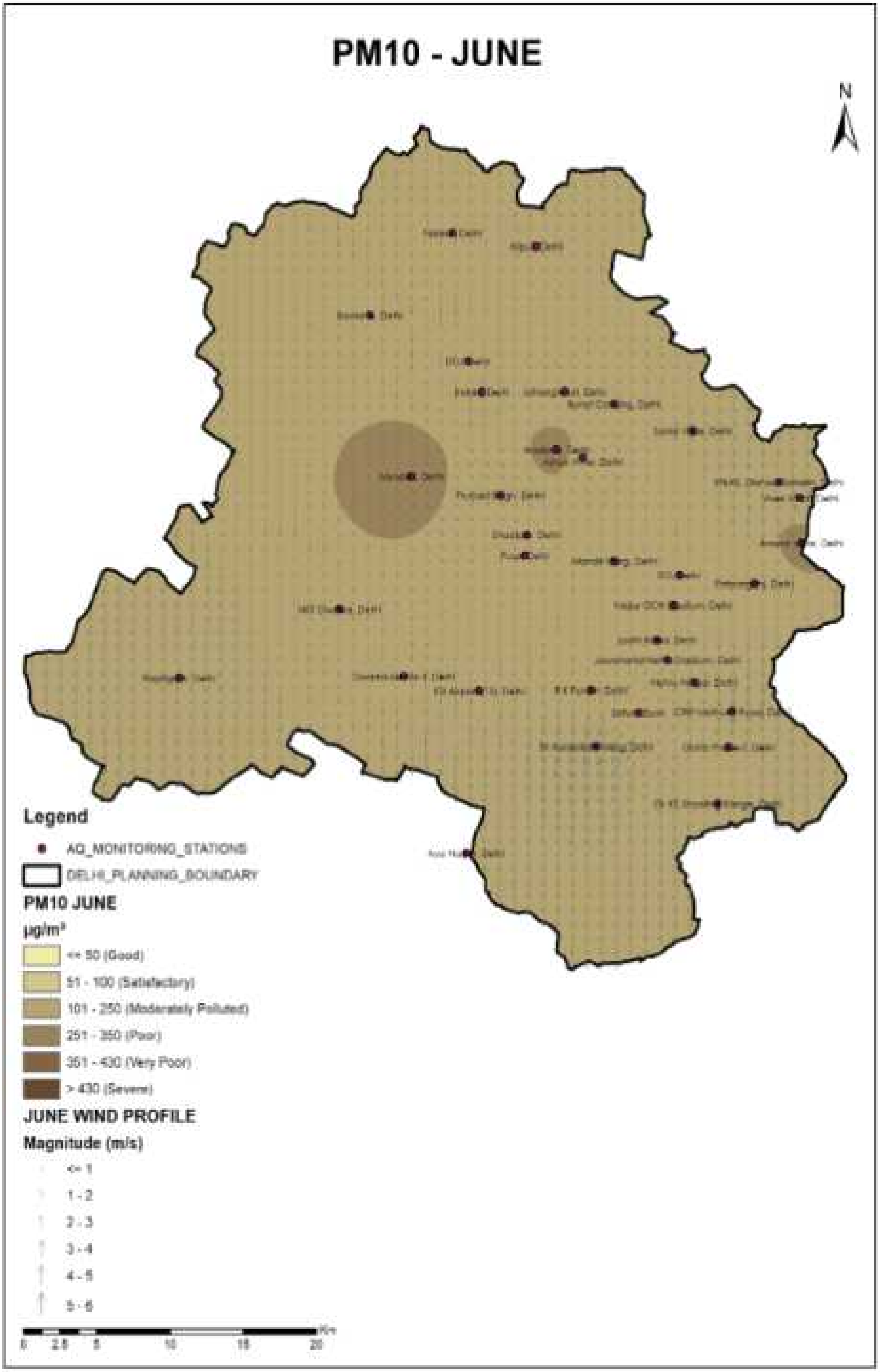
Map 26: PM 10 Concentration in March, 2019



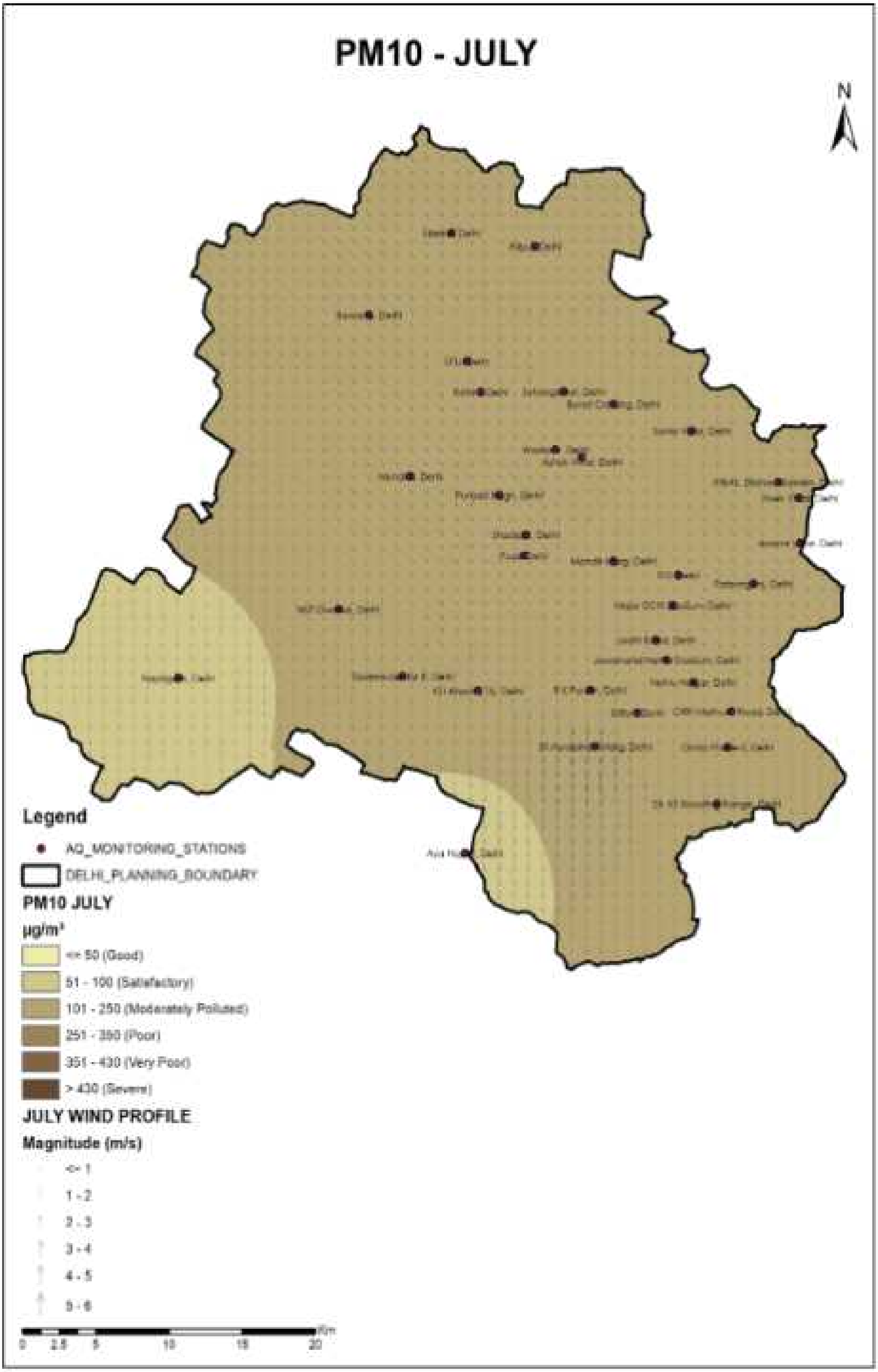
Map 27: PM 10 Concentration in April, 2019



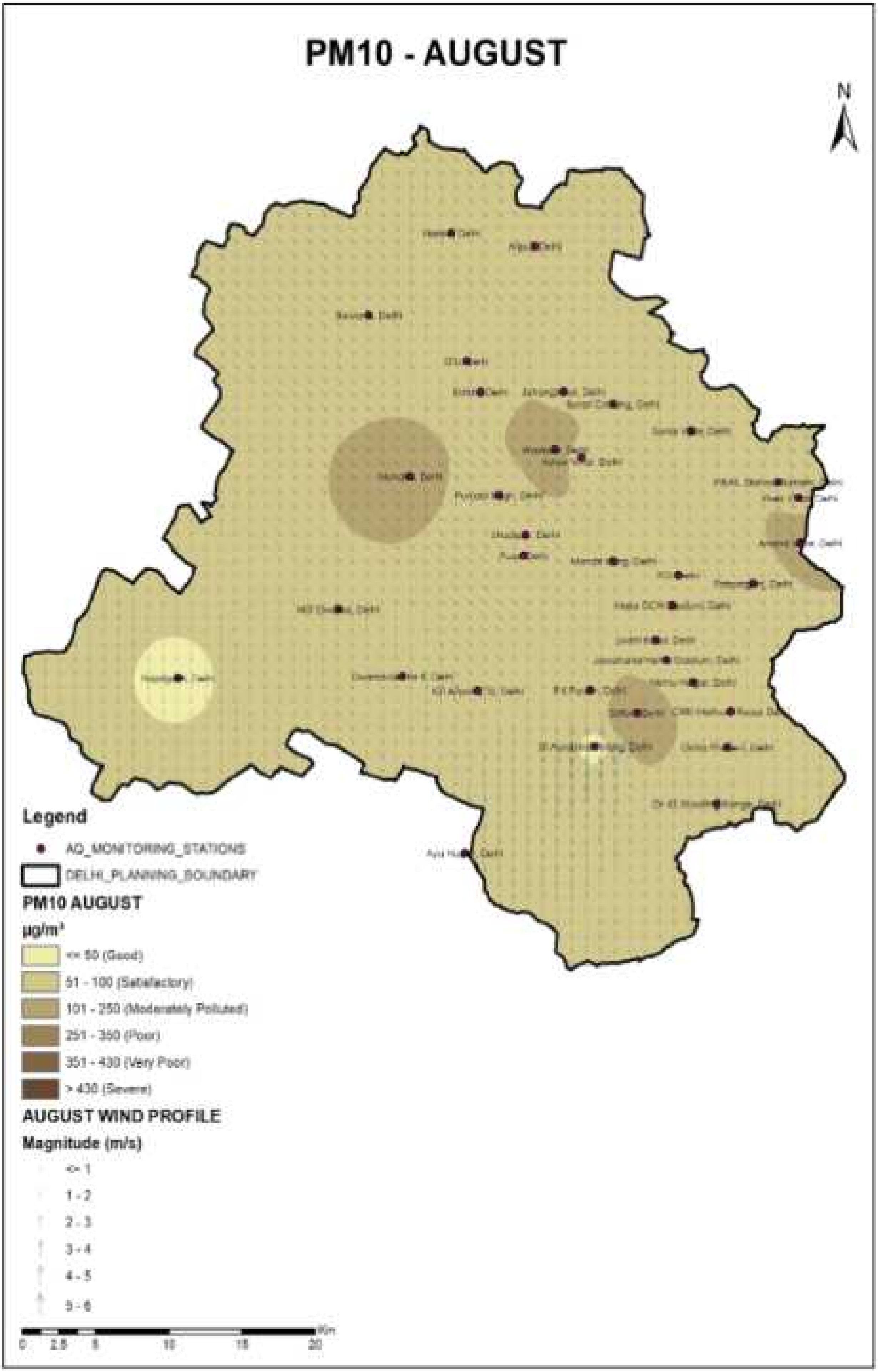
Map 28: PM 10 Concentration in May, 2019



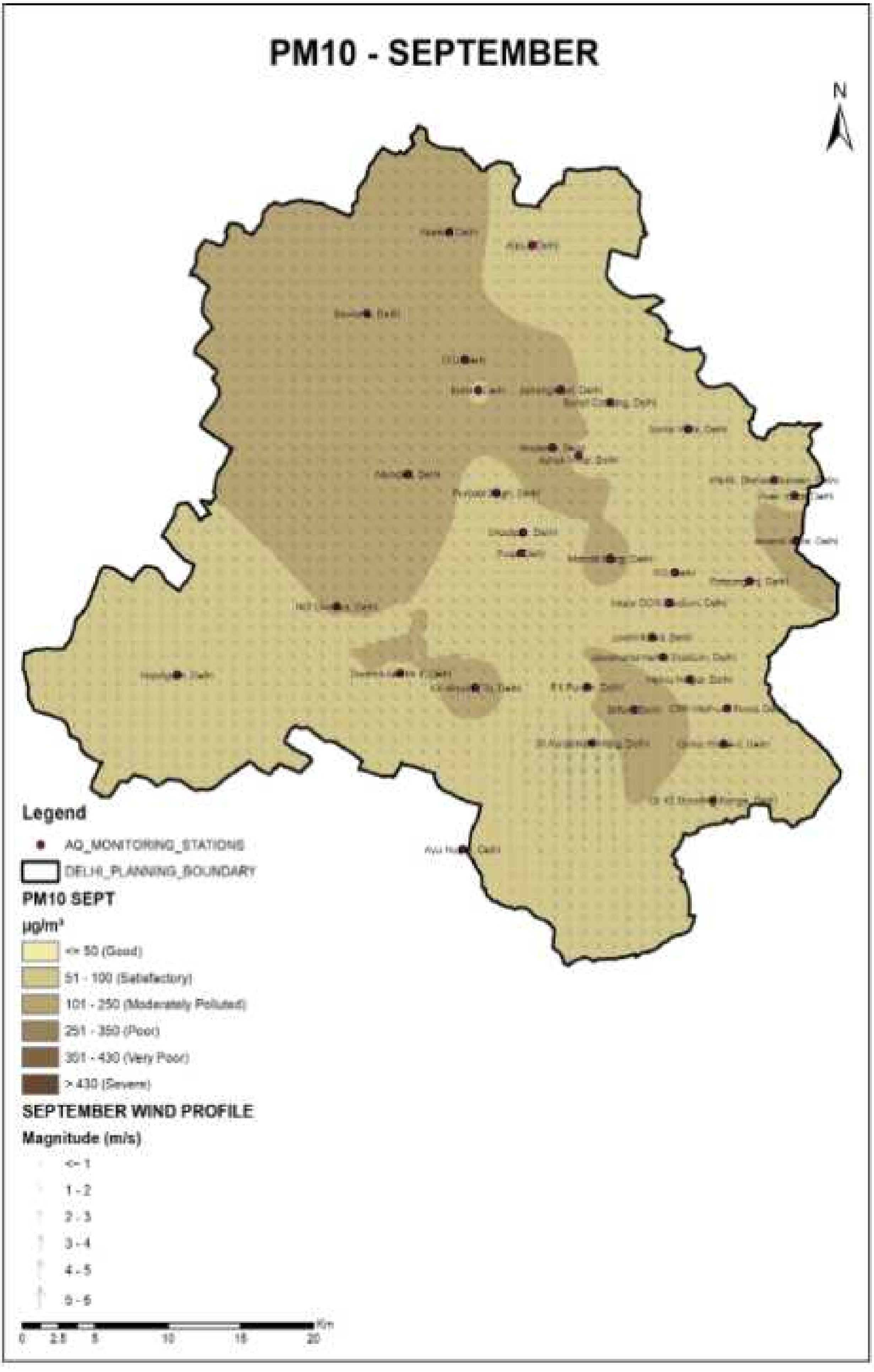
Map 29: PM 10 Concentration in June, 2019



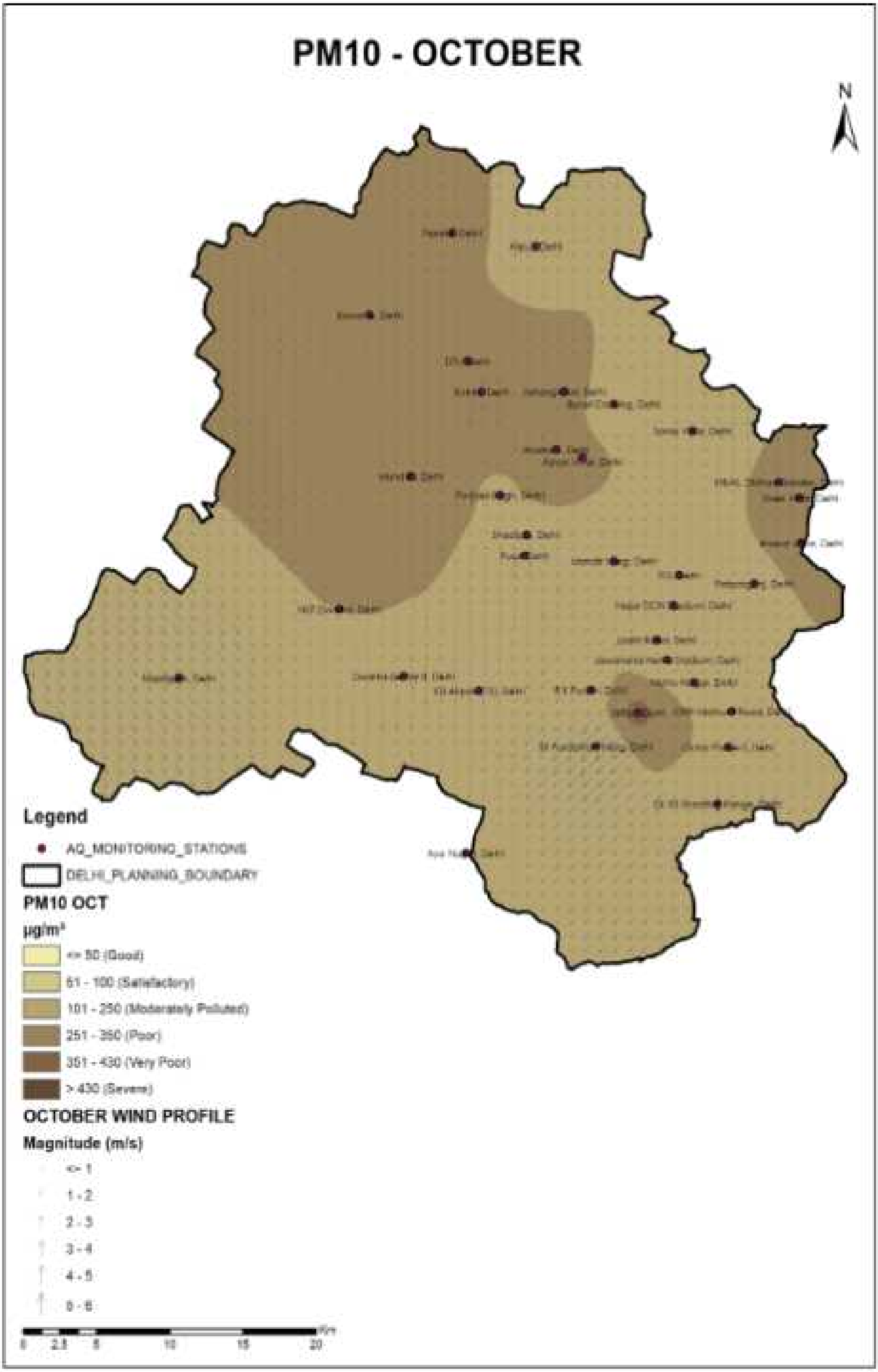
Map 30: PM 10 Concentration in July, 2019



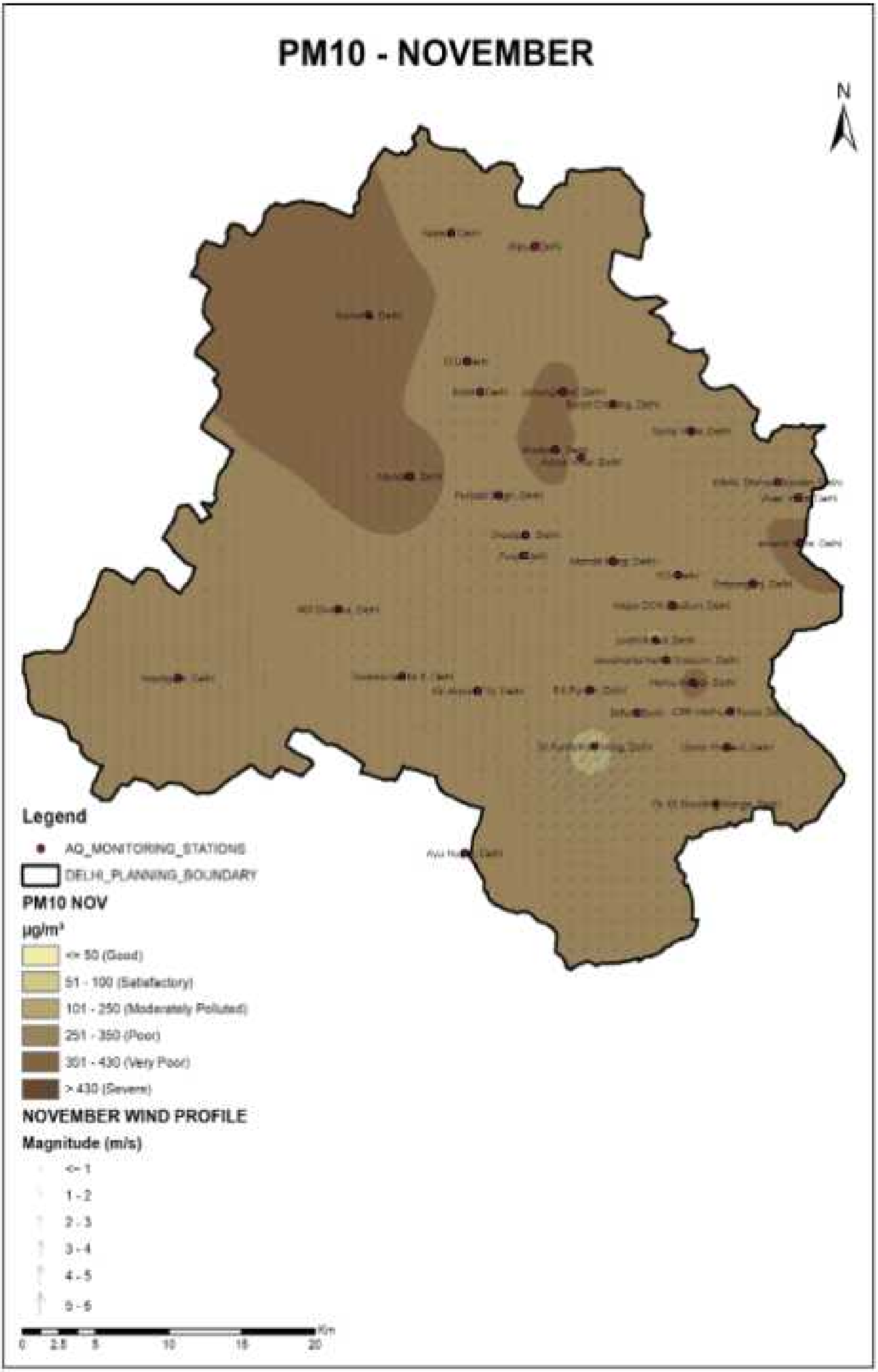
Map 31: PM 10 Concentration in August 2019



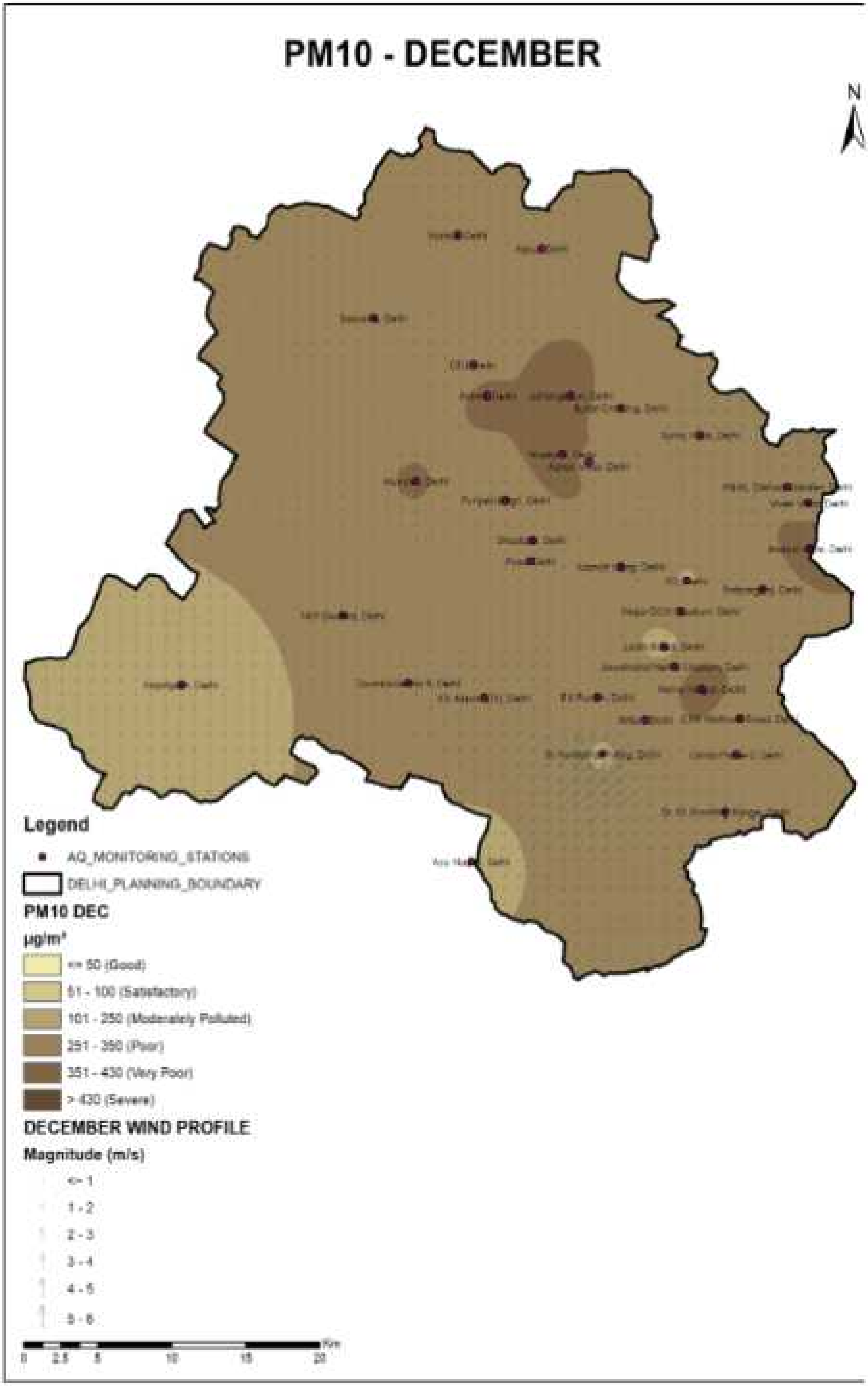
Map 32: PM 10 Concentration in September, 2019



Map 33: PM 10 Concentration in October, 2019



Map 34: PM 10 Concentration in November, 2019

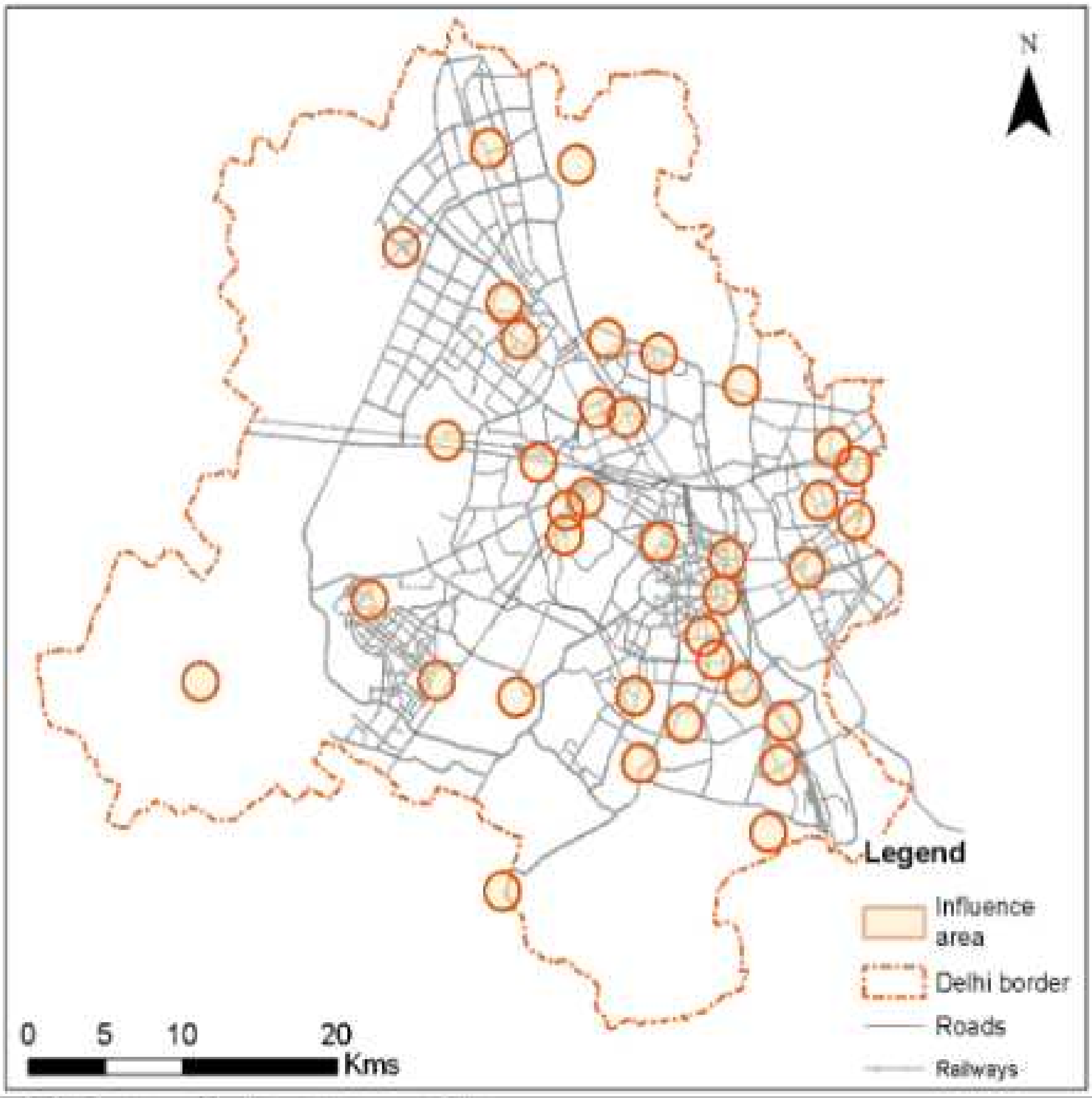


Map 35: PM 10 Concentration in December, 2019

6.7.3. Monitoring stations and their influence zones

In Delhi the data is for 38 real time monitoring stations, of which seven are operated by Indian Meteorological Department (IMD), seven by CPCB and 24 by DPCC. East Arjun Nagar station, manned by CPCB, has no data for 2019.The dataset of all other stations have been presented in this chapter. As per CPCB, all the monitoring stations have an influence area of 1km, so all the activities and urban fabric have been accessed in the chapter surrounding a buffer of 1km from all the monitoring stations.

The activities in the buffer zone are presented using four different maps; 1) one presents the Google earth imagery of the buffer area, 2) land-use, 3), urban built form using LCZs explained in Map 10, 4) location of activities that influence traffic rate like; schools, hospitals, restaurants, multiplexes, etc. The following map shows the buffer zones of all the monitoring stations across Delhi.

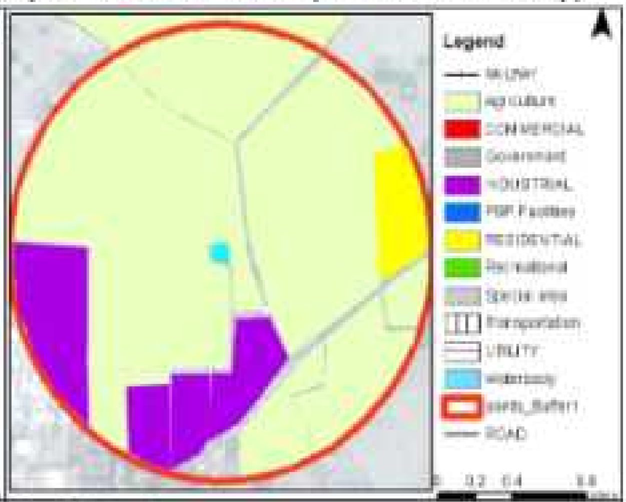


Map 38: Influence area of monitoring stations across Delhi

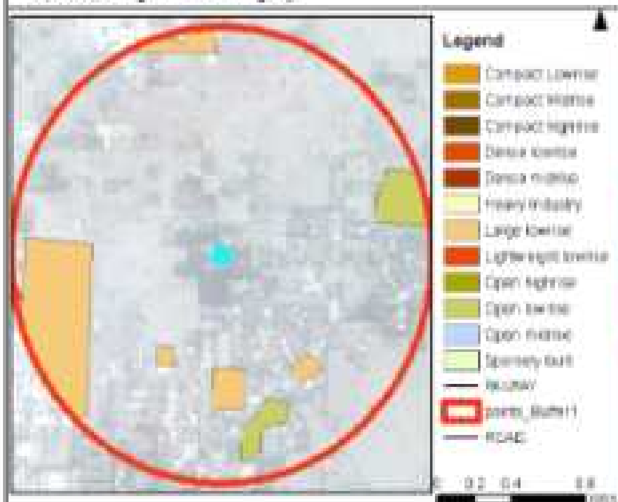
6.7.3.1 Alipur, Delhi - DPCC

The majority (80%) of the influence area lies in agricultural zone, with very less distribution of roads and contains mainly industrial settlements. Data of wind speed wasn't available. Concentration of $PM_{2.5}$ & 10 was observed in poor to severe category for almost 5 months (October to February).

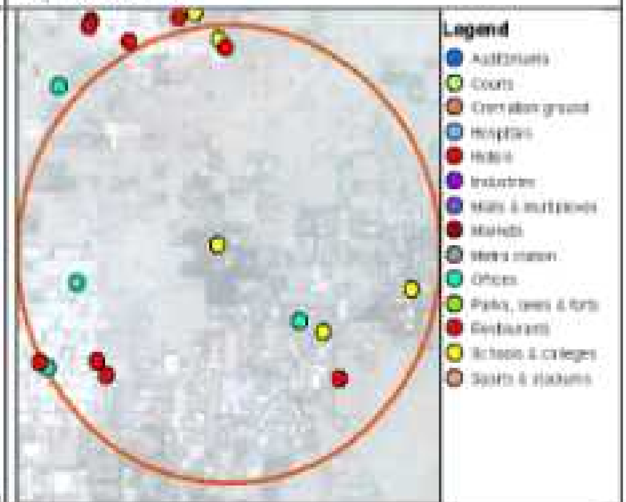
Map 35: Google earth imagery



Map 36: Land-use



Map 37: Built-form



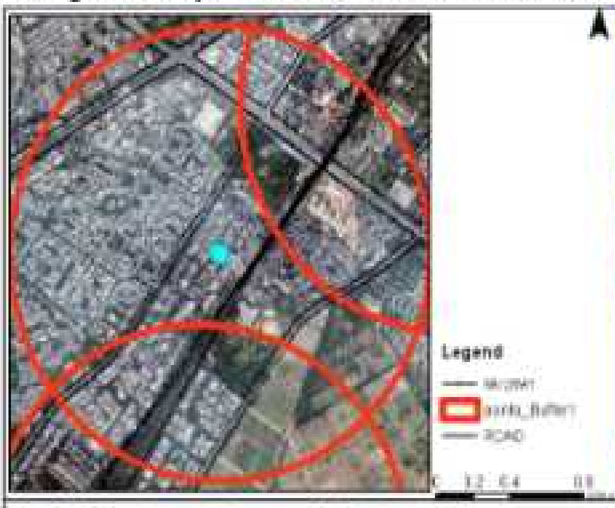
Map 38: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%			MONTHS	PM2.5	PM10		
Dense lowrise	0.002	0.06	COMMERCIAL	0	0.0			January	193.5	285.736		
Dense midrise	0.000	0.00	INDUSTRIAL	0.6	19.1			Februaray	145.28	232.592		
Open midrise	0.000	0.00	TRANSPORTATION	0.17	5.4			March	88.56	166.367		
Open highrise	0.000	0.00	RECREATIONAL	0	0.0			April	93.02	235.218		
Open lowrise	0.081	2.58	RESIDENTIAL	0.2	6.4			May	85.28	244.477		
Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0			June	63.58	213.692		
Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0			July	44.59	118.848		
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	31.56	57.6946		
Large lowrise	0.283	9.02	SPECIAL AREA		0.0			September	36.73	72.4616		
Sparsely built	0.000	0.00	WATERBODY		0.0			October	128.16	220.637		
Green belt	2.600	82.80	GREEN BELT	2.18	69.4			November	203.76	305.071		
Open area	0.000	0.00						December	194.85	279.997		
Waterbody	0.000	0.00										
Road	0.170	5.41										
Heavy Industry	0	0.00										

Table 85: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

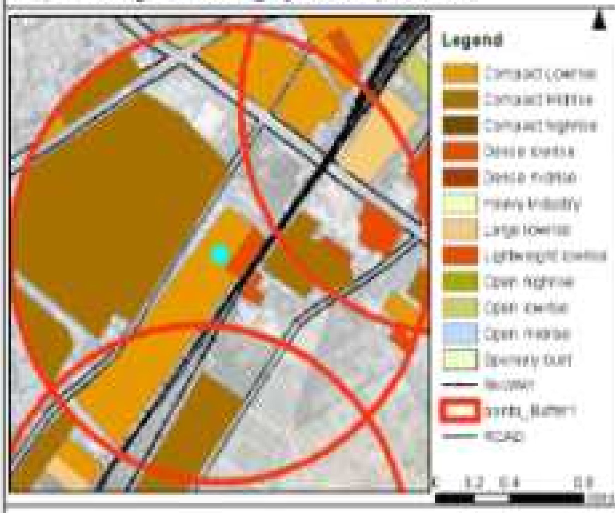
6.7.3.2 Shadipur, Delhi - CPCB

Concentration of $PM_{2.5}$ was observed in poor to severe category for almost 9 months (October to June), it could be because of the emissions from industrial and construction activities happening throughout the year in the area which can be seen from following maps.

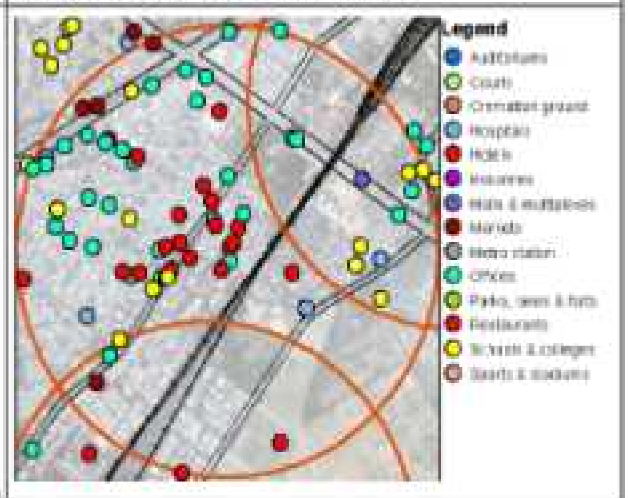


Map 39: Google earth imagery of Shadipur station

Map 40: Land-use around Shadipur station



Map 41: Built-form around Shadipur station



Map 42: Major activities around Shadipur station

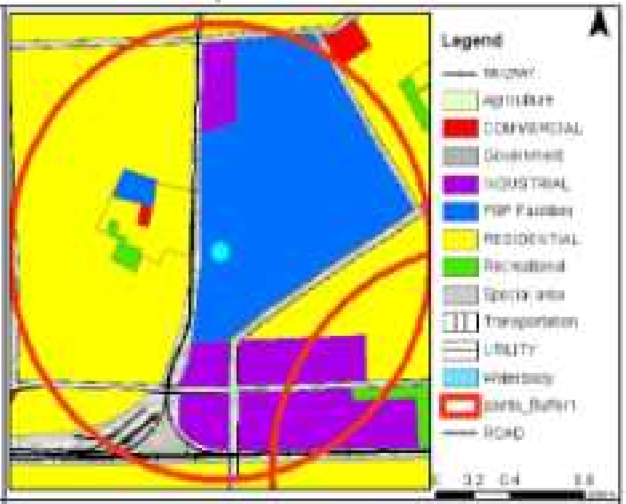
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.074	2.35	COMMERCIAL	0.11	3.5			January	204.69	0	135.064	0.873729
Dense midrise	0.000	0.00	INDUSTRIAL	0.7737	24.6			Februaray	209.79	0	162.791	0.929286
Open midrise	0.000	0.00	TRANSPORTATION	0.355	11.3			March	107.61	0	211.134	1.117419
Open highrise	0.000	0.00	RECREATIONAL	0.2717	8.7			April	129.17	0	160.931	1.160667
Open lowrise	0.012	0.37	RESIDENTIAL	1.0265	32.7			May	126.76	0	155.299	1.145645
Compact Lowrise	0.452	14.39	PSP FACILITIES	0	0.0			June	112.3	0	162.534	1.236667
Compact Midrise	0.994	31.66	GOVERNMENT	0	0.0			July	67.36	0	209.254	1.115645
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-240		August	46.86	0	193.113	0.998
Large lowrise	0.057	1.80	SPECIAL AREA	0.209	6.7			September	58.15	0	120.12	0.9295
Sparsely built	0.000	0.00	WATERBODY		0.0			October	105.34	0	77.2908	0.567250
Green belt	1.000	31.05	GREEN BELT	0.4	12.7			November	148.77	0	83.0508	0.645667
Open area	0.200	6.37						December	179.94	0	57.135	0.616935
Waterbody	0.000	0.00										
Road	0.34	10.83										
Heavy Industry												

Table 86: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

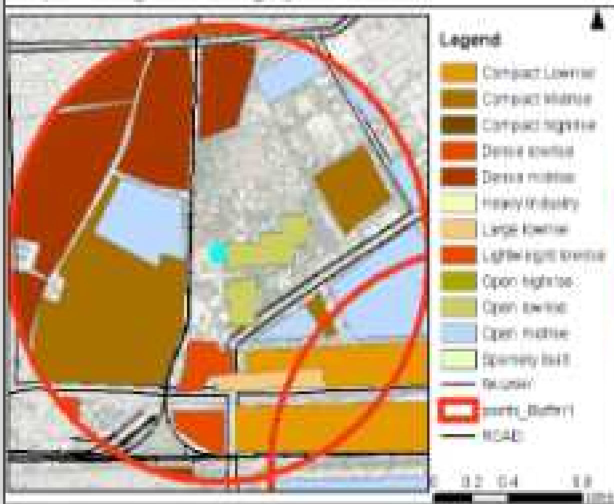
6.7.3.3 IHBAS, Dilshad Garden, Delhi - CPCB

The zone comprises of about 50% residential land-use and 30% public and semi public land-uses with built form varying from compact to dense. It comprises of land open land (without vegetation) which could be responsible for increase in pollutant concentration even during high wind speeds. The emission rate would be high as there is PSP land-use which attracts traffic throughout the day and negligible green spaces in the vicinity which acts as sinks for pollutants .

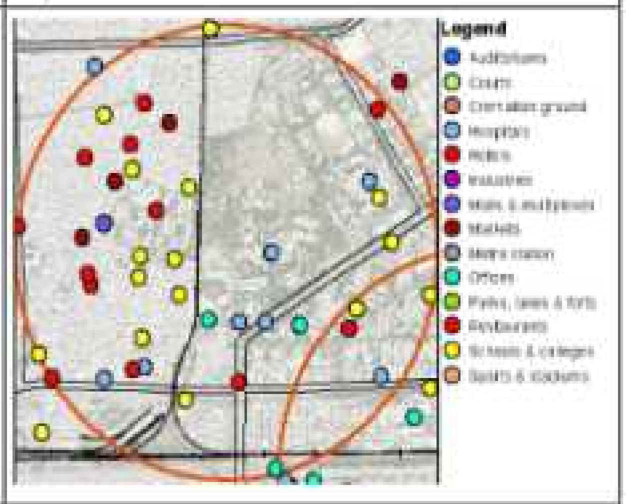
Map 43: Google earth imagery of IHBAS station



Map 44: Land-use around IHBAS station



Map 45: Built-form around IHBAS station



Map 46: Major activities around IHBAS station

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%			MONTHS	PM2.5	PM10		
Dense lowrise	0.094	1.66	COMMERCIAL	0.0053	0.2			January	208.58		176.798	1.1437037
Dense midrise	0.591	18.82	INDUSTRIAL	0.4249	13.5			Febrauray	128.12		274.378	1.56625
Open midrise	0.379	12.08	TRANSPORTATION	0.3	9.6			March	92.62		332.86	1.7667742
Open highrise	0.000	1.00	RECREATIONAL	0.1134	3.6			April	111.27		157.257	1.1341667
Open lowrise	0.080	1.64	RESIDENTIAL	1.4398	45.9			May	113.52		164.098	1.2104839
Compact Lowrise	0.220	7.00	PSP FACILITIES	0.858	27.3			June	95.83		229.146	1.7433
Compact Midrise	0.493	15.70	GOVERNMENT	0	0.0			July	72.83		267.084	1.4000065
Compact Highrise	0.000	1.00	UTILITY	0	0.0	200-220		August	52.11		373.127	1.9193011
Large lowrise	0.041	1.30	SPECIAL AREA		0.0			September	37.40		172.028	1.3331667
Sparsely built	0.000	1.00	WATERBODY		0.0			October	112.78		131.092	0.9959677
Green belt	0.400	12.74	GREEN BELT		0.0			November	163.62		163.285	1.2773333
Open area	0.850	27.07						December	171.28		126.308	1.3624194
Waterbody	0.000	1.00										
Road	0.000	1.00										
Heavy industry		1.00										

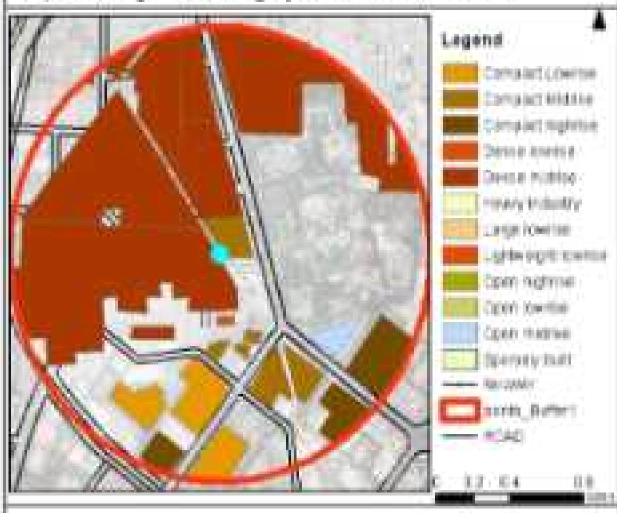
Table 87: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.4 NSIT Dwarka, Delhi - CPCB

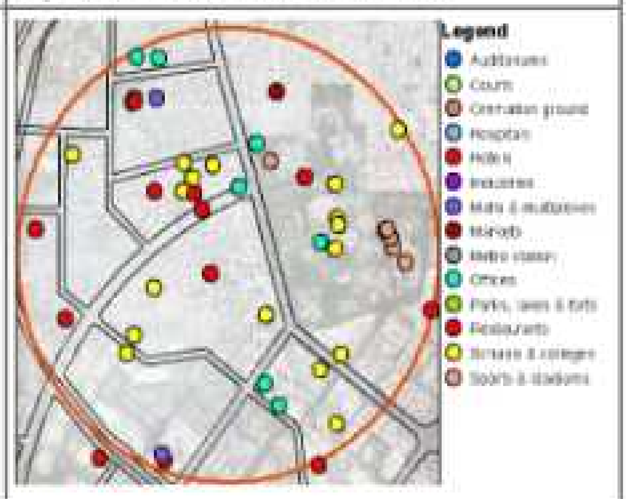
Residential shares about 65 % of land-use with dense mid rise built up, which influences local wind speed and causes lower dispersion rates of pollutants. Also, the hospitals and college in the zone attracts lot of traffic, increasing the emission rates further.

Map 47: Google earth imagery of NSIT Dwarka station

Map 48: Land-use around NSIT Dwarka station



Map 49: Built-form around NSIT Dwarka station



Map 50: Major activities around NSIT Dwarka station

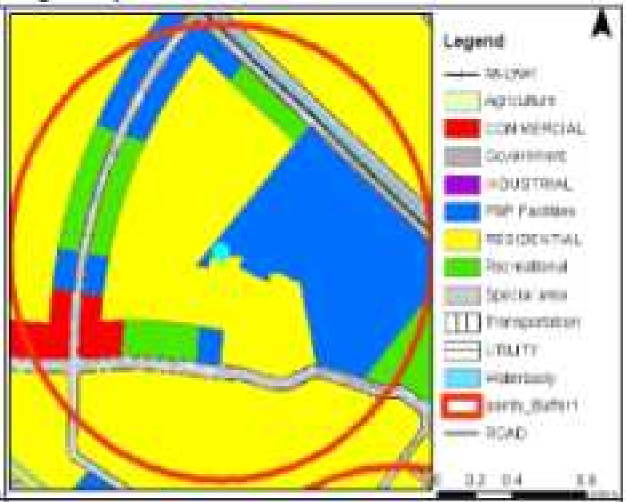
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%			MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0.1633	5.2			January	104.63		132.144	1.0541935
Dense midrise	1.229	39.15	INDUSTRIAL	0	0.0			Febrauray	134.74		175.492	1.0017857
Open midrise	0.021	0.67	TRANSPORTATION	0.28	8.9			March	92.03		214.195	1.1377419
Open highrise	0.000	0.00	RECREATIONAL	0.1166	3.7			April	112.39		182.053	1.313
Open lowrise	0.121	3.87	RESIDENTIAL	1.9259	61.3			May	112.00		177.95	1.2127419
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.6497	20.7			June	34.54		195.58	1.4881034
Compact Midrise	0.093	2.98	GOVERNMENT	0	0.0			July	67.35		219.514	1.1759677
Compact Highrise	0.125	3.97	UTILITY	0.0067	0.2			August	47.50		211.414	1.0529000
Large lowrise	0.000	0.00	SPECIAL AREA		0.0	200-220		September	53.13		139.853	1.076
Sparsely built	0.000	0.00	WATERBODY		0.0			October	114.72		100.641	0.7646774
Green belt	0.350	11.15	GREEN BELT		0.0			November	182.04		96.8145	0.7575333
Open area	0.910	28.98						December	187.52		68.1855	0.7354839
Waterbody	0.000	0.00										
Road	0.280	8.92										
Heavy Industry		0.00										

Table 88: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

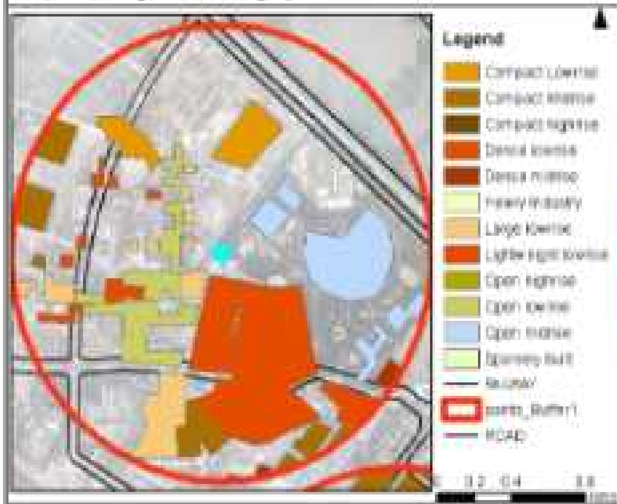
6.7.3.5 DTU, Delhi - CPCB

Due to the agricultural areas nearby, the concentrations of $PM_{2.5}$ & 10 were significantly high. They causes high biogenic emissions such as VOCs which when mixes with NO2, forms smog. High concentration was observed even in May with high wind speeds, possible reason for this could be because of the open areas (non-vegetative), blowing away the loose soil.

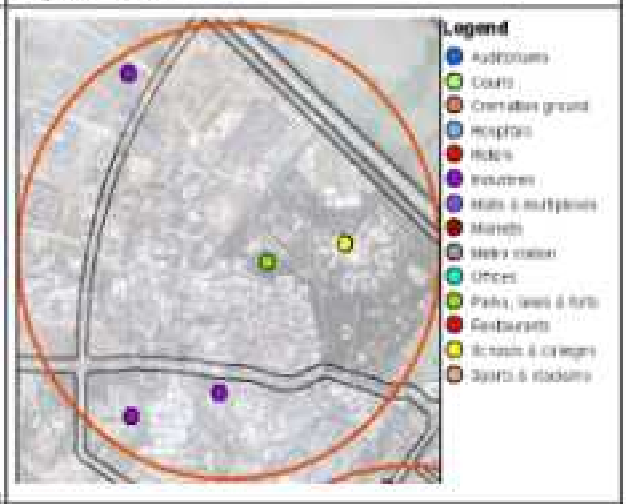
Map 51: Google earth imagery



Map 52: Land-use



Map 53: Built-form



Map 54: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%			MONTHS	PM2.5	PM10		
Dense lowrise	0.404	12.87	COMMERCIAL	0	0.0			January	212.35	341.667	77.64	0.5035464
Dense midrise	0.015	0.45	INDUSTRIAL	0	0.0			Febrauray	119.02	204.49	34.1677	0.537951
Open midrise	0.176	5.61	TRANSPORTATION	0.23	7.3			March	92.82	194.771	113.319	0.5996774
Open highrise	0.000	0.00	RECREATIONAL	0.3449	11.0			April	88.60	261.245	138.189	0.9389474
Open lowrise	0.134	4.26	RESIDENTIAL	1.6967	54.0			May	105.34	291.837	292.448	2.1578565
Compact Lowrise	0.084	2.67	PSP FACILITIES	0.7726	24.6			June	64.58	228.938	108.604	0.8263333
Compact Midrise	0.121	3.86	GOVERNMENT	0	0.0			July	55.13	147.415	131.362	0.7037255
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	44.46	92.7569	134.519	0.6972981
Large lowrise	0.110	3.50	SPECIAL AREA		0.0			September	49.95	108.42	88.5663	0.6853333
Sparsely built	0.000	0.00	WATERBODY	0.1	3.2			October	136.13	277.654	80.9632	0.6151613
Green belt	0.600	19.11	GREEN BELT		0.0			November	228.30	320.297	81.2398	0.6355
Open area	1.260	40.13						December	229.03	317.367	53.3522	0.5754839
Waterbody	0.000	0.00										
Road	0.230	7.32										
Heavy Industry		0.00										

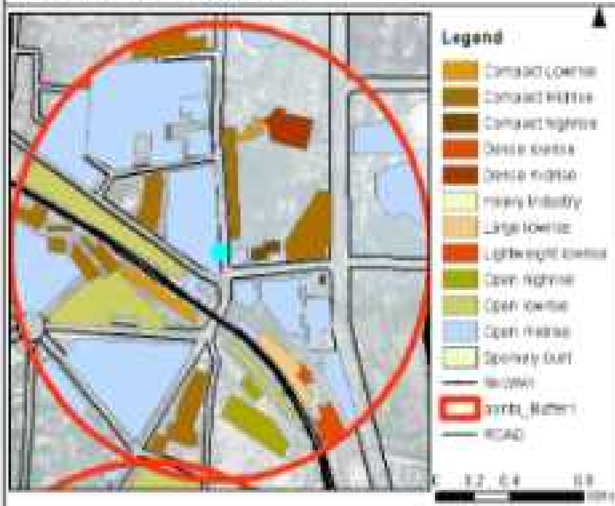
Table 59: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.6 ITO, Delhi - CPCB

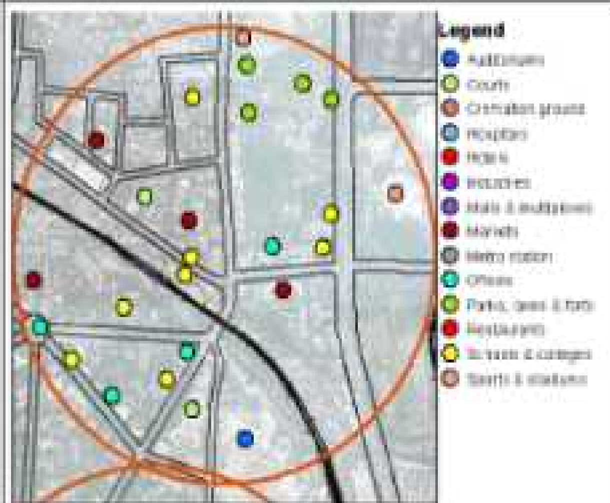
There is 40% public and semi-public land-use in the zone, which attracts a lot of traffic in the area. Also, the share of area under roads is about 10%, with arterial roads and junctions, creating major emissions from vehicular sector in this zone.

Map 55: Google earth imagery

Map 56: Land-use



Map 57: Built-form



Map 58: Major activities

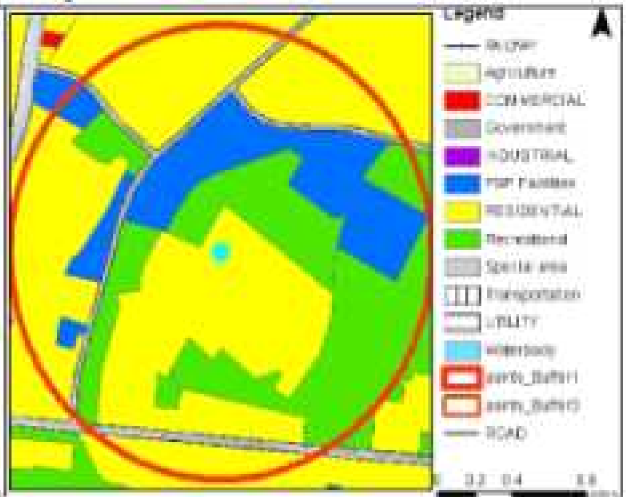
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%			MONTHS	PM2.5	PM10		
Dense lowrise	0.023	0.73	COMMERCIAL	0.0499	1.6			January	202.64	265.314		
Dense midrise	0.029	0.92	INDUSTRIAL	0	0.0			Febrauray	127.67	178.806		
Open midrise	0.880	28.02	TRANSPORTATION	0.3	9.6			March	87.16	144.552		
Open highrise	0.041	1.32	RECREATIONAL	0.5974	19.0			April	89.93	180.909		
Open lowrise	0.167	5.33	RESIDENTIAL	0.5974	19.0			May	85.50	204.823		
Compact Lowrise	0.026	0.84	PSP FACILITIES	1.0899	34.7			June	65.48	167.984		
Compact Midrise	0.204	6.49	GOVERNMENT	0.3469	11.0			July	46.80	113.084		
Compact Highrise	0.009	0.30	UTILITY	0.158	5.0	200-220		August	38.34	66.2582		
Large lowrise	0.025	0.78	SPECIAL AREA		0.0			September	43.06	70.7019		
Sparsely built	0.000	0.00	WATERBODY		0.0			October	122.47	171.89		
Green belt	1.340	42.68	GREEN BELT		0.0			November	204.06	253.767		
Open area	0.100	3.18						December	195.66	248.423		
Waterbody	0.000	0.00										
Road	0.300	9.55										
Heavy Industry		0.00										

Table 90: Percentage distribution of Built-form (LCZ) & land-use: pollution concentration, wind speed and ventilation coefficient

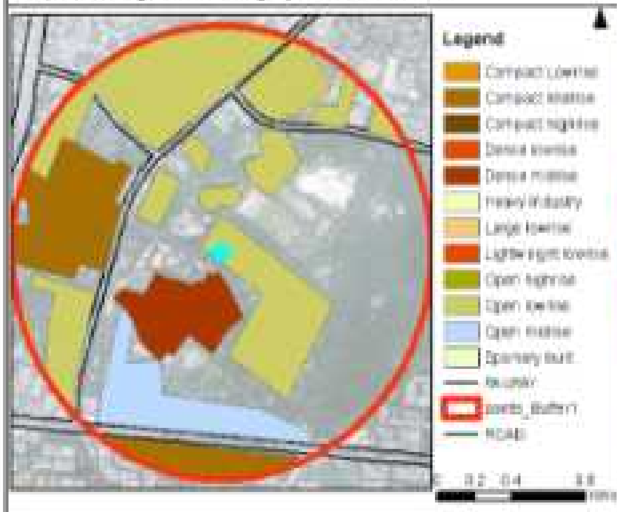
6.7.3.7 Sirifort, Delhi - CPCB

The average monthly pollution concentration of PM_{10} were in poor and severe category throughout the year (for about 9 months), whereas PM2.5 concentrations were poor only in winters. The built up structure is dense to compact mid-rise and major land-uses are PSP, residential and recreational. As PSP influences the vehicular traffic rate, so the major emissions would be from this sector.

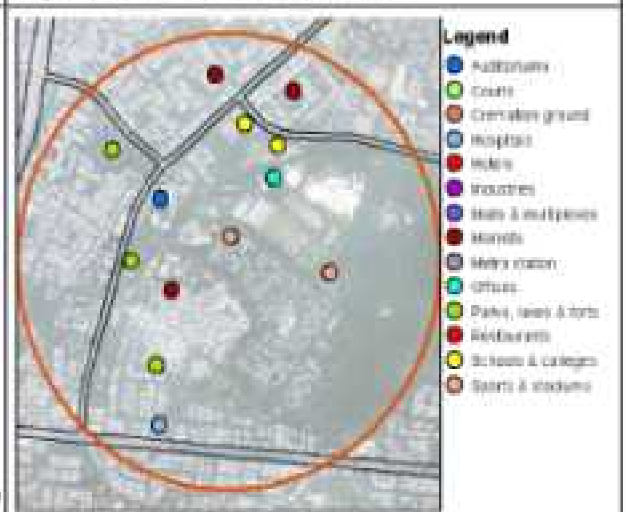
Map 59: Google earth imagery of Sirifort station



Map 60: Land-use around Sirifort station



Map 61: Built-form around Sirifort station



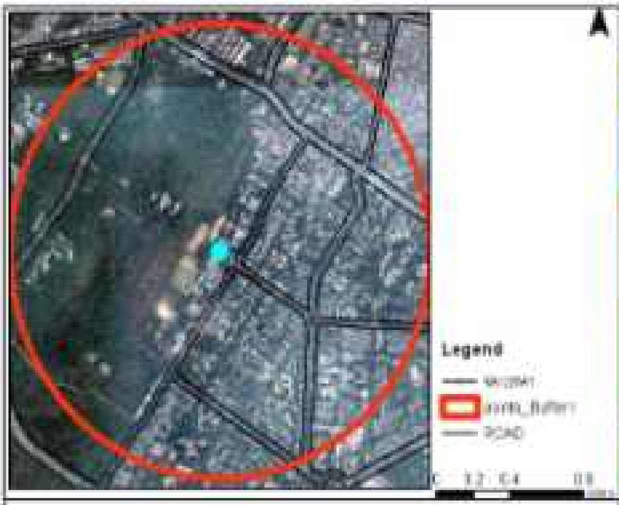
Map 62: Major activities around Sirifort station

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0	0.0			January	198.09	366.666	65.1114	0.4212068
Dense midrise	0.145	4.63	INDUSTRIAL	0	0.0			Febraurary	146.77	319.884	48.0941	0.2742
Open midrise	0.189	6.02	TRANSPORTATION	0.18	5.7			March	30.44	263.627	64.8275	0.3430645
Open highrise	0.000	0.00	RECREATIONAL	0.865	27.5			April	83.21	321.19	61.3133	0.4465306
Open lowrise	0.885	28.18	RESIDENTIAL	1.6259	51.8			May	76.59	294.272	64.2255	0.4737931
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.4991	15.9			June	55.69	240.329	83.2384	0.6333333
Compact Midrise	0.326	10.37	GOVERNMENT	0	0.0			July	41.36	190.567	85.5608	0.4583607
Compact Highrise	0.000	0.00	UTILITY	0	0.0	220-240		August	34.13	176.921	67.94	0.3511111
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	46.10	242.299	49.9909	0.3868333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	192.68	357.287	31.3112	0.2379032
Green belt	1.420	45.22	GREEN BELT		0.0			November	206.28	344.313	39.6292	0.31
Open area		0.00						December	213.52	319.771	26.9153	0.2903226
Waterbody		0.00										
Road	0.180	5.73										
Heavy Industry		0.00										

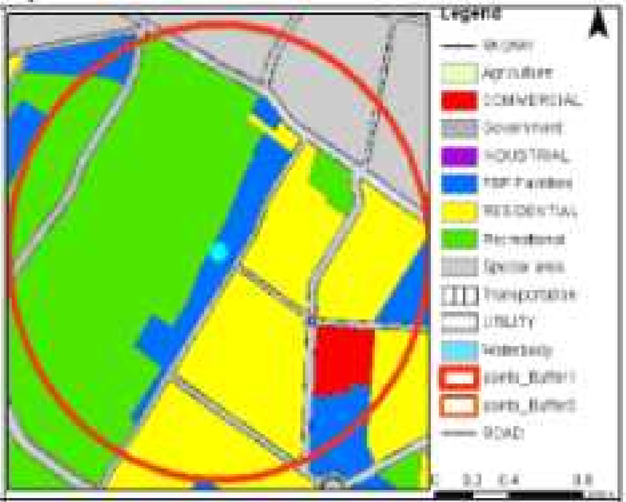
Table 91: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.8 Mandir Marg, Delhi - DPCC

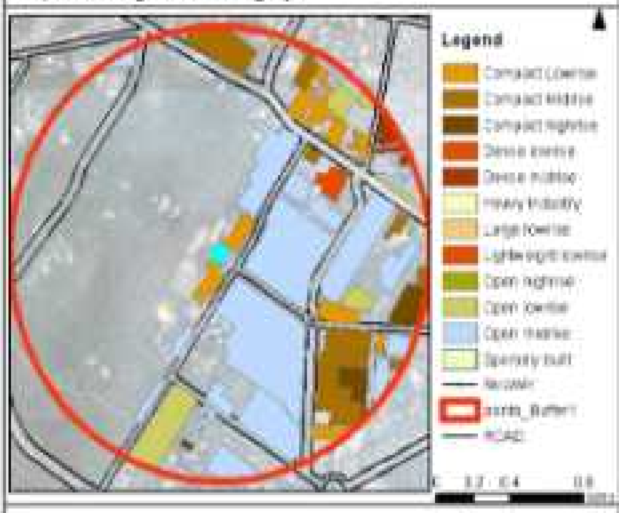
The average monthly concentrations of PM_{10} were in poor category for about 2 months only, whereas PM2,5 concentrations were poor through-out winters. The built up structures are open mid-rise and major land-uses are PSP, residential and recreational. The schools, hospitals and markets in the zone influences the vehicular traffic rate, so the major emissions would be from vehicular sector.



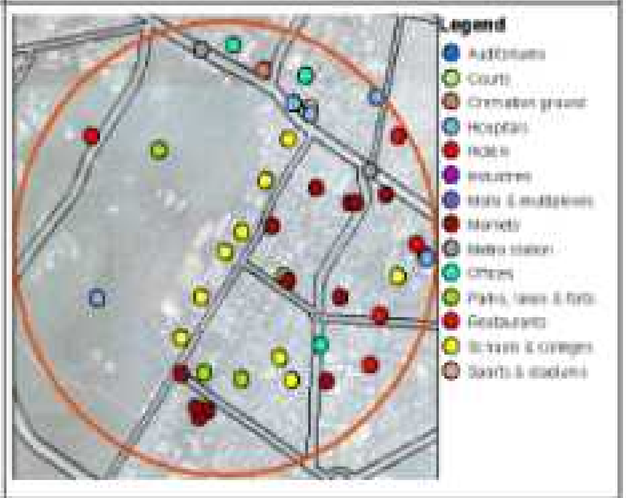
Map 63: Google earth imagery



Map 64: Land-use



Map 65: Built-form



Map 66: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.015	0.48	COMMERCIAL	0.0788	2.5			January	187.80	298.241	153.162	0.9908085
Dense midrise	0.017	0.53	INDUSTRIAL	0	0.0			Febraurary	245.71	299.092	227.014	1.29875
Open midrise	0.583	16.74	TRANSPORTATION	0.306	9.7			March	81.69	169.61	293.358	1.4256052
Open highrise	0.000	0.00	RECREATIONAL	1.2859	41.0			April	72.27	290.084	300.332	1.4448888
Open lowrise	0.094	2.98	RESIDENTIAL	0.8936	28.5			May	85.77	249.292	202.241	1.4919855
Compact Lowrise	0.101	3.22	PSP FACILITIES	0.2936	9.3			June	72.47	201.917	236.776	1.8015517
Compact Midrise	0.150	4.77	GOVERNMENT	0	0.0	220-240		July	48.85	153.136	251.278	1.346125
Compact Highrise	0.045	1.44	UTILITY	0	0.0			August	33.48	92.9163	227.893	1.1773413
Large lowrise	0.000	0.00	SPECIAL AREA	0.2809	8.9			September	39.57	109.452	153.117	1.1848888
Sparsely built	0.000	0.00	WATERBODY		0.0			October	117.99	196.093	106.441	0.7935496
Green belt	1.850	58.92	GREEN BELT		0.0			November	186.80	270.343	110.727	0.8661667
Open area	0.000	0.00						December	192.87	262.989	78.0365	0.8417742
Waterbody	0.000	0.00										
Road	0.305	9.71										
Heavy Industry		0.00										

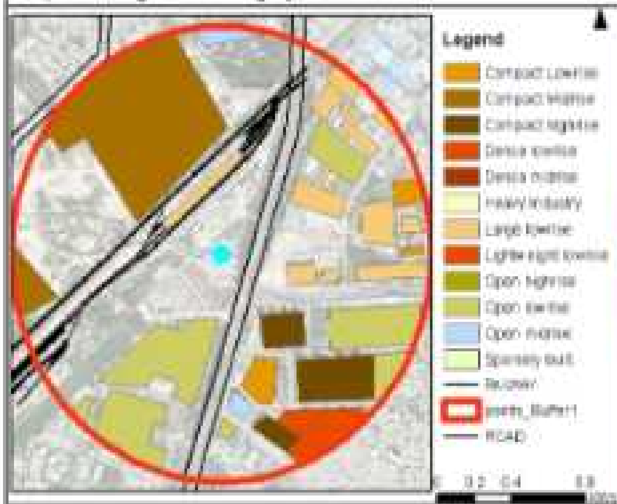
Table 92: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.9 Anand Vihar, Delhi - DPCC

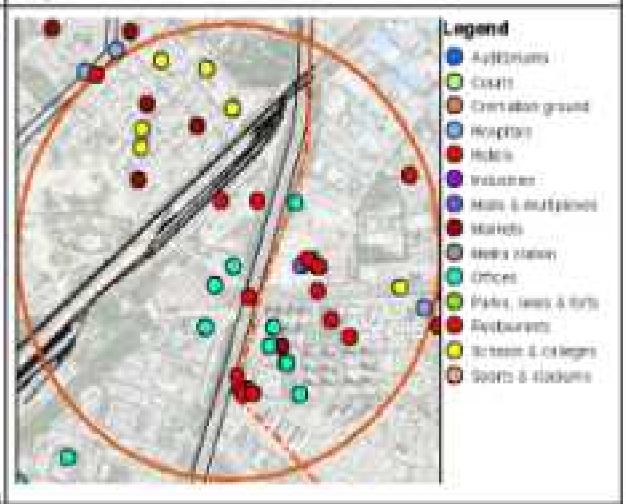
The concentrations were extremely high throughout the year (about 9 months), as 60% of the total share of land-use lies in transportation and industrial sector, which causes high movement of vehicular traffic in this zone. Even there is a shift to cleaner fuels in industries, the activities of loading & unloading influences the emissions rate. Also, there are numerous restaurants & hotels, which uses coal as fuel for barbecues.

Map 67: Google earth imagery

Map 68: Land-use



Map 69: Built-form



Map 70: Major activities

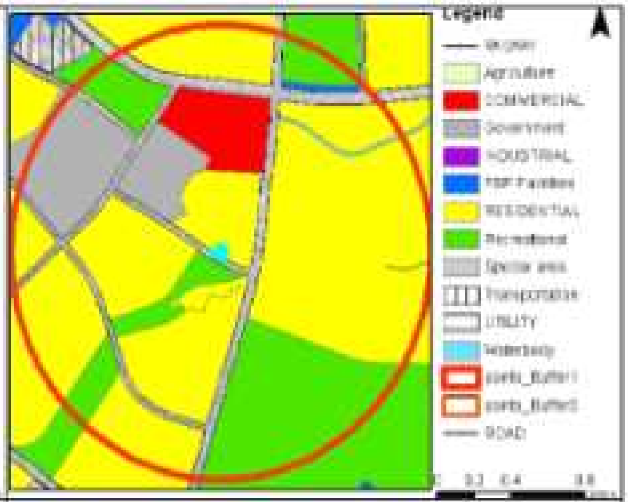
LCZ			LANDUSE			ALTITUDE	POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)	MONTHS	PM2.5	PM10		
Dense lowrise	0.063	2.01	COMMERCIAL	0	0.0		January	235.81	372.837	114.342	0.7336774
Dense midrise	0.000	0.00	INDUSTRIAL	0.9505	30.3		Febraury	140.31	274.437	205.96	1.1757143
Open midrise	0.028	0.89	TRANSPORTATION	0.7884	25.1		March	101.90	258.866	213.399	1.1292982
Open highrise	0.000	0.00	RECREATIONAL	0.0485	1.6		April	97.79	297.502	208.618	1.4901667
Open lowrise	0.341	10.87	RESIDENTIAL	1.3246	42.2		May	110.90	287.206	194.37	1.433871
Compact Lowrise	0.044	1.41	PSP FACILITIES	0	0.0		June	73.48	263.501	237.264	1.8052632
Compact Midrise	0.415	13.22	GOVERNMENT	0	0.0		July	54.92	183.865	216.363	1.1590323
Compact Highrise	0.118	3.75	UTILITY	0	0.0		August	42.10	121.89	183.787	0.9498039
Large lowrise	0.175	5.56	SPECIAL AREA		0.0	200-220	September	43.97	118.41	120.162	0.9298214
Sparsely built	0.000	0.00	WATERBODY		0.0		October	154.71	324.06	73.6396	0.5595161
Green belt	0.200	6.37	GREEN BELT		0.0		November	243.66	391.116	77.6604	0.6075
Open area	1.480	47.13					December	244.76	378.814	54.1356	0.5839344
Waterbody	0.000	0.00									
Road	0.300	9.56									
Heavy Industry		0.00									

Table 93: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

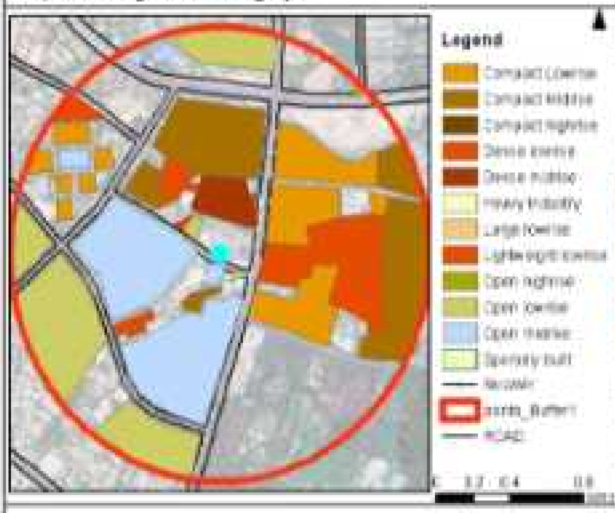
6.7.3.10 R K Puram, Delhi - DPCC

The residential sector occupies a major share in the land use distribution in the influence zone, so emission loads could be from use of LPG. Also, there is commercial land-use, which includes restaurants, markets, mall and multiplexes, attracting vehicular traffic on weekends and in the evenings and the use of coal in restaurants as fuel for barbecues also increases the emission loads.

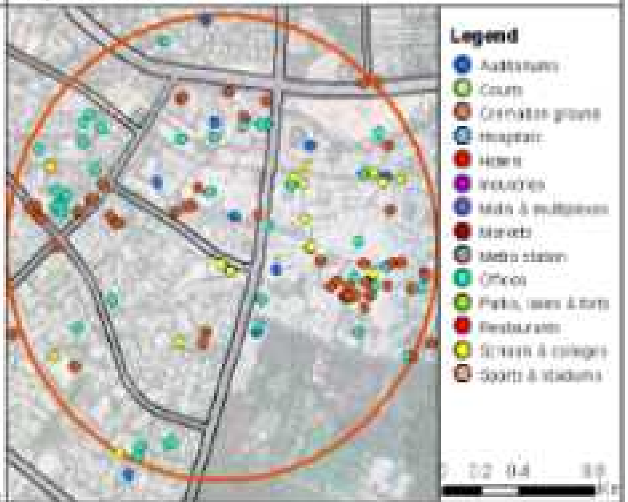
Map 71: Google earth imagery



Map 72: Land-use



Map 73: Built-form



Map 74: Major activities

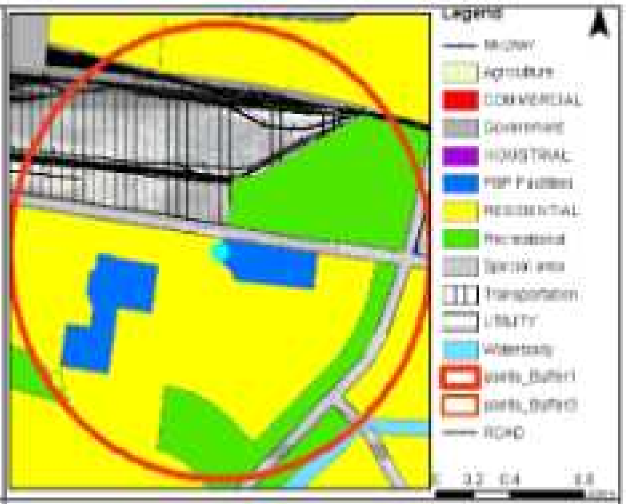
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.229	7.31	COMMERCIAL	0.1411	4.5			January	219.68	363.512	134.213	0.8682258
Dense midrise	0.053	1.70	INDUSTRIAL	0	0.0			Febraursy	171.66	267.559	164.856	0.9410714
Open midrise	0.389	12.39	TRANSPORTATION	0.29	9.2			March	105.92	197.857	165.063	0.8736066
Open highrise	0.000	0.00	RECREATIONAL	0.6178	19.7			April	60.29	242.906	146.997	1.0601724
Open lowrise	0.379	12.05	RESIDENTIAL	1.7889	57.0			May	60.82	231.712	143.799	1.0608065
Compact Lowrise	0.301	9.58	PSP FACILITIES	0.0104	0.3			June	61.45	202.076	207.767	1.5808333
Compact Midrise	0.365	11.61	GOVERNMENT	0.298	9.5			July	49.84	145.306	200.426	1.0737097
Compact Highrise	0.000	0.00	UTILITY	0	0.0	220-240		August	35.22	77.1692	198.811	1.0067742
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	39.75	95.4227	131.794	1.0198333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	95.62	236.851	76.1238	0.5783871
Green belt	0.320	10.19	GREEN BELT		0.0			November	176.66	295.979	82.6888	0.6468333
Open area	0.800	25.48						December	170.80	307.885	57.1801	0.6167742
Waterbody	0.020	0.64										
Road	0.290	9.24										
Heavy Industry		0.00										

Table 94: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

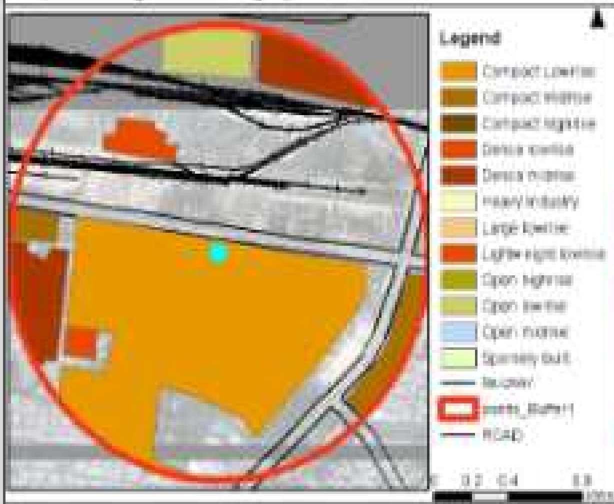
6.7.3.11 Punjabi Bagh, Delhi - DPCC

The influence zone of Punjabi bagh has about 4 metro stations and a railway station, due to which there is an accumulation of vehicular traffic of all kinds (especially 3 wheelers and local buses) in these points, which also causes congestion on the roads for the ongoing traffic, increasing the emission loads in the area.

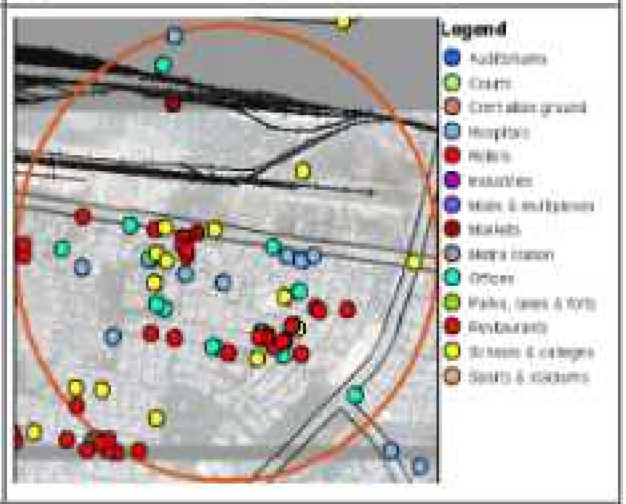
Map 75: Google earth imagery



Map 76: Land-use



Map 77: Built-form



Map 78: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.063	2.01	COMMERCIAL	0	0.0			January	217.19	322.402	116.212	0.7517742
Dense midrise	0.209	6.66	INDUSTRIAL	0	0.0			Februaray	161.36	256.669	156.879	0.8865357
Open midrise	0.000	0.00	TRANSPORTATION	0.9369	29.8			March	86.28	179.4	165.437	0.8754839
Open highrise	0.000	0.00	RECREATIONAL	0.6202	19.8			April	77.51	228.746	118.596	0.8559999
Open lowrise	0.097	3.09	RESIDENTIAL	1.3880	44.2			May	79.77	228.722	110.429	0.8145902
Compact Lowrise	0.995	31.70	PSP FACILITIES	0.1939	6.2			June	53.46	190.989	156.089	1.1876271
Compact Midrise	0.103	3.29	GOVERNMENT	0	0.0			July	40.41	137.402	167.007	0.8966774
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	36.29	78.1262	164.069	0.8479032
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	40.57	88.4549	94.6832	0.7926667
Sparsely built	0.000	0.00	WATERBODY		0.0			October	128.79	267.806	62.1386	0.4721311
Green belt	0.980	31.21	GREEN BELT		0.0			November	211.01	306.698	65.5373	0.5126667
Open area	0.350	11.15						December	200.62	291.549	46.9373	0.5062903
Waterbody	0.000	0.00										
Road	0.350	11.15										
Heavy industry		0.00										

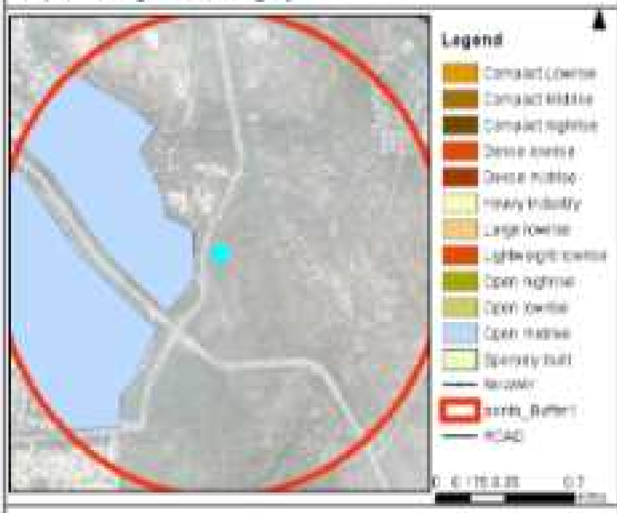
Table 95: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.12 Aya Nagar, Delhi - IMD

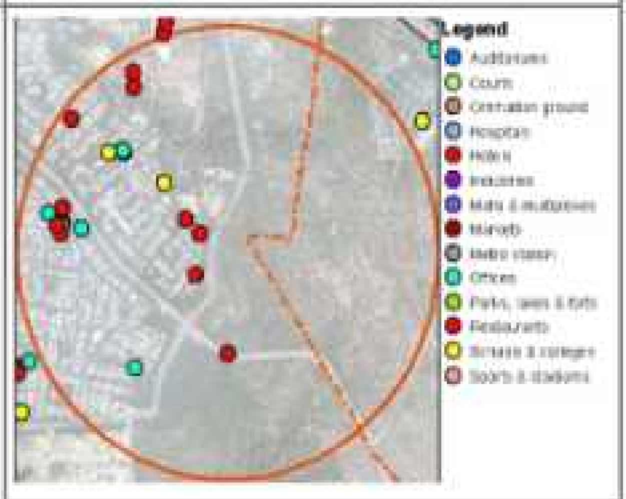
The concentration of pollutants is considerably low with respect to other stations in Delhi, as it is located at a higher elevation (260m) and also high wind speeds increases the rate of dispersion. The emission loads in the region could be due to the influence of regional activities.

Map 79: Google earth imagery

Map 80: Land-use



Map 81: Built-form



Map 82: Major activities

SNO.	STATION NAME	LCZ Types	LCZ Area (sq.km)	LCZ %	LANDUSE Types	LANDUSE Area (sq.km)	LANDUSE %	ALTITUDE	MONTHS	PM2.5	PM10	VC	WS (m/s)
12	Aya Nagar, Delhi - IMD	Dense lowrise	0.000	0.00	COMMERCIAL	0	0.0	240-280	January	130.08	292.1	109.9	0.7111
		Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0		February	78.04	151		
		Open midrise	0.702	25.24	TRANSPORTATION	0.24	7.6		March	59.75	133.1		
		Open highrise	0.000	0.00	RECREATIONAL	0	0.0		April	51.99	155.6		
		Open lowrise	0.000	0.00	RESIDENTIAL	1.2	38.2		May	59.90	188.6	170	1.2343
		Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0		June	51.33	177.9	297	2.26
		Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0		July	44.02	56.25		
		Compact Highrise	0.000	0.00	UTILITY	0	0.0		August	31.06	62.37		
		Large lowrise	0.000	0.00	SPECIAL AREA		0.0		September	24.75	92.83	5.169	0.04
		Sparsely built	0.000	0.00	WATERBODY	0	0		October	111.65	192.3	11.45	0.087
		Green belt	2.060	25.28	GREEN BELT	1.7	54.1		November	172.50	261.5	13.64	0.1067
		Open area	0.060	1.59					December	161.69	289.9	39.25	0.3598
		Waterbody	0.000	0.00									
		Road	0.240	7.64									
		Heavy Industry		0.00									

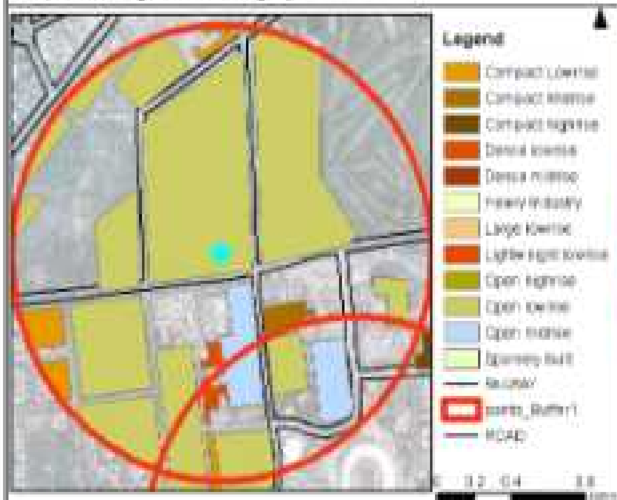
Table 96: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.13 Lodhi Road, Delhi - IMD

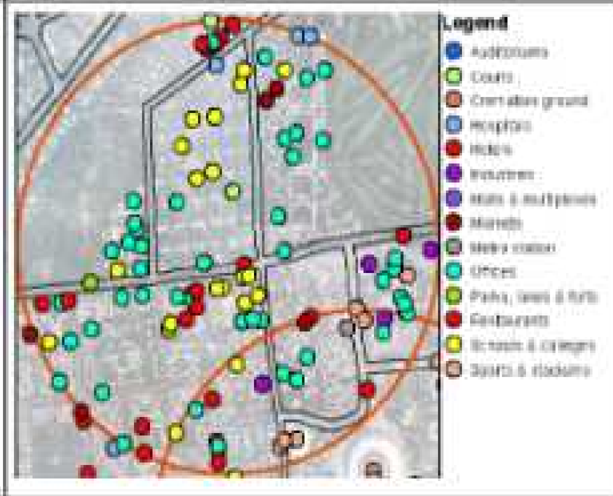
Average monthly concentrations of PM_{10} did not cross the moderate category of pollution standards throughout the year. The built up structure is open, and major land-uses are PSP, residential and recreational. As PSP (offices,etc) influences the vehicular traffic rate, so the major emissions would be from this sector.

Map 83: Google earth imagery

Map 84: Land-use



Map 85: Built-form



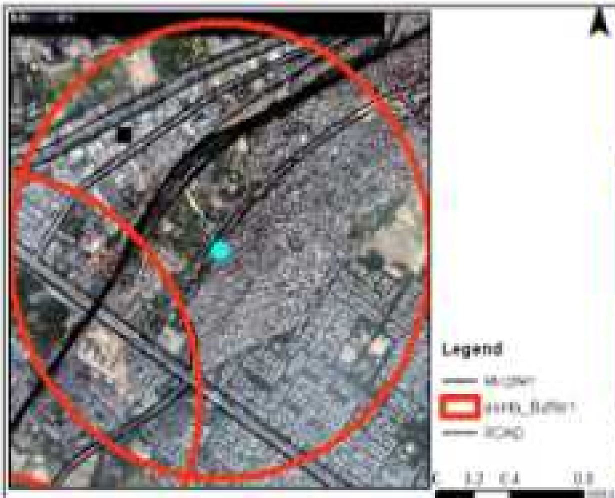
Map 86: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.020	0.63	COMMERCIAL	0.0296	0.9			January	147.01	243.815	68.7994	0.465
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0			Februaray	101.07	184.261		
Open midrise	0.136	4.34	TRANSPORTATION	0.29	9.2			March	61.16	130.307		
Open highrise	0.002	0.06	RECREATIONAL	0.6333	20.2			April	59.78	182.774		
Open lowrise	1.392	44.32	RESIDENTIAL	1.4886	47.4			May	65.05	187.731		
Compact Lowrise	0.067	2.13	PSP FACILITIES	0.5309	16.9			June	58.64	170.541		
Compact Midrise	0.022	0.70	GOVERNMENT	0.1814	5.8			July	43.85	116.96		
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	30.93	60.1017		
Large lowrise	0.000	0.00	SPECIAL AREA		0.0	200-220		September	38.42	70.295	6.89292	0.053333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	112.68	181.573	8.11614	0.061667
Green belt	1.120	35.57	GREEN BELT		0.0			November	174.85	246.812	53.6911	0.42
Open area	0.100	3.18						December	148.71	219.374	41.3479	0.446
Waterbody	0.000	0.00										
Road	0.290	9.24										
Heavy industry		0.00										

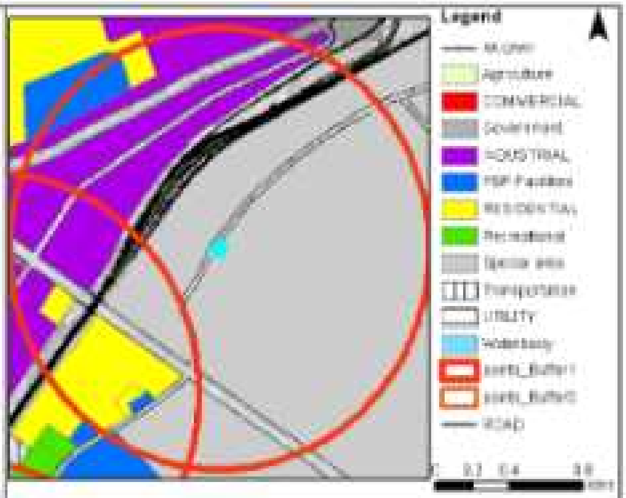
Table 97: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.14 North Campus, DU, Delhi - IMD

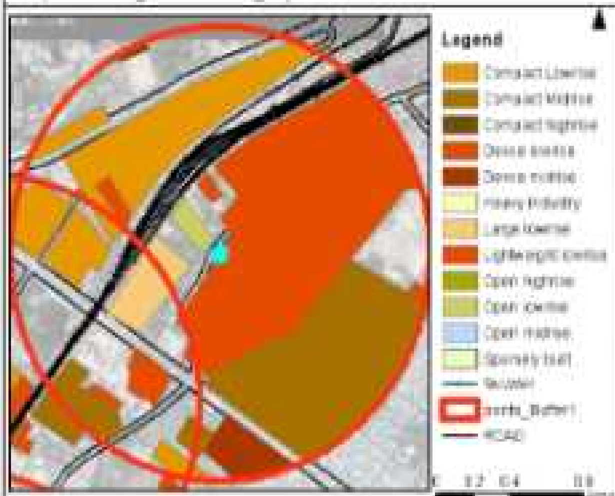
Concentration of $PM_{2.5}$ & 10 was observed to be in poor to severe category for almost 8 months (October to May). The major emission loads would be from industrial and PSP facilities. Even if there is a shift to cleaner fuels, the supporting activities like loading & unloading influences the vehicular traffic rate. Also, schools & colleges attracts traffic movement which further influences the emission loads.



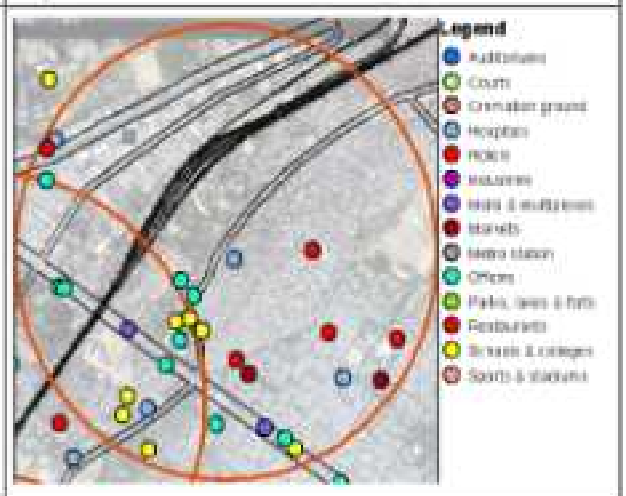
Map 87: Google earth imagery



Map 88: Land-use



Map 89: Built-form



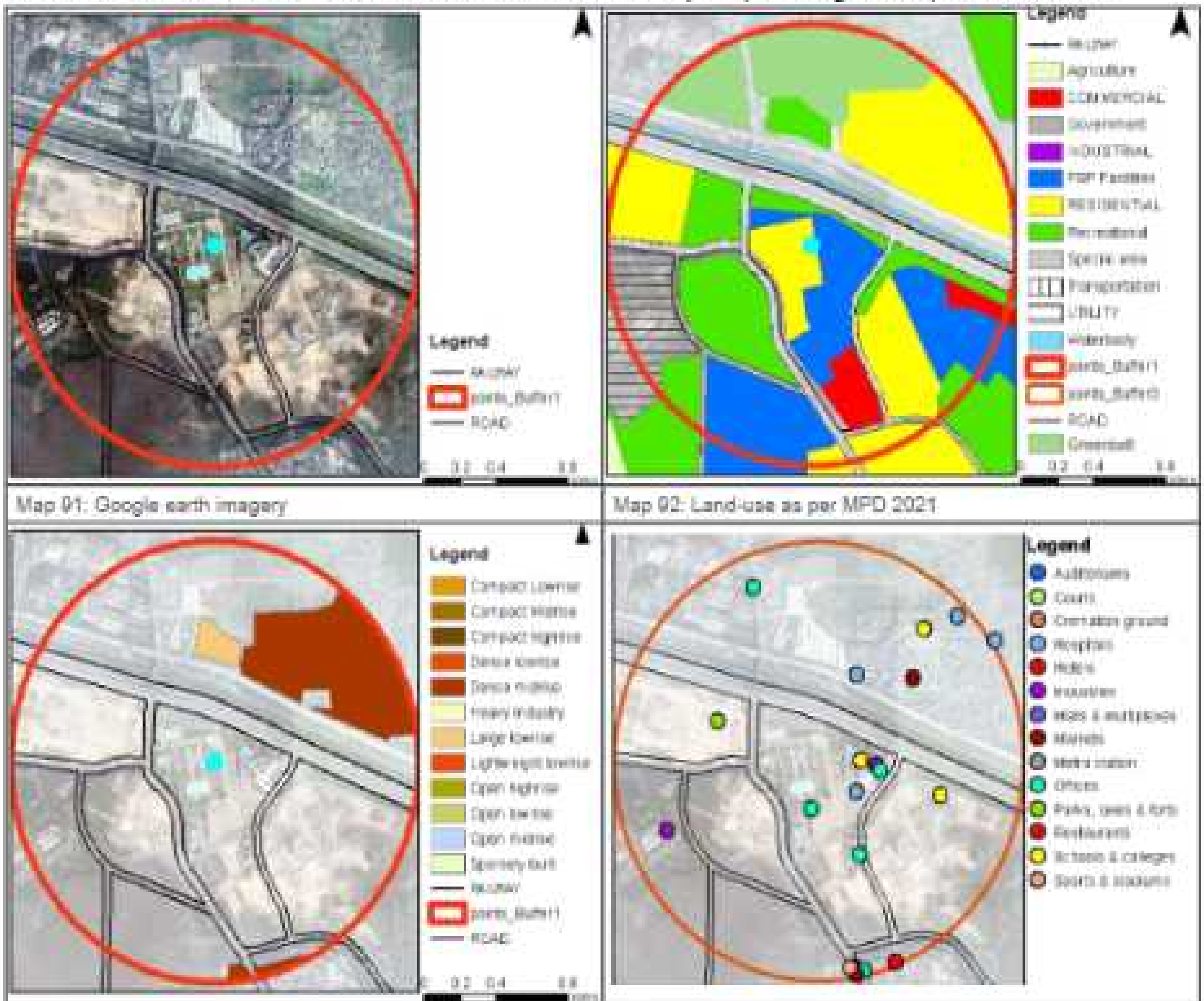
Map 90: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.826	26.31	COMMERCIAL	0	0.0			January	135.04	381.782	128.306	0.83
Dense midrise	0.067	2.13	INDUSTRIAL	0.5987	19.1			Februaury	134.06	317.911		
Open midrise	0.000	0.00	TRANSPORTATION	0.31	9.9			March	102.98	218.845		
Open highrise	0.000	0.00	RECREATIONAL	0.13	4.1			April	100	295.113		
Open lowrise	0.022	0.69	RESIDENTIAL	1.9376	61.7			May	100.19	303.599		
Compact Lowrise	0.442	14.07	PSP FACILITIES	0.153	4.9			June	51.18	229.836		
Compact Midrise	0.539	17.18	GOVERNMENT	0	0.0			July	38.37	136.658		
Compact Highrise	0.006	0.19	UTILITY	0	0.0	220-240		August	32.9	74.3467		
Large lowrise	0.079	2.52	SPECIAL AREA		0.0			September	35.63	81.9429		
Sparsely built	0.000	0.00	WATERBODY		0.0			October	121.81	216.228		
Green belt	0.150	4.78	GREEN BELT		0.0			November	136.19	287.961		
Open area	0.700	22.29						December	176.19	285.526		
Waterbody	0.000	0.00										
Road	0.310	9.87										
Heavy Industry		0.00										

Table 98: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.15 Burari Crossing, Delhi - IMD

Even though, MPD 2021 proposed different land-uses but it has not been achieved yet in the influence zone of burari crossing. The contributions to emission loads would be significant from soil dust in the influence zone as about 50% of the area is open (non-vegetative) with loose soil.



Map 91: Google earth imagery

Map 92: Land-use as per MPD 2021

Map 93: Built-form

Map 94: Major activities

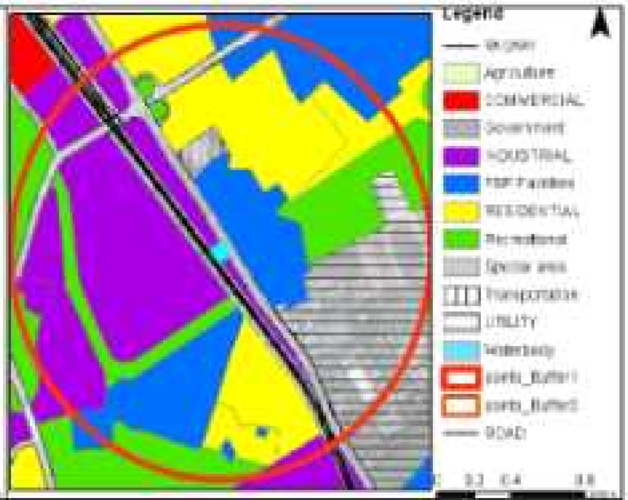
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0.0945	3.0			January	189.72	309.747	32.5819	0.210769
Dense midrise	0.355	11.30	INDUSTRIAL	0	0.0			Febraunay	107.77	189.196		
Open midrise	0.000	0.00	TRANSPORTATION	0.35	11.1			March	79.72	147.908		
Open highrise	0.000	0.00	RECREATIONAL	0.431	13.7			April	89.91	168.716		
Open lowrise	0.000	0.00	RESIDENTIAL	0.4496	14.3			May	92.08	206.691	27.1112	0.2
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.2257	7.2			June	61.53	169.555		
Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0			July	45.58	107.484		
Compact Highrise	0.000	0.00	UTILITY	0.1617	5.1	200-220		August	43.25	67.9084		
Large lowrise	0.031	1.00	SPECIAL AREA		0.0			September		72.9361		
Sparsely built	0.000	0.00	WATERBODY	0.15	4.8			October	130.99	196.332	1.75489	0.013333
Green belt	0.750	23.89	GREEN BELT	1.3	41.4			November	191.83	263.656	3.1559	0.025
Open area	1.500	47.77						December	177.46	256.694	15.6891	0.169231
Waterbody	0.150	4.78										
Road	0.350	11.15										
Heavy industry		0.00										

Table 99: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

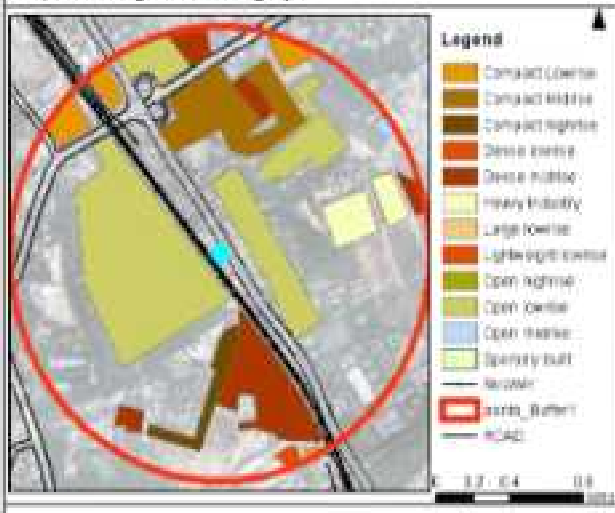
6.7.3.16 CRRI Mathura Road, Delhi - IMD

About 40% area in the influence zone lies in industrial and PSP sector. PSP sector attracts the vehicular traffic movement through its commuters everyday. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading.

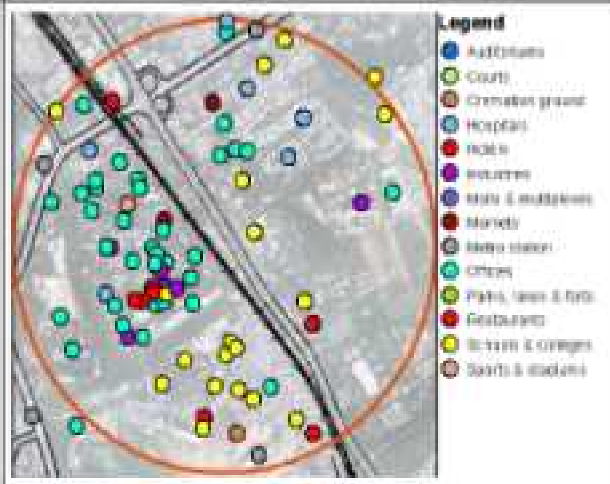
Map 95: Google earth imagery



Map 96: Land-use



Map 97: Built-form



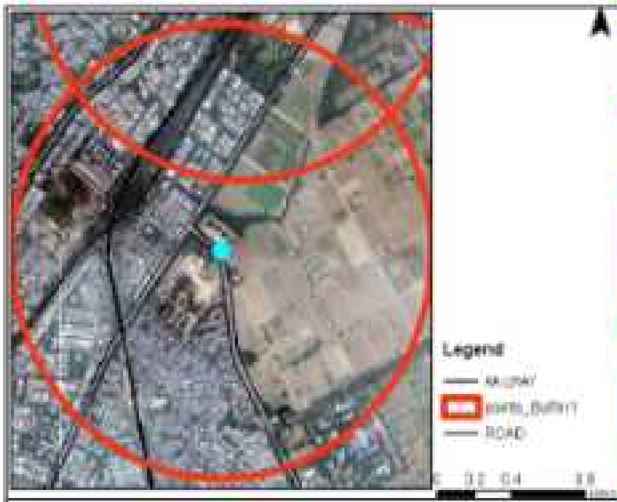
Map 98: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.008	0.25	COMMERCIAL	0	0.0			January	212.34	301.782	61.2767	0.3564
Dense midrise	0.195	6.22	INDUSTRIAL	0.7725	24.6			Febraurary	104.39	170.379		
Open midrise	0.008	0.27	TRANSPORTATION	0.3195	10.2			March	81.8	158.224		
Open highrise	0.000	0.00	RECREATIONAL	0.4324	13.8			April	83.09	224.702		
Open lowrise	0.629	20.02	RESIDENTIAL	0.6379	20.3			May	76.43	285.198	189.948	1.40125
Compact Lowrise	0.064	2.04	PSP FACILITIES	0.527	16.8			June	61.28	224.579	530.973	4.04
Compact Midrise	0.163	5.19	GOVERNMENT	0	0.0			July	49.68	197.811		
Compact Highrise	0.047	1.49	UTILITY	0.4406	14.0	200-220		August	36.35	75.3946		
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	37.38	80.647	8.40002	0.065
Sparsely built	0.000	0.00	WATERBODY		0.0			October	121.75	248.482	23.0923	0.175
Green belt	0.950	30.25	GREEN BELT		0.0			November	197.36	323.908	18.8558	0.1475
Open area	0.700	22.29						December	183.27	306.938	27.0063	0.291304
Waterbody	0.000	0.00										
Road	0.300	9.55										
Heavy Industry		0.00										

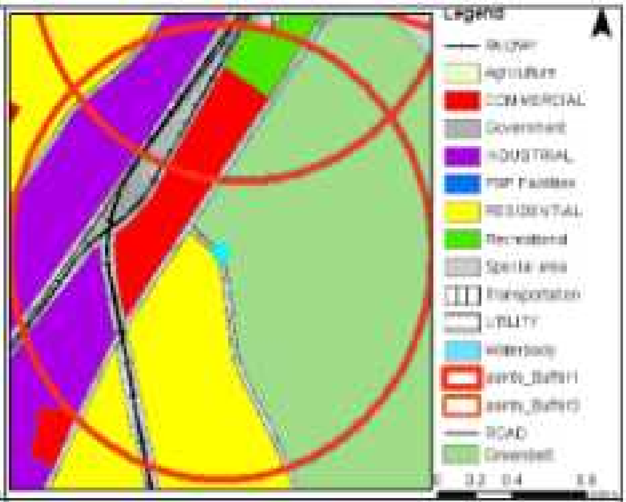
Table 100: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.17 Pusa, Delhi - IMD

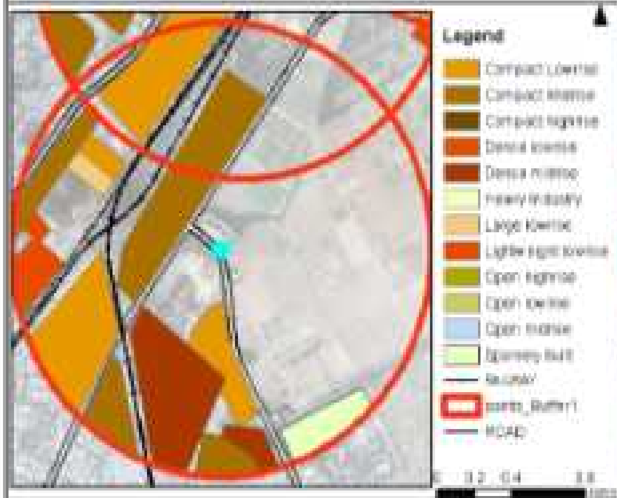
Average monthly concentrations of PM_{10} crossed the moderate category of pollution standards only in November. Although the values for $PM_{2.5}$ still crossed for about 5 months. The emission loads in the zone would be from the generated traffic movements because of the industrial and commercial land-uses.



Map 99: Google earth imagery



Map 100: Land-use



Map 101: Built-form

Map 102: Major activities

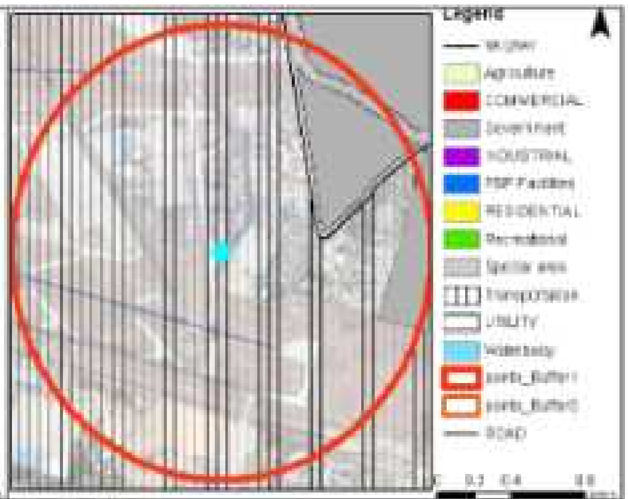
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.050	1.59	COMMERCIAL	0.2435	7.8			January	152.61	232.447	184.203	1.1916129
Dense midrise	0.224	7.13	INDUSTRIAL	0.5751	18.3			Febrauray	106.08	185.436	240.183	1.3710714
Open midrise	0.000	0.00	TRANSPORTATION	0.271	8.6			March	60.93	107.763	246.875	1.9064516
Open highrise	0.000	0.00	RECREATIONAL	0.0653	2.1			April	57.95	134.359	205.162	1.4796667
Open lowrise	0.000	0.00	RESIDENTIAL	0.561	17.9			May	83.22	181.022	206.351	1.5722581
Compact Lowrise	0.388	12.37	PSP FACILITIES	0	0.0			June	50.25	162.567	286.763	1.8166667
Compact Midrise	0.394	12.55	GOVERNMENT	0	0.0			July	40.01	117.315	282.763	1.5148333
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	27.68	54.526	273.709	1.4145161
Large lowrise	0.020	0.62	SPECIAL AREA		0.0	200-240		September	38.24	63.6633	174.893	1.3533333
Sparsely built	0.065	2.06	WATERBODY		0.0			October	107.60	183.767	305.537	2.3974579
Green belt	1.930	61.46	GREEN BELT	1.45	46.2			November	172.21	280.208	310.982	2.4326667
Open area	0.080	2.55						December	139.59	246.427	90.8541	0.98
Waterbody	0.000	0.00										
Road	0.270	8.60										
Heavy industry		0.00										

Table 101: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

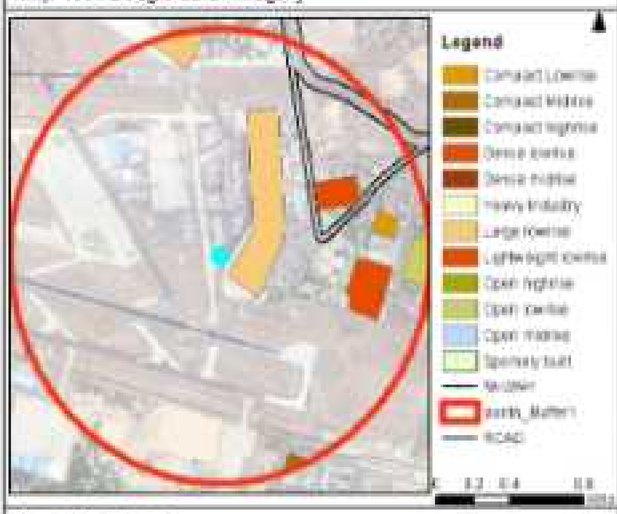
6.7.3.18 IGI Airport (T3), Delhi - IMD

The emission load in the zone would be from the vehicular movement of commuters and the emissions from aircrafts throughout the year.

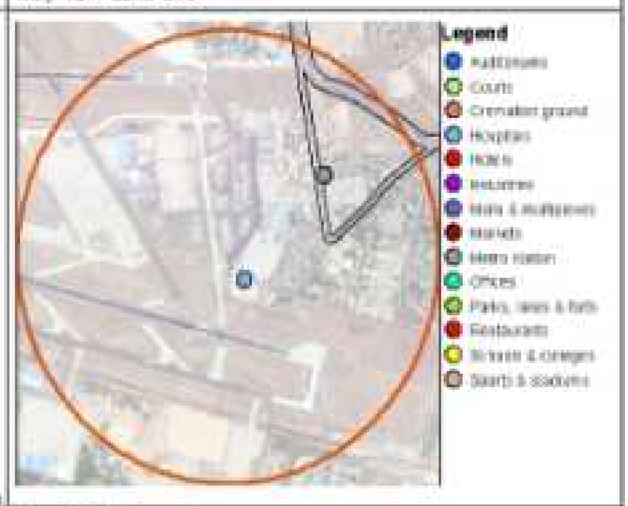
Map 103: Google earth imagery



Map 104: Land-use



Map 105: Built-form



Map 106: Major activities

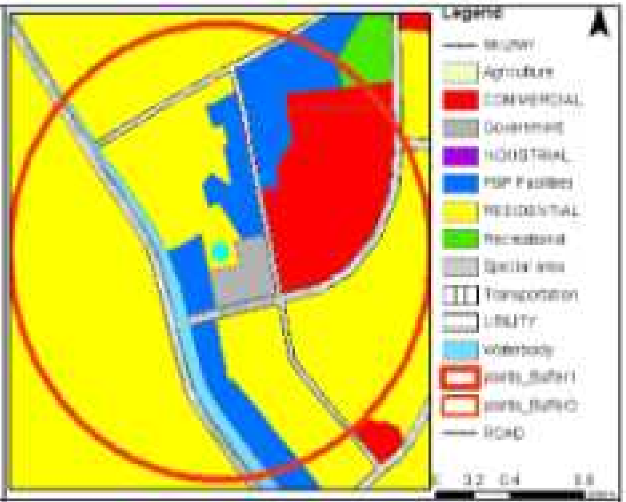
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.065	2.08	COMMERCIAL	0	0.0			January	159.19	279.983	0	
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0			Febrauray	100.1	186.422	0	
Open midrise	0.000	0.00	TRANSPORTATION	2.8709	91.4			March	72.56	174.844	0	
Open highrise	0.000	0.00	RECREATIONAL	0	0.0			April	69.56	225.076	0	
Open lowrise	0.025	0.78	RESIDENTIAL	0	0.0			May	67.52	239.173	0	
Compact Lowrise	0.010	0.32	PSP FACILITIES	0	0.0			June	40.64	157.047	0	
Compact Midrise	0.005	0.16	GOVERNMENT	0.2936	9.4			July	34.36	128.269	0	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-240		August	29.69	68.4497	0	
Large lowrise	0.150	4.78	SPECIAL AREA		0.0			September	36.27	100.411	0	
Sparsely built	0.000	0.00	WATERBODY		0.0			October	102.54	235.017	0	
Green belt	0.000	0.00	GREEN BELT		0.0			Novembar	194.43	303.118	0	
Open area	2.500	79.62						December	163.61	267.075	0	
Waterbody	0.000	0.00										
Road	0.400	12.74										
Heavy industry		0.00										

Table 102: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

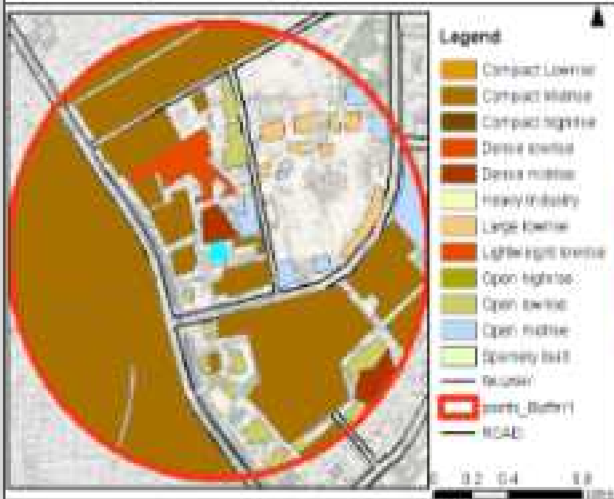
6.7.3.19 East Arjun Nagar, Delhi - CPCB

Although concentrations of this stations weren't available but the possible emissions would be from the commercial and PSP activities in the area. Also, as there is open area (without vegetation), so the concentrations would be high due to the soil dust particles. The area lacks vegetative spaces which could have acted as sinks. The compact built form further would reduce the local wind flow and reduce the dispersion rates.

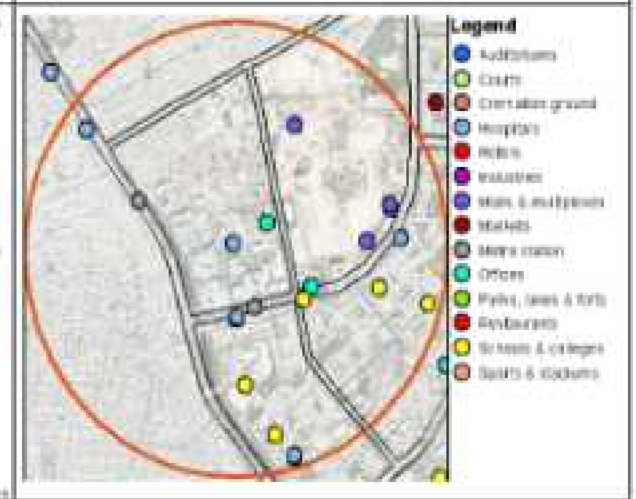
Map 107: Google earth imagery



Map 108: Land-use



Map 109: Built-form



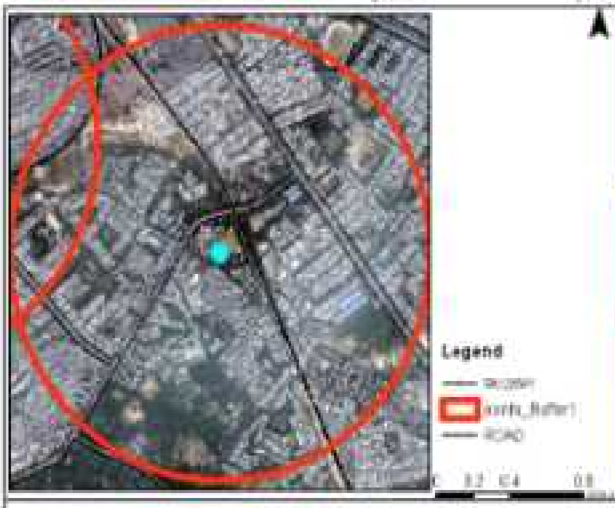
Map 110: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.065	2.07	COMMERCIAL	0.4059	12.9	200-220		January				
Dense midrise	0.049	1.56	INDUSTRIAL	0	0.0			Febraurary				
Open midrise	0.091	2.88	TRANSPORTATION	0.24	7.6			March				
Open highrise	0.000	0.00	RECREATIONAL	0.0057	0.2			April				
Open lowrise	0.086	2.72	RESIDENTIAL	1.956	62.3			May				
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.3893	12.4			June				
Compact Midrise	1.621	51.63	GOVERNMENT	0.064	2.0			July				
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August				
Large lowrise	0.052	1.64	SPECIAL AREA		0.0			September				
Sparsely built	0.000	0.00	WATERBODY	0.1	3.2			October				
Green belt	0.000	0.00	GREEN BELT		0.0			November				
Open area	0.850	27.07						December				
Waterbody	0.100	3.18										
Road	0.240	7.64										
Heavy Industry		0.00										

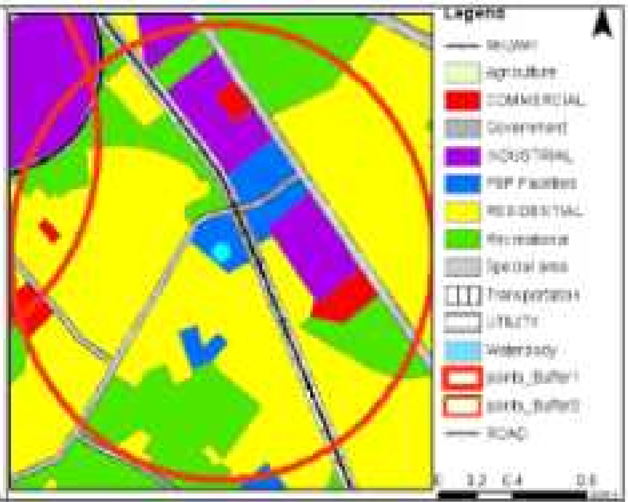
103: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.20 Ashok Vihar, Delhi - DPCC

The emission loads in the zone would be mainly from the generated traffic movements because of the industrial and commercial land-uses. The built form is mostly compact mid-rise which reduces the local wind speed and prevents dispersion. There is a chunk of exposed land or non vegetative area, in the direction of wind (form north-west), whose soil dust would add to the emission loads.

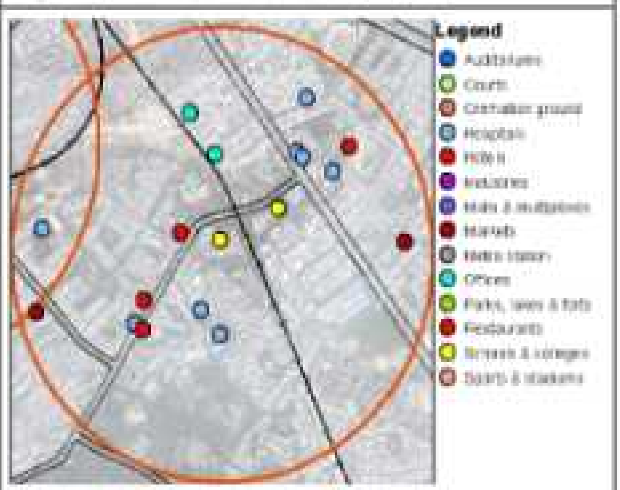


Map 111: Google earth imagery



Map 112: Land-use

Map 113: Built-form



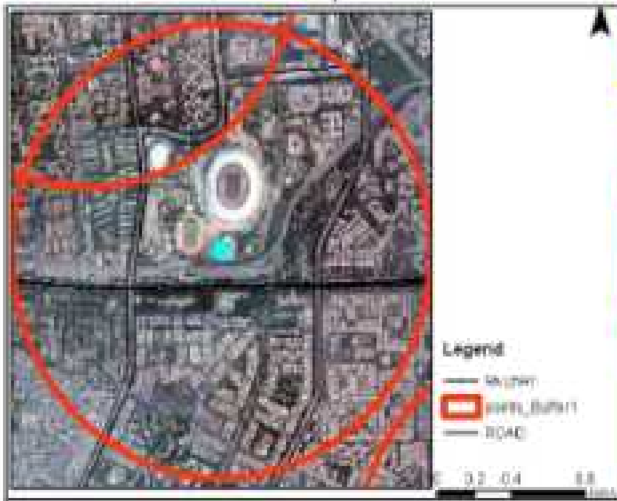
Map 114: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.122	3.88	COMMERCIAL	0.0857	2.7			January	240.15	329.008	90.9894	0.588612
Dense midrise	0.182	5.78	INDUSTRIAL	0.2864	9.1			Febrauray	142.66	237.849	116.465	0.664894
Open midrise	0.063	2.02	TRANSPORTATION	0.29	9.2			March	92.91	199.5	112.992	0.597948
Open highrise	0.000	0.00	RECREATIONAL	0.6824	21.7			April	95.38	168.204	99.7075	0.71911
Open lowrise	0.021	0.67	RESIDENTIAL	1.6555	52.7			May	99.66	275.437	109.663	0.808983
Compact Lowrise	0.044	1.41	PSP FACILITIES	0.1501	4.8			June	59.38	229.998	136.783	1.028515
Compact Midrise	1.222	38.93	GOVERNMENT	0	0.0			July	42.79	156.16	197.518	1.05813
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	30.95	82.8559	177.82	0.918966
Large lowrise	0.044	1.40	SPECIAL AREA		0.0			September	37.18	92.5406	129.719	0.957947
Sparsely built	0.000	0.00	WATERBODY		0.0			October	139.32	252.768	65.9197	0.50088
Green belt	0.800	25.48	GREEN BELT		0.0			November	232.68	337.553	75.8012	0.600779
Open area	0.350	11.15						December	238.62	341.571	51.7839	0.558561
Waterbody	0.000	0.00										
Road	0.230	5.24										
Heavy industry		0.00										

Table 104: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

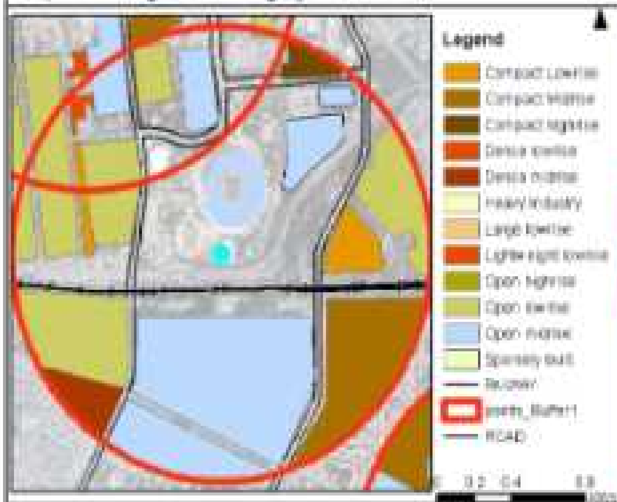
6.7.3.21 Jawaharlal Nehru Stadium, Delhi - DPCC

Average monthly concentrations of PM_{10} did not cross the moderate category of pollution standards throughout the year. The built up structure is open, and major land-uses are residential, mixed use and recreational. The zone includes lajpat nagar which is mixed land-use and attracts a large number of vehicular traffic with high congestion rate throughout the day, although it is not in the direction of wind, so its impact would be less.

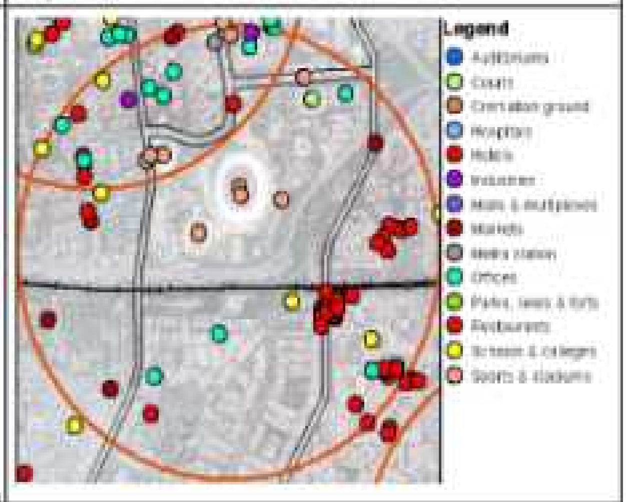


Map 115: Google earth imagery

Map 116: Land-use



Map 117: Built-form



Map 118: Major activities

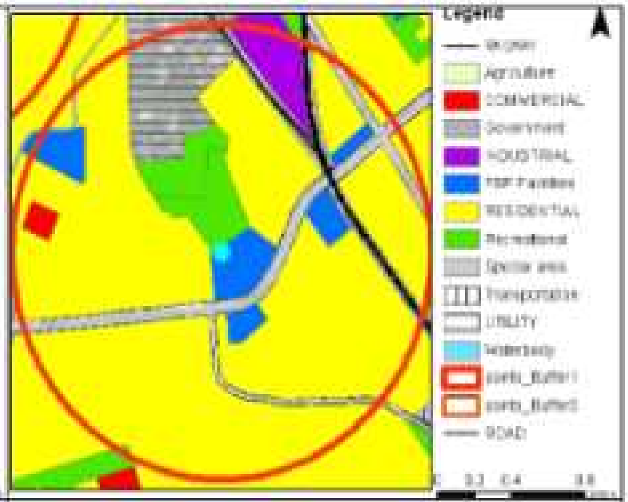
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.011	0.34	COMMERCIAL	0.0331	1.1			January	218.88	334.333		
Dense midrise	0.059	1.89	INDUSTRIAL	0	0.0			Februsuray	157.2	257.417		
Open midrise	0.692	22.04	TRANSPORTATION	0.22	7.0			March	85.36	181.502		
Open highrise	0.000	0.00	RECREATIONAL	0.7066	22.6			April	67.67	231.598		
Open lowrise	0.649	20.68	RESIDENTIAL	1.9584	62.4			May	68.76	236.098		
Compact Lowrise	0.077	2.46	PSP FACILITIES	0.0297	0.9			June	51.38	203.269		
Compact Midrise	0.233	7.41	GOVERNMENT	0.15	6.1			July	34.71	143.173		
Compact Highrise	0.031	1.00	UTILITY	0	0.0			August	24.69	69.6522		
Large lowrise	0.000	0.00	SPECIAL AREA		0.0	200-220		September	32.49	79.15		
Sparsely built	0.000	0.00	WATERBODY		0.0			October	118.39	233.341		
Green belt	0.300	9.55	GREEN BELT		0.0			November	205.26	329.067		
Open area	0.870	27.71						December	230.66	346.565		
Waterbody	0.000	0.00										
Road	0.220	7.01										
Heavy industry		0.00										

Table 105: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

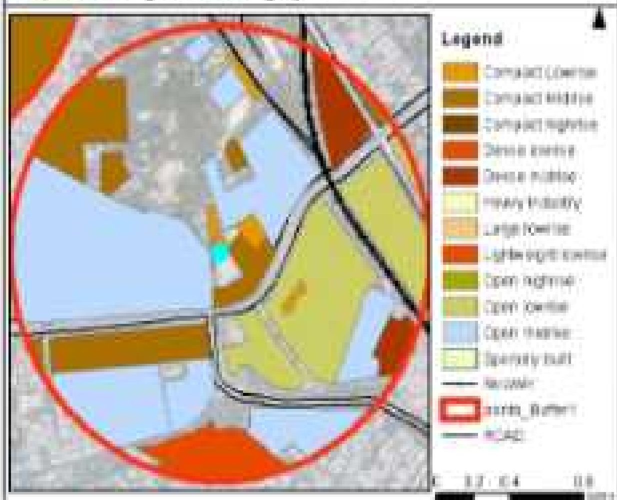
6.7.3.22 Nehru Nagar, Delhi - DPCC

There are open chunks of land(without vegetation), so the concentrations would be high due to the soil dust particles when wind speed is high. Sarai Kale khan lies in the north east of the influence area, so when wind blows form North-east in winters, the emission loads increase drastically showing impact of transportation activities of sarai kale khan into this influence zone.

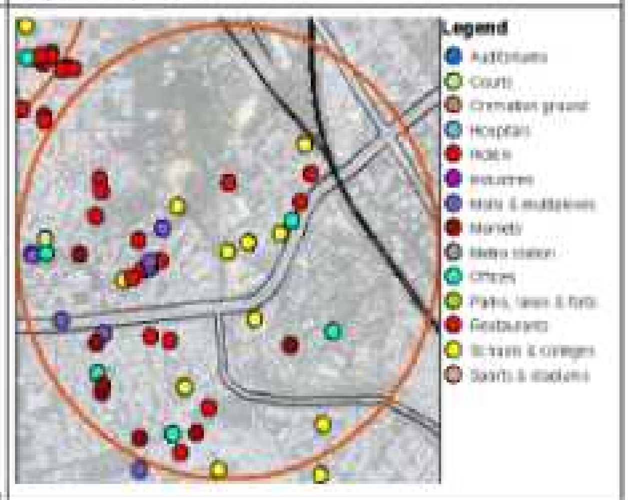
Map 119: Google earth imagery



Map 120: Land-use



Map 121: Built-form



Map 122: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	[m]		MONTHS	PM2.5	PM10		
Dense lowrise	0.111	3.54	COMMERCIAL	0.0182	0.6	200-240		January	269.65	382.968	101.875	0.659032
Dense midrise	0.112	3.56	INDUSTRIAL	0.0794	2.5			Febrauray	199.66	290.372	151.655	0.865714
Open midrise	1.034	32.93	TRANSPORTATION	0.3	9.6			March	100.84	185.097	173.949	0.93
Open highrise	0.000	0.00	RECREATIONAL	0.1577	5.0			April	76.58	226.388	157.765	1.137833
Open lowrise	0.455	14.48	RESIDENTIAL	2.199	70.0			May	71.86	209.097	151.056	1.114355
Compact Lowrise	0.039	1.23	PSP FACILITIES	0.1726	5.5			June	52.04	182.937	309.296	2.353333
Compact Midrise	0.338	10.77	GOVERNMENT	0	0.0			July	39.68	129.835	172.697	0.925161
Compact Highrise	0.000	0.00	UTILITY	0.213	6.8			August	32.36	73.9775	173.776	0.898065
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	38.43	88.4885	111.949	0.866271
Sparsely built	0.000	0.00	WATERBODY		0.0			October	137.98	262.091	61.3062	0.465806
Green belt	0.750	23.89	GREEN BELT		0.0			November	299.26	365.365	63.5132	0.496833
Open area	0.020	0.64						December	279.05	380.744	47.4906	0.512258
Waterbody	0.000	0.00										
Road	0.300	9.55										
Heavy Industry		0.00										

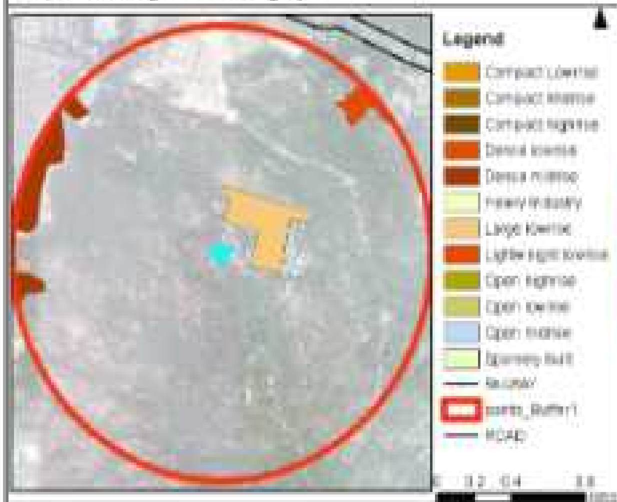
Table 106: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.23 Dr. Karni Singh Shooting Range, Delhi - DPCC

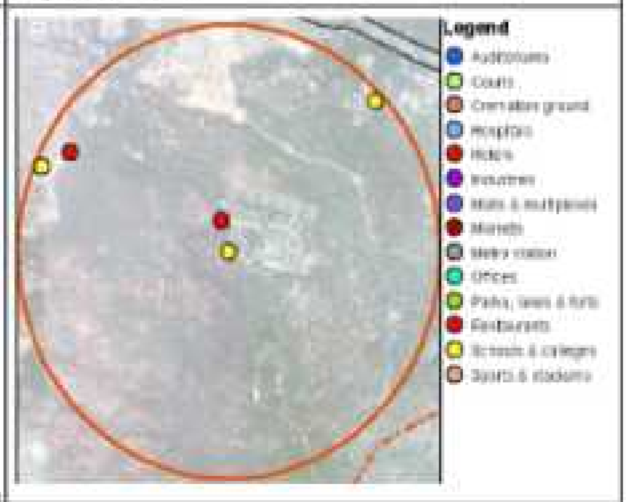
The emission loads from the activities inside the influence zone would be negligible. Although the vegetation impacts the concentration of pollutants in winters, as these have high biogenic emissions such as VOCs, which mixes with NO2 to form smog. So, there is drastic increase in concentration of pollutants throughout the winters.

Map 123: Google earth imagery

Map 124: Land-use



Map 125: Built-form



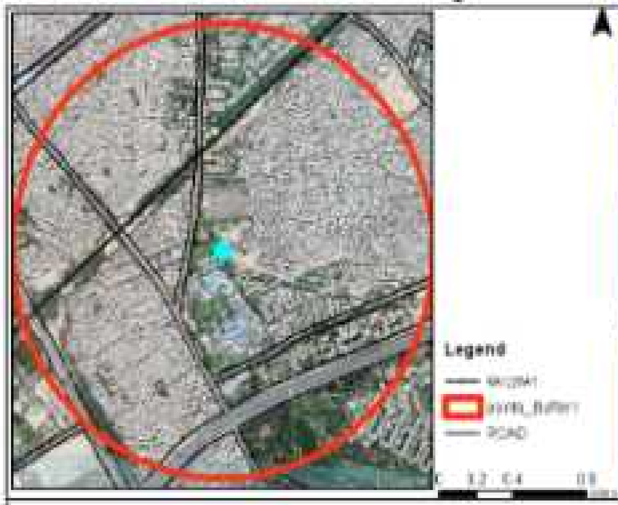
Map 126: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.021	0.67	COMMERCIAL	0	0.0	220-260		January	181.21	282.213	202.254	1.3088871
Dense midrise	0.075	2.38	INDUSTRIAL	0	0.0			Febraruray	110.96	195.084	269.776	1.54
Open midrise	0.000	0.00	TRANSPORTATION	0	0.0			March	69.86	164.547	306.698	1.6177419
Open highrise	0.000	0.00	RECREATIONAL	3.0128	96.0			April	65.86	209.451	213.134	1.5971667
Open lowrise	0.000	0.00	RESIDENTIAL	0	0.0			May	67.43	217.799	229.155	1.6904839
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.1084	3.3			June	50.18	181.009	257.842	1.9618333
Compact Midrise	0.000	0.00	GOVERNMENT	0.0252	0.8			July	36.01	116.468	242.325	1.2981667
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	22.89	57.6681	222.981	1.1520968
Large lowrise	0.074	2.37	SPECIAL AREA		0.0			September	32.36	72.1321	149.111	1.1538333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	114.36	216.903	118.07	0.8070968
Green belt	2.800	89.17	GREEN BELT		0.0			November	208.37	308.042	148.354	1.1605
Open area	0.200	6.37						December	216.20	313.419	98.6885	1.0645161
Waterbody	0.000	0.00										
Road	0.000	0.00										
Heavy Industry		0.00										

Table 107: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

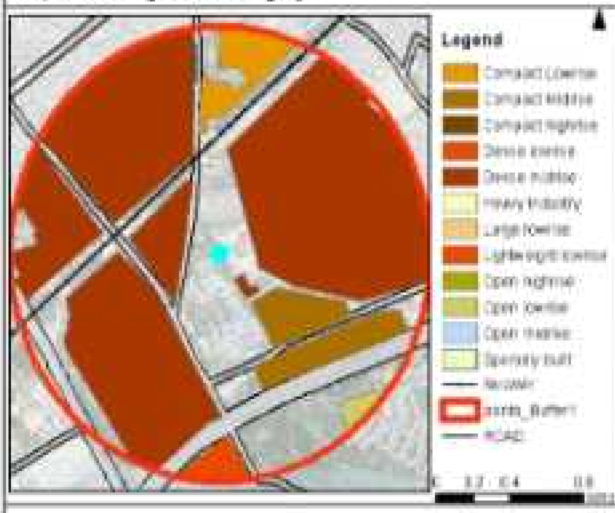
6.7.3.24 Patparganj, Delhi - DPCC

Around 60% of area in influence zone has dense mid-rise built up, which alters the local wind patterns drastically. It reduces the wind speed and prevents dispersion, 70% area lies in residential land-use with possible emissions from LPGs, which would be low. Industrial area would have emissions from loading & unloading activities.

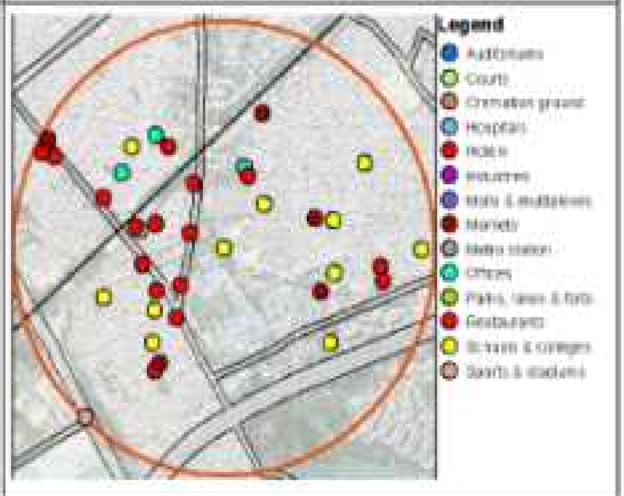


Map 127: Google earth imagery

Map 128: Land-use



Map 129: Built-form



Map 130: Major activities

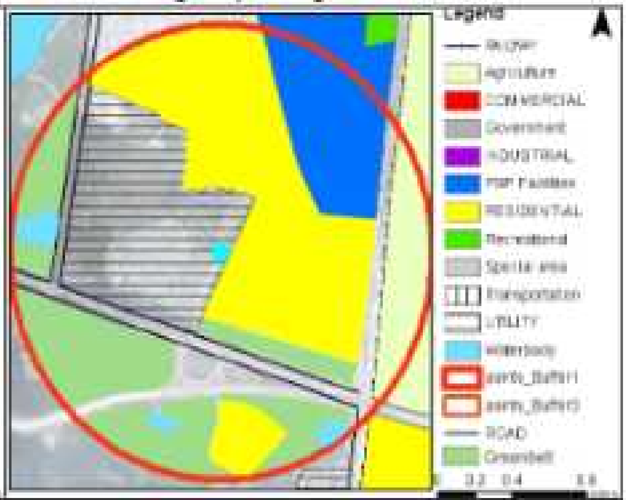
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.040	1.26	COMMERCIAL	0	0.0			January	193.87	299.677	143.457	0.9670968
Dense midrise	1.724	54.90	INDUSTRIAL	0.1957	6.2			Febraurary	139.87	230.741	191.289	1.0919643
Open midrise	0.000	0.00	TRANSPORTATION	0.36	11.5			March	78.39	147.442	164.304	0.8694315
Open highrise	0.000	0.00	RECREATIONAL	0.1741	5.5			April	74.88	189.206	142.744	1.0235
Open lowrise	0.023	0.72	RESIDENTIAL	2.2394	71.3			May	88.48	223.753	137.305	1.0129032
Compact Lowrise	0.093	2.97	PSP FACILITIES	0.0533	1.7			June	61.73	189.197	204	1.5521667
Compact Midrise	0.164	5.22	GOVERNMENT	0	0.0			July	49.95	110.733	262.93	1.4085484
Compact Highrise	0.000	0.00	UTILITY	0.045	1.4			August	28.04	60.9438	257.012	1.3282258
Large lowrise	0.040	1.28	SPECIAL AREA		0.0	200-220		September	33.79	85.7942	169.037	1.3126667
Sparsely built	0.000	0.00	WATERBODY	0.07	2.2			October	112.36	205.688	109.612	0.8330645
Green belt	0.200	6.37	GREEN BELT		0.0			November	188.40	291.307	103.888	0.8126667
Open area	0.500	15.92						December	200.16	292.188	70.0347	0.7553226
Waterbody	0.000	0.00										
Road	0.360	11.46										
Heavy industry		0.00										

Table 106: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

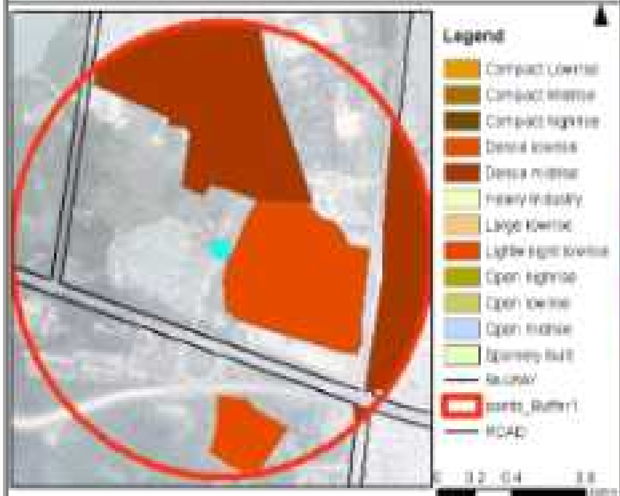
6.7.3.25 Sonia Vihar, Delhi - DPCC

The $PM_{2.5}$ and PM_{10} concentrations were high from November to February. The influence area comprises of mainly residential, PSP and utility land-uses. The residential land-use has dense mid-rise built form. There are slum settlements in the flood plains of Yamuna in this influence zone, which might be using kerosene or fuelwood as fuels for cooking, impacting the emission loads.

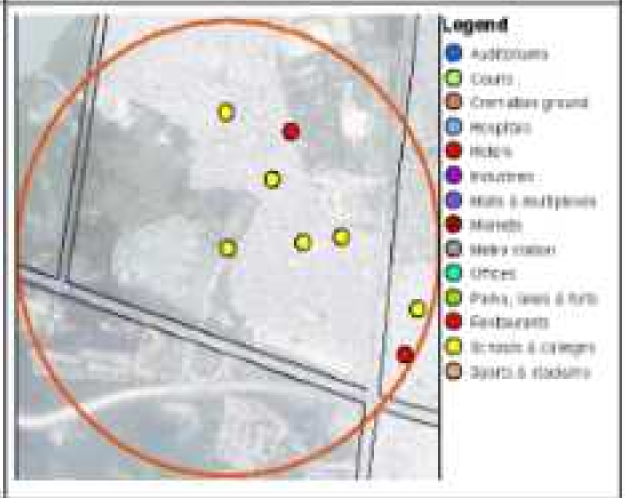
Map 131: Google earth imagery



Map 132: Land-use



Map 133: Built-form



Map 134: Major activities

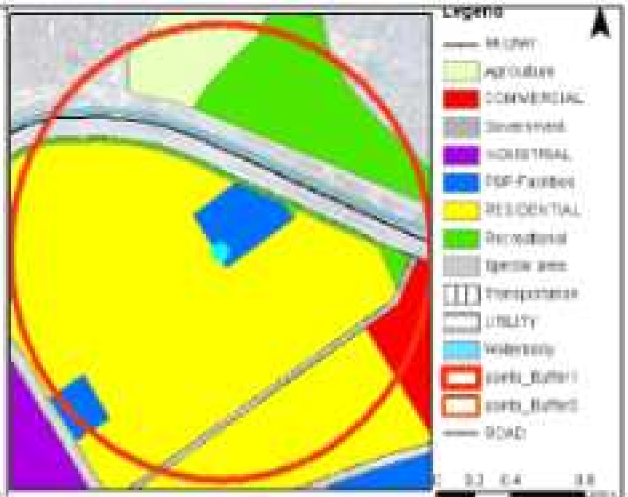
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.344	10.95	COMMERCIAL	0	0.0			January	224.45	339.445	158.714	1.2654833
Dense midrise	0.693	22.06	INDUSTRIAL	0	0.0			Febraurary	154.48	237.337	288.357	1.6460714
Open midrise		0.00	TRANSPORTATION	0.2	6.4			March	99.30	181.919	337.579	1.7864516
Open highrise		0.00	RECREATIONAL	0.02	0.6			April	91.13	243.057	247.359	1.794
Open lowrise		0.00	RESIDENTIAL	0.88	28.0			May	80.15	225.208	246.559	1.818871
Compact Lowrise		0.00	PSP FACILITIES	0.2985	9.5			June	60.79	208.557	265.508	2.0201667
Compact Midrise		0.00	GOVERNMENT	0	0.0			July	51.22	135.13	231.782	1.5631148
Compact Highrise		0.00	UTILITY	0.5995	19.1			August	39.09	82.5368	281.418	1.4543548
Large lowrise		0.00	SPECIAL AREA		0.0	200-220		September	39.57	87.2214	176.206	1.3535
Sparsely built		0.00	WATERBODY	0.3	9.6			October	106.60	236.776	143.798	1.0925806
Green belt	1.500	47.77	GREEN BELT	0.87	27.7			November	188.89	311.229	140.918	1.1023333
Open area	0.100	3.18						December	189.26	305.924	128.939	1.3903065
Waterbody	0.300	9.55										
Road	0.200	6.37										
Heavy industry		0.00										

Table 109: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

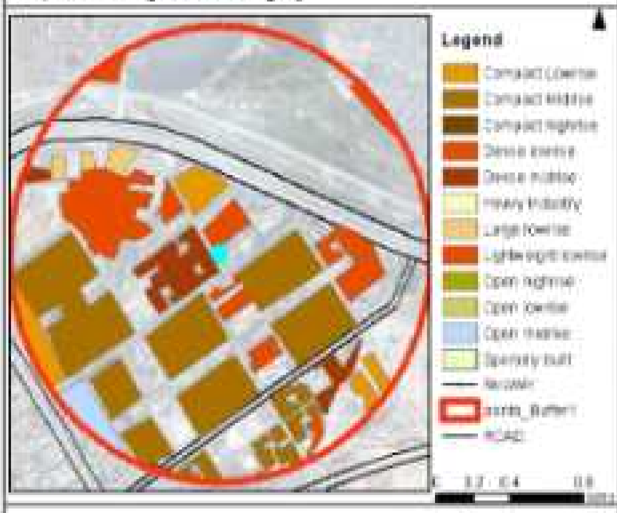
6.7.3.26 Jahangirpuri, Delhi - DPCC

The concentration were high almost throughout the year from October to May. The major land-uses are PSP and residential. PSP sector attracts the vehicular traffic movement through its commuters everyday. Emission loads at this station would be from the Bhalswa landfill site located just outside the influence zone in the direction of wind from North-west.

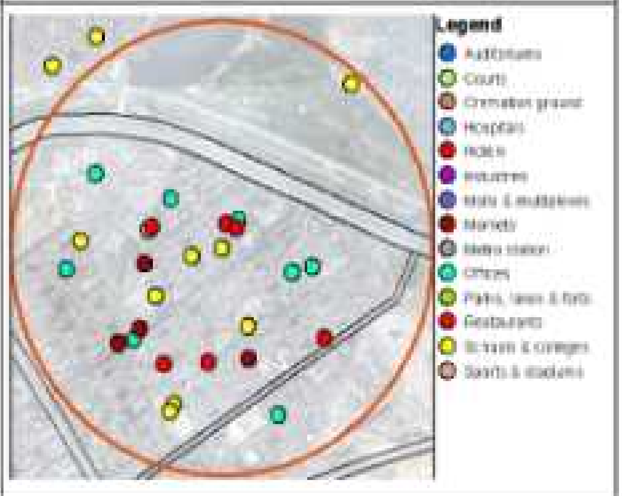
Map 135: Google earth imagery



Map 136: Land-use



Map 137: Built-form



Map 138: Major activities

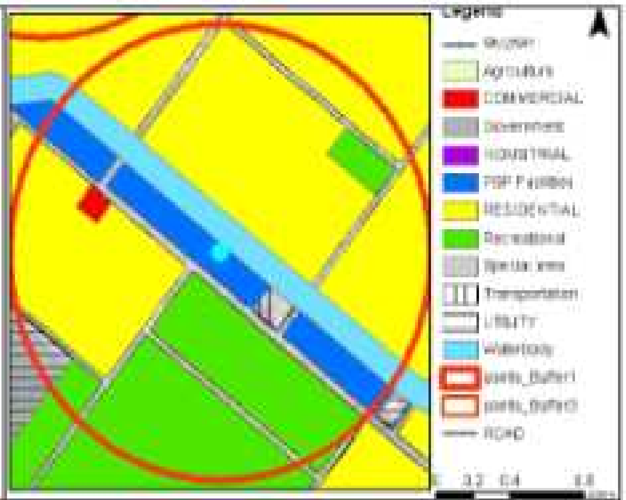
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.279	8.87	COMMERCIAL	0.0713	2.3			January	248.48	400.112	88.9302	0.575161
Dense midrise	0.105	3.35	INDUSTRIAL	0	0.0			Februaray	144.96	264.451	137.297	0.78875
Open midrise	0.040	1.28	TRANSPORTATION	0.15	4.8			March	107.36	232.509	152.605	0.807581
Open highrise	0.000	0.00	RECREATIONAL	0.4169	13.3			April	108.9	269.315	103.852	0.745
Open lowrise	0.000	0.00	RESIDENTIAL	1.8772	59.8			May	100.43	281.87	99.9179	0.732097
Compact Lowrise	0.094	3.00	PSP FACILITIES	0.1261	4.0			June	74.55	214.54	130.531	0.999167
Compact Midrise	0.608	19.35	GOVERNMENT	0	0.0			July	55.54	137.065	122.619	0.656885
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	40.11	96.9991	119.159	0.615806
Large lowrise	0.025	0.80	SPECIAL AREA		0.0	200-220		September	42.98	102.6	107.176	0.829999
Sparsely built	0.000	0.00	WATERBODY	0.5	15.9			October	144.7	282.758	55.9992	0.425484
Green belt	0.640	20.38	GREEN BELT		0.0			November	213.19	357.944	51.8062	0.405338
Open area	0.700	22.29						December	258.52	391.062	86.3787	0.381613
Waterbody	0.500	15.92										
Road	0.150	4.78										
Heavy industry		0.00										

Table 110: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

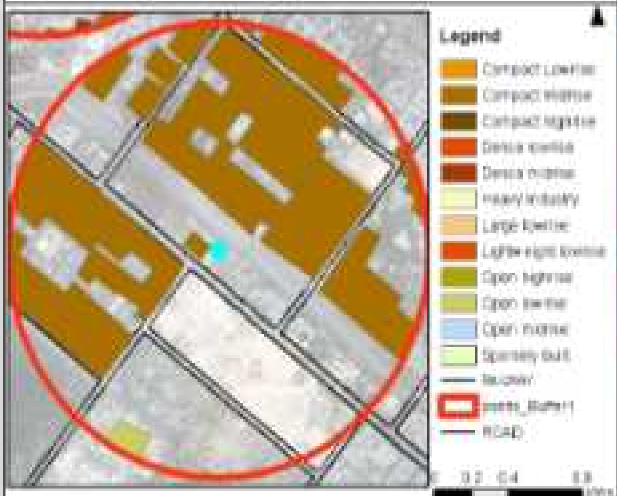
6.7.3.27 Rohini, Delhi - DPCC

The average monthly concentrations are high in winters and have major land-use of residential and PSP. There is open area (without vegetation), so the concentrations would be high due to the soil dust particles. Also, as per the activities map there are many hotels and restaurants in the area that might be using coal as fuel for barbecues which would increase the emission loads.

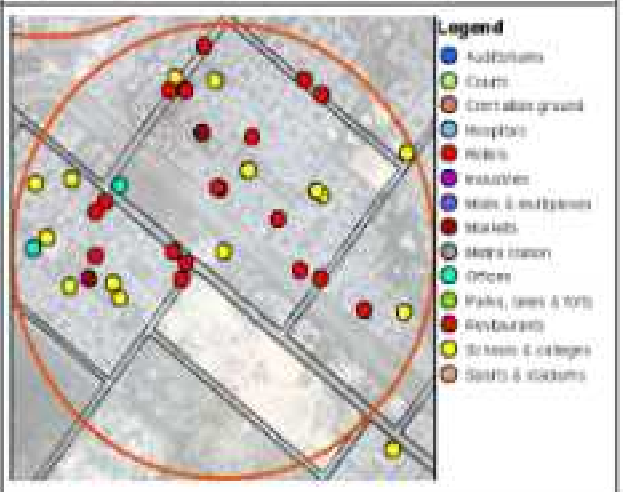
Map 139: Google earth imagery



Map 140: Land-use



Map 141: Built-form



Map 142: Major activities

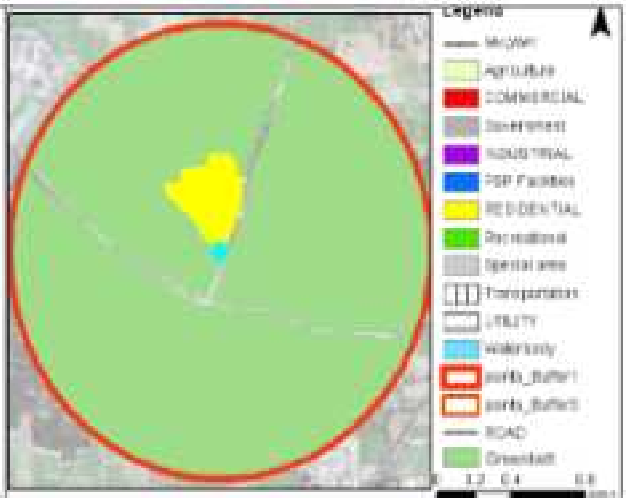
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0.0039	0.1			January	249.51	377.818	221.672	1.434
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0			Februaray	177.28	287.567	300.182	1.7135714
Open midrise	0.000	0.00	TRANSPORTATION	0.291	9.3			March	106.74	200.104	360.46	1.907541
Open highrise	0.000	0.00	RECREATIONAL	0.6324	20.1			April	104.94	289.475	285.454	2.0659649
Open lowrise	0.021	0.68	RESIDENTIAL	1.6187	51.6			May	100.66	261.228	276.115	2.0969565
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.2479	7.9			June	66.78	213.039	313.173	2.3828333
Compact Midrise	1.215	38.69	GOVERNMENT	0	0.0			July	45.87	147.03	340.878	1.826129
Compact Highrise	0.000	0.00	UTILITY	0.0332	1.1			August	40.64	91.4805	333.562	1.7238333
Large lowrise	0.000	0.00	SPECIAL AREA	0.2	6.4	200-220		September	49.28	99.5776	222.879	1.7246552
Sparsely built	0.000	0.00	WATERBODY		0.0			October	148.19	277.239	164.94	1.2532209
Green belt	0.200	6.37	GREEN BELT		0.0			November	238.81	340.369	159.902	1.2508333
Open area	1.200	38.22						December	256.75	358.21	102.622	1.1089355
Waterbody	0.250	7.96										
Road	0.270	8.60										
Heavy Industry		0.00										

Table 111: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.28 Najafgarh, Delhi - DPCC

Major land-use of the influence zone is agriculture. The concentration was high in November which could be because of the emissions from stubble burning in and around the region.

Map 143: Google earth imagery



Map 144: Land-use

Map 145: Built-form

Map 146: Major activities

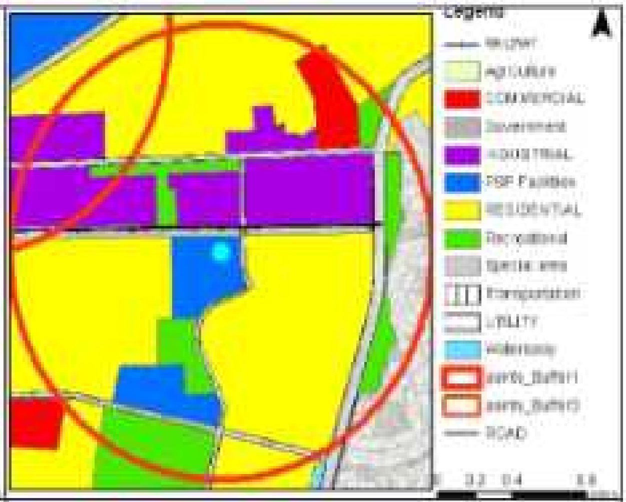
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0	0.0			January	166.15	232.329	292.573	1.5045161
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0			Febrouray	124.51	178.354	309.598	1.7673214
Open midrise	0.031	0.99	TRANSPORTATION	0.15	4.8			March	88.26	147.298	306.872	1.7774194
Open highrise		0.00	RECREATIONAL	0	0.0			April	74.45	205.83	272.987	1.9688333
Open lowrise		0.00	RESIDENTIAL	0.2	6.4			May	78.08	176.78	290.112	2.1401613
Compact Lowrise		0.00	PSP FACILITIES	0	0.0			June	56.45	140.383	344.322	2.6198333
Compact Midrise		0.00	GOVERNMENT	0	0.0			July	34.28	82.7451	342.082	1.8825806
Compact Highrise		0.00	UTILITY	0	0.0	200-220		August	22.25	49.531	331.228	1.7117742
Large lowrise		0.00	SPECIAL AREA		0.0			September	32.64	71.4842	212.855	1.6470909
Sparsely built		0.00	WATERBODY		0.0			October	103.37	184.666	364.101	2.7064516
Green belt	2.260	71.97	GREEN BELT	2.78	88.5			November	193.38	261.534	165.733	1.2985
Open area	0.700	22.29						December	154.67	213.814	110.667	1.1937097
Waterbody	0.010	0.32										
Road	0.150	4.78										
Heavy Industry		0.00										

Table 112: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

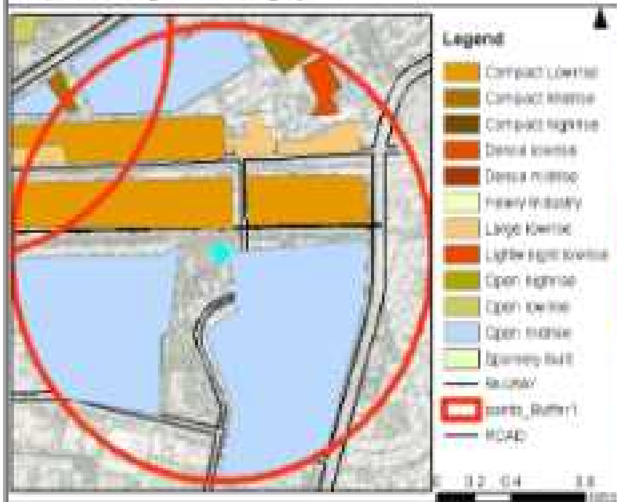
6.7.3.29 Vivek Vihar, Delhi - DPCC

About 25% area in the influence zone lies in industrial and PSP sector. PSP sector attracts the vehicular traffic movement through its commuters everyday. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading.

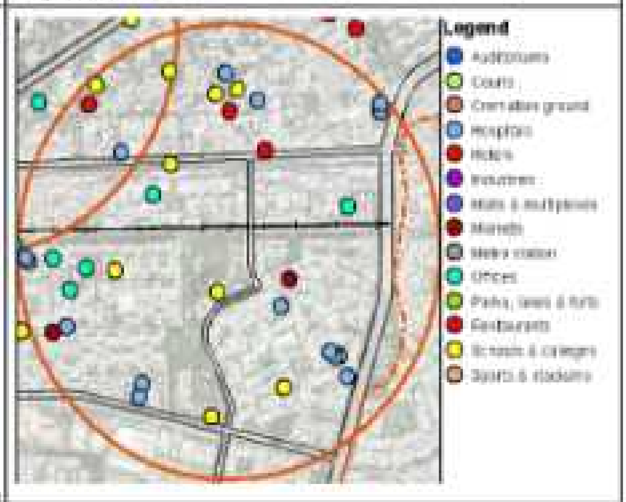
Map 147: Google earth imagery



Map 148: Land-use



Map 149: Built-form



Map 150: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.029	0.93	COMMERCIAL	0.081	2.6			January	221.52	355.661	408.872	2.645
Dense midrise	0.000	0.00	INDUSTRIAL	0.5198	16.6			Febrauray	153.27	276.736	395.536	1.9382143
Open midrise	1.239	39.44	TRANSPORTATION	0.257	8.2			March	91.25	198.569	366.625	1.9401639
Open highrise	0.000	0.00	RECREATIONAL	0.3009	9.6			April	95.91	255.22	252.016	1.8175862
Open lowrise	0.000	0.00	RESIDENTIAL	1.7929	57.1			May	79.39	247.072	206.179	1.9636066
Compact Lowrise	0.597	19.01	PSP FACILITIES	0.189	6.0			June	60.29	215.242	489.599	3.6796
Compact Midrise	0.211	6.73	GOVERNMENT	0	0.0			July	46.98	169.404	426.099	2.2826667
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	39.26	96.481	528.13	2.7299548
Large lowrise	0.080	2.55	SPECIAL AREA		0.0			September	38.26	97.3832	269.059	2.1903333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	137.58	255.179	219.03	1.6641935
Green belt	0.250	7.96	GREEN BELT		0.0			November	219.91	325.191	253.563	1.9835
Open area	0.500	15.92						December	232.42	341.492	154.613	1.6680645
Waterbody	0.000	0.00										
Road	0.257	8.18										
Heavy industry		0.00										

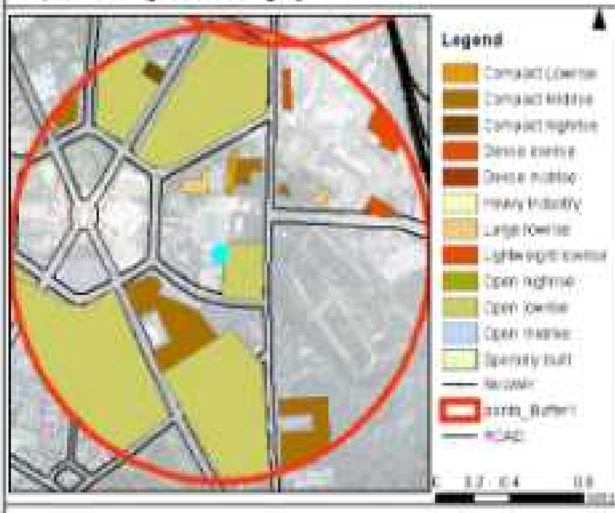
Table 113: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.30 Major Dhyan Chand National Stadium, Delhi - DPCC

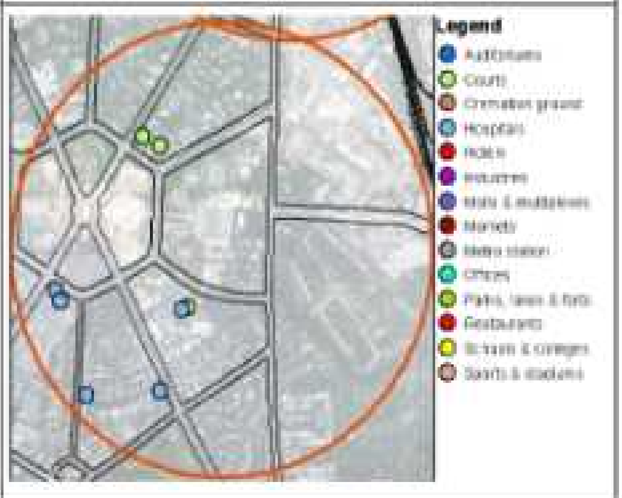
About 25% area in the influence zone lies in PSP sector. PSP sector attracts the vehicular traffic movement through its commuters everyday. The ongoing construction at Pragati Maidan in the influence zone could be the reason of high PM concentration.

Map 151: Google earth imagery

Map 152: Land-use



Map 153: Built-form



Map 154: Major activities

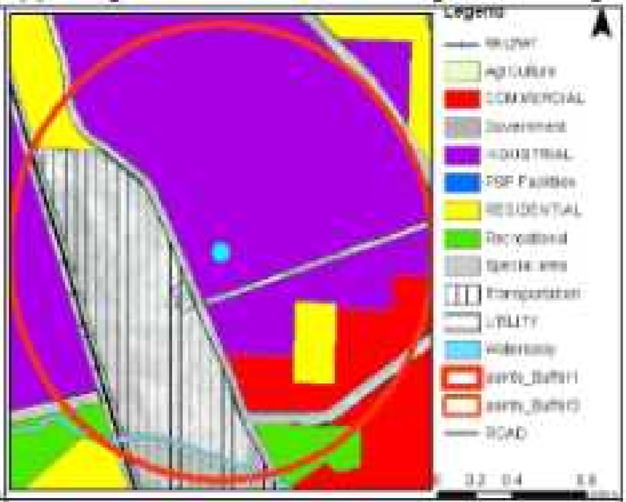
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.032	1.02	COMMERCIAL	0	0.0			January	171.07	322.864	110.153	0.712581
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0			Febrauray	134.06	242.439	133.335	0.794643
Open midrise	0.006	0.18	TRANSPORTATION	0.0253	0.8			March	75.74	163.216	130.49	1.008085
Open highrise	0.000	0.00	RECREATIONAL	1.4277	45.5			April	72.71	209.444	125.297	0.903667
Open lowrise	0.884	28.15	RESIDENTIAL	0.825	26.3			May	76.5	213.599	125.433	0.925329
Compact Lowrise	0.007	0.21	PSP FACILITIES	0.78	24.8			June	59.75	186.679	155.042	1.173667
Compact Midrise	0.153	4.87	GOVERNMENT	0.0761	2.4			July	40.99	129.384	169.343	0.907193
Compact Highrise	0.006	0.20	UTILITY	0	0.0			August	29.77	76.6898	170.435	0.880645
Large lowrise	0.013	0.42	SPECIAL AREA		0.0	200-220		September	34.99	87.0983	108.834	0.842167
Sparsely built	0.000	0.00	WATERBODY		0.0			October	111.06	225.511	82.0671	0.623546
Green belt	0.400	12.74	GREEN BELT		0.0			November	182.14	308.409	83.7113	0.654839
Open area	0.980	31.21						December	171.48	317.145	58.6006	0.632097
Waterbody	0.200	6.37										
Road	0.456	14.52										
Heavy industry		0.00										

Table 114: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

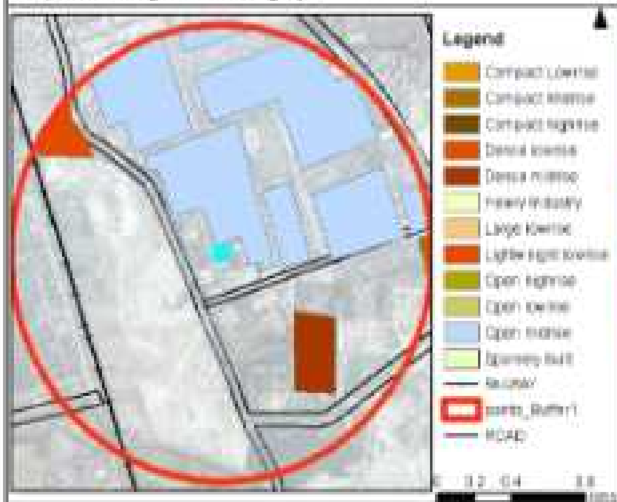
6.7.3.31 Narela, Delhi - DPCC

There is open (non vegetative) land in about 30% of the total area, which could be the reason for high concentration in this zone in summers too when wind speed is high. About 60% area in the influence zone lies in industrial land-use. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading.

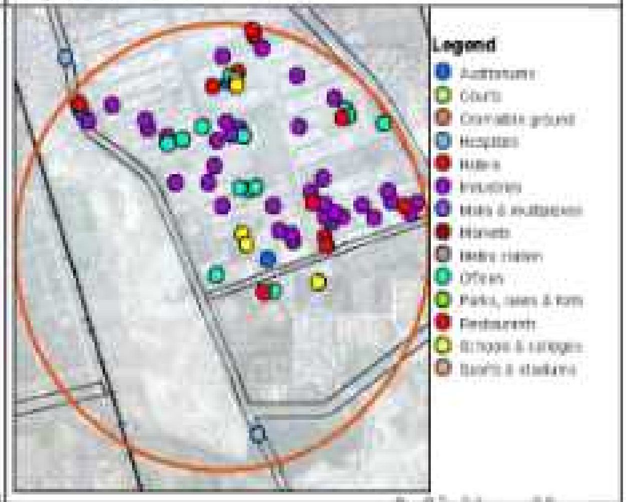
Map 155: Google earth imagery



Map 156: Land-use



Map 157: Built-form



Map 158: Major activities

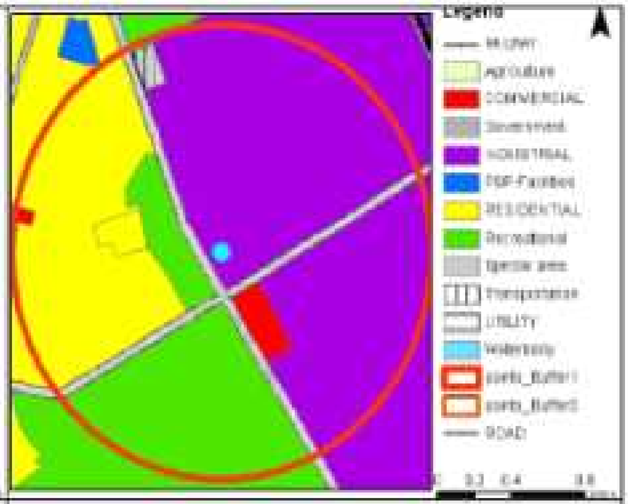
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.038	1.21	COMMERCIAL	0.2449	7.8	200-220		January	196.45	320.898	154.733	1.0009677
Dense midrise	0.067	2.12	INDUSTRIAL	1.7119	54.5			Febrauray	134.79	236.971	197.17	1.1255357
Open midrise	0.801	25.52	TRANSPORTATION	1.0071	32.1			March	85.52	188.488	250.289	1.3245161
Open highrise	0.000	0.00	RECREATIONAL	0.0759	2.4			April	101.48	295.881	290.859	1.605
Open lowrise	0.000	0.00	RESIDENTIAL	0.1007	3.2			May	96.46	288.874	184.006	1.3574194
Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0			June	73.18	238.352	309.564	1.5945
Compact Midrise	0.008	0.25	GOVERNMENT	0	0.0			July	52.91	152.279	224.271	1.2014516
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	32.16	89.3083	216.158	1.1170968
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	40.49	115.041	141.745	1.0968333
Sparsely built	0.000	0.00	WATERBODY		0.0			October	129.98	261.468	110.297	0.8975806
Green belt	0.500	15.92	GREEN BELT		0.0			November	208.13	341.416	111.629	0.8792203
Open area	1.700	54.14						December	198.84	299.545	70.5181	0.7806452
Waterbody	0.000	0.00										
Road	0.000	0.01										
Heavy Industry		0.00										

Table 115: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

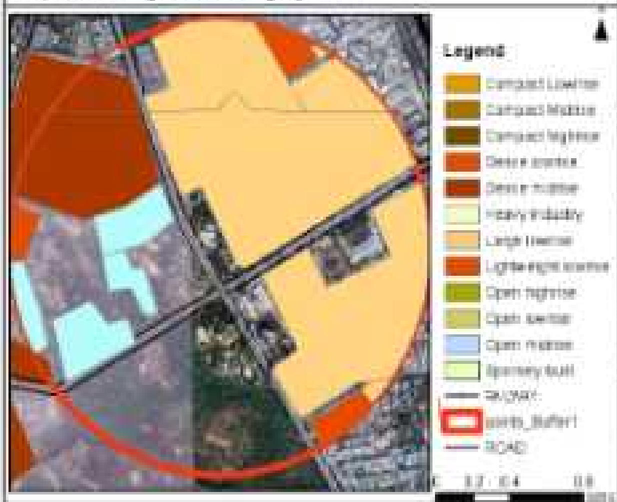
6.7.3.32 Okhla Phase-2, Delhi - DPCC

The average monthly concentrations are high from October to February. The significant amount of vegetation ensures the lower concentrations of PM for about 8 months throughout the year. The influence of vehicular movement for industrial activities would be contributing to the emission loads in the area.

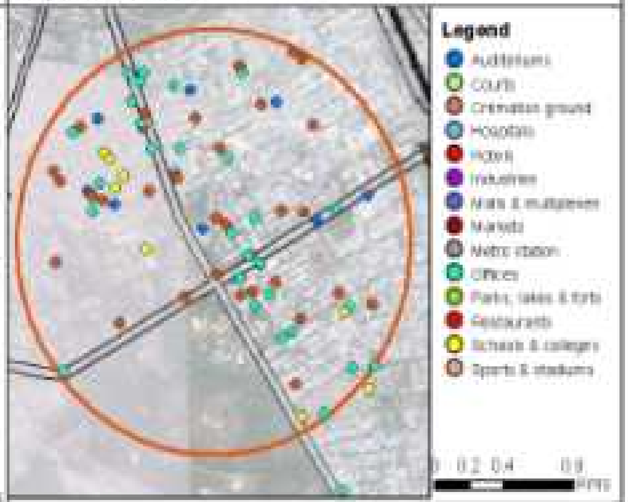
Map 159: Google earth imagery



Map 160: Land-use



Map 161: Built-form



Map 162: Major activities

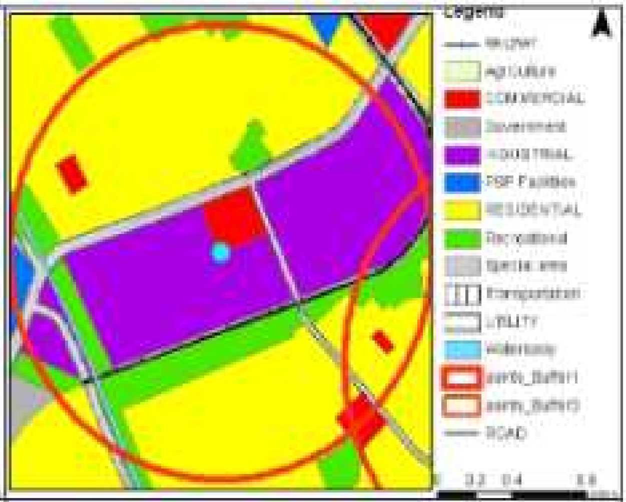
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.090	2.85	COMMERCIAL	0.0551	1.8			January	217.77	341.74	177.671	1.149355
Dense midrise	0.309	9.83	INDUSTRIAL	1.5187	48.4			Februaray	133.96	259.662	176.18	1.005714
Open midrise	0.118	3.74	TRANSPORTATION	0.1911	6.1			March	85.94	183.421	230.356	1.219082
Open highrise	0.000	0.00	RECREATIONAL	0.6412	20.4			April	81.86	197.361	147.875	1.0665
Open lowrise	0.000	0.00	RESIDENTIAL	0.729	23.2			May	70.6	198.607	154.621	1.140645
Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0			June	51.43	201.677	194.252	1.478
Compact Midrise	0.102	3.24	GOVERNMENT	0	0.0			July	41.89	146.804	130.456	0.698871
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	30.14	79.9316	173.167	0.894918
Large lowrise	1.279	40.72	SPECIAL AREA		0.0	220-240		September	36.54	94.5455	144.962	1.121726
Sparsely built	0.000	0.00	WATERBODY		0.0			October	121.51	246.655	126.497	0.961129
Green belt	0.940	29.94	GREEN BELT		0.0			November	206.62	325.714	121.359	0.949388
Open area	0.140	4.46						December	230.54	339.515	77.8301	0.698516
Waterbody	0.000	0.00										
Road	0.170	5.41										
Heavy industry		0.00										

Table 116: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

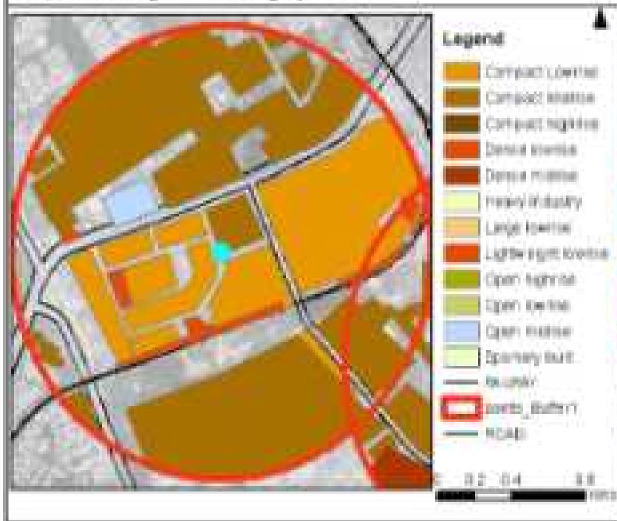
6.7.3.33 Wazirpur, Delhi - DPCC

Major land-uses in the area are residential and industrial. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading. There are very few vegetative spaces which would have acted as pollution sinks to reduce the emission loads in the influence area.

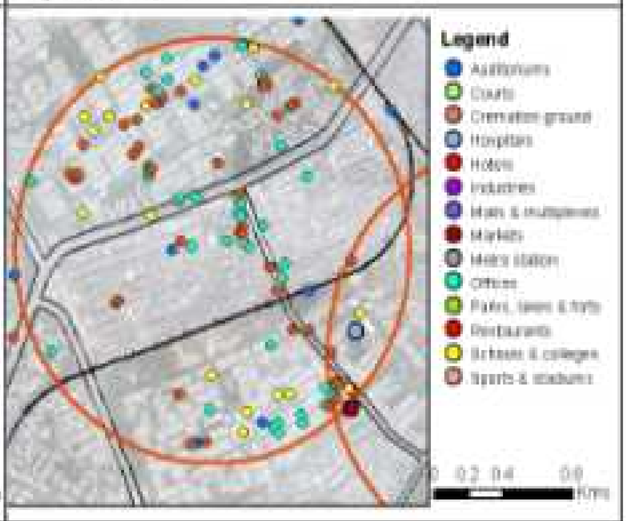
Map 163: Google earth imagery



Map 164: Land-use



Map 165: Built-form



Map 166: Major activities

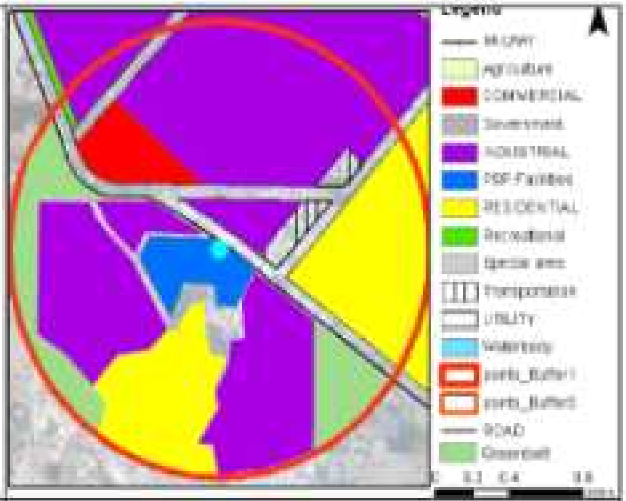
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.075	2.40	COMMERCIAL	0.094	3.0	200-220		January	265.46	409.238	216.461	1.4132258
Dense midrise	0.000	0.00	INDUSTRIAL	0.9106	29.0			Febrauray	208.08	361.411	294.618	1.6247279
Open midrise	0.032	1.03	TRANSPORTATION	0.2515	8.0			March	112.32	241.679	323.924	1.7141935
Open highrise	0.000	0.00	RECREATIONAL	0.3674	11.7			April	105.77	317.381	293.871	1.73
Open lowrise	0.007	0.21	RESIDENTIAL	1.4953	47.6			May	105.18	308.024	298.753	1.7612903
Compact Lowrise	0.679	21.63	PSP FACILITIES	0.0205	0.7			June	67.94	266.67	273.231	2.1245763
Compact Midrise	1.355	43.15	GOVERNMENT		0.0			July	54.27	212.208	296.547	1.5999548
Compact Highrise	0.000	0.00	UTILITY	0	0.0			August	43.39	145.279	305.133	1.5772581
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	58.23	173.51	204.513	1.5825862
Sparsely built	0.000	0.00	WATERBODY		0.0			October	149.54	309.461	161.502	1.2270968
Green belt	0.350	11.15	GREEN BELT		0.0			November	244.78	381.627	162.65	1.2723333
Open area	0.400	12.74						December	256.82	399.103	112.88	1.2175806
Waterbody	0.000	0.00										
Road	0.252	8.01										
Heavy Industry		0.00										

Table 117: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

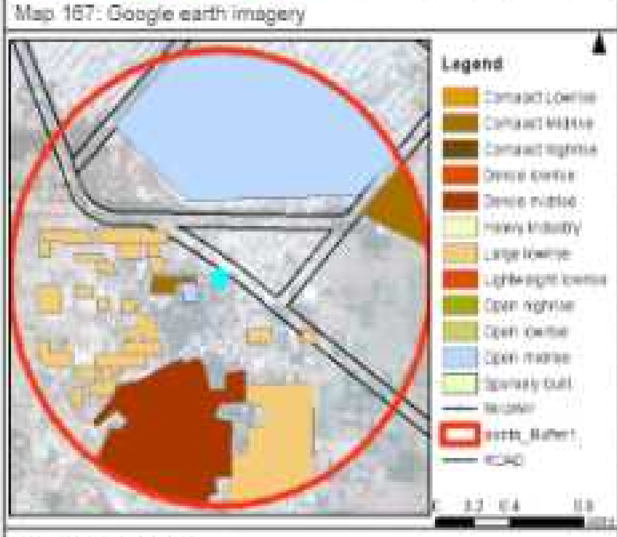
6.7.3.34 Bawana, Delhi - DPCC

Major land-uses in the area are residential and industrial. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading. The station lies on the outskirts of urban area, with agricultural areas in the vicinity. The concentration was high in November which could be because of the emissions from stubble burning.

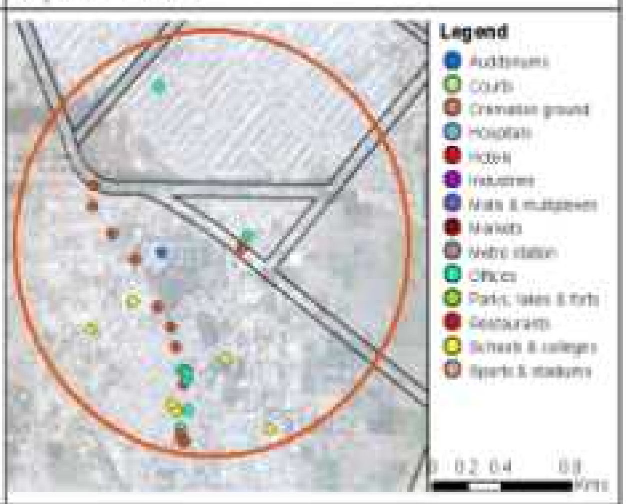
Map 167: Google earth imagery



Map 168: Land-use



Map 169: Built-form



Map 170: Major activities

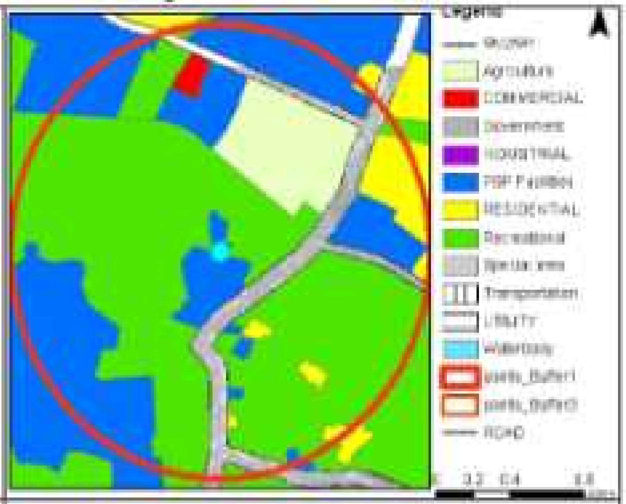
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise		0.00	COMMERCIAL	0	0.0			January	295.08	371.276	161.514	1.0448387
Dense midrise	0.309	9.84	INDUSTRIAL	1.2764	40.7			Februaruy	149.86	230.326	205.524	1.1709286
Open midrise	0.890	28.33	TRANSPORTATION	0.2347	7.5			March	108.28	222.893	256.506	1.3574194
Open highrise		0.00	RECREATIONAL	0.0042	0.1			April	103.11	293.84	197.952	1.4276667
Open lowrise		0.00	RESIDENTIAL	0.971	30.9			May	120.97	278.721	184.798	1.3632258
Compact Lowrise		0.00	PSP FACILITIES	0.1164	3.7			June	70.17	226.298	192.567	1.4633333
Compact Midrise	0.068	2.18	GOVERNMENT		0.0			July	51.31	153.889	245.135	1.3132203
Compact Highrise		0.00	UTILITY		0.0	200-220		August	42.92	84.0242	233.698	1.2077419
Large lowrise	0.339	10.78	SPECIAL AREA		0.0			September	54.96	115.574	152.859	1.1828333
Sparsely built		0.00	WATERBODY	0.12	3.8			October	154.71	273.382	121.402	0.9224196
Green belt	0.940	29.94	GREEN BELT	0.42	13.4			November	250.33	413.15	121.742	0.9523333
Open area	0.300	9.55						December	229.30	337.749	78.8918	0.8509677
Waterbody	0.120	3.82										
Road	0.180	5.73										
Heavy industry		0.00										

Table 118: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

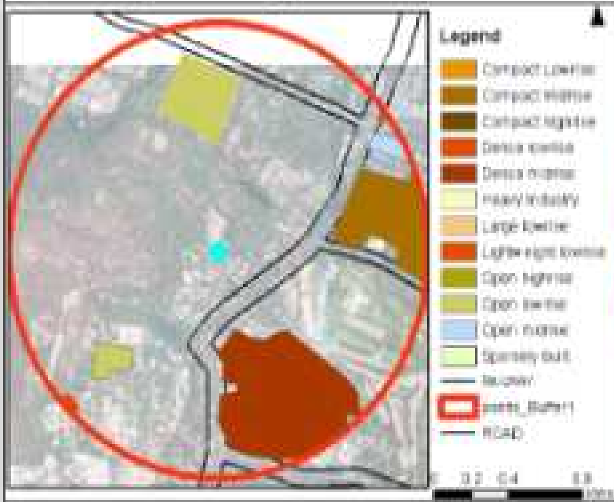
6.7.3.35 Sri Aurobindo Marg, Delhi - DPCC

The average monthly pollution concentration of PM_{10} were in moderate category throughout the year, whereas PM2,5 concentrations were poor in winters. The ventilation coefficient of the station were high compared to other locations in Delhi, ensuring higher dispersion rates in the influence area. There are few restaurants & hotels, which could be using coal as fuel for barbecues.

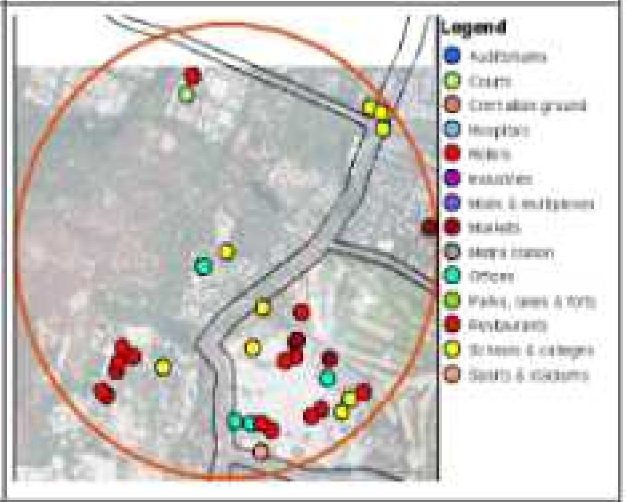
Map 171: Google earth imagery



Map 172: Land-use



Map 173: Built-form



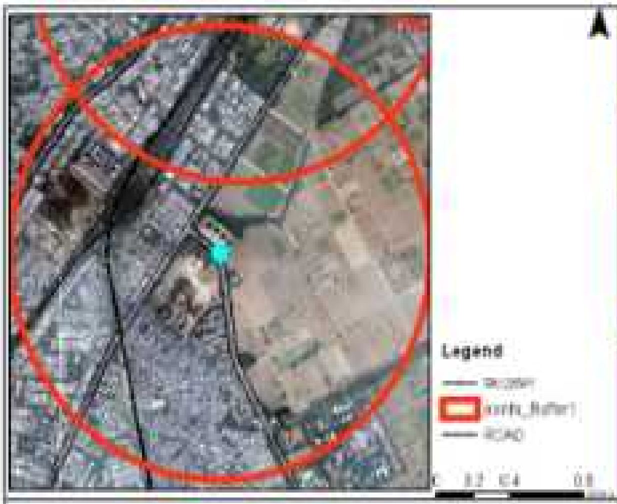
Map 174: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.005	0.16	COMMERCIAL	0.0214	0.7			January	171.59	259.022	818.891	5.2974196
Dense midrise	0.290	9.23	INDUSTRIAL	0	0.0			Februaray	125.58	195.865	923.256	5.2703571
Open midrise	0.265	8.44	TRANSPORTATION	0.2	6.4			March	74.39	144.302	1001.4	5.2993548
Open highrise		0.00	RECREATIONAL	1.9902	63.4			April	62.61	205.778	704.547	5.0613333
Open lowrise	0.023	0.74	RESIDENTIAL	0.1318	4.2			May	62.82	196.667	721.901	5.3254839
Compact Lowrise		0.00	PSP FACILITIES	0.802	25.5			June	47.70	194.497	685.84	5.2183333
Compact Midrise	0.138	4.38	GOVERNMENT		0.0			July	37.23	123.943	892.704	4.7823333
Compact Highrise		0.00	UTILITY		0.0	220-260		August	24.55	47.2775	909.368	4.5096774
Large lowrise		0.00	SPECIAL AREA		0.0			September	34.20	60.9285	908.469	4.7083333
Sparsely built		0.00	WATERBODY		0.0			October	102.59	156.242	572.623	4.3608065
Green belt	2.070	65.92	GREEN BELT		0.0			November	194.42	240.301	900.829	4.7
Open area	0.150	4.78						December	181.78	247.923	456.917	4.9285484
Waterbody	0.000	0.00										
Road	0.200	6.37										
Heavy Industry		0.00										

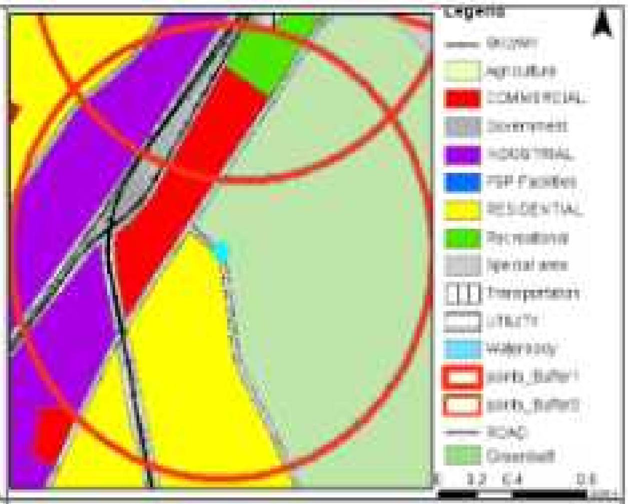
Table 119: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.36 Pusa, Delhi - DPCC

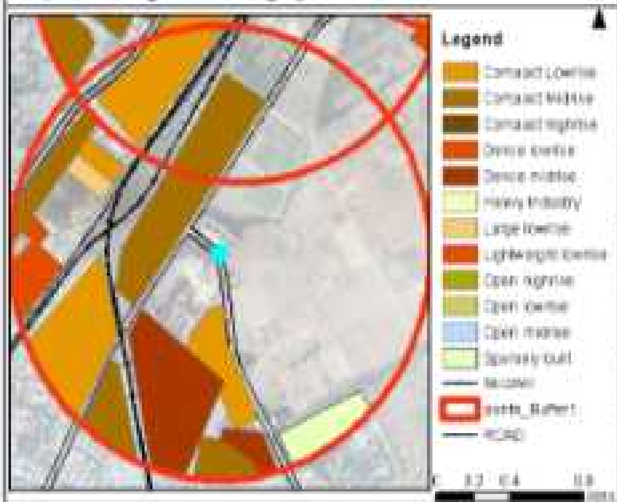
Major land-uses in the area are residential, commercial and industrial. Although industries have moved to cleaner fuel, they influences the movement of traffic through their supporting activities such as loading & unloading. Commercial land-use attracts vehicular traffic increasing the emission loads.



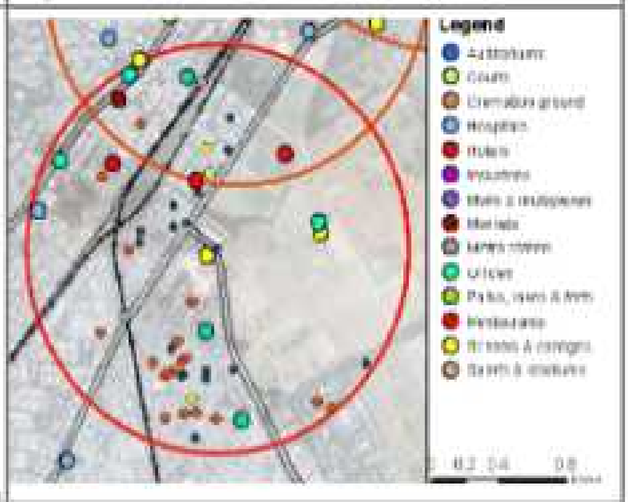
Map 175: Google earth imagery



Map 176: Land-use



Map 177: Built-form



Map 178: Major activities

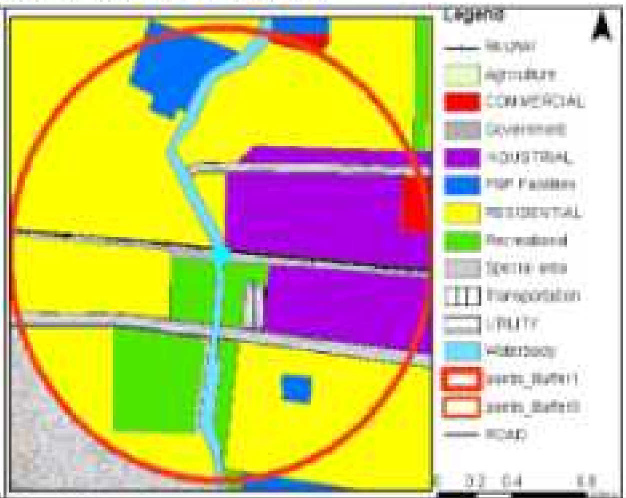
LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.050	1.59	COMMERCIAL	0.2435	7.8			January	201.09	339.653	184.203	1.1916129
Dense midrise	0.224	7.13	INDUSTRIAL	0.5751	18.3			Febrauray	149.09	270.1	240.188	1.3710714
Open midrise	0.000	0.00	TRANSPORTATION	0.271	8.6			March	80.46	131.213	246.875	1.3064516
Open highrise	0.000	0.00	RECREATIONAL	0.0653	2.1			April	62.64	219.824	205.162	1.4796667
Open lowrise	0.000	0.00	RESIDENTIAL	0.561	17.9			May	70.18	240.252	206.361	1.5225581
Compact Lowrise	0.388	12.37	PSP FACILITIES	0	0.0			June	46.77	200.296	238.768	1.8166667
Compact Midrise	0.394	12.55	GOVERNMENT	0	0.0			July	36.42	148.74	282.768	1.5148333
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-240		August	25.66	68.5877	273.709	1.4145161
Large lowrise	0.020	0.62	SPECIAL AREA		0.0			September	31.77	69.6462	174.989	1.3533333
Sparsely built	0.065	2.06	WATERBODY		0.0			October	110.52	204.623	315.537	2.3374576
Green belt	1.930	61.46	GREEN BELT	1.45	46.2			November	210.92	305.357	310.982	2.4326667
Open area	0.080	2.55						December	216.81	326.678	90.8541	0.98
Waterbody	0.000	0.00										
Road	0.270	8.60										
Heavy Industry		0.00										

Table 120: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

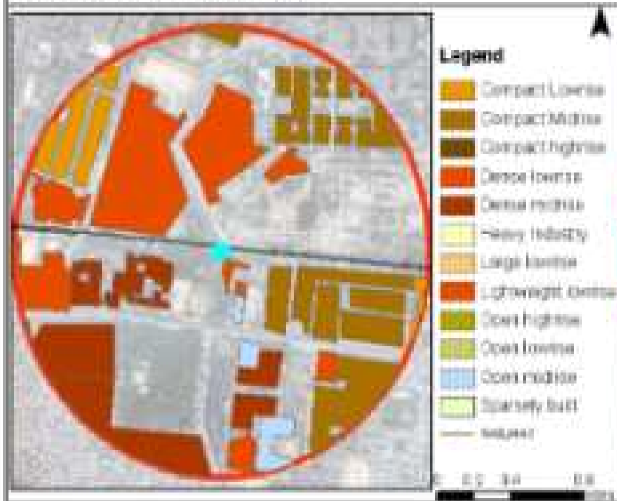
6.7.3.37 Mundka, Delhi - DPCC

The emission loads in the zone would be mainly from the generated traffic movements because of the industrial land-use. There are chunks of exposed land or non vegetative area, in the direction of wind (form north-west), whose soil dust would add to the emission loads.

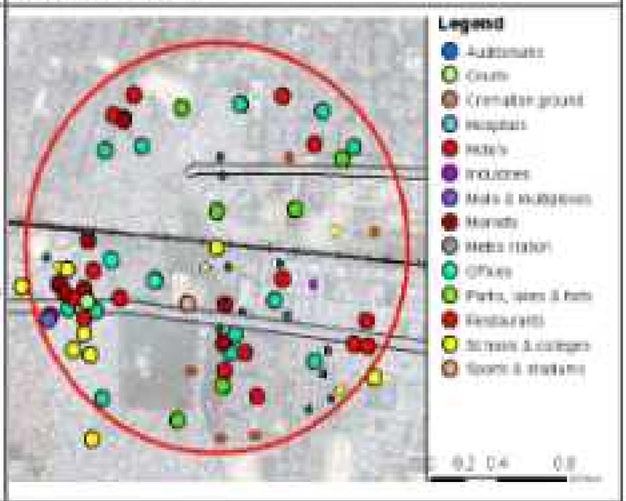
Map 179: Google earth imagery



Map 180: Land-use



Map 181: Built-form



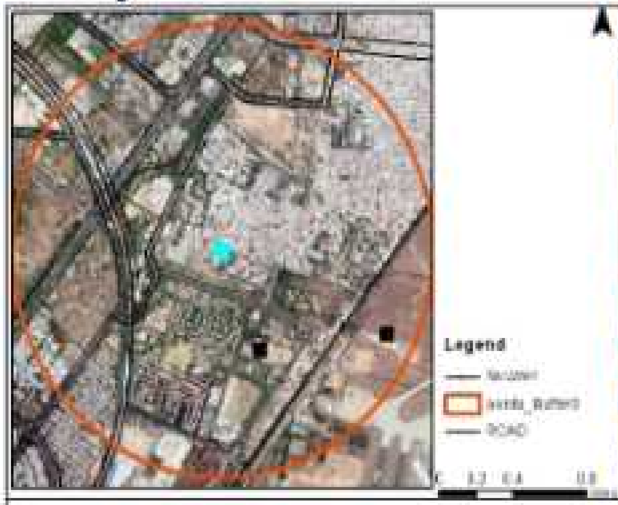
Map 182: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.810	25.80	COMMERCIAL	0.0345	1.1			January	295.52	422.124	197.467	1.2774194
Dense midrise		0.00	INDUSTRIAL	0.6222	19.8			Febraruray	166.97	323.51	255.699	1.4596429
Open midrise	0.048	1.54	TRANSPORTATION	0.2015	6.4			March	111.51	260.061	290.703	1.5360871
Open highrise		0.00	RECREATIONAL	0.2758	8.8			April	102.49	358.24	200.617	1.4483333
Open lowrise		0.00	RESIDENTIAL	1.9058	60.7			May	107.30	341.314	233.156	1.72
Compact Lowrise	0.100	3.17	PSP FACILITIES	0.1266	4.0			June	64.20	274.98	222.465	1.6866667
Compact Midrise	0.391	12.44	GOVERNMENT		0.0			July	42.69	175.469	260.805	1.3971667
Compact Highrise		0.00	UTILITY		0.0	200-220		August	35.52	110.433	258.585	1.3353226
Large lowrise		0.00	SPECIAL AREA		0.0			September	44.09	128.401	170.133	1.3165
Sparsely built		0.00	WATERBODY		0.0			October	140.51	313.439	127.367	0.9677419
Green belt	0.600	19.11	GREEN BELT		0.0			November	262.84	362.438	146.372	1.165
Open area	0.820	26.11						December	266.31	360.444	97.1364	1.0477419
Waterbody	0.200	6.37										
Road	0.180	5.73										
Heavy Industry		0.00										

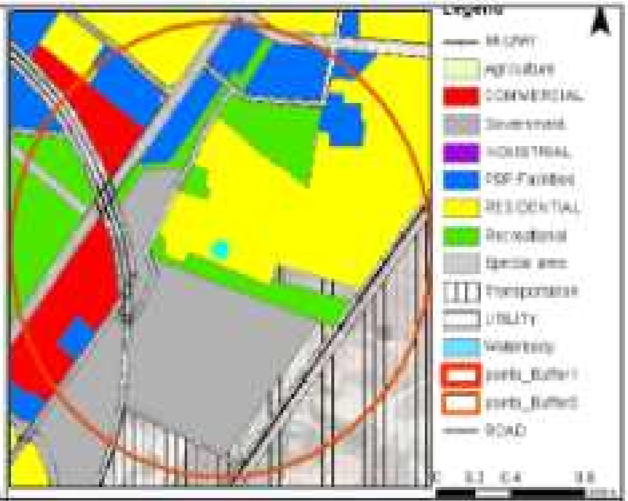
Table 121: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.7.3.38 Dwarka-Sector 8, Delhi - DPCC

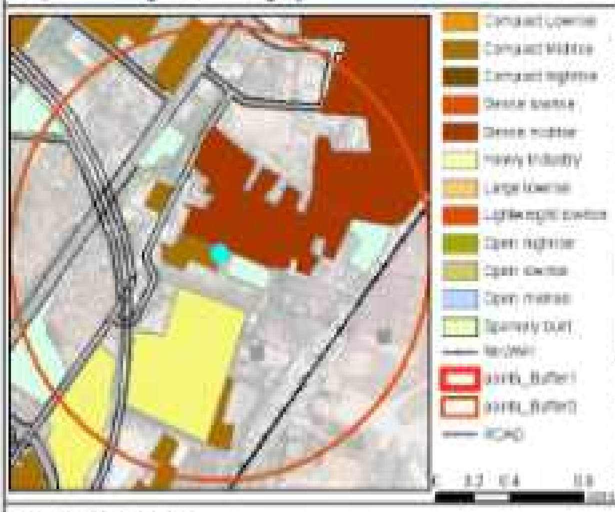
The average monthly pollution concentration of PM_{10} were in poor and severe category throughout the year except August & September, whereas PM2,5 concentrations were poor only in winters. Built form all above the influence zone is dense mid-rise, affecting the local wind speeds and reducing the dispersion rate. Lot of land is exposed or non vegetative area, whose soil dust would be adding to the emission loads.



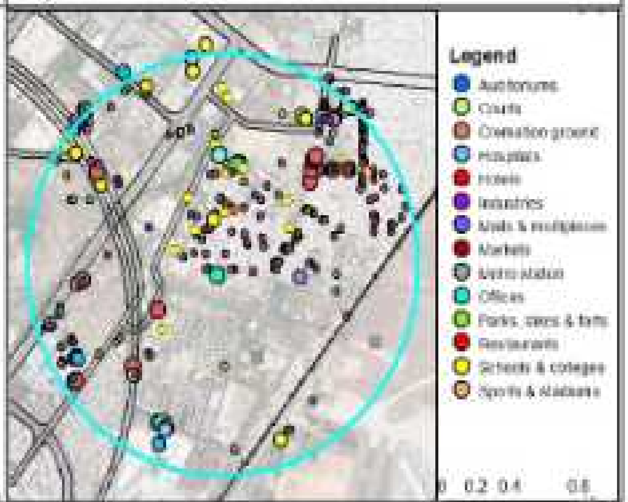
Map 183: Google earth imagery



Map 184: Land-use



Map 185: Built-form



Map 186: Major activities

LCZ			LANDUSE			ALTITUDE		POLLUTION CONC.			VC	WS (m/s)
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)		MONTHS	PM2.5	PM10		
Dense lowrise	0.000	0.00	COMMERCIAL	0	0.0			January	185.46	384.242	139.374	0.901613
Dense midrise	0.465	14.82	INDUSTRIAL	0	0.0			Febrauray	96.54	273.9	172.364	0.989829
Open midrise	0.113	3.60	TRANSPORTATION	0.8068	25.7			March	85.94	246.607	209.722	1.109839
Open highrise	0.000	0.00	RECREATIONAL	0.4161	13.3			April	79.05	282.653	169.094	1.175833
Open lowrise	0.305	9.71	RESIDENTIAL	0.7066	22.5			May	91.1	328.714	166.636	1.214516
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.18	5.7			June	67.43	303.528	172.441	1.312045
Compact Midrise	0.114	3.63	GOVERNMENT	0.6232	19.8			July	45.37	242.109	205.009	1.098226
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220		August	37.19	144.119	202.395	1.045560
Large lowrise	0.000	0.00	SPECIAL AREA		0.0			September	42.51	172.094	127.659	0.987833
Sparsely built	0.000	0.00	WATERBODY		0.0			October	190.25	357.78	95.4806	0.739065
Green belt	0.400	12.74	GREEN BELT	0.41	13.1			November	224.99	390.153	96.6014	0.755667
Open area	1.400	44.57						December	222.39	403.559	65.8098	0.720645
Waterbody	0.000	0.00										
Road	0.350	11.15										
Heavy Industry		0.00										

Table 122: Percentage distribution of Built-form (LCZ) & land-use; pollution concentration, wind speed and ventilation coefficient

6.8. Observations

The pollution inventories that have been discussed chapter 2, varies drastically when are compared to each other. Methodology, scale, season of study and the pollution estimation, all differ from each other (except the pollution sources) and there isn't any common parameter where significant inferences can be taken out. All the studies were done for different time slots and none of them were covered for entire year. The resolution of the grid used also varied from 400 x 400 sq. to 4 x 4 sq.km. There was drastic difference observed in the sectoral emissions of the all the studies, which leads to large variance in the concentration of pollution and uncertainty around the actual contribution of each source to pollution. The studies didn't incorporate the impact of land use on air pollution or how the trend of pollution differs at each zone geographically. Also, various unaccountable factors or sources of pollution linked to the main pollution source have not been emphasized. Like the impact of loading and unloading of goods linked to the industrial activities and the effect of informal sector and their emissions have been missed out. Even there is fuel change in industries which have lowered the direct emissions; these supporting activities continue to impact emission contribution from this sector. There are many more unaccountable factors which put immense pressure on the concentration of air pollution in the city. If receptor modeling at all the monitoring stations is being carried out throughout the year month wise, significant observations can be made, which could further enhance the data quality and bold out better inferences. It will subsequently lead to effective policy measures.

Air Pollution is influenced by:
- Regional Factors (Macro-Level)
- Local Factors (Micro-Level)

At regional level, the factors include:
- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind
- speed
- Topography
- Land Use and Land Cover
- Activities around the city limits and its location.

At Local level, the factors include:
- Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
- Land Use: Primary activity and Secondary activity (Travel Demand)
- Location of Activities – Industries, Power Plants, Commercial Centres, etc.
- Building Heights: Local Climatic Zones

Delhi faces frequent dust storms every year during the months of March to June, which increases the pollution concentration in the region. These storms originate from Thar Desert located in the western parts of India or from distant source of the Arabian Peninsula. Erosion of forests along the northern and central Aravalli tracts has caused the advancement of the desert particularly in the gap area with increasing intensity of dust storms. So, increase in forest cover in the Aravalli might reduce the intensity of such storms.

The city receives most of the rainfall in July, August and September and during these months only the pollution concentrations are low, as the rain settles down the atmospheric pollutants onto the ground. So, it can be said that for these months only Delhi can handle its pollution with activities normally running. Sirifort station showed higher PM_{10} concentration in this season (20 polluted days in July), it could be because there is urban forest in the area, which increases the moisture in the area due to increase in humidity. The increase of relative humidity in the atmosphere reduces the amount of solar radiation reaching the earth's surface. The heat from the solar radiation is observed by the air, resulting in minimizing atmospheric temperature nearer to the surface of earth. The air layer nearer to the surface of the earth becomes colder than the upper layers, thus reducing the upgoing currents and leading to the increase of pollutant concentrations. But station like Dwarka sec-8, showed higher PM_{10} concentration as it had uncovered open spaces which on high wind speed increases the dust in the air on non-rainy days in these months. During this season the wind speed is often higher compared to the rest of the year, it increases the dispersion rate of the pollutants hence lowering the concentration. Also, it was found that built form (refer map 8) also affects the wind speed inside the city, which creates chunks of land where there is negligible wind speed when compared to the areas nearby.

Predominant wind direction in Delhi is from North West. Westerly and north-westerly winds bring dust from western regions and smoke caused by burning of crop residue in neighbouring Punjab and Haryana to Delhi-NCR. Despite a ban on stubble burning in Punjab and Haryana, farmers continue to defy it amid a lack of financial incentives.

When temperature is high in summers, mixing height in Delhi is observed to be high and hence low pollution is observed in these areas. And when temperature is low in winters, mixing height reduces significantly, increasing the pollution in the city. So, in the months November to January when the temperature is low, the concentration is expected to be higher, as the dispersion rate is negligible and mixing height is really low.

These meteorological factors constitute the variable factors which are uncontrollable and highly influence the concentration of pollution in the atmosphere. Although certain alterations can be done to influence the factors like wind speed and direction by changing the urban form, but it is difficult to achieve in already developed city like Delhi.

Built-form map (figure 10) and the vegetation map (figure 4) of Delhi present how unevenly the vegetation has been distributed in the city. There are large pieces of land which are densely midrise and without any open spaces. These increase the activity rate in the zone and the decreases the pollution absorption areas. It lowers the scope of deposition, absorption or dispersion of pollution in the area.

In absence of mixing height data, solar radiation values can be accounted due to its higher correlation or dependency with mixing height. As solar radiation increases so does mixing height and vice versa. The solar radiation varies over region to region and the cloud cover over the region has strong influences over it. Solar radiation and wind speed are predominant factor of atmospheric stability (refer to Pasquill Atmospheric Stability Classes).

Hours above standard are total hours where pollutant concentration is beyond 60 µg/m3

Table 1.22: Number of pollution days with respect to PM_{10}

	January	February	March	April	May	June	July	August	September	October	November	December	Total Polluted Days
Alipur	28.2	19.3	29.2	9	19.4	12.3	6.3	2.6	4	21.8	25.1	25.1	194
Shadipur	24.7	11.8	37.1	12.8	38.9	24	12.8	8.1	7.1	21.9	25.5	26.9	247.4
IHBAS, Dilshad Garden	23.3	22.9	21.1	23.1	25.3	21.5	14.1	9.3	3.5	21.3	23.9	28.9	241.8
NSIT, Dwarka	28.8	10.6	36.6	12.9	39.1	24.5	13.9	6.3	8.4	25.7	27.9	29.8	265.3
DTU	28.2	17.7	19.8	18.3	18.8	13	9.4	6.5	3.4	23.4	24.5	29.2	218.3
ITO	27.2	23.2	19.6	17.8	19.7	18.3	7.3	3.6	8.3	21.4	25.8	29.1	215.4
Sirifort	27.9	9.9	30.9	7.9	19.3	11.3	6.2	2.7	7.3	23.8	26.6	29	203.8
Mandir Marg	28	19.3	27.6	6.7	30.4	16.9	8.5	3	5.9	22.4	24.7	29.4	214.8
Anand Vihar	29.5	23	29.4	19.7	21.3	16.8	11	5.7	8.3	23.8	24.9	27.8	230.4
RK Puram	26.7	10.5	26.9	4.8	14.7	12.6	9.1	4.2	6.4	12.5	25.7	27.7	179.6
Punjabi Bagh	26.9	10.8	29	7	23.9	9.8	5.4	3.4	6.9	20.4	26	29.1	196.9
Aya Nagar	23.5	13	10.3	8.8	12.4	8.5	7.7	2.3	3.5	22.6	24.8	27.4	164.6
Lodhi Road	26.1	8.6	17.3	6.7	19.4	12.3	6.9	1.3	6.1	22	25.4	23.3	173.4
Burari Crossing	24.7	19.2	17.5	13	19.6	13.7	7	0.9	0	22.8	25.3	10.8	174.6
CRRI Mathura	27.8	19.3	18.9	18.5	18.8	13	10.6	3.4	5.5	22.9	28.5	28.8	207.7
IGI Airport	25.2	17.7	15.3	14.1	11.3	2.7	2.8	1.8	2.9	17.2	26.1	28.6	165.5
Ashok Vihar	29.4	23.6	25.1	22.8	18.8	18.3	8.8	2.5	4.3	22.8	26.2	30.3	230
Jawaharlal Nehru Stadium	28.4	10.5	27.6	6	21.6	9.7	3.7	0.8	3.5	21.4	25.8	27.7	186.5
Nehru Nagar	29.3	11.2	31.3	6.5	23.6	9.2	3.1	1.9	5.3	23.6	27.5	29.8	204.8
Dwarka Sector 8	27.4	16	19.5	15.9	18.1	16	7.2	5	0.8	23.6	26.6	30	209.9
Dr. Karni Singh Shooting Range	27.5	20.4	15.8	13.5	13.6	8.3	4	0.2	2.3	21.4	26.3	26.8	180.6
Patparganj	27.4	19.4	26	6.8	22.1	13	6.7	1.6	2.9	21.1	25.6	26.6	190.2
Sonia Vihar	28.7	16.6	30.8	9	24.8	11.8	6.8	2.7	2	22.1	25.5	29.3	207.2
Jahangirpuri	29.8	24.8	29.4	24	18.7	17.4	11.3	6	6	24.9	26.9	29.8	246
Rohini	29.6	16.9	33.5	8.3	28.3	14.6	7.4	6.7	6	23.7	25.9	29.6	226.7
Najafgarh	27.5	10.1	29.5	7.1	23.3	10.8	3.8	0.4	2.9	19.3	25.5	28	187.3
Vivek Vihar	27.7	15.8	29.8	8.5	25.2	12.8	7	3.2	4.7	21.8	25.8	29.7	209.4
Major Dhyan Chand National Stadium	27.7	9.8	25.9	7.3	25.3	12.5	6	1.1	4	21.8	25.5	28.2	190.1
Narela	28.5	13	29.8	8.3	26.4	17.3	10	2.8	4.3	23.3	26	28.2	217

	January	February	March	April	May	June	July	August	September	October	November	December	Total Polluted Days
Okhla Phase 2	26.9	10	38	7.2	21.8	6.3	5.8	1.5	4.5	22.4	26.3	28.9	195.5
Wazirpur	30.4	11.7	30.9	8.9	33.1	14.4	10.2	6.3	9.3	24.3	27	30	242.2
Bawana	30.2	24.8	22.4	15.7	29.8	14.8	9.7	6.1	10	24.5	26.6	29.6	236.8
Sri Aurobindo Marg	28.2	10	24.3	8.8	19.8	7.8	3.8	0.6	4.3	20.8	28.8	28.4	179.1
Pusa	29	10.7	28.2	6.8	22	6.3	4.8	0.7	3.4	22.2	28.8	28.8	189.2
Mundka	29.3	10.1	28.3	8.9	28.4	11.4	8	3.3	8.7	23.8	28.9	28.2	215.4

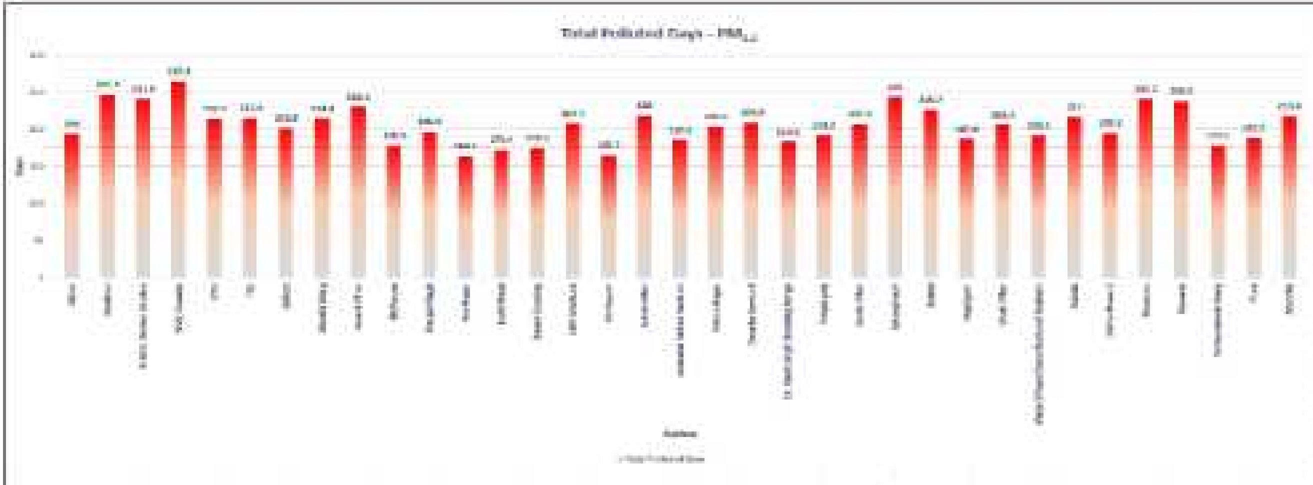


Figure 200: No. of days $PM_{2.5}$ concentration exceeds standards

Table 124: Number of pollution days with respect to PM$_{10}$

	January	February	March	April	May	June	July	August	September	October	November	December	Total Polluted Days
Alipur	27.3	18.6	33.9	13.6	30.2	25.3	11.7	4.4	6.2	24.5	28	25.8	238.7
Shadipur													
IHBAS, Dilshad Garden													
NSIT, Dwarka													
DTU	26.7	19.6	29.3	23.3	29.2	29.2	18	10.8	14.1	29.4	25.3	25.4	271.3
ITO	25.8	22.7	21.5	21.8	26.7	24.1	12.8	3.7	5.1	21.9	25.4	27.1	235.8
Sirifort	26.3	11.3	44.1	13	37.2	26.5	16.9	17.3	23.1	28	27.9	25.7	308.6
Mandir Marg	28.5	11.7	43.8	13.8	42.6	27.4	20	11.8	15.4	28	25.8	27.6	295.8
Anand Vihar	28	17.6	29.5	28.7	27	27.5	20.1	18.3	14.7	28	25.7	27.5	290.6
RK Puram	19.9	8.8	38	13.7	40	25.8	16.6	7.5	10.3	26.5	27.6	27.5	258.5
Punjabi Bagh	29.3	11.5	40.1	13.6	38.1	25.5	16.5	7.1	6.9	24.6	25.4	28.4	271
Aya Nagar	26.9	17.8	30.1	17.9	22.4	19.1	1.1	4.7	0.0	25.4	25.8	24.9	213.6
Lodhi Road	26.8	16.8	26.3	18.7	34.9	23.9	12.8	2.8	8	23.8	25.8	22.8	227.6
Burari Crossing	27	26.7	21.2	18.8	25.4	24.8	12.1	5.5	6.3	24.2	25.3	11	222.1
CRRI Mathura	27.7	19.8	21.3	26.3	28.4	26.6	15.9	7.5	8.8	27.6	27.1	29	266.4
IGI Airport	27.8	21.5	23.7	26.9	24.8	10.8	16.7	4.2	8.8	27.1	26.8	27.9	246.7
Ashok Vihar	29.8	27.1	28.7	28.2	27.9	28.8	16.4	8.8	11.4	27	27.4	28.9	288.1
Jawaharlal Nehru Stadium	27.1	8.9	38.1	13.8	40.2	25.4	14.3	8	7.8	26.6	27.5	27.7	263.5
Nehru Nagar	28.5	11.3	34.4	11.8	39.3	23.5	18	6.6	10.1	28.6	28.5	29.4	268.6
Dwarka Sector 8	28	28.1	29.2	21.4	28.8	28	24.3	19.3	22.4	29.7	28.9	29.4	318.5
Dr. Karni Singh Shooting Range	28.1	23.8	26.3	28.1	26.3	24.1	12.7	3.3	6.4	28	27.8	28.1	267.7
Patparganj	26.3	11	34.7	13.3	31.9	26	12	2.9	9	24.7	27.3	27.9	248
Sonia Vihar	30.7	16.6	38	13.3	37.7	28.6	18	9.3	8.8	26.8	26.7	28.6	281.4
Jahangirpuri	28	26.5	29.5	27.7	28	26.8	17.3	12	13.8	29.2	27.2	29.5	294.5
Rohini	28	11.6	38.1	13.3	38.8	26	16.7	10.8	12.8	27.3	26.3	29.1	279.3
Najafgarh	27.1	10.1	32.4	6.9	21.8	20.2	8	1.8	4.8	23.6	24.8	25.1	216.7
Vivek Vihar	28.8	11.4	42.4	14	41.8	29.8	14.7	8.8	10.4	29.8	26.8	29.3	288.8
Major Dhyan Chand National Stadium	29.3	10.9	30.1	12.7	38.9	24.5	14	7.8	5.5	26.4	27.6	29.4	261.1

	January	February	March	April	May	June	July	August	September	October	November	December	Total Polluted Days
Narela	29.5	11.5	29.2	12.3	40.4	27.4	17.3	11.4	15.9	28.6	26.1	28.1	287.8
Okhla Phase 2	29.4	11.3	36.7	12.3	36.9	26.3	17.2	6.4	11	27.6	28.2	28.7	272
Wazirpur	30	12	38.8	13.9	44.3	30.8	26.7	23.9	23.8	30	28.8	29.5	330
Bawana	28.8	26.3	17.7	27.3	28.4	26.1	18.4	10	16.2	27.7	18.1	14.1	259.1
Sri Aurobindo Marg	28.8	10.8	38.1	13.8	38.8	24.8	12.7	1	3.4	22	28.3	28.1	243.1
Pusa	28.9	11.1	43.8	12.8	42.8	25.8	18.7	6	6.8	27.4	28.3	28.8	278.7
Mundka	28.4	10.8	34.7	13.8	40.3	28.3	18.8	14.7	19.3	28.8	28	28.8	291.8

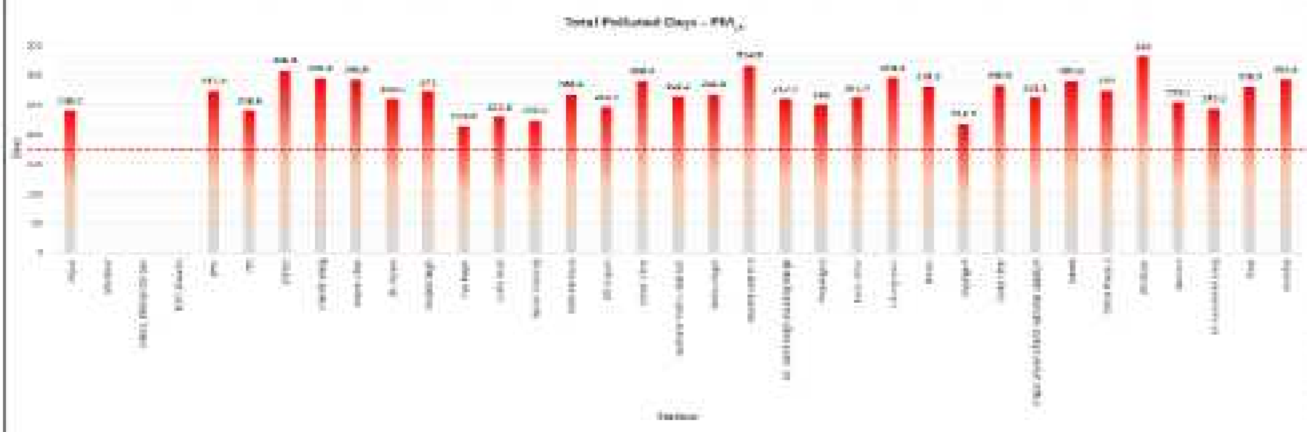


Figure 2??: No. of days PM_{10} concentration exceeds standard breakpoint for $PM_{2.5}$ and 100 µg/m3 breakpoint for PM_{10}.

Equivalent Polluted Days is equal to total hours where pollutant concentration is beyond 60 µg/m3 breakpoint for $PM_{2.5}$ and 100 µg/m3 breakpoint for PM_{10} divided by 24.

The case of Delhi is unique in the sense that it has both geographical and meteorological disadvantages.

Data shows that even during high conditions of higher mixing heights, Delhi observes higher pollutant concentration. The main region is the concentration and growing number of activities. Concentration of activities has huge influences on air pollutant concentration.

Even with revised fuel standards such as shifting of industries and vehicles to cleaner fuel, the situation of air pollution in Delhi would remain similar. The factors being

- increased population growth,
- increased number of activities,
- increased count of vehicles,
- increased demand for goods (transportation of goods)
- improper zoning of industries w.r.t air environment

Table 125: No. of polluted day ($PM_{2.5}$), Landuses and activities

Sno.	Monitoring Stations	No. of days $PM_{2.5}$ concentration exceeding standards	% Area under Landuses- (Industrial + Transportation)	% Area under Landuses- (Recreational+ Green belt+ Agriculture)	Remarks
1	Aya Nagar	164.5	7.6	54.1	
2	IGI Airport	165.5	91.4	0.0	Although landuse falls in transportation, but IGI has mostly green surfaces
3	Lodhi Road	173.4	9.2	20.2	"Landuse falls in PSP & Residential but have significant amount of trees "
4	Burari Crossing	174.5	11.1	55.1	More the % of greens, less is the no. of polluted days
5	RK Puram	178.5	9.2	19.7	Delhi Cantt. With significant greens lie in the direction from which the wind is blowing
6	Sri Aurobindo Marg	179.1	6.4	63.4	More the % of greens, less is the no. of polluted days
7	Dr. Karni Singh Shooting Range	183.6	0.0	96.0	
8	Jawharlal Nehru Stadium	186.5	7.0	22.6	Although landuse falls in PSP, but stadium has mostly green surfaces and less activities
9	Najafgarh	187.8	4.8	88.5	More the percentage of greens, less the no. of activities and lesser is the no. of polluted days
10	Pusa	189.2	26.9	48.3	
11	Major Dhyan Chand National Stadium	193.1	0.8	45.5	
12	Patparganj	193.2	17.7	5.5	Lies on the Yamuna bank with the river in the direction of wind implying no major activities except residential
13	Alipur	194	24.5	69.4	More the percentage of greens, less is the no. of polluted days
14	Okhla Phase 2	195.6	54.5	20.4	The area under recreation is high

Sno.	Monitoring Stations	No. of days $PM_{2.5}$ concentration exceeding standards	% Area under Landuses- (Industrial + Transportation)	% Area under Landuses- (Recreational+ Green belt+ Agriculture)	Remarks
15	Punjabi Bagh	196.9	29.8	19.8	The area above monitoring station mainly has greens, although is under transportation
16	Sirifort	202.8	5.7	27.5	More the percentage of greens, less is the no. of polluted days
17	Nehru Nagar	204.5	12.1	5.0	Less percentage of greens, more are other activities, causing more polluted days in a year
18	Vivek Vihar	206.4	24.7	9.6	
19	Sonia Vihar	207.2	6.4	28.3	Due to advection, the area would have more polluted days even though has more greens
20	CRRI Mathura	207.7	34.8	13.8	Less percentage of greens, more are other activities, causing more polluted days in a year
21	Dwarka Sector 8	209.9	25.7	26.3	The green land-uses which are located, are non-vegetative and exposed to soil dust
22	DTU	214.3	7.3	11.0	Less percentage of greens, more are other activities, causing more polluted days in a year
23	Mandir Marg	214.8	9.7	41.0	It has major roads with heavy traffic throughout the year.
24	ITO	215.4	9.6	19.0	Less percentage of greens, more are other activities, causing more polluted days in a year
25	Narela	217	86.6	2.4	
26	Mundka	218.4	26.2	8.8	
27	Ashok Vihar	220	18.4	21.7	
28	Rohini	226.7	9.3	11.5	
29	Anand Vihar	230.4	55.4	1.6	
30	Bawana	238.6	48.1	13.5	
31	IHBAS, Dilshad Garden	241.8	23.1	3.6	
32	Wazirpur	242.2	37.0	11.7	
33	Jahangirpuri	245	4.8	13.3	
34	Shadipur	247.4	28.3	24.0	The greens are in the opposite direction of the wind
35	NSIT Dwarka	265.3	8.9	3.7	Less percentage of greens, more are other activities, causing more polluted days in a year
36	EAST ARJUN NAGAR		7.6	0.2	Data not available
37	NORTH CAMPUS		28.9	4.1	

It is quite evident from the above table how activities and land uses affect the number of days the air is polluted at each station. Mostly all the areas which have more 40 % land use under greens have considerably less no. of polluted days when compared to the areas with more no. of polluted days. Those stations (with less polluting days) which doesn't show correlation directly with land-uses have significant number of trees or green cover. Some stations continue to show high number of polluted days even if the greens are more than 20 %, it is because either the greens are in the opposite direction of the wind or lies in the major traffic junctions. Rest all shows how with the decrease in greens or increase in activity rate effects the no. of polluting days.

Landuse Planning and Air Quality

Land use planning is a process through which government agencies assess current physical, social, and economic conditions within an area, project future trends based on this information, and consider strategies and alternatives for developing land that meet the needs of the community at large. Part of the planning process involves making decisions about the physical characteristics and layout of development in a metropolitan area, including development of transportation infrastructure, and building design and orientation.

Land use planning involves consideration of a multitude of community concerns, including environmental concerns such as air quality.

To understand the severity of air quality in Delhi we shall answer to some of the important questions.

What is the concern about air quality and transportation in Delhi?

Transportation sources are significant contributors to emissions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx), the two major air pollutants related to smog. Transportation sources also contribute to the other criteria pollutants that EPA regulates.

Has air pollution from transportation sources improved?

In general, yes. Much has been done to reduce emissions of air pollutants from cars and trucks over the last 25 years. These efforts have focused on the use of technology and tailpipe controls and have been quite successful at reducing the emissions of criteria air pollutants from transportation sources. When compared to passenger cars in 1970, a vehicle today emits 60 to 90 percent less air pollution over its lifetime due to EPA's vehicle emissions standards.

However, although EPA's emissions standards and the improved emissions control technology used to meet them are expected to continue to positively affect air quality, the number of kilometers being driven are expected to continue to increase.

This increase in vehicle kilometers travelled (VKT) can be attributed to a number of changes in travel behavior. Since 2008, the number of cars and trucks in Delhi has more than quadrupled while the population in Delhi has less than doubled. People are taking more local trips and more long-distance trips, and the trips are, on average, longer than they were 20 years ago.

The majority of this travel activity occurs in personal automobiles. In many communities, alternative modes of transportation, such as transit and the infrastructure needed to make biking and walking safe and convenient, may be scarcely available, thus limiting personal transportation choices. Also, given average trip lengths of nearly 10 Kms, walking and biking options are, in many cases, not viable.

For the many areas of the country that are working hard to improve air quality, these trends toward more cars on the road, people driving more often, and increased trip lengths may offset the benefits gained from cleaner vehicles. To combat these trends, state and local government agencies seeking to reduce emissions from cars are increasingly looking not just at technological solutions, but at strategies to reduce driving. One such strategy is to explore ways to develop land within communities that will increase transportation options and provide people with more choices to use of alternative modes of travel and drive less.

What is the air quality planning process?

There is no mandate as of now in India where the state and urban local bodies are required to prepare air quality plans (also considered as State Implementation Plans, or SIPs in U.S.). The Source Apportionment Studies and Emission Inventories are prepared on need basis. The reports however do not follow a standard procedure such as maintaining a standard area of study and scale of study and type of land uses considered. The Source Apportionment Studies estimates future air quality and describes in detail a city's plans to achieve air quality goals.

Graded Response Action Plan (GRAP) was prepared by the Ministry of Environment, Forests & Climate Change (MoEFCC) after the order of Supreme Court of December 2016. GRAP includes the measures which will be taken by different government agencies to prevent worsening of Air Quality of Delhi-NCR (National Capital Region) and prevent $PM_{2.5}$ and PM_{10} levels to go beyond 'moderate' national Air Quality Index (AQI) category. The EPCA is mandated to enforce the Graded Response Action Plan (GRAP) in the city as per the pollution levels.

The approved Source Apportionment study and Graded Response Action Plan (GRAP) serves as the city's commitment to actions that will reduce air quality problems.

The Pollution Control Board conducts source apportionment studies with support from agencies or universities having technological advantages and capabilities with input from the metropolitan planning organizations, industrial pollution sources operating in the state, and members of the public.

At present there are only a few Indian cities (non-attainment) where source apportionment studies and emission inventories have been conducted. The importance of these reports are the control strategies and maintenance plans. The source apportionment studies provide an initial forecast of the city's future emissions i.e., emissions in the year(s) addressed by the source apportionment study that will result if no additional control strategies are implemented other than what is required by law. The source apportionment study also describes action plans or programs (control strategies) that will be used to achieve the needed emission reductions in the area and calculate future emissions that result when the control strategies are considered. The non-attainment city(s) must adopt enough control strategies to show that it:

a. meets the standards in the future attainment year or

b. continues to meet the standard after attainment is reached.

The Source Apportionment Study done in India is somewhat similar to the State Implementation Plans (SIPs) prepared in U.S. but lack the important ingredient such as impact of land use and transportation planning. The source apportionment studies only rely on emissions directly reflected by land uses and does not highlight the efficiency of land uses or urban forms. The Master Plan of Delhi does not provide any study as such of implications of land uses on air quality. The study should be focused on micro-level(zonal) analysis to meso-level(regional). The source apportionment studies do not mention the total allowable emissions in a control strategy i.e., the amount of emissions the area can have and still achieve the air quality goals (National Ambient Air Quality Standards).

The State Implementation Plans (SIPs) prepared in U.S. accounts for the total allowable emissions in their control strategy measures. The portion of the total allowable emissions that is allocated to highway and transit vehicle use is called the motor vehicle emissions budget, referred to as "the budget." The SIPs described as -- 15% plans, rate-of-progress plans, attainment demonstrations, and maintenance plans -almost always contain these budgets. Motor vehicle emissions must stay within these budgets.

Who gets involved in the air quality planning process?

State Pollution Control Board, and in some cases, local air quality planning agencies, are responsible for creating and monitoring progress of the Source Apportionment Study. State and local air quality planning agencies, and other organizations who are responsible for developing, submitting, or implementing provisions of a source apportionment study works in isolation from other State and local air quality planning agencies which can be observed by the degree of changes in procedures of carrying out source apportionment studies. In India, the agency responsible for the preparation of source apportionment studies and preparation of emission inventory work solely in their own capacity to model and assess the impacts of emissions from various land uses. The report is later published with approval from State or Local Pollution Control Board. There is no process of review and public opinion in the preparation of source apportionment studies and control strategies suggested there within.

On the other hand, in foreign nations (SIPs developed in U.S. and other countries), air quality agencies and transportation planning agencies work together to model and assess the transportation network's impact on emissions from automobiles. In addition, citizens are allowed to review and comment on the proposed plan.

What is the transportation planning process?

The transportation plan is a long-term plan for maintenance and improvement of the area's transportation system. The plan must address at least a twenty-year planning horizon.

Two Plans have been prepared so far i.e. Transport Demand Forecast Study and Development of an Integrated Road cum Multi-Modal Public Transport Network for NCT of Delhi by RITES, April 2010 & Functional Plan on Transport for National Capital Region – 2032 by NCR Planning Board. Both the reports acknowledge the traffic data from year 2008. However, the situation in Delhi has drastically changed over the years and with increase in number of vehicles, changes in land uses the vehicle kilometers travelled (VKT) have changed. The figures are outdated and therefore should not be accounted in newer studies. No recent studies have been found to support the viability of air quality studies (source apportionment studies) w.r.t transportation.

Metropolitan planning Authorities (MPAs) are responsible for transportation planning, specifically the creation of the area's long-range transportation plan (or called as Comprehensive Mobility Plan) and its shorter-term transportation improvement program (TIP).

There are no studies which shows that the area's planned transportation activities are consistent with (or "conform" to) the purpose of the Source Apportionment Studies in nonattainment cities; this process is also known as the transportation conformity determination process (as mentioned in SIP).

The transportation conformity determination process links transportation and air quality planning. The transportation conformity process is designed to make sure that new investments in transportation infrastructure do not worsen air quality or interfere with the "purpose" of the source apportionment studies. The Comprehensive Mobility Plan and TIP must result in emissions consistent with those allowed in the source apportionment studies, which clearly has no mention in Indian cities.

To demonstrate that the transportation plans are in conformity, the MPA must show that the area's future emissions from highway and transit transportation activities meet the motor vehicle emissions budgets in the source apportionment studies.

As of today, such comprehensive study has not been conducted in Delhi where one can say the conformity of transportation network with already existed source apportionment studies.

How are the air quality and transportation planning processes linked?

In the past, transportation plans were developed independently of the air quality planning process and were not required to consider the effects of transportation activities on air quality. Similarly, source apportionment studies prepared by State Pollution Control Boards/ Agencies often failed to consider the feasibility of their plans with respect to the development of transportation infrastructure. Air quality specialists cannot guarantee a continuing reduction in motor vehicle related pollutants if vehicle miles traveled continue to grow, and transportation specialists cannot improve mobility if the emissions budget for an area is created without regard to air quality impacts. The transportation conformity process ensures the integration of the air quality and transportation planning processes to ensure consistency between the emissions resulting from highway and transit transportation projects and the motor vehicle emissions budget in the

Source Apportionment Study.

What is the relationship between land use, transportation, and air quality?

The physical characteristics and patterns of land development in a region, also known as the urban form, can affect air quality by influencing the travel mode choices citizens have available to them. Certain types of urban form necessitate the use of personal cars and trucks for travel. For example, when jobs and housing are far away from each other, and mass transit is not available, people are dependent on cars for daily travel. Urban forms that make automobile travel a necessity can contribute to air quality problems.

However, other options for urban form do exist. For example, development patterns that locate jobs, housing and recreation in closer proximity to each other, can mean shorter and fewer car and truck trips, thus reducing vehicle kilometers traveled (VKT) and likely reducing motor vehicle emissions. Other development patterns have the potential to improve or mitigate air quality problems by providing and promoting alternatives to vehicular travel, such as mass transit, walking, or biking.

In what ways does urban form impact travel activity?

Numerous studies have been conducted over the years to explore the connection between urban form and travel activity, and the weight of the empirical evidence suggests that characteristics of urban form can be important factors in reducing VKT and emissions. In a 1998 review of literature on the link between urban form and travel behavior, Apogee/ Hagler Bailly concluded that urban form can have a discernible effect on travel behavior. The authors found that, based on both empirical studies and simulation (modeled) studies conducted primarily in the early to mid-1990's, evidence exists to suggest that changing the current patterns of development (generally low density, single use, and auto-oriented) can reduce vehicle travel and, hence, air pollutant emissions from vehicles. According to the authors, "even though changes in urban form may take years to occur, the best regional transportation models suggest that altering urban form can affect travel and emissions measurably within a time frame of 10 to 20 years." In the report, the authors note that there are a number of urban form features that can affect travel activity, the most significant of which are:

- Density,
- Land use mix,
- Transit accessibility,
- Pedestrian-environment/ urban design factors, and
- Regional patterns of development.

Five characteristics of urban form that influence travel and air quality

Density

- Refers to the compactness of a neighborhood, a development, or a region
- Can reduce vehicle travel by reducing the distances that people have to drive, reducing the necessity of owning a vehicle, and increasing the viability of using other modes of travel such as walking or biking
- Higher density development also makes mass transit more economically feasible for the
- public sector

Land Use Mix

- Refers to incorporating different land uses (e.g., recreation, housing, employment, shopping) within a development, a neighborhood, or a region
- Can lead to shorter trip distances and greater use of walking, as well as a reduced need for vehicle ownership
- Can reduce required commute distances

Transit Accessibility

- Refers to locating high-density commercial and residential development around transit stations; also known as "transit-oriented development," or TOD
- Can increase the market for such services, increase ridership, and decrease auto use
- Can lead to decreased auto ownership

Pedestrian-Environment/Urban Design Factors

- Refers to features that improve the pedestrian environment such as sidewalks, clearly marked crosswalks, shade trees, benches, and landscaping; also refers to features that

improve the bicycling environment such as bike paths and dedicated bike lanes, bike parking and clear signs
- Can reduce driving by increasing the desirability of walking and biking
- Can lead to decreased auto ownership

Regional Patterns of Development
- Refers to patterns of dispersion, centralization or clustering of activities within a metropolitan area, as well as to the relationship of development to highway and transit systems; involves the interrelationships between employment and residential development and the transportation connection between sets of origin and destination points
- Can reduce driving by locating trip origins and destinations closer together
- Can encourage transit use and reduce vehicle trip making by concentrating development around transit networks and clustering development

Among other findings, Apogee/Hagler Bailly concluded that the weight of the evidence suggests that:
- Trip lengths can be reduced when compact development and integration of land uses occurs, even where automobiles are the dominant mode of transportation;
- Increased accessibility to multiple uses reduces average trip lengths;
- Urban form can have a measurable impact on the desirability of using different modes of transportation;
- Rates of vehicle ownership are lower in places where personal vehicles are not required for personal mobility, even when income/economic factors are considered;
- Accessibility to a variety of trip purposes, as in mixed use developments, may induce additional trips; however, these trips are shorter and are more likely to be made by walking than trips in areas where mixed land uses are not available; and
- Synergies between different land use factors can be important in influencing travel behavior and changing one single factor may not be enough to change travel behavior.

All of these considerations suggest that decisions about urban form have the potential to influence such problems as traffic congestion, sprawl, air pollution, and other environmental and social conditions that are important to communities.

Numerous studies have attempted to quantify the impacts of urban form on VKT and emissions. It is important to note that due to the many variations between communities, locations, and project characteristics, it is not possible to provide a simplified table of emissions reductions. Each land use activity should be examined individually to assess the impact it may have on VKT and emissions.

How can urban form be changed to improve air quality?

Communities make decisions about how best to direct future growth as part of their land use planning process. Across the country, an increasing number of communities are spreading further and further away from urban cores into low-density, car-dependent communities with housing, employment, shopping and recreation in separate locations. This suburbanization development pattern, sometimes referred to as sprawl, has been linked to a variety of community concerns, such as loss of open space, air and water pollution, fractured neighborhoods and traffic congestion.

Some communities are beginning to consider ways to accommodate future growth that take into consideration not just economic concerns, but environmental and quality of life concerns as well. As described previously, strategies for land development that encourage higher densities, a mixture of land uses, greater accessibility to transit, development of pedestrian/ bicycle infrastructure, and consideration of broader regional development patterns can slow or curb the potentially adverse effect that sprawl can have on air quality. Some examples of land use strategies include:

- Transit-oriented development (TOD): encouraging transit travel by developing moderate to high-density housing, shopping, and employment centers along a regional transit system, with pedestrian access.
- Infill development: encouraging pedestrian and transit travel by locating new development in already developed areas, so that activities are closer together.
- Brownfield redevelopment: remediation and redevelopment of under-utilized or abandoned lands, usually in already developed areas, that have been contaminated during previous use.
- Mixed-use development: development that locates complementary land uses such as housing, retail, office, services, and public facilities within walking distance of each other.
- Neo-traditional design/ pedestrian-oriented development: creating a combination of land development and urban design elements with the purpose of creating pedestrian oriented neighborhoods.
- Developing concentrated activity centers: encouraging pedestrian and transit travel by creating "nodes" of high-density mixed development, that can be more easily linked by a transit network.
- Strengthening downtowns: encouraging pedestrian and transit travel by making central business districts concentrated activity centers that can be the focal point for a regional transit system.
- Jobs/housing balance: reducing the disparity between the number of residences and the number of employment opportunities available within a sub-region by directing employment developments to areas with housing, and vice versa.

Note that this is not an exhaustive list; other possible strategies exist and are being considered in various communities around the country.

These kinds of land development strategies are often characterized as "smart growth" strategies. The term "smart growth" has been used by a variety of groups, and many people interpret its meaning in different ways. In some states and municipalities, existing policies and regulations make smart growth strategies impossible to achieve or discourage their implementation. Changes to existing policies or creation of new policies may be necessary to make smart growth possible.

What kinds of actions are needed to make "smart growth" strategies achievable?

There are many actions that all levels of government can take to encourage land use strategies that promote alternatives to single occupancy vehicle travel. Some of these are discussed below.

At the local level, actions generally fall into three categories: regulations such as zoning and subdivision regulations, monetary incentives, and non-monetary incentives.

Zoning

Zoning can be used to allow or require mixed use development. Special districts can be designated where development must meet specific requirements for mixing of housing, employment, shopping and public services. Local governments can also use zoning to increase density levels in downtown areas or in areas surrounding transit stations. Other zoning policies such as fine grain zoning (replacing large single use areas with smaller zones that can accommodate a mix of uses) and over-lay zoning (adding a second use to an already-zoned area), as well as standards for street design (requiring narrower, better connected streets with sidewalks, bicycle lanes, and bus stops) provide local governments with the regulatory means to redirect urban form in their communities.

Monetary incentives

Another way that local governments can implement smart growth strategies is to give tax breaks to developers who build in desired locations. For example, local governments can encourage employers to locate near existing housing areas and near transit routes by offering tax incentives. In cities where developers are required to pay impact fees (fees to pay for additional infrastructure needs that the new development generates), local governments can set those fees higher in outlying areas than in existing urban cores, thus potentially making urban development more economically feasible for the developer. Local and state governments can also partner with financial institutions to provide financial incentives to home buyers (such as reduced rate mortgages or financial credits toward home purchases), to encourage them to live closer to their employers or closer to transit.

Non-monetary incentives

Local governments can also provide non-monetary incentives, such as accelerated permit processing or reduced parking requirements to encourage developers to use smart growth principles.

The combination of several local regulatory- and incentive-based programs may increase the likelihood that development will occur in desired areas.

While these state-level activities do not directly alter local planning and decision-making processes, they can indirectly encourage urban form patterns that decrease automobile use. In addition to these strategies, which encourage development in urban cores and discourage development at the urban fringe, many states and local communities are reexamining existing policies and funding practices to make sure that they aren't inadvertently encouraging development in untargeted areas. Examples include limiting access to new highways and bypasses and limiting state funding for infrastructure improvements outside of designated growth areas. Some states have designated growth boundaries, outside of which the state will not fund infrastructure improvements needed to support development. Other states have implemented policies such as purchasing development rights on rural lands to ensure that they remain undeveloped.

POLICY AND TECHNICAL CONSIDERATIONS - ACCOUNTING FOR THE AIR QUALITY BENEFITS OF LAND USE ACTIVITIES

Land use activities are actions initiated by local, regional or state governments, individuals, organizations, and developers that change urban form in ways that may decrease the use of motor vehicles and encourage alternative modes of transportation. Where these land use activities can be shown to reduce emissions from motor vehicles, they may be accounted for in the air quality and transportation planning processes.

Land use activities may be policies or projects.

Specific policies that do have the force of law and therefore could be considered for air quality accounting include zoning ordinances, subdivision regulations, parking codes, and development standards. These policies are generally adopted by local governments. Other specific policies may be incentive programs, which require voluntary participation by developers or citizens. Specific Projects are generally site-specific, and usually occur on a relatively small scale, although large-scale developments, such as master planned communities, do occur. Usually, land use projects are initiated by private sector actions; however, partnerships and initiatives between government agencies, public advocacy organizations, and developers are often the catalyst for such development projects.

Some projects can be accounted for in air quality and transportation planning processes if their emission benefits can be quantified. Note that supporting transportation elements of land use developments, such as the addition of transit lines and stops in the area, may be accounted for as transportation control measures.

How are land use activities incorporated into the air quality and transportation processes?

Land use activities are incorporated into the air quality and transportation processes by modeling the emission reduction impacts of land use activities. The way land is developed–how residences, jobs, shopping, recreation, and other destinations are situated within an area–can impact the length and number of vehicle trips, as well as the speed at which they occur. Therefore, land use patterns can have an effect on travel activity and emissions.

To calculate the amount of pollution from motor vehicles, planners consider the ways that land will be used in the future and how the future transportation network will support those uses. In general, there are three steps to this process:

- Establish land use planning assumptions (Proposed Master Plan),
- Conduct travel demand forecasting, and
- Perform emissions modeling.

Firstly, to establish the land use planning assumption, the proposed land use plan for Delhi have been provided in Delhi Master Plan 2021 and the new Master Plan of Delhi for year 2042 is on way. No existing land use plan of Delhi exist and thus makes it hard to provide a comprehensive assessment and ground truth reality of its implications on air quality.
Second, Travel demand forecasting is a process where transportation planners predict expected travel activity throughout a region.

First, an area is divided up into travel analysis zones, from which trips originate and to which trips are destined. The amount of population, households and employment forecasted for a zone will affect how much travel will occur in and between zones. Employment is used to represent not only work activities, but also shopping, lunch and other types of trips. Then, the model performs the following 4 steps:

- Trip Generation: The trip generation step uses the land use assumptions to estimate the number of trip ends (productions and attractions) for each zone. The trips are generated by trip type, such as "home-based work," "home-based other" or "non-home based."
- Trip Distribution: The trip distribution step links the productions with the attractions. Demand for travel between two zones is related to the number of trips in and out of the zone, and the amount of impedance (i.e., the effect of time, distance, and/or cost on travel activity).
- Modal Choice: In some areas, the travel demand model also produces estimates of trips by mode (e.g., highway, transit, or other modes). Mode choice models may take into consideration factors such as demographic group, cost, trip purpose, and relative travel times.
- Trip Assignment: Trip assignment involves assigning vehicle trips to specific links of the travel network. Travel demand models also estimate the speeds that vehicles travel, based on how congested the road network is.

This process generates VKT and speed data that is directly used to estimate motor vehicle emissions.

The whole process of Travel Demand Forecasting is currently not available for Delhi NCR (latest dataset) and thus the air quality assessment lies incomplete and so is source apportionment study.

The last step in the process is to model the emissions produced. Emission rate models are used to estimate emissions for the area, taking into consideration factors such as the mix of vehicles types, temperature, etc. These rates are then applied to the VKT and speed estimates from the travel demand model to calculate motor vehicle emissions rates.
As of now, there is no report which shows the relationship between land use, travel demand and emission produced. The Master Plan of Delhi, 2021 states the projected growth of vehicles and modal share over the years based on 2008 data. The severity of air quality as per the reports published by CPCB have been acknowledged in the Master Plan but no further details have been provided as to how the proposed land use plans and existing transportation network would impact the air quality.

INCLUDING A LAND USE ACTIVITY AS A CONTROL STRATEGY IN THE SOURCE APPORTIONMENT STUDIES

What is a control strategy?

A control strategy is a policy, program, or project used by a non-attainment city to reduce ambient air pollution levels in order achieve National Ambient Air Quality Standards, demonstrating reasonable progress towards attainment, or maintaining the standards. Control strategies are listed and described in the source apportionment studies. Collectively, all of the control strategies must reduce emissions enough to show attainment, maintenance, or further progress, depending on the type of action plans. Some examples of control strategies include use of clean fuels or advanced control technology to reduce emissions.

How can we account for land use activities as control strategies in Source Apportionment Study?

There are three ways that land use activities can be accounted for as control strategies in the source apportionment study.

A specific land use activity that can be shown to have air quality benefits can be considered a control strategy in a source apportionment study if certain requirements, outlined in the Air Act, are met. These control strategies are also known as "traditional control strategies".

In addition, EPA has developed two specific policies that address innovative, voluntary control measures, which may also be applicable when accounting for land use activities as control strategies in a source apportionment study. They are:

- Voluntary Mobile Source Emission Reduction Program policy (VMEP policy), and
- Economic Incentive Programs policy (EIP policy).

What are traditional control strategies?

Traditional control strategies are control strategies that can be shown to have air quality benefits and meet certain requirements outlined in the Air Act. Land use activities that meet the existing statutory requirements of the Air Act can be accounted for as traditional control strategies.

The traditional control strategies would mean moderation of existing land uses which in some way would be tough to enforce and might not be adequately supported by the Urban Local Bodies. This also means transforming the area permanently and as such needs a high-risk evaluation.

What is the voluntary mobile source emission reduction program (VMEP) policy?

The Voluntary Mobile Source Emissions Reduction Programs policy, also known as the VMEP guidance or the "voluntary measures policy", was developed to allow states to account for the benefits of voluntary mobile source measures. These are measures that rely on the voluntary actions of businesses or individuals to achieve emissions reductions. According to the policy, "Voluntary mobile source measures have the potential to contribute, in a cost-effective manner, emissions reductions needed for progress toward attainment and maintenance of the National Ambient Air Quality Standards (NAAQS). The control measures suggested in the Source Apportionment Studies are in line with the voluntary mobile source measures. Some examples of voluntary measures, or VMEPs, include economic and market-based incentive programs, trip reduction programs, and growth management strategies.

The common thread among all VMEPs is that, for these measures to be successful, voluntary participation of businesses and citizens is necessary. In other words, VMEPs are not required, and state and local governments do not have the authority to make participants take action.

Therefore, under the VMEP policy, the definition of enforceable for voluntary measures is different than for traditional control strategies. Voluntary measures that are included in source apportionment studies are not enforceable against the source; rather, the state/city is responsible for ensuring that the emission reductions accounted for in the source apportionment study do indeed occur. The state must make an enforceable commitment to monitor, assess and report on the emission reductions resulting from the voluntary measures and to remedy any shortfalls from forecasted emission reductions in a timely manner.

When should the governing authorities/ULBs use the VMEP policy to include a land use activity in Air Quality Improvement Plan?

For land use activities where the state or local government does not have the authority to enforce the activity, a state could not include a land use activity as a traditional control strategy because they would not be able to meet the enforceability requirements stipulated in the Air Act. In these cases, the State and Local Pollution Control Boards may wish to account for the air quality benefits of the activity under the VMEP policy.

The VMEP policy allows for more innovation than most other programs. It is the appropriate policy to use for many newer programs that do not have well established quantification methodologies. In addition, by not requiring that the state directly enforce against a party implementing a measure, businesses and individuals may be more willing to try newer policies and programs.

Due to the innovative nature of voluntary measures, issues in quantifying them, and the inability to enforce these measures against individual sources, the VMEP measures are not 100 percent achievable and thus can only be accounted for 40-50 percent emission reduction. EPA has set a limit on the amount of emission reductions allowed under the VMEP policy in air quality improvement plan. This limit is set at three percent (3%) of the total emission reductions needed to reach attainment.

What are the Economic Incentive Programs (EIP) policy?

The Economic Incentive Programs (EIP) policy is a regulatory program designed to encourage the use of market-based incentives or information to reduce emissions. The purpose of the EIP policy is to provide flexibility in how sources meet their emission reductions targets and empowers sources to find the most suitable and cost-effective means of meeting the goals of attainment or maintenance. The policy covers stationary, area, and mobile source emissions.

The EIP guidance document, "Guidance on Economic Incentive Programs for Air Quality, "provides specific details on how to ensure that incentive programs meet the Air Act criteria of quantifiable, enforceable, surplus, permanent, and adequately supported as listed in the traditional control strategy.

The guidance describes four categories of EIPs: financial mechanisms, public information programs, clean air investment funds, and trading programs. At this time, financial mechanisms and public information programs are most applicable to including land use activities as EIPs in control measure suggested by source apportionment studies.

An example of a land use activity that could be a financial mechanism EIP might be a program

that offers some type of monetary reward or incentive to developers. This incentive could be in many forms, including tax breaks, grants for brownfield redevelopment, or a flexible development fee structure. Alternatively, incentives could also be offered to home buyers or companies moving into areas where development is desired. These monetary incentives could be offered by local, state, regional government agencies, or perhaps even by non-governmental agencies.
A public information program, such as a labeling program to designate environmentally sound or "smart growth" developments as being supported by the state could also be a land use EIP.

The EIP requires three main components.

- The EIP submittal includes fully adopted contingency measures and contains a state commitment to automatically implement contingency measures, if necessary;
- The state will only count emission reductions on a retrospective basis; or
- The state has used the control strategy in a similar situation, has achieved positive results, and gets preliminary approval from EPA to use the provision.

What steps are necessary for quantifying land use activities as traditional, VMEP, or EIP control strategies?

There are five general steps to follow in order to quantify land use activities in a control measure. They are:

1. Completely describe the land use activity.
2. Describe how employment and housing and other infrastructure are affected by the activity.
3. Describe how the travel activity effects arising from the land use activity.
4. Determine the emissions reduction associated with the travel activity effects.
5. Demonstrate that the emissions reductions are surplus.

The above-mentioned processes are time taking and would require a year to fully develop the model. At present, studies in these regards are limited and researchers have floated their observations with due limitations. Therefore, a brief study needs to be carried out in order to fully determine land use as control measures.
Various control measures floated in the Source Apportionment Studies of Delhi city have been implemented but so far no detail information exist on how far it has been carried out successfully and if such measures had any impact on improvement of air quality in Delhi.

What are transportation control measures?

Transportation control measures (TCMs) are adopted for the purpose of reducing emissions or concentration of air pollutants from transportation sources by reducing vehicle use, changing traffic flow, or mitigating congestion conditions. TCMs may be voluntary programs, incentives, regulatory programs, and/or market based/pricing programs. Note that, for the purposes of conformity, vehicle technology-based or fuel-based measures are not TCMs.
A land use project, such as a site-specific land use development, generally should not be considered a TCM. However, transportation aspects of specific land use projects such as transit stations or bike facilities can be considered TCMs.

Examples of TCMs that support land use activities:

- Parking management programs

• Area-wide ride-share incentives
• Improved public transit
• Bicycle and pedestrian measures
• Park-and-ride programs

By designating transportation components of a land use activity as TCMs, the local area provides additional evidence that the overall land use activity will actually occur. TCMs are supportive and complementary to land use activities.

Congestion relief can contribute to air quality improvements by reducing travel delays, engine idle time, and unproductive fuel consumption.
Various TCMs have been introduced in Delhi such as shifting of fuel from BS IV to BS VI as of 2020 and introducing park and ride programs, parking management programs. Efforts have been made to materialized the bicycle and pedestrian measures but so far it is out of ambit of Delhi city due to one factor or the another.
Shifting from personal vehicles to public transport and cleaner modes such as bicycles, electric vehicles, etc. will take time and need huge investment. The major flaw one can observe in Delhi city would be the location of household and distance to work place. The large distances between home and work places makes it easier to use personal vehicles and avoid public transport.
Freight traffic and movement of goods within city and passing through inter-city traffic affects the overall city mobility. Since the transportation of goods will grow with economic growth, the planning for the movement of goods needs to be given a much greater focus. The planning for freight movement should address the problem of intermixing of local and regional traffic.

The plan should assess the expected growth of freight by taking into consideration the past trends, extent of industrial and commercial activities distribution and storage facilities in the city, location of wholesale markets, direction of city growth etc. and indicate the need for relocation of wholesale markets and shifting of truck terminals at appropriate locations, preferably on the periphery of city.
The freight management plan should address issues regarding the location of distribution centers, mode of transport, time restrictions, air and noise pollution etc. For example, a regional distribution center can be located on the periphery of the city in conjunction with transport network infrastructure and a local distribution centers can be located suitable at a number of locations within the city preferably closer to commercial centers.

How will the time frame for implementing the land use activities affect chosen accounting option?
Areas that are designated non-attainment have a defined period of time to reach their air quality goals. For example, in a region that has been experiencing considerable sprawl-type development over many years, land use policy actions to encourage high density, mixed use development in existing urban cores may take 10 to 20 years to have a significant impact on development trends and emissions from motor vehicle travel. Many areas may include control strategies in Air Quality Improvement Plan, without explicitly accounting for emissions benefits from them,as measures that will assist in meeting or maintaining air quality standards. To do so

may allow governing authorities/ULBs to highlight land use activities and help ensure that the control strategies are supported by all levels of government.

In cases where land use activities are not expected to achieve emissions reductions within the time frame, but are expected to achieve emissions reductions in the future, these land use activities could be included in a future maintenance/improvement plan. The maintenance period is 20 years, covered by two ten-year maintenance plans (the second is submitted eight years after the first). Alternatively, one may choose to take account of the land use activity in a conformity determination, which involves a planning horizon of at least 20 years (Master Plan – 20years; Comprehensive Mobility Plan – 20 years).

While many policy decisions take long periods of time to yield emission reductions, specific projects initiated by private developers and financial institutions may occur more rapidly. For example, numerous developers are building housing communities, office complexes, and shopping centers which build in principles such as high density, orientation near public transit, reducing the number of parking spaces, and designing streets and buildings to encourage walking. These specific projects may yield localized emission benefits in a shorter time frame than regional policies. Projects that are large scale or that are constructed in phases would take a longer time to show benefits.

A combination of short-term localized projects and longer-term, regional policy, incentive, and education strategies is the best approach to creating significant benefits.

What other important issues should the governing authorities/ULBs be aware of in quantifying air quality benefits?

There are a number of additional issues the governing authorities/ULBs should consider when quantifying the air quality benefits of land use policies and projects. These include:

- The synergistic or antagonistic interactions between policies and projects;
- Deciding whether to quantify the benefits of policies and projects individually, or with other policies and projects;
- Ensuring that the estimates are conservative enough, and the potential consequences of not being conservative; and
- The effect of the scale of project on the uncertainty associated with the estimate of emissions reductions.

Accounting for interactions between land use activities

Relationships between land use and travel are complex. Land use activities may interact with each other, either enhancing the emissions reductions they achieve, or in some cases diminishing the beneficial effects.

For example, microscale changes such as adding sidewalks and bike paths may not be enough by themselves to alter vehicle ownership or mode choice if the region is largely vehicle-oriented. A combination of actions, such as mixed-use development, increased access to transit, and pedestrian improvements, may yield more success in shifting travel activity from vehicles to other modes.

In addition, in areas where congestion is a current problem, increased density of development may yield increases in localized emissions.

It is important to consider the potential interactions of certain land use activities with other

control strategies, or with current conditions when quantifying the emission effects.
Quantifying land use activities individually or as a group

Calculating the emission benefits of land use control strategies together can result in fewer modeling steps. If we model several strategies together, we will need to calculate an initial forecast of future emissions without the land use activities and compare that to a calculation of the emissions with all of the land use activities included. Quantifying the effects of land use activities together will likely better capture the interactions and synergies produced by several land use policies or projects.

By determining the explicit amount of emissions reduced by a single land use activity, one can determine the air quality benefits of that control strategy and the cost effectiveness of pursuing it. This will allow us to compare several land use control strategy options in terms of emission reductions and cost effectiveness. In addition, by going through the process of calculating the benefits of the control strategy, we are likely to gain more insight into how the land use control strategy is working. Calculating a specific benefit for the control strategy can also help explain the effectiveness of the control strategy to the public. This can be particularly important if quantifying the control strategy's effectiveness is needed for it to be adopted.

Using conservative estimates

Modeling the air quality impacts of land use activities is an inherently uncertain process, and it is important that we are confident in the emissions benefits that we account for in Air Quality Improvement Plan or conformity determination. If we overestimate the emission reductions for land use activities, we ultimately may not meet the air quality standards. If a land use activity does not result in the expected emission benefits, the governing authorities/ULBs will have to find new reductions to make up the shortfall.

Taking into account the scale of the land use activity

Land use and transportation models are likely to more accurately predict the benefits of a land use project or land use policy when its impact is large in scale. For larger-scale projects, the law of averages will tend to even out outlying discrepancies, whereas smaller-scale projects will be more affected by individual variation. The governing authorities/ULBs need to be aware that for very small projects and policies, the inherent errors in the modeling can even be greater than the modeled emission benefits of the project. The scale of the project can therefore greatly impact the confidence levels of the modeling, and thus the amount of emissions reductions claimed.

Some examples of Land Use Strategies include:

- Concentrated activity centers: Encourage pedestrian and transit travel by creating "nodes" of high-density mixed development, that can be more easily linked by a transit network.
- Strong downtowns: Encourage pedestrian and transit travel by making the central business district a special kind of concentrated activity center, that can be the focal point for a regional transit system.
- Mixed-use development: Encourage pedestrian and transit travel by locating a variety of compatible land uses within walking distance of each other.
- Infill and densification: Encourage pedestrian and transit travel by locating new development

in already developed areas, so that activities are closer together.

- Increased density near transit stations: Encourage transit travel by increasing development density within walking distance (500 to 800 m) of high capacity transit stations and incorporate direct pedestrian access.
- Increased density near transit corridors: Encourage transit travel by increasing development density within walking distance (500 to 800 m) of a high capacity transit corridor.
- Pedestrian and bicycle facilities: Encourage pedestrian and bicycle travel by increasing sidewalks, paths, crosswalks, protection from fast vehicular traffic, pedestrian-activated traffic signals, and shading. Interconnected street network: Encourage pedestrian and bicycle travel by providing more direct routes between locations. Also, alleviate traffic congestion by providing multiple routes between origins and destinations.
- Strategic parking facilities: Encourage non-automobile modes of transit by limiting the parking supply and encourage carpooling by reserving parking close to buildings for carpools and vanpools.

Some examples of Land Use Polices include:

Encourage focused higher density by:

- Allowing transfer of unused development density capacity in outlying areas to permit development density above maximum limits near central areas and transit (zoning/ regulations and non-monetary incentives);
- Allowing increased density for residential, retail, and employment generating uses in central areas and around transit (zoning/regulations and non-monetary incentives);
- Setting minimum densities for residential, retail, and employment generating uses in central areas and around transit (zoning/regulations);
- Requiring no net decrease in residential density for redevelopment (zoning/regulations);
- Stating densities in terms of square feet of land per dwelling unit, rather than minimum lot size, to encourage clustering (zoning/regulations);
- Granting incentives (e.g., reduced parking requirements, accelerated permit processing, infrastructure upgrades) for development that focuses on existing urban areas and infill (nonmonetary incentives);
- Adjusting development impact fee structures or giving tax breaks to encourage infill and increased density development near transit and activity centers, and to discourage outlying development (monetary incentives).

Encourage mixed-use zones by:

- Allowing mixed use, which is now prohibited in many places (zoning/regulations);
- Requiring mixed uses, with certain percentages of residential, public, and commercial uses in target areas (zoning/regulations);
- Using fine-grained zoning to achieve mixed use while ensuring residential zones are buffered from heavy industrial zones with light industrial and commercial zones (zoning/ regulations);
- Using mixed-use overlay zoning, to add a second use to an area that is primarily in another use, e.g., commercial corridors along major arterials in a primarily residential area (zoning/ regulations);

- Granting incentives (e.g., reduced parking requirements, accelerated permit processing, infrastructure upgrades) for development that locates transit- or pedestrian-oriented amenities, like housing or child care near commercial uses and pedestrian-oriented design (non-monetary incentives);
- Adjusting development impact fee structures or giving tax breaks to encourage mixed use (monetary incentives).

Encourage pedestrian, bicycle, transit, and carpooling activity by:

- Requiring connected, narrower streets with trees and sidewalks in new development (zoning/regulations);
- Requiring bicycle lanes and transit stops on larger streets in new development (zoning/ regulations);
- Requiring traffic-calming devices in new development; e.g., textured paving at crossings, frequent intersections with pedestrian-activated traffic signals, and traffic circles (zoning/ regulations);
- Reducing requirements for setbacks and minimum lot sizes to create a stronger connection between buildings and sidewalks (zoning/regulations and non-monetary incentives);
- Requiring pedestrian scale signs in pedestrian- and transit-oriented areas (zoning/ regulations).

6.9. Air Quality During COVID-19 Pandemic Lock-down In Delhi

On 24 March 2020, the Government of India under Prime Minister Narendra Modi ordered a nationwide lock-down for 21 days, limiting movement of the entire 1.3 billion population of India as a preventive measure against the COVID-19 pandemic in India.[9] It was ordered after a 14-hour voluntary public curfew on 22 March, followed by enforcement of a series of regulations in the country's COVID-19 affected regions.[10] The lock-down was placed when the number of confirmed positive coronavirus cases in India was approximately 500. Observers stated that the lock-down had slowed the growth rate of the pandemic by 6 April to a rate of doubling every six days[11], and by 18 April, to a rate of doubling every eight days.[12]

As the end of the first lock-down period approached, state governments and other advisory committees recommended extending the lock-down.[13] The governments of Odisha and Punjab extended the state lockdowns to 1 May.[14] Maharashtra, Karnataka, West Bengal and Telangana followed suit.[15] On 14 April, Prime minister Narendra Modi extended the nationwide lock-down until 3 May, with a conditional relaxations after 20 April for the regions where the spread had been contained or was minimal.[16]

On 1 May, the Government of India extended the nationwide lock-down further by two weeks until 17 May. The Government divided all the districts into three zones based on the spread of the virus—green, red and orange—with relaxations applied accordingly.[17] On 17 May, the lock-down was further extended till 31 May by the National Disaster Management Authority.[18]

On 30 May, it was announced that the ongoing lock-down would be further extended till 30 June in containment zones, with services resuming in a phased manner starting from 8 June. It is termed as "Unlock 1".[19]

Table 128: Lock-down stages

Lock-down Stages	Number of days	Period	
		From	To
Janata Curfew	One day	Sunday, 22nd March, 2020	
Lock-down 1.0	21 days	24th March 2020	14th April 2020
Lock-down 2.0	19 days	15th April 2020	3rd May 2020
Lock-down 3.0	14 days	4th May 2020	17th May 2020

9 Gettleman, Jeffrey; Schultz, Kai (24 March 2020). "Modi Orders 3-Week Total Lock-down for All 1.3 Billion Indians". The New York Times. ISSN 0362-4331.

10 "COVID-19: Lock-down across India, in line with WHO guidance". UN News. 24 March 2020; Helen Regan; Esha Mitra; Swati Gupta. "India places millions under lock-down to fight coronavirus". CNN.

11 Sandhya Ramesh (14 April 2020). "R0 data shows India's coronavirus infection rate has slowed, gives lock-down a thumbs-up". The Print. Retrieved 2 May 2020.

12 Gupta, Shekhar (18 April 2020). "Covid hasn't gone viral in India yet, but some in the world & at home can't accept the truth". The Print. Retrieved 2 May 2020.

13 "Close schools, all religious activities, extend lock-down: States tell Centre". India Today. 7 April 2020.

14 Anuja (10 April 2020). "Taking cues from Odisha, Punjab extends lock-down till 1 May". Livemint. Retrieved 11 April 2020.

15 "Covid-19: Karnataka extends lock-down by 2 weeks, throws in some relaxations". HT Digital Streams Ltd. 11 April 2020. Retrieved 12 April 2020; "Coronavirus India Live Updates: Telangana follows Maha and West Bengal, extends lock-down till April 30". Bennett, Coleman & Co. Ltd. 12 April 2020. Retrieved 13 April 2020.

16 "PM Modi announces extension of lock-down till 3 May". Livemint. 14 April 2020.

17 "2 More Weeks of Lock-down Starting May 4". NDTV.com. Retrieved 1 May 2020.

18 "Centre extends nationwide lock-down till May 31, new guidelines issued". Tribuneindia News Service. 17 May 2020. Retrieved 17 May 2020.

19 Sharma, Neeta (30 May 2020). Ghosh, Deepshikha (ed.). ""Unlock1": Malls, Restaurants, Places Of Worship To Reopen June 8". NDTV. Retrieved 30 May 2020.

Lock-down Stages	Number of days	Period	
		From	To
Lock-down 4.0	14 days	18th May 2020	31st May 2020
Lock-down 5.0 / Unlock 1.0	30 days	1st June 2020	30th June 2020

6.9.1 Janata Curfew

The Janata Curfew (transl. People's curfew) was a 14-hour curfew on 22 March (from 7 a.m. to 9 p.m.). Everyone except people of 'essential services' such as police, medical services, media, home delivery professionals and firefighters were needed to take part in the curfew. At 5 p.m. that day, all citizens were asked to stand in their doorways, balconies or windows, and clap their hands or ring their bells in appreciation for the professionals delivering these essential services.[20] People belonging to National Cadet Corps and National Service Scheme were to enforce the curfew in the country. The Prime Minister also urged the youth to inform 10 others about Janata Curfew and encourage everyone to observe the curfew.[21]

Effect of Janata Curfew in Delhi

On the day of Janata Curfew, as a result of combination of reduced vehicles on the road, functioning of only essential commercial units and prevailing weather conditions, a significant reduction was noted for PM_{10} and NOx levels. On March 21, 2020, AQI was 'Moderate' in Delhi which gradually improved from higher to lower end of the category. Overall, up to 44% reduction in PM_{10} levels was observed in Delhi during March 22-23, 2020 compared to previous day. The $PM_{2.5}$ reduction was though 8% on the curfew day but declined to 34% next day owing to negligible combustion activities on March 22-23, 2020 in and around the city. The hourly data analysis reveals a consistent decrease in concentration values starting 10.00 am onwards on the day of Janata Curfew. PM_{10} and $PM_{2.5}$ levels dropped as low as 67 µg/m3 and 34µg/m3 at 05.00 pm.

The reduction in number of on-road vehicles, resulted in up to 51% reduction in NOx levels and 32% reduction in CO levels during March 22-23, 2020 as compared to March 21, 2020. The location specific data analysis reveals that maximum reductions of 48% for PM_{10} was observed at Mundaka & Alipur, 32% for $PM_{2.5}$ at Narela, 74% for NOx at Pusa and 67% for CO at Dwarka Sector 8 station. It is to be noted that Pusa and Dwarka are residential cum institutional sites with substantial traffic movements, thus sharp decline in NOx and CO levels further affirm that traffic restrictions were instrumental in improving air quality.

The graphs below depict hourly concentration trend for $PM_{2.5}$ and PM_{10}, for pre hours (00:00 Hrs to 06:00 Hrs) and curfew period (07:00 Hrs to 21:00 Hrs) for 21st (pre curfew), 22nd (curfew) and 23rd (post curfew) March 2020.

20. Delhi, March 19, India Today Web Desk New, March 19, India Today Web Desk New; Ist, India Today Web Desk New. "What is Janata Curfew: A curfew of the people, by the people, for the people to fight coronavirus". India Today. Retrieved 19 March 2020.
21. "PM Modi Speech on Coronavirus Highlights: Janata Curfew on Sunday, Avoid Panic Buying". News18. Retrieved 19 March 2020.

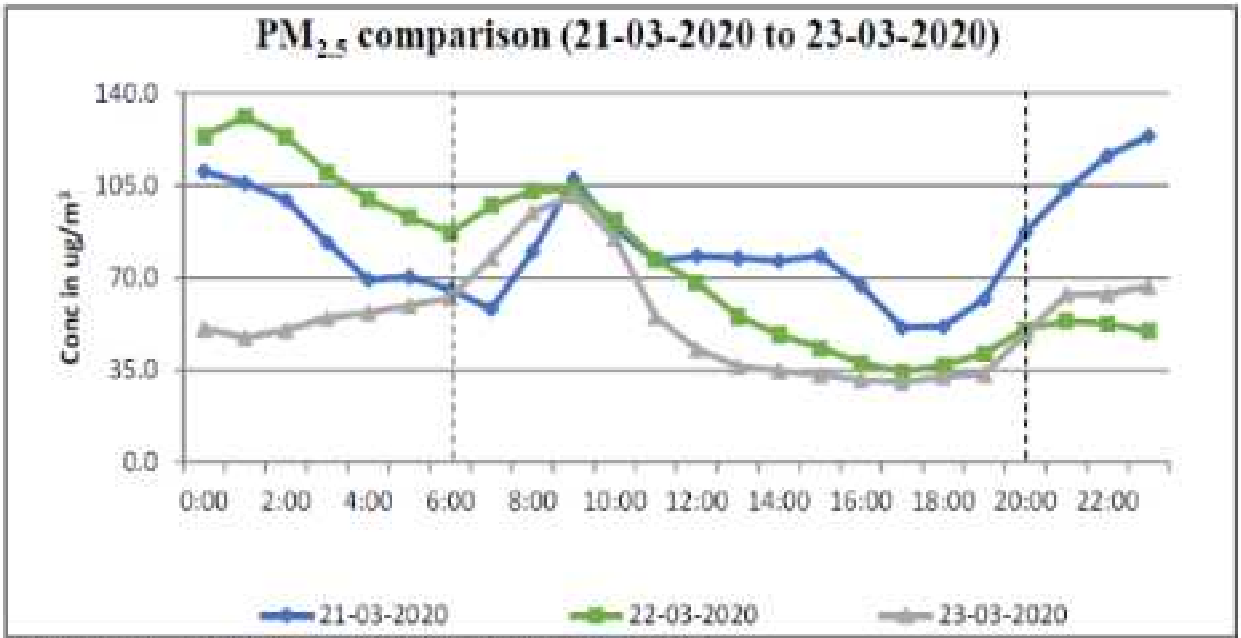


Figure 115: $PM_{2.5}$ Concentration comparison from 21st to 23rd March 2020

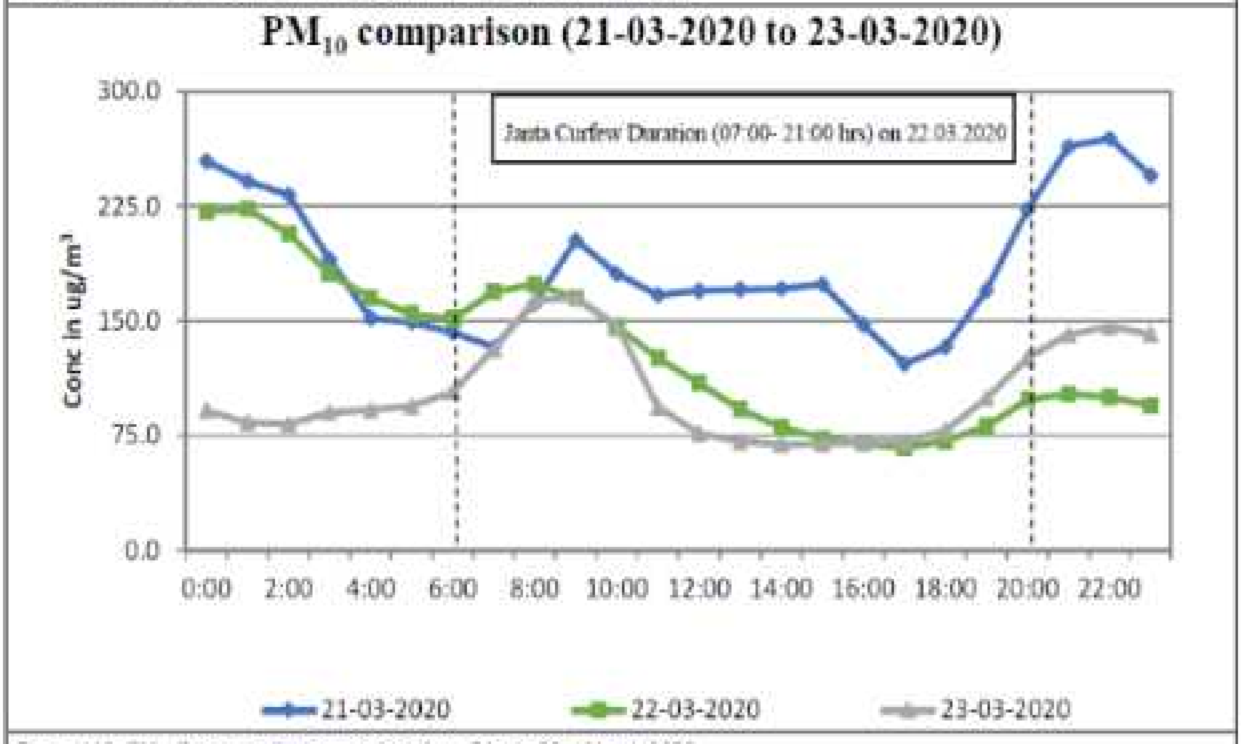


Figure 116: PM_{10} Concentration comparison from 21st to 23rd March 2020

The hourly comparison of average concentration values shows a clear declining trend in levels of PM_{10} and $PM_{2.5}$ during March 21-23, 2020. On March 21, 2020 the maximum value of PM_{10} was 269 µg/m3 at 22:00 Hrs, which dropped to 100 µg/m3 on March 22, 2020. Similarly, the lowest concentration observed on March 21, 2020 at 17:00 Hrs was 121.8 µg/m3, which dropped to 67 µg/m3 on March 22, 2020. The drop in coarse particles may be attributed to restriction on construction activities, less road dust resuspension and to some extent curb on industrial activities. A similar and clear decline was seen for $PM_{2.5}$ with concentration value falling from 130.9 µg/m3 at 01:00 Hrs (before start of curfew period) to a minimum value of 34.3 µg/m3 at 17:00 Hrs during curfew hours, further dropping to 30.4 µg/m3 on March 23, 2020. The absence of non-essential vehicles and combustion activities in industrial and commercial sites during the period is attributable to the decline.

It is important to mention here, the impact of meteorological factors was partially favourable, with mixing height of 2900m on March 22, 2020 higher than previous (2500m) and post curfew day (800m). Wind speed was slightly higher on March 22, 2020 (2.3m/s) as compared to post curfew day (1.5 m/s). The ventilation coefficient on day of curfew was 1856 m^2/s, thus the reduction in air pollution can be largely attributed to transport & commercial-industrial restrictions.

As reported in source apportionment study conducted by TERI & ARAI, 2018, during summers, dust & construction activities (35%), transport sector (20%) and industry (20%), are major source of $PM_{2.5}$ in Delhi. With regard to PM_{10}, dust & construction activities (43%), industry (20%) and transport (17%) are major contributing sources. As result of complete restrictions on non-essential vehicular movement and commercial activities, the emissions from construction activities and industries were stopped. The on-road vehicles were relatively sparse compared to normal days thus contribution from road dust resuspension & transport sector was much reduced. A broad analysis is attempted to explain the improved air pollution levels due to lock-down. Air quality monitoring data reveal that during lock-down period PM_{10} and $PM_{2.5}$ levels were reduced by about 35 to 40%, which may be explained as possible reduction from industries (~10%; considering continued operation of power plants with ~7 – 8% share, conversion of industries to natural gas, etc.), and transport (~15%; with essential service vehicles and a small part of fleet still plying on roads), and dust (~10-15%; with continued contribution due to soil and wind-blown dust because of high surface winds). There may be some reduction from other activities such as refuse burning, airport, etc. as well.

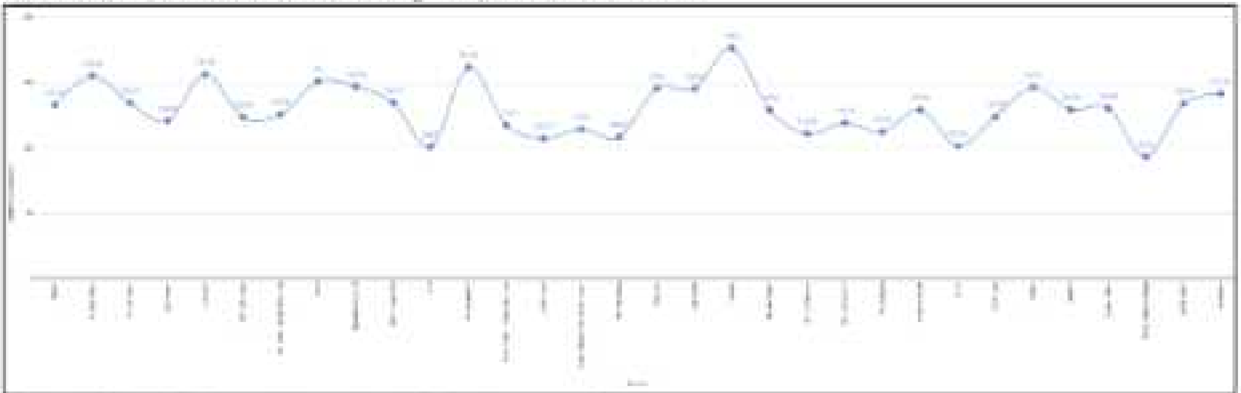


Figure 117: PM 2.5 Concentration on Janta Curfew day across Delhi

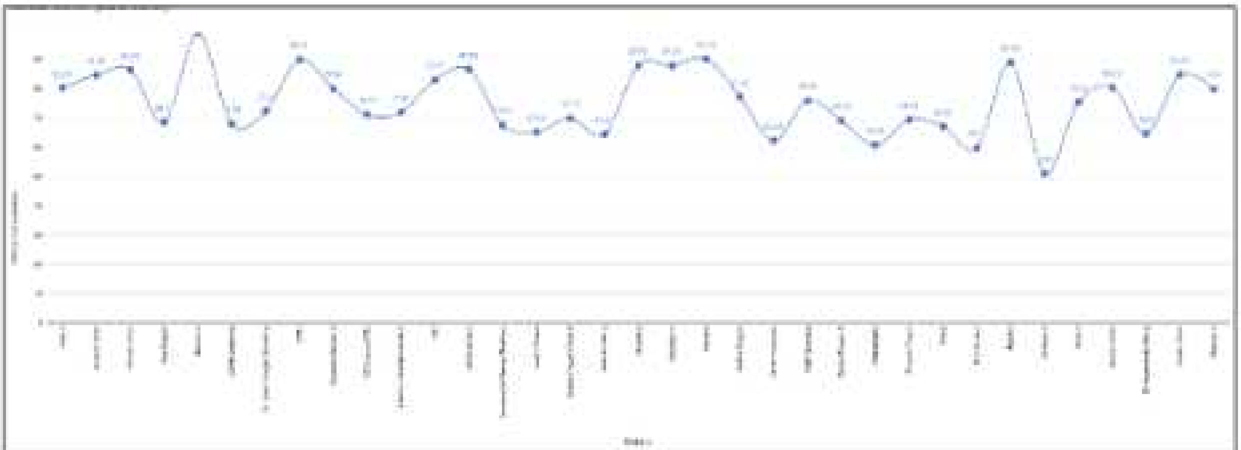


Figure 118: PM_{10} Concentration on Janta Curfew day across Delhi

6.9.2 EFFECT OF LOCKDOWN IN DELHI NCR

Substantial improvement in air quality of Delhi NCR is noted during the lock-down period, as the major contributing sources to PM & NOx emissions (prominent pollutants in Delhi NCR) have been restricted. The AQI in Delhi NCR was under 'moderate' category on March 23, 2020 at start of lock-down period, with exception of Gurugram which recorded AQI under 'Satisfactory' category.

Table 127: AQI of Delhi NCR from 23rd to 29th March, 2020 during Janta curfew and initial lock-down

Date	Surface Wind Speed (kmph)	Mixing Height (m)	Delhi	Faridabad	Gurugram	Ghaziabad	Noida
23.03.2020	10	800	124	130	91	159	123
24.03.2020	10	2700	122	187	127	166	130
25.03.2020	12	2500	77	100	69	86	80
26.03.2020	25	1100	92	88	61	84	72
27.03.2020	15	500	69	75	42	72	60
28.03.2020	14	2250	45	64	54	39	38
29.03.2020	20	2600	62	83	62	48	58

Source: Impact of Janata Curfew & Lock-down on Air Quality, 31st March, CPCB

As days progressed, under cumulated effect of restricted vehicle movement & commercial activities and increased mixing height, the AQI improved to 'Satisfactory' category. On March 26, 2020, high surface winds (25 kmph) maintained AQI category even though mixing height dropped to 1100 m. Next day, though wind speed and mixing height were reduced to half value, AQI value improved further and Gurugram recorded 'Good' AQI category. During March 28-29, 2020 as wind speed and mixing height increased, AQI value improved further, with Delhi, Ghaziabad and Noida recording 'Good' AQI category on March 28, 2020.

Prohibitions

The lock-down restricts people from stepping out of their homes. All transport services–road, air and rail–were suspended, with exceptions for transportation of essential goods, fire, police and emergency services. Educational institutions, industrial establishments and hospitality services were also suspended. Services such as food shops, banks and ATMs, petrol pumps, other essentials and their manufacturing are exempted. The Home Ministry stated that anyone who fails to follow the restrictions can face up to a year in jail.[22]

22 "Guidelines.pdf" (PDF). Ministry of Home Affairs.

On 25 March, the first day of the lock-down, nearly all services and factories were suspended.[1] People were hurrying to stock essentials in some parts.[2] Arrests across the states were made for violating norms of lock-down such as venturing out for no emergency, opening businesses and home quarantine violations.[3] The government held meetings with e-commerce websites and vendors to ensure a seamless supply of essential goods across the nation during the lock-down period. Several states announced relief funds for the poor and affected people while the central government was finalizing a stimulus package.[4]

Table 123: Landuses and their activities in phase 1

LAND USE/ ACTIVITIES	TYPE	PHASE 1 (25th March to 14th April)	
		RESTRICTIONS	EXCEPTIONS
RESIDENTIAL	RESIDENTIAL AREA		EXCEPTION
	FOREIGN MISSION		EXCEPTION
COMMERCIAL	RETAIL SHOPPING	COMMERCIAL AND PRIVATE ESTABLISHMENTS SHALL REMAIN CLOSED	
	GENERAL BUSINESS & COMMERCE		1. SHOPS, INCLUDING RATION SHOPS (UNDER PDS), DEALING WITH FOOD, GROCERIES, FRUITS AND VEGETABLES, DAIRY AND MILK BOOTHS, MEAT AND FISH, ANIMAL FODDER. 2. BANKS, INSURANCE OFFICES AND ATMS. 3. PRINT AND ELECTRONIC MEDIA. 4. TELECOMMUNICATIONS, INTERNET SERVICES, BROADCASTING AND CABLE SERVICES. IT AND IT ENABLED SERVICES ONLY AND AS FAR AS POSSIBLE TO WORK FROM HOME. 5. CAPITAL AND DEBT MARKET SERVICES AS NOTIFIED BY THE SECURITIES AND EXCHANGE BOARD OF INDIA
	DISTRICT CENTRE		
	COMMUNITY CENTRE		
	NON-HIERARCHICAL COMMERCIAL CENTRES		
	WHOLESALE		SHALL REMAIN FUNCTIONAL
	WAREHOUSING		SHALL REMAIN FUNCTIONAL
	COLD STORAGE		SHALL REMAIN FUNCTIONAL
	OIL DEPOT		SHALL REMAIN FUNCTIONAL
	HOTELS	HOSPITALITY SERVICES TO REMAIN SUSPENDED	1. HOTELS, HOMESTAYS, LODGES AND MOTELS, WHICH ARE ACCOMMODATING TOURISTS AND PERSONS STRANDED DUE TO LOCKDOWN, MEDICAL AND EMERGENCY STAFF, AIR AND SEA CREW. 2. ESTABLISHMENTS USED/EARMARKED FOR QUARANTINE FACILITIES

1 Singh, Karan Deep; Goel, Vindu; Kumar, Hari; Gettleman, Jeffrey (25 March 2020). "India, Day 1: World's Largest Coronavirus Lockdown Begins". The New York Times. ISSN 0362-4331.

2 Covid-19: People flock to wholesale markets in UP, West Bengal amid lockdown. ANI. 24 March 2020

3 "Day 1 of coronavirus lock-down: India registers 101 new cases, 3 deaths; Govt says working to deliver essential services". India Today.

4 "Rs 2.3 trillion for 1.3 billion: Govt to announce stimulus package to fight coronavirus, says report". India Today.

LAND USE/ ACTIVITIES	TYPE	PHASE 1 (25th March to 14th April)	
		RESTRICTIONS	EXCEPTIONS
RECREATIONAL	REGIONAL PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CITY PARK		
	DISTRICT PARK		
	COMMUNITY PARK		
	HISTORICAL MONUMENTS		
INDUSTRIAL	MANUFACTURING	INDUSTRIAL ESTABLISHMENTS WILL REMAIN CLOSED	1. MANUFACTURING UNITS OF ESSENTIAL COMMODITIES 2. PRODUCTION UNITS WHICH REQUIRE CONTINUOUS PROCESS, AFTER OBTAINING REQUIRED PERMISSION FROM THE STATE GOVT. 3. MANUFACTURING UNITS OF DRUGS, PHARMACEUTICALS, MEDICAL DEVICES, MEDICAL OXYGEN, THEIR PACKAGING MATERIAL AND INTERMEDIATES. 4. CONSTRUCTION OF MEDICAL/HEALTH INFRASTRUCTURE INCLUDING MANUFACTURE OF AMBULANCE
	SERVICES	SERVICES TO REMAIN SUSPENDED	
	REPAIR	SERVICES TO REMAIN SUSPENDED	
TRANSPORTATION	AIRPORT	ALL TRANSPORT SERVICE - AIR, RAIL AND ROADWAYS WILL REMAIN SUSPENDED	1. TRANSPORTATION FOR ESSENTIAL GOODS ONLY 2. FIRE, LAW AND ORDER AND EMERGENCY SERVICES 3. DELIVERY OF ALL ESSENTIAL GOODS INCLUDING FOOD, PHARMACEUTICALS, MEDICAL EQUIPMENT THROUGH E-COMMERCE. 4. THE TRANSPORTATION FOR ALL MEDICAL PERSONNEL, NURSES, PARA MEDICAL STAFF, OTHER HOSPITAL SUPPORT SERVICES.
	TERMINAL/DEPOT - RAIL		
	TERMINAL/DEPOT - MRTS		
	TERMINAL/DEPOT - BUS		
	TERMINAL/DEPOT - TRUCK		
UTILITIES	WATER		ONLY STAFF REQUIRED FOR ESSENTIAL SERVICES LIKE SANITATION, PERSONNEL RELATED TO WATER SUPPLY, ETC.
	SEWERAGE		
	ELECTRICITY		
	SOLID WASTE		
	DRAIN		
GOVERNMENT	PRESIDENTIAL ESTATE AND PARLIAMENT HOUSE		SHALL REMAIN FUNCTIONAL
	GOVERNMENT OFFICE/COURTS		SHALL REMAIN FUNCTIONAL

LAND USE/ ACTIVITIES	TYPE	PHASE 1 (25th March to 14th April)	
		RESTRICTIONS	EXCEPTIONS
PSP	HOSPITAL		HOSPITALS AND RELATED MEDICAL ESTABLISHMENTS, INCLUDING THEIR MANUFACTURING AND DISTRIBUTION UNITS, BOTH IN PUBLIC AND PRIVATE SECTORS, SUCH AS DISPENSARIES, CHEMIST AND MEDICAL EQUIPMENT SHOPS, LABORATORIES, CLINICS, NURSING HOMES, AMBULANCE ETC. WILL CONTINUE TO REMAIN FUNCTIONAL.
	EDUCATION & RESEARCH UNIVERSITY	ALL EDUCATIONAL, TRAINING, RESEARCH, COACHING INSTITUTIONS ETC. SHALL REMAIN CLOSED	
	UNIVERSITY CENTRES		
	COLLEGE		
	SOCIO-CULTURAL	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CULTURAL COMPLEX/CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CULTURAL COMPLEX/CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	POLICE/POLICE HEADQUARTERS/POLICE LINES		SHALL REMAIN FUNCTIONAL
	FIRE STATIONS		SHALL REMAIN FUNCTIONAL
	DISASTER MANAGEMENT CENTRES		SHALL REMAIN FUNCTIONAL
	RELIGIOUS	ALL PLACES OF WORSHIP SHALL BE CLOSED FOR PUBLIC. NO RELIGIOUS CONGREGATIONS WILL BE PERMITTED, WITHOUT ANY EXCEPTION	
	BURIAL GROUND		IN CASE OF FUNERALS, CONGREGATION OF NOT MORE THAN 20 PERSONS WILL BE PERMITTED
	CREMATION		
	TRANSMISSION SITE/CENTRE		POWER GENERATION, TRANSMISSION AND DISTRIBUTION UNITS AND SERVICES SHALL REMAIN FUNCTIONAL
	SPORTS FACILITIES/COMPLEX/STADIUM SPORTS CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
GREEN BELT	PLANT NURSERY		ALL AGRICULTURAL AND HORTICULTURAL ACTIVITIES TO REMAIN FULLY FUNCTIONAL
	GREEN BELT/AGRICULTURAL GREEN		
	RIVER AND WATER BODY		

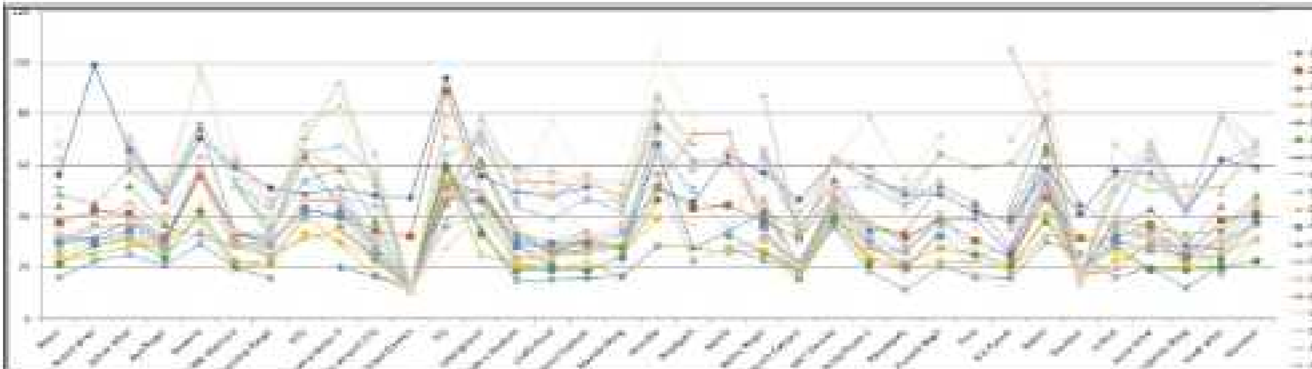


Figure 119: PM_{10} concentrations in Phase 1 in Delhi across all stations

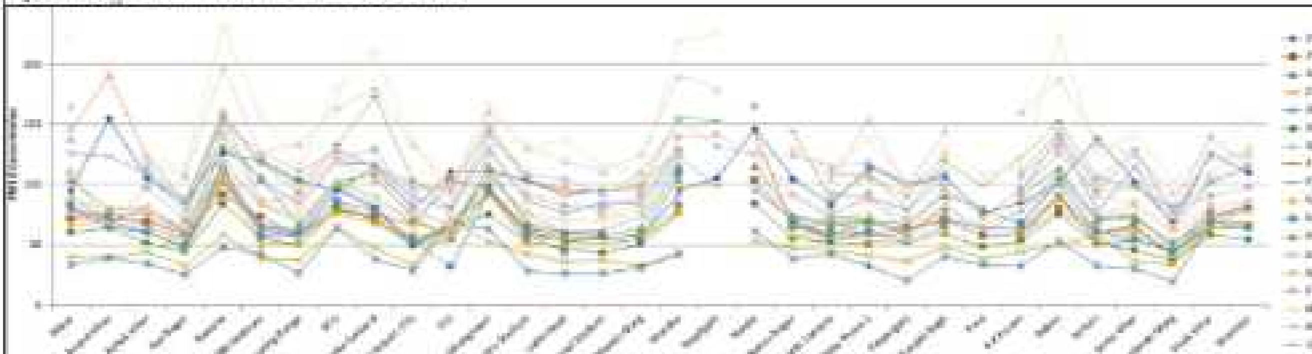


Figure 120: $PM_{2.5}$ concentrations in Phase 1 in Delhi across all stations

6.9.3 PHASE 2 (15 APRIL – 3 MAY)

On 14 April, PM Modi extended the nationwide lockdown till 3 May, with a conditional relaxation promised after 20 April for the regions where the spread had been contained by then. He said that every town, every police station area and every state would be carefully evaluated to see if it had contained the spread. The areas that were able to do so would be released from the lockdown on 20 April. If any new cases emerged in those areas, lockdown could be re-imposed.[1]

On 16 April, lockdown areas were classified as "red zone", indicating the presence of infection hotspots, "orange zone" indicating some infection, and "green zone" with no infections.[2] The government also announced certain relaxations from 20 April, allowing agricultural businesses, including dairy, aquaculture and plantations, as well as shops selling farming supplies, to open. Public works programmes were also allowed to reopen with instructions to maintain social distancing. Cargo transportation vehicles, including trucks, trains and planes, would run. Banks and government centres distributing benefits would open as well.[3]

On 25 April, small retail shops were allowed to open with half the staff. Again, social distancing norms were to be followed.[4]

On 29 April, The Ministry of Home Affairs issued guidelines for the states to allow inter-state movement of the stranded persons. States have been asked to designate nodal authorities and form protocols to receive and send such persons. States have also been asked to screen the people, quarantine them and to do periodic health check-ups.

As per the Ministry of Home Affairs (MHA) Order No. 40-3/2020-DM-I (A) dated 15th April 2020, the following activities continued to remain prohibited across the country until 3rd May 2020.

Table 125: Landuses and their activities in phase 2

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUTSIDE HOTSPOT & CONTAINMENT ZONE)
RESIDENTIAL	RESIDENTIAL AREA		EXCEPTION
	FOREIGN MISSION		EXCEPTION
COMMERCIAL	RETAIL SHOPPING	COMMERCIAL AND PRIVATE ESTABLISHMENTS SHALL REMAIN CLOSED	

1. Dutta, Prashasti K. (14 April 2020). "In coronavirus lockdown extension, Modi wields stick, offers carrot on exit route". India Today.
2. "India coronavirus: All major cities named Covid-19 'red zone' hotspots". BBC. 16 April 2020.
3. "India to allow farmers back to work amid lockdown". BBC News. 15 April 2020.
4. Alam, Zeeshan (25 April 2020). "India takes a small step toward relaxing its strict lockdown". Vox.

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUTSIDE HOTSPOT & CONTAINMENT ZONE)
COMMERCIAL	GENERAL BUSINESS & COMMERCE	COMMERCIAL AND PRIVATE ESTABLISHMENTS SHALL REMAIN CLOSED	1. SHOPS, INCLUDING RATION SHOPS (UNDER PDS), DEALING WITH FOOD, GROCERIES, FRUITS AND VEGETABLES, DAIRY AND MILK BOOTHS, MEAT AND FISH, ANIMAL FODDER. 2. BANKS, INSURANCE OFFICES AND ATMS 3. PRINT AND ELECTRONIC MEDIA 4. TELECOMMUNICATIONS, INTERNET SERVICES, BROADCASTING AND CABLE SERVICES. IT AND IT ENABLED SERVICES ONLY AND AS FAR AS POSSIBLE TO WORK FROM HOME. 5. CAPITAL AND DEBT MARKET SERVICES AS NOTIFIED BY THE SECURITIES AND EXCHANGE BOARD OF INDIA.
	DISTRICT CENTRE		
	COMMUNITY CENTRE		
	NON-HIERARCHIAL COMMERCIAL CENTRES		
	WHOLESALE		SHALL REMAIN FUNCTIONAL
	WAREHOUSING		SHALL REMAIN FUNCTIONAL
	COLD STORAGE		SHALL REMAIN FUNCTIONAL
	OIL DEPOT		SHALL REMAIN FUNCTIONAL
	HOTELS	HOSPITALITY SERVICES TO REMAIN SUSPENDED	1. HOTELS, HOMESTAYS, LODGES AND MOTELS, WHICH ARE ACCOMMODATING TOURISTS AND PERSONS STRANDED DUE TO LOCKDOWN, MEDICAL AND EMERGENCY STAFF, AIR AND SEA CREW. 2. ESTABLISHMENTS USED/EARMARKED FOR QUARANTINE FACILITIES
RECREATIONAL	REGIONAL PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CITY PARK		
	DISTRICT PARK		
	COMMUNITY PARK		
	HISTORICAL MONUMENTS		

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUT SIDE HOT SPOT & CONTAINMENT ZONE)
INDUSTRIAL	MANUFACTURING	INDUSTRIAL ESTABLISHMENTS WILL REMAIN CLOSED	1. MANUFACTURING UNITS OF ESSENTIAL COMMODITIES 2. PRODUCTION UNITS WHICH REQUIRE CONTINUOUS PROCESS, AFTER OBTAINING REQUIRED PERMISSION FROM THE STATE GOVT. 3. MANUFACTURING UNITS OF DRUGS, PHARMACEUTICALS, MEDICAL DEVICES, MEDICAL OXYGEN, THEIR PACKAGING MATERIAL AND INTERMEDIATES. 4. CONSTRUCTION OF MEDICAL/HEALTH INFRASTRUCTURE INCLUDING MANUFACTURE OF AMBULANCE. 5. INDUSTRIES OPERATING IN RURAL AREAS, I.E., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS & MUNICIPALITIES. 6. MANUFACTURING AND OTHER INDUSTRIAL ESTABLISHMENTS WITH ACCESS CONTROL IN SEZs AND EXPORT ORIENTED UNITS (EOUs), INDUSTRIAL ESTATES AND INDUSTRIAL TOWNSHIPS. THE TRANSPORTATION OF WORKERS TO WORK PLACE SHALL BE ARRANGED BY THE EMPLOYERS IN DEDICATED TRANSPORT BY ENSURING SOCIAL DISTANCING. 7. FOOD PROCESSING INDUSTRIES IN RURAL AREAS I.E., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES. 8. MANUFACTURING OF IT HARDWARE. 9. COAL PRODUCTION, MINES AND MINERAL PRODUCTION, THEIR TRANSPORTATION, SUPPLY OF EXPLOSIVES AND ACTIVITIES INCIDENTAL TO MINING OPERATIONS. 10. MANUFACTURING UNITS OF PACKAGING MATERIAL. 11. JUTE INDUSTRIES WITH STAGGERED SHIFTS AND SOCIAL DISTANCING. 12. OIL AND GAS EXPLORATION/REFINERY. 13. BRICK KILN IN RURAL AREAS I.E., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES.

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUTSIDE HOTSPOT & CONTAINMENT ZONE)
	SERVICES: CONSTRUCTION & TRANSPORTATION SERVICES	SERVICES TO REMAIN SUSPENDED	1. MNREGA WORKS TO BE ALLOWED 2. CONSTRUCTION OF ROADS, IRRIGATION PROJECTS, BUILDINGS AND ALL KINDS OF INDUSTRIAL PROJECTS, INCLUDING MSMEs, IN RURAL AREAS, I.E. OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES AND ALL KINDS OF PROJECTS IN INDUSTRIAL ESTATES. 3. CONSTRUCTION OF RENEWABLE ENERGY PROJECTS. 4. CONTINUATION OF WORKS IN CONSTRUCTION PROJECTS, WITHIN THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES, WHERE WORKERS ARE AVAILABLE ON SITE AND NO WORKERS ARE REQUIRED TO BE BROUGHT IN FROM OUTSIDE (IN SITU CONSTRUCTION).
	REPAIR	SERVICES TO REMAIN SUSPENDED	
TRANSPORTATION	AIRPORT	ALL TRANSPORT SERVICE - AIR, RAIL AND ROADWAYS WILL REMAIN SUSPENDED	1. TRANSPORTATION FOR ESSENTIAL GOODS ONLY 2. FIRE, LAW AND ORDER AND EMERGENCY SERVICES 3. DELIVERY OF ALL ESSENTIAL GOODS INCLUDING FOOD, PHARMACEUTICALS, MEDICAL EQUIPMENT THROUGH E-COMMERCE 4. THE TRANSPORTATION FOR ALL MEDICAL PERSONNEL, NURSES, PARA MEDICAL STAFF, OTHER HOSPITAL SUPPORT SERVICES. 5. VEHICLES USED BY E-COMMERCE OPERATORS WILL BE ALLOWED TO PLY WITH NECESSARY PERMISSIONS 6. PRIVATE VEHICLES FOR EMERGENCY SERVICES, INCLUDING MEDICAL AND VETERINARY CARE, AND FOR PROCURING ESSENTIAL COMMODITIES. IN SUCH CASES, ONE PASSENGER BESIDES THE PRIVATE VEHICLE DRIVER CAN BE PERMITTED IN THE BACKSEAT, IN CASE OF 4-WHEELERS; HOWEVER, IN CASE OF 2-WHEELER, ONLY THE DRIVER OF THE VEHICLE IS TO BE PERMITTED. 7. ALL PERSONNEL TRAVELING TO PLACE OF WORK AND BACK IN EXEMPTED CATEGORIES, AS PER THE INSTRUCTIONS OF THE STATE/UT LOCAL AUTHORITY.
	TERMINAL/DEPOT - RAIL		
	TERMINAL/DEPOT - MRTS		
	TERMINAL/DEPOT - BUS		
	TERMINAL/DEPOT - TRUCK		
UTILITIES	WATER		ONLY STAFF REQUIRED FOR ESSENTIAL SERVICES LIKE SANITATION, PERSONNEL RELATED TO WATER SUPPLY, ETC.
	SEWERAGE		
	ELECTRICITY		
	SOLID WASTE		
	DRAIN		
GOVERNMENT	PRESIDENTIAL ESTATE AND PARLIAMENT HOUSE		SHALL REMAIN FUNCTIONAL

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUTSIDE HOTSPOT & CONTAINMENT ZONE)
GOVERNMENT	GOVERNMENT OFFICE/ COURTS		1. DEFENCE, CENTRAL ARMED POLICE FORCES, HEALTH AND FAMILY WELFARE, DISASTER MANAGEMENT AND EARLY WARNING AGENCIES (IMD, INCOIS, SASE AND NATIONAL CENTRE OF SEISMOLOGY (NCS)), NATIONAL INFORMATICS CENTRE (NIC), FOOD CORPORATION OF INDIA (FCI), NCC, NEHRU YUVA KENDRAS (NYKS), AND CUSTOMS TO FUNCTION WITHOUT ANY RESTRICTIONS. 2. OTHER MINISTRIES AND DEPARTMENT, AND OFFICES UNDER THEIR CONTROL, ARE TO FUNCTION WITH 100% ATTENDANCE OF DEPUTY SECRETARY AND LEVELS ABOVE THAT. REMAINING OFFICERS AND STAFF TO ATTEND UPTO 33% AS PER REQUIREMENT. 3. POLICE, HOME GUARDS, CIVIL DEFENCE, FIRE AND EMERGENCY SERVICES, DISASTER MANAGEMENT, PRISONS AND MUNICIPAL SERVICES WILL FUNCTION WITHOUT ANY RESTRICTIONS. 4. ALL OTHER DEPARTMENTS OF STATE/UT GOVERNMENTS TO WORK WITH RESTRICTED STAFF. GROUP A AND B OFFICERS MAY ATTEND AS REQUIRED. GROUP C AND LEVELS BELOW THAT MAY ATTEND UPTO 33% STRENGTH, AS PER REQUIREMENT TO ENSURE SOCIAL DISTANCING. HOWEVER, DELIVERY OF PUBLIC SERVICES SHALL BE ENSURED, AND NECESSARY STAFF WILL BE DEPLOYED FOR SUCH PURPOSES. 5. DISTRICT ADMINISTRATION AND TREASURY WILL FUNCTION WITH RESTRICTED STAFF. 6. RESIDENT COMMISSIONER OF STATES/UTS, IN NEW DELHI, ONLY TO THE EXTENT OF COORDINATING COVID-19 RELATED ACTIVITIES AND INTERNAL KITCHEN OPERATIONS. 7. FOREST OFFICES: STAFF/WORKERS REQUIRED TO OPERATE AND MAINTAIN ZOO, NURSERIES, WILDLIFE, FIRE-FIGHTING IN FOREST, WATERING PLANTATIONS, PATROLLING AND THEIR NECESSARY TRANSPORT MOVEMENTS.
PSP	HOSPITAL		1. HOSPITALS AND RELATED MEDICAL ESTABLISHMENTS, INCLUDING THEIR MANUFACTURING AND DISTRIBUTION UNITS, BOTH IN PUBLIC AND PRIVATE SECTORS, SUCH AS DISPENSARIES, CHEMIST AND MEDICAL EQUIPMENT SHOPS, LABORATORIES, CLINICS, NURSING HOMES, AMBULANCE, ETC. WILL CONTINUE TO REMAIN FUNCTIONAL.
	EDUCATION & RESEARCH UNIVERSITY	ALL EDUCATIONAL, TRAINING, RESEARCH, COACHING INSTITUTIONS, ETC. SHALL REMAIN CLOSED	
	UNIVERSITY CENTRES		

LAND USE/ ACTIVITIES	TYPE	PHASE 2 (15th April to 3rd May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (OUTSIDE HOTSPOT & CONTAINMENT ZONE)
PSP	COLLEGE		
	SOCIO-CULTURAL	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CULTURAL COMPLEX/ CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	POLICE POLICE HEADQUARTERS/POLICE LINES		SHALL REMAIN FUNCTIONAL
	FIRE STATIONS		SHALL REMAIN FUNCTIONAL
	DISASTER MANAGEMENT CENTRES		SHALL REMAIN FUNCTIONAL
	RELIGIOUS	ALL PLACES OF WORSHIP SHALL BE CLOSED FOR PUBLIC. NO RELIGIOUS CONGREGATIONS WILL BE PERMITTED, WITHOUT ANY EXCEPTION	
	BURIAL GROUND		IN CASE OF FUNERALS, CONGREGATION OF NOT MORE THAN 20 PERSONS WILL BE PERMITTED
	CREMATION		
	TRANSMISSION SITE/ CENTRE		POWER GENERATION, TRANSMISSION AND DISTRIBUTION UNITS AND SERVICES SHALL REMAIN FUNCTIONAL
	SPORTS FACILITIES/ COMPLEX/ STADIUM/ SPORTS CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
GREEN BELT	PLANT NURSERY		ALL AGRICULTURAL AND HORTICULTURAL ACTIVITIES TO REMAIN FULLY FUNCTIONAL
	GREEN BELT/ AGRICULTURAL GREEN		
	RIVER AND WATER BODY		

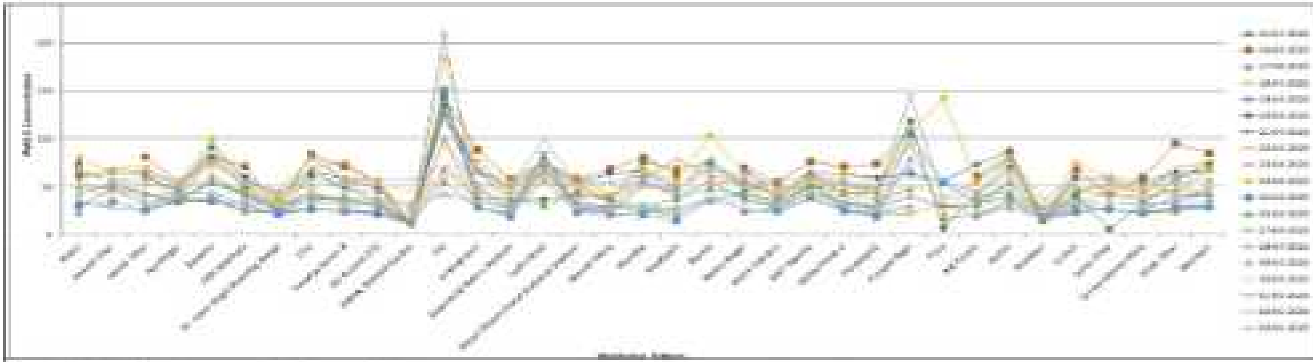


Figure 121: PM_{10} Concentration during Phase 2 across Delhi

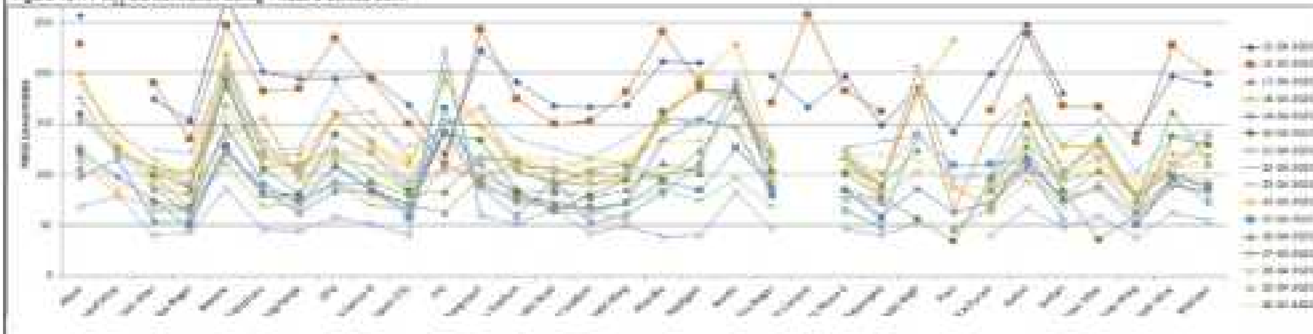


Figure 122: $PM_{2.5}$ Concentration during Phase 2 across Delhi

6.9.4 Phase 3 (4 – 17 May)

On 1 May, the Ministry of Home Affairs (MHA) and the Government of India (GoI) further extended the lockdown period to two weeks beyond 4 May, with some relaxations.[1] The country has been split into 3 zones: red zones (130 districts), orange zones (284 districts) and green zones (319 districts).[2] Red zones are those with high coronavirus cases and a high doubling rate, orange zones are those with comparatively fewer cases and green zones are those without any cases in the past 21 days.

Normal movement is permitted in green zones with buses limited to 50 percent capacity. Orange zones would allow only private and hired vehicles but no public transportation. The red zones would remain under lockdown. The zone classification would be revised once a week.

Table 130: Landuses and their activities in phase 3

LAND USE/ ACTIVITIES	TYPE	PHASE 3 (4th May to 17th May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (GREEN ZONE AND OUTSIDE CONTAINMENT ZONES)
RESIDENTIAL	RESIDENTIAL AREA		
	FOREIGN MISSION		
COMMERCIAL	RETAIL SHOPPING	IN THE CONTAINMENT ZONES, ONLY ESSENTIAL ACTIVITIES SHALL BE ALLOWED.	1. E-COMMERCE ACTIVITIES WILL BE PERMITTED ONLY IN RESPECT OF ESSENTIAL GOODS 2. PRIVATE OFFICES CAN OPERATE WITH UPTO 33% STRENGTH AS PER REQUIREMENT, WITH REMAINING PERSONS WORKING FROM HOME
	GENERAL BUSINESS & COMMERCE	IN THE CONTAINMENT ZONES, ONLY ESSENTIAL ACTIVITIES SHALL BE ALLOWED.	
	DISTRICT CENTRE	ALL MALLS SHALL REMAIN CLOSED	
	COMMUNITY CENTRE		
	NON-HIERARCHIAL COMMERCIAL CENTRES	ALL MARKETS AND MARKET COMPLEXES SHALL REMAIN CLOSED	SHOPS SELLING ESSENTIAL GOODS IN MARKETS AND MARKET COMPLEXES ARE PERMITTED
	WHOLESALE		
	WAREHOUSING		
	COLD STORAGE		
	OIL DEPOT		

1. "Lockdown extended till May 17: Read MHA guideline". News World24. 1 May 2020. Retrieved 1 May 2020.
2. Thacker, Teena (1 May 2020). "Centre issues state-wise division of Covid-19 red, orange & green zones". The Economic Times.

LAND USE/ ACTIVITIES	TYPE	PHASE 3 (4th May to 17th May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (GREEN ZONE AND OUTSIDE CONTAINMENT ZONES)
	HOTELS		HOSPITALITY SERVICES OTHER THAN THOSE USED FOR HOUSING HEATH POLICE/GOVERNMENT OFFICIALS/ HEALTH CARE WORKERS, STRANDED PERSONS INCLUDING TOURISTS AND THOSE USED FOR QUARANTINE FACILITIES
RECREATIONAL	REGIONAL PARK		
	CIT PARK Y		
	DISTRICT PARK		
	COMMUNITY PARK		
	HISTORICAL MONUMENTS		
INDUSTRIAL	MANUFACTURING		
	SERVICES		1. ONLY IN-SITU CONSTRUCTION (WHERE WORKERS ARE AVAILABLE ON SITE AND NO WORKERS ARE REQUIRED TO BE BROUGHT FROM OUTSIDE) AND CONSTRUCTION OF RENEWABLE ENERGY PROJECTS ARE PERMITTED 2. ALL CONSTRUCTION ACTIVITIES ARE PERMITTED IN RURAL AREAS
	REPAIR		

LAND USE/ ACTIVITIES	TYPE	PHASE 3 (4th May to 17th May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (GREEN ZONE AND OUTSIDE CONTAINMENT ZONES)
TRANSPORTATION	AIRPORT		1. MOVEMENT OF INDIVIDUALS AND VEHICLES ONLY FOR PERMITTED ACTIVITIES. FOUR-WHEELER VEHICLES WILL HAVE MAXIMUM OF 2 PASSENGERS BESIDE THE VEHICLE DRIVER. FOR TWO WHEELERS, PILLION RIDER IS NOT ALLOWED. 2. ALL DOMESTIC AND INTERNATIONAL AIR TRAVEL OF PASSENGERS, EXCEPT FOR MEDICAL SERVICES, AIR AMBULANCE AND FOR SECURITY PURPOSES OR FOR PURPOSES AS PERMITTED BY MHA. 3. ALL PASSENGER MOVEMENT BY TRAINS, EXCEPT FOR SECURITY PURPOSES OR FOR PURPOSES PERMITTED BY MHA. 4. INTER STATE BUSES FOR PUBLIC TRANSPORT, EXCEPT PERMITTED BY MHA. 5. BUSES CAN OPERATE WITH UPTO 50% SEATING CAPACITY. (GREEN ZONE) 6. BUS DEPOTS CAN OPERATE WITH UPTO 50% CAPACITY. (GREEN ZONE) 7. ALL STATES/UTS SHALL ALLOW INTER-STATE MOVEMENT OF GOODS/ CARGO INCLUDING EMPTY TRUCKS. 8. NO STATE/UTS SHALL STOP THE MOVEMENT OF CARGO FOR CROSS LAND-BORDER TRADE UNDER TREATIES WITH NEIGHBOURING COUNTRIES. 9. THE MOVEMENT OF INDIVIDUAL FOR ALL NON-ESSENTIAL ACTIVITIES SHALL REMAIN STRICTLY PROHIBITED BETWEEN 7PM TO 7AM.
	TERMINAL/DEPOT - RAIL		
	TERMINAL/DEPOT - MRTS		
	TERMINAL/DEPOT - BUS		
	TERMINAL/DEPOT - TRUCK		

LAND USE/ ACTIVITIES	TYPE	PHASE 3 (4th May to 17th May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (GREEN ZONE AND OUTSIDE CONTAINMENT ZONES)
UTILITIES	WATER		
	SEWERAGE		
	ELECTRICITY		
	SOLID WASTE		
	DRAIN		
GOVERNMENT	PRESIDENTIAL ESTATE AND PARLIAMENT HOUSE		
	GOVERNMENT OFFICE/COURTS		
PSP	HOSPITAL		1. HOSPITALS AND RELATED MEDICAL ESTABLISHMENTS, INCLUDING THEIR MANUFACTURING AND DISTRIBUTION UNITS, BOTH IN PUBLIC AND PRIVATE SECTORS, SUCH AS DISPENSARIES, CHEMIST AND MEDICAL EQUIPMENT SHOPS, LABORATORIES, CLINICS, NURSING HOMES, AMBULANCE, ETC. WILL CONTINUE TO REMAIN FUNCTIONAL.
	EDUCATION & RESEARCH UNIVERSITY	ALL EDUCATIONAL, TRAINING, RESEARCH, COACHING INSTITUTIONS, ETC. SHALL REMAIN CLOSED	
	UNIVERSITY CENTRES		
	COLLEGE		
	SOCIO-CULTURAL	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CULTURAL COMPLEX/CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	POLICE/POLICE HEADQUARTERS/POLICE LINES		SHALL REMAIN FUNCTIONAL
	FIRE STATIONS		SHALL REMAIN FUNCTIONAL
	DISASTER MANAGEMENT CENTRES		SHALL REMAIN FUNCTIONAL

LAND USE/ ACTIVITIES	TYPE	PHASE 3 (4th May to 17th May)	
		RESTRICTIONS (RED AND ORANGE ZONES)	EXCEPTIONS (GREEN ZONE AND OUTSIDE CONTAINMENT ZONES)
PSP	RELIGIOUS	ALL PLACES OF WORSHIP SHALL BE CLOSED FOR PUBLIC. NO RELIGIOUS CONGREGATIONS WILL BE PERMITTED WITHOUT ANY EXCEPTION	
	BURIAL GROUND		IN CASE OF FUNERALS, CONGREGATION OF NOT MORE THAN 20 PERSONS WILL BE PERMITTED
	CREMATION		
	TRANSMISSION SITE/CENTRE		POWER GENERATION, TRANSMISSION AND DISTRIBUTION UNITS AND SERVICES SHALL REMAIN FUNCTIONAL
	SPORTS FACILITIES/ COMPLEX/ STADIUM/ SPORTS CENTRE	ALL SORTS OF GATHERINGS SHALL BE BARRED	
GREEN BELT	PLANT NURSERY		ALL AGRICULTURAL AND HORTICULTURAL ACTIVITIES TO REMAIN FULLY FUNCTIONAL
	GREEN BELT/AGRICULTURAL GREEN		
	RIVER AND WATER BODY		

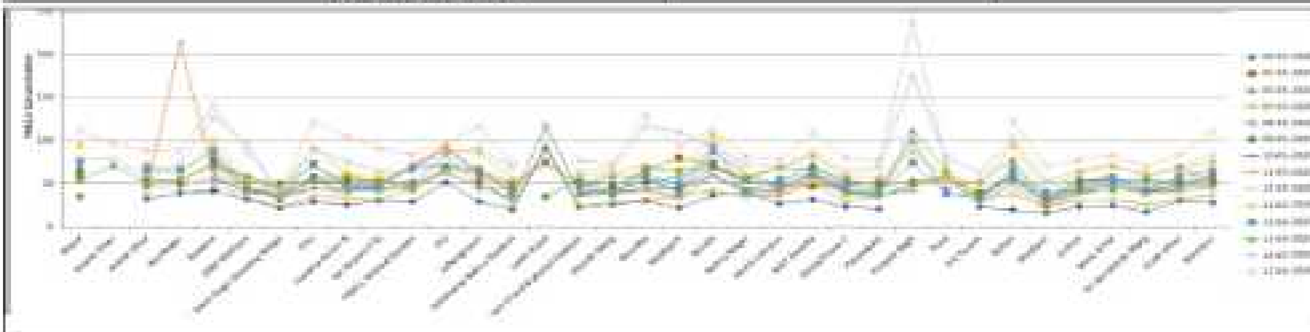


Figure 122: PM 2.5 Concentration during Phase 3 across Delhi

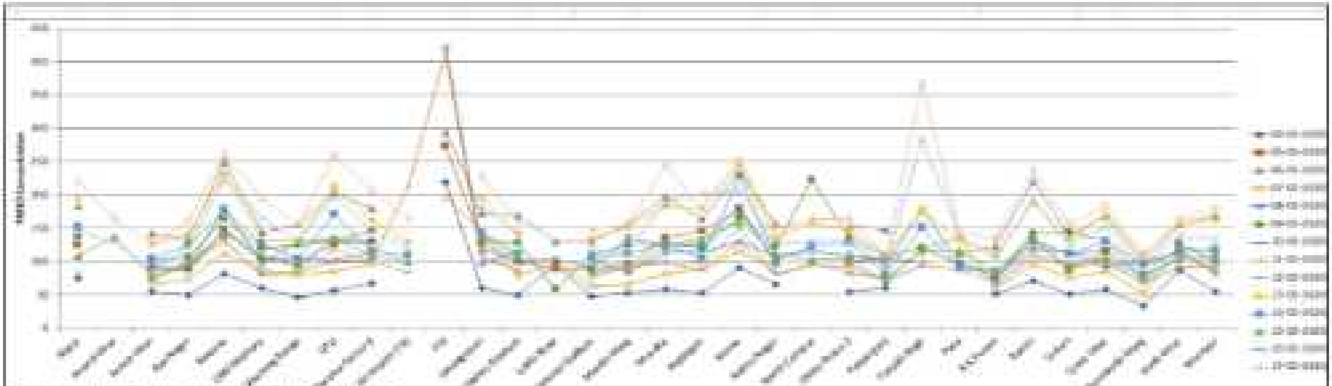


Figure 124: PM_{10} Concentration during Phase 3 across Delhi

6.9.5 Phase 4 (18 – 31 May)

On 17 May, the National Disaster Management Authority (NDMA) and the Ministry of Home Affairs (MHA) extended the lockdown for a period for two weeks beyond 18 May, with additional relaxations. Unlike the previous extensions, states were given a larger say in the demarcation of Green, Orange and Red zones and the implementation roadmap. Red zones were further divided into containment and buffer zones. The local bodies were given the authority to demarcate containment and buffer zones. [1,2,3]

Table 131: Landuses and their activities in phase 4

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUTSIDE CONTAINMENT ZONES)
RESIDENTIAL	RESIDENTIAL AREA		EXCEPTION
	FOREIGN MISSION		EXCEPTION
COMMERCIAL	RETAIL SHOPPING	IN THE CONTAINMENT ZONES, ONLY ESSENTIAL ACTIVITIES SHALL BE ALLOWED.	1. E-COMMERCE ACTIVITIES WILL BE PERMITTED ONLY IN RESPECT OF ESSENTIAL GOODS 2. PRIVATE OFFICES CAN OPERATE WITH UPTO 33% STRENGTH AS PER REQUIREMENT, WITH REMAINING PERSONS WORKING FROM HOME.
	GENERAL BUSINESS & COMMERCE		1. SHOPS, INCLUDING RATION SHOPS (UNDER PDS), DEALING WITH FOOD, GROCERIES, FRUITS AND VEGETABLES, DAIRY AND MILK BOOTHS, MEAT AND FISH, ANIMAL FODDER. 2. BANKS, INSURANCE OFFICES AND ATMS 3. PRINT AND ELECTRONIC MEDIA 4. TELECOMMUNICATIONS, INTERNET SERVICES, BROADCASTING AND CABLE SERVICES. IT AND IT ENABLED SERVICES ONLY AND AS FAR AS POSSIBLE TO WORK FROM HOME. 5. CAPITAL AND DEBT MARKET SERVICES AS NOTIFIED BY THE SECURITIES AND EXCHANGE BOARD OF INDIA.
	DISTRICT CENTRE	ALL MALLS SHALL REMAIN CLOSED.	
	COMMUNITY CENTRE		
	NON-HIERARCHICAL COMMERCIAL CENTRES	ALL MARKETS AND MARKET COMPLEXES SHALL REMAIN CLOSED	SHOPS SELLING ESSENTIAL GOODS IN MARKETS AND MARKET COMPLEXES ARE PERMITTED
	WHOLESALE		SHALL REMAIN FUNCTIONAL
	WAREHOUSING		SHALL REMAIN FUNCTIONAL

1 "Coronavirus lockdown extended till 31 May, says NDMA". Livemint. 17 May 2020. Retrieved 17 May 2020.
2 "Lockdown 4.0 guidelines | What's allowed and what's not". The Hindu. 17 May 2020. ISSN 0971-751X. Retrieved 17 May 2020.
3 "Lockdown 4.0 guidelines: Centre extends nationwide lockdown till May 31 with considerable relaxations". The Economic Times. 18 May 2020. Retrieved 17 May 2020.

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUTSIDE CONTAINMENT ZONES)
	COLD STORAGE		SHALL REMAIN FUNCTIONAL
	OIL DEPOT		SHALL REMAIN FUNCTIONAL
	HOTELS		HOTELS, RESTAURANTS AND OTHER HOSPITALITY SERVICES, EXCEPT THOSE MEANT FOR HOUSING HEALTH/ POLICE/ GOVERNMENT OFFICIALS/ HEALTHCARE WORKERS/ STRANDED PERSONS INCLUDING TOURISTS AND FOR QUARANTINE FACILITIES; AND RUNNING OF CANTEENS AT BUS DEPOTS, RAILWAY STATIONS AND AIRPORTS. RESTAURANTS SHALL BE PERMITTED TO OPERATE KITCHENS FOR HOME DELIVERY OF FOOD ITEMS.
RECREATIONAL	REGIONAL PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	CITY PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	DISTRICT PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	COMMUNITY PARK	ALL SORTS OF GATHERINGS SHALL BE BARRED	
	HISTORICAL MONUMENTS	ALL SORTS OF GATHERINGS SHALL BE BARRED	

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUTSIDE CONTAINMENT ZONES)
INDUSTRIAL	MANUFACTURING		1. MANUFACTURING UNITS OF ESSENTIAL COMMODITIES 2. PRODUCTION UNITS WHICH REQUIRE CONTINUOUS PROCESS, AFTER OBTAINING REQUIRED PERMISSION FROM THE STATE GOVT. 3. MANUFACTURING UNITS OF DRUGS, PHARMACEUTICALS, MEDICAL DEVICES, MEDICAL OXYGEN, THEIR PACKAGING MATERIAL AND INTERMEDIATES 4. CONSTRUCTION OF MEDICAL/HEALTH INFRASTRUCTURE INCLUDING MANUFACTURE OF AMBULANCE. 5. INDUSTRIES OPERATING IN RURAL AREAS, i.e., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS & MUNICIPALITIES 6. MANUFACTURING AND OTHER INDUSTRIAL ESTABLISHMENTS WITH ACCESS CONTROL IN SEZs AND EXPORT ORIENTED UNITS (EOUs), INDUSTRIAL ESTATES AND INDUSTRIAL TOWNSHIPS, THE TRANSPORTATION OF WORKERS TO WORK PLACE SHALL BE ARRANGED BY THE EMPLOYERS IN DEDICATED TRANSPORT BY ENSURING SOCIAL DISTANCING. 7. FOOD PROCESSING INDUSTRIES IN RURAL AREAS i.e., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES. 8. MANUFACTURING OF IT HARDWARE 9. COAL PRODUCTION, MINES AND MINERAL PRODUCTION, THEIR TRANSPORTATION, SUPPLY OF EXPLOSIVES AND ACTIVITIES INCIDENTAL TO MINING OPERATIONS. 10. MANUFACTURING UNITS OF PACKAGING MATERIAL. 11. JUTE INDUSTRIES WITH STAGGERED SHIFTS AND SOCIAL DISTANCING. 12. OIL AND GAS EXPLORATION/ REFINERY 13. BRICK KILN IN RURAL AREAS i.e., OUTSIDE THE LIMITS OF MUNICIPAL CORPORATIONS AND MUNICIPALITIES.
	SERVICES		1. ONLY IN-SITU CONSTRUCTION (WHERE WORKERS ARE AVAILABLE ON SITE AND NO WORKERS ARE REQUIRED TO BE BROUGHT FROM OUTSIDE) AND CONSTRUCTION OF RENEWABLE ENERGY PROJECTS ARE PERMITTED 2. ALL CONSTRUCTION ACTIVITIES ARE PERMITTED IN RURAL AREAS
	RETAIL		

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUTSIDE CONTAINMENT ZONES)
			1. MOVEMENT OF INDIVIDUALS AND VEHICLES, ONLY FOR PERMITTED ACTIVITIES. FOUR-WHEELER VEHICLES WILL HAVE MAXIMUM OF TWO PASSENGERS BESIDES THE VEHICLE DRIVER; FOR TWO WHEELERS, PILLION RIDER IS NOT ALLOWED. 2. INTER-STATE MOVEMENT OF PASSENGER VEHICLES AND BUSES, WITH MUTUAL CONSENT OF THE STATE(S)/ UT(S) INVOLVED. 3. INTRA-STATE MOVEMENT OF PASSENGER VEHICLES AND BUSES, AS DECIDED BY THE STATES AND UTS. 4. THE MOVEMENT OF INDIVIDUALS SHALL REMAIN STRICTLY PROHIBITED BETWEEN 7.00 PM TO 7.00 AM, EXCEPT FOR ESSENTIAL ACTIVITIES. 5. ALL STATES/ UTS SHALL ALLOW INTER-STATE AND INTRA-STATE MOVEMENT OF MEDICAL PROFESSIONALS, NURSES AND PARA MEDICAL STAFF, SANITATION PERSONNEL AND AMBULANCES, WITHOUT ANY RESTRICTION. 7. ALL STATES/ UTS SHALL ALLOW INTER-STATE MOVEMENT OF ALL TYPES OF GOODS/ CARGO, INCLUDING EMPTY TRUCKS. 8. NO STATE/ UT SHALL STOP THE MOVEMENT OF ANY TYPE OF GOODS/ CARGO FOR CROSS LAND-BORDER TRADE UNDER TREATIES WITH NEIGHBOURING COUNTRIES.
TRANSPORTATION	AIRPORT		
	TERMINAL/DEPOT - RAIL		
	TERMINAL/DEPOT - MRTS		
	TERMINAL/DEPOT - BUS		
	TERMINAL/DEPOT - TRUCK		
UTILITIES	WATER		ONLY STAFF REQUIRED FOR ESSENTIAL SERVICES LIKE SANITATION, PERSONNEL RELATED TO WATER SUPPLY, ETC.
	SEWERAGE		
	ELECTRICITY		
	SOLID WASTE		
	DRAIN		
GOVERNMENT	PRESIDENTIAL ESTATE AND PARLIAMENT HOUSE		SHALL REMAIN FUNCTIONAL

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUT SIDE CONTAINMENT ZONES)
	GOVERNMENT OFFICE/COURTS		1. DEFENCE, CENTRAL ARMED POLICE FORCES, HEALTH AND FAMILY WELFARE, DISASTER MANAGEMENT AND EARLY WARNING AGENCIES (IMD, INCOIS, SASE AND NATIONAL CENTRE OF SEISMOLOGY, CWC), NATIONAL INFORMATICS CENTRE (NIC), FOOD CORPORATION OF INDIA (FCI), NCC, NEHRU YUVA KENDRAS (NYKS), AND CUSTOMS TO FUNCTION WITHOUT ANY RESTRICTIONS. 2. OTHER MINISTRIES AND DEPARTMENT, AND OFFICES UNDER THEIR CONTROL, ARE TO FUNCTION WITH 100% ATTENDANCE OF DEPUTY SECRETARY AND LEVELS ABOVE THAT. REMAINING OFFICERS AND STAFF TO ATTEND UPTO 33% AS PER REQUIREMENT. 3. POLICE, HOME GUARDS, CIVIL DEFENCE, FIRE AND EMERGENCY SERVICES, DISASTER MANAGEMENT, PRISONS AND MUNICIPAL SERVICES WILL FUNCTION WITHOUT ANY RESTRICTIONS. 4. ALL OTHER DEPARTMENTS OF STATE/UT GOVERNMENTS TO WORK WITH RESTRICTED STAFF. GROUP A AND B OFFICERS MAY ATTEND AS REQUIRED. GROUP C AND LEVELS BELOW THAT MAY ATTEND UPTO 33% STRENGTH, AS PER REQUIREMENT TO ENSURE SOCIAL DISTANCING. HOWEVER, DELIVERY OF PUBLIC SERVICES SHALL BE ENSURED, AND NECESSARY STAFF WILL BE DEPLOYED FOR SUCH PURPOSES. 5. DISTRICT ADMINISTRATION AND TREASURY WILL FUNCTION WITH RESTRICTED STAFF. 6. RESIDENT COMMISSIONER OF STATES/UTS, IN NEW DELHI, ONLY TO THE EXTENT OF COORDINATING COVID-19 RELATED ACTIVITIES AND INTERNAL KITCHEN OPERATIONS. 7. FOREST OFFICES: STAFF/WORKERS REQUIRED TO OPERATE AND MAINTAIN ZOO, NURSERIES, WILDLIFE, FIRE-FIGHTING IN FOREST, WATERING PLANTATIONS, PATROLLING AND THEIR NECESSARY TRANSPORT MOVEMENTS.
PSP	HOSPITAL		1. HOSPITALS AND RELATED MEDICAL ESTABLISHMENTS, INCLUDING THEIR MANUFACTURING AND DISTRIBUTION UNITS, BOTH IN PUBLIC AND PRIVATE SECTORS, SUCH AS DISPENSARIES, CHEMIST AND MEDICAL EQUIPMENT SHOPS, LABORATORIES, CLINICS, NURSING HOMES, AMBULANCE ETC. WILL CONTINUE TO REMAIN FUNCTIONAL.
	EDUCATION & RESEARCH UNIVERSITY	SCHOOLS, COLLEGES, EDUCATIONAL / TRAINING/ COACHING INSTITUTIONS ETC. WILL REMAIN CLOSED.	ONLINE/ DISTANCE LEARNING SHALL CONTINUE TO BE PERMITTED AND SHALL BE ENCOURAGED.
	UNIVERSITY CENTRES		

LAND USE/ ACTIVITIES	TYPE	PHASE 4 (18th May to 31st May)	
		RESTRICTIONS	EXCEPTIONS (OUTSIDE CONTAINMENT ZONES)
	COLLEGE		
	SOCIO-CULTURAL	ALL SOCIAL/ POLITICAL/ SPORTS/ ENTERTAINMENT/ ACADEMIC/ CULTURAL/ RELIGIOUS FUNCTIONS/ OTHER GATHERINGS AND LARGE CONGREGATIONS	
	CULTURAL COMPLEX/ CENTRE		
	POLICE/POLICE HEADQUARTERS/ POLICE LINES		SHALL REMAIN FUNCTIONAL
	FIRE STATIONS		SHALL REMAIN FUNCTIONAL
	DISASTER MANAGEMENT CENTRES		SHALL REMAIN FUNCTIONAL
	RELIGIOUS	ALL RELIGIOUS PLACES/ PLACES OF WORSHIP SHALL BE CLOSED FOR PUBLIC. RELIGIOUS CONGREGATIONS ARE STRICTLY PROHIBITED	
	BURIAL GROUND		IN CASE OF FUNERALS, CONGREGATION OF NOT MORE THAN 20 PERSONS WILL BE PERMITTED
	CREMATION		
	TRANSMISSION SITE/ CENTRE		POWER GENERATION, TRANSMISSION AND DISTRIBUTION UNITS AND SERVICES SHALL REMAIN FUNCTIONAL
	SPORTS FACILITIES COMPLEX/ STADIUM/ SPORTS CENTRE		SPORTS COMPLEXES AND STADIUM WILL BE PERMITTED TO OPEN; HOWEVER, SPECTATORS WILL NOT BE ALLOWED
GREEN BELT	PLANT NURSERY		ALL AGRICULTURAL AND HORTICULTURAL ACTIVITIES TO REMAIN FULLY FUNCTIONAL
	GREEN BELT/ AGRICULTURAL GREEN		
	RIVER AND WATER BODY		

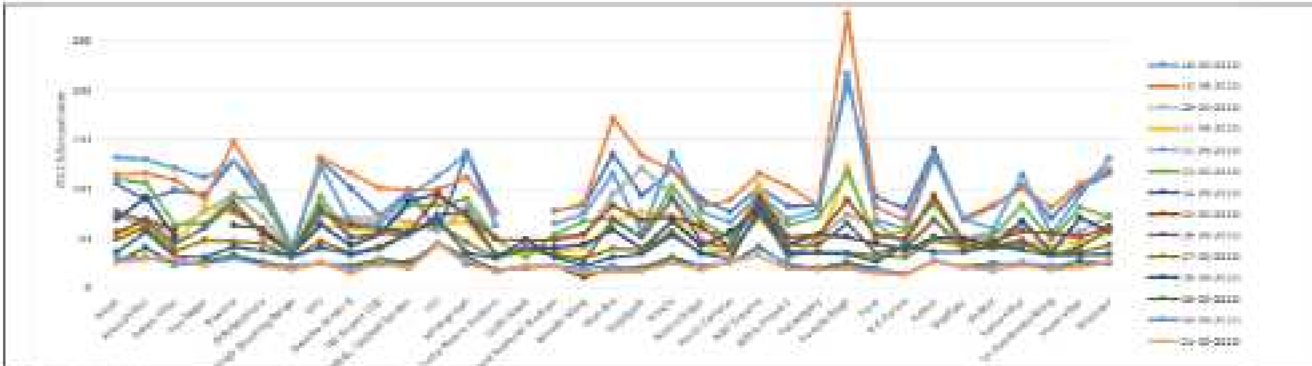


Figure [illegible]: PM 2.5 Concentration during Phase 4 across Delhi

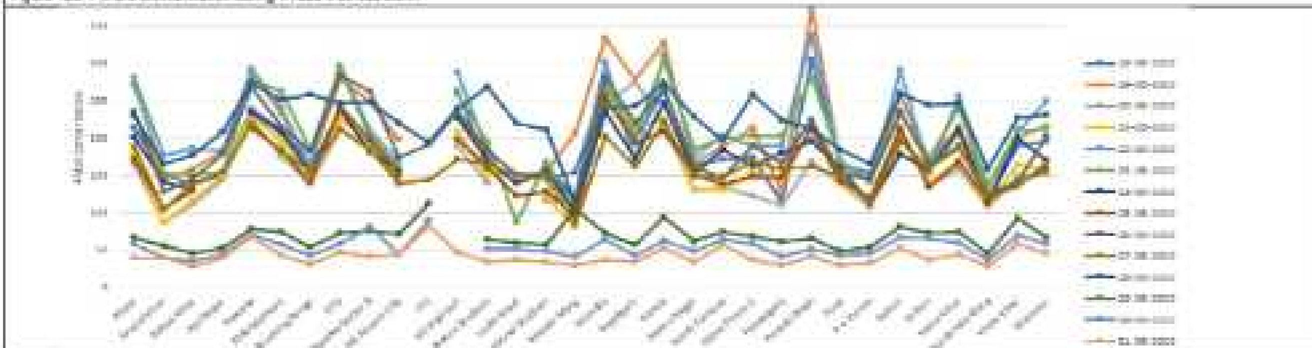


Figure [illegible]: PM 10 Concentration during Phase 4 across Delhi

6.9.6 Status of Landuse based activities during all four phases in lockdown:

Legend	
	Some form of restrictions
	Operations as Usual

Land Use	Use Zones	Associated activities as sources of Background Primary PM Emission	Associated emissions as sources of Secondary PM Emission	Phase 1	Phase 2	Phase 3	Phase 4
Residential	Residential Area	Cooking - LPG/PNG, Kerosene, Cow Dung Cake, Wood, Coke/Coal/Lignite, Biogas, Crop-residue, Electricity, Others & Vehicular Movement & dust resuspension	SOx and NOx from wood, coal,etc. combustion				
	Foreign Mission	Cooking - LPG/PNG, Kerosene, Cow Dung Cake, Wood, Coke/Coal/Lignite, Bio-gas, Crop-residue, Electricity, Others & Vehicular Movement & dust resuspension	SOx and NOx from wood, coal,etc. combustion				
Commercial	Retail Shopping - Retail Shop, Repair Shop, Personnel Service Shop	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Touluene, Oxidation of SO2 and NO2				
	General Business and Commerce - Commercial Office, Bank, Cinema/Cineplex, Restaurant	Cooking & Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Touluene, Oxidation of SO2 and NO2				
	District Centre - Service Markets, Organized Informal Bazaar, Organized Informal Sector Places (Haat)	Cooking & Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Touluene, Oxidation of SO2 and NO2				
	Community Centre - Service Markets, Organized Informal Bazaar, Organized Informal Sector Places (Haat)	Cooking & Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Touluene, Oxidation of SO2 and NO2				

Land Use	Use Zones	Associated activities as sources of Background Primary PM Emission	Associated emissions as sources of Secondary PM Emission	Phase 1	Phase 2	Phase 3	Phase 4
Commercial	Non-Hierarchial Commercial Centres - Weekly Markets	Cooking & Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Warehousing – Storage and Godown	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Cold Storage	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Oil Depot	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Hotels	Cooking & Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
Industrial	Manufacturing	Fuel Usage - LPG/PNG, LDO, Biogas, Coal, Vehicular Movement & dust resuspension, Construction & Demolition waste and dust	Oxidation of SO_2 and NO_2, Solvents				
	Service and Repair Industry						
Recreational	Regional Park	Vehicular Movement, Biogenic Emission, cooking & dust	VOCs - Monoterpenes				
	City Park	Vehicular Movement, Biogenic Emission, cooking & dust	VOCs - Monoterpenes				
	District Park	Vehicular Movement, Biogenic Emission, cooking & dust	VOCs - Monoterpenes				
	Community Park	Vehicular Movement, Biogenic Emission & dust	VOCs - Monoterpenes				
	Historical Monuments	Vehicular Movement & dust resuspension	VOCs - Monoterpenes				
Transportation	Airport	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Rail Terminal	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	MRTS Terminal	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Bus Terminal	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Truck Terminal	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				

Land Use	Use Zones	Associated activities as sources of Background Primary PM Emission	Associated emissions as sources of Secondary PM Emission	Phase 1	Phase 2	Phase 3	Phase 4
Transportation	Rail Circulation	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	MRTS Circulation	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Road Circulation	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
Utility	Water (Treatment Plant, etc.)	Not applicable	Aerosol form of Particulates such as Ammonium sulphates and Ammonium nitrates				
	Sewerage (Treatment Plant, etc.)	Not applicable	-				
	Electricity (Power House, Sub-station, etc.)	Fuel Usage	-				
	Solid Waste (Sanitary landfill etc.)	Solid Waste Burning	SOx and NOx from combustion of waste				
	Drain	Not applicable	-				
Government	President Estate and Parliament House	Cooking & vehicular movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Government Office / Courts	Cooking & vehicular movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Government Land (use undetermined)	Cooking	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
Public & Semi-Public	Hospital	Cooking & vehicular movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Education and Research University/ University campus	Cooking & vehicular movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	College	Cooking & vehicular movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Socio - Cultural	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				
	Socio Cultural Complex / Centre	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO2 and NO2				

Land Use	Use Zones	Associated activities as sources of Background Primary PM Emission	Associated emissions as sources of Secondary PM Emission	Phase 1	Phase 2	Phase 3	Phase 4
Public & Semi-Public	Police / Police Headquarters / Police Lines	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Fire Stations / Disaster Management Centres	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Religious	Fuel Usage	SO_x and NO_x from combustion of wood				
	Burial Ground / Cremation	Fuel Usage	SO_x and NO_x from combustion of wood				
	Transmission Site / Centre	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
	Sports Facilities / Complex / Stadium / Sports Centre	Vehicular Movement & dust resuspension	Organic Carbon, Aromatic Compounds such as Benzene and Toluene, Oxidation of SO_2 and NO_2				
Green Belt & Water Body	Plant Nursery	Biogenic Emission	VOCs - Monoterpenes, Ammonia (NH_3)				
	Green Belt / Agriculture Green	Refuse Burning, Biogenic Emission	VOCs – Monoterpenes, Ammonia (NH_3) – manure, livestock waste				
	River and Water body	Not applicable	Aerosol form of Particulates such as Ammonium Sulphates and Ammonium Nitrates				

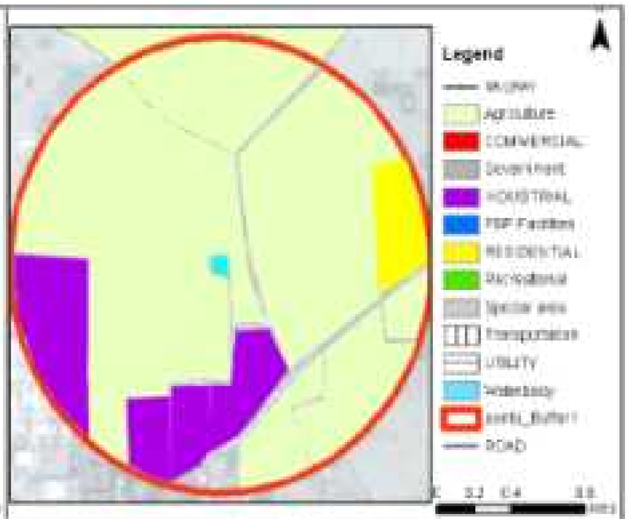
6.10. Effect of Lock-down at few monitoring stations

In the following section, the detailed impact of meteorological conditions, landuse, built-form and activities on pollution concentrations during the phases of lock-down have been discussed. A buffer area of 1km around the monitoring stations have been analysed with respect to the above mentioned factors in it.

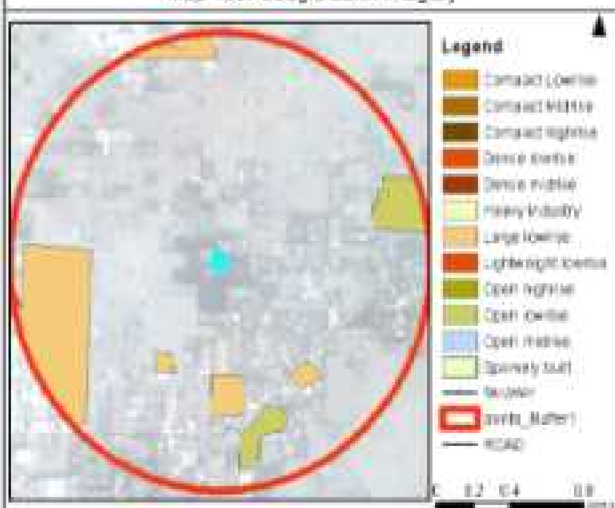
6.10.1. Alipur

The station lies in the North-east region of the city, with predominant landuse under greenbelt carrying out agricultural activities. Industrial areas and godowns can also be seen in the buffer area.

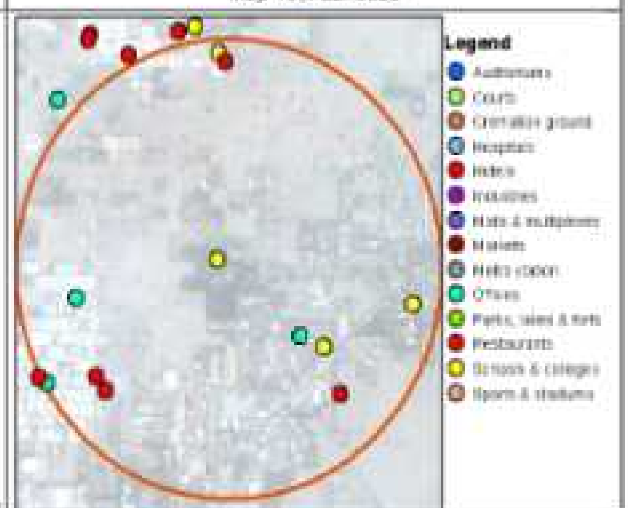
Map 189: Google earth imagery



Map 190: Landuse



Map 191: Built-form



Map 192: Activities

During the month of March and April, wheat is sown in Delhi. Agricultural practices are at peak during this period in Delhi. Paddy, Jowar and Bajra during Kharif and Wheat and Mustard crops during the Rabi seasons are the major crops in Delhi. The cultivation of vegetables is a continuous process throughout the year. Overcoming lock-down restrictions, sown area of summer crops has increased significantly, registering an increase of 36 per cent over the previous year, pushed up mainly by rice cultivation, said Ministry of Agriculture & Farmers Welfare.

The area is predominantly agricultural land. Being located at the periphery, a large share of banquet halls, farm houses and warehouses/godowns are observed nearby the monitoring stations. It might alter the concentration of pollutants as there are huge gatherings with large amount of vehicles and celebrations using crackers in some particular times in the year. The monitoring stations is also in proximity to NH 1 with heavy traffic flow from Panipat, Murthal, Sonipat, etc. The first phase of lock-down brought a strict restriction while agricultural activities and traffic movement of goods and daily essential products were functional. A large share of barren land with no vegetation cover can also be observed around the monitoring station. The low wind speeds during this month, however, reduces the suspension of dust particles.

The higher concentration during the days 6th – Mahavir Jayanti, 10th – Good Friday, 12th - Easter, 13th – Vaisakhi and 14th - Ambedkar Jayanti/ Bihu can also be attributed to movement of people for religious purposes and festive occasions. There was also a large share of migrant workers who were traveling back to their hometowns during this period. The pollutant concentration reduced due to lower activity rate during this period with the Delhi government putting ban on many activities.

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	
Dense lowrise	0.017	[illegible]	COMMERCIAL	0	0.0	
Dense midrise	0.000	0.00	INDUSTRIAL	3.6	19.1	
Open midrise	0.000	0.00	TRANSPORTATION	0.17	5.4	
Open highrise	0.000	0.00	RECREATIONAL	0	0.0	
Open lowrise	0.000	2.58	RESIDENTIAL	1.2	6.4	
Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0	
Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220
Large lowrise	0.288	9.23	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY		0.0	
Green belt	2.618	82.80	GREEN BELT	2.16	69.4	
Open area	0.000	0.00				
Waterbody	0.000	0.00				
Road	0.170	5.41				
Heavy Industry	0	0.00				

Table 132: Landuse and built form percentages

Figure 127: Wind direction at monitoring station

Table 133 shows how the concentration of $PM_{2.5}$ and 10 varied below and during the phases of lock-down. It was observed that the concentration reduced in the first phase of lock-down but kept on increasing during the next three phases as more and more relaxations were introduced. Before the lock-down in March 2020, the concentrations varied from good to poor quality but in the first phase, the concentrations were mainly good to satisfactory in the initial 12 days and were observed to be moderate during the next 10 days.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
Alipur, Delhi - DPCC	1st March	43.88	81.75	24th March	53.14	96.13	15th April	75.19	257.15	4th May	46.34	75.37	18th May	124.79	213.9
	2nd March	69.11	185.20	25th March	37.02	71.73	16th April	68.36	220.7	5th May	59.17	125.43	19th May	138.25	236.13
	3rd March	78.19	137.5	26th March	45.69	85.08	17th April	[illegible]	105.86	6th May	56.29	118.15	20th May	73.25	185.6
	4th March	93.56	196.97	27th March	[illegible]	[illegible]	18th April	[illegible]	116.93	7th May	76.76	90.76	21st May	48.09	176.56
	5th March	23.03	41.35	28th March	22.44	36.13	19th April	30.08	97.9	8th May	39.43	155.93	22nd May	135.56	281.25
	6th March	18.99	28.3	29th March	22.82	20.75	20th April	61.01	159.34	9th May	33.93	130.43	23rd May	130.06	271.34
	7th March	35.85	67.51	30th March	26.26	90.2	21st April	52.05	125.25	10th May	37.5	130.45	24th May	63.1	103.6
	8th March	58.58	90.97	31st March	20.5	73.08	22nd April	37.57	130.52	11th May	50.54	110.85	25th May	50.15	120.53
	9th March	42.9	98.95	1st April	31.28	77.35	23rd April	69.96	175.3	12th May	51.85	131.46	26th May	75.95	205.35
	10th March	73.14	150.96	2nd April	14.54	96.5	24th April	60.94	175.5	13th May	91.6	176.9	27th May	49.7	167.7
	11th March	35.68	89.14	3rd April	20.85	50.54	25th April	30.04	124.81	14th May	70.54	151.79	28th May	50.47	229.28
	12th March	53.62	135.85	4th April	48.12	106.5	26th April	49.95	154.27	15th May	53.56	100.43	29th May	22.95	67.4
	13th March	91.90	213.7	5th April	62.98	125.6	27th April	39.53	86.49	16th May	76.61	146.15	30th May	[illegible]	53.69
	14th March	56.96	94.13	6th April	66.73	145.76	28th April	56.37	114.18	17th May	111.44	[illegible]	31st May	[illegible]	[illegible]
	15th March	51.72	89.08	7th April	17.88	106.93	29th April	68.93	153.85						
	16th March	59.72	171.14	8th April	[illegible]	26.08	30th April	60.69	179.9						
	17th March	56.72	125.48	9th April	35.77	97.08	1st May	71.38	138.74						
	18th March	50.85	133.03	10th April	51.29	138.73	2nd May	35.73	127						
	19th March	93.85	229.77	11th April	49.1	150.53	3rd May	42.17	104.73						
	20th March	35.28	180.46	12th April	33.24	105.95									
	21st March	108.51	[illegible]	13th April	59.18	166.4									
	22nd March	86.39	150.77	14th April	73.76	223									
	23rd March	32.47	81.96												

Table 133: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend PM2.5		
Good	30	
Satisfactory	60	
Moderately Polluted	90	
Poor	120	
Very Poor	250	
Severe	>250	

Legend PM10		
Good	50	
Satisfactory	100	
Moderately Polluted	250	
Poor	350	
Very Poor	430	
Severe	>430	

Legend

It showed significant reduction in concentration of $PM_{2.5}$ and PM_{10} in Alipur with only transport (truck movement) and residential activity functional. The restriction on only goods traffic movement during this period showed better traffic conditions as observed from Google Traffic Maps.

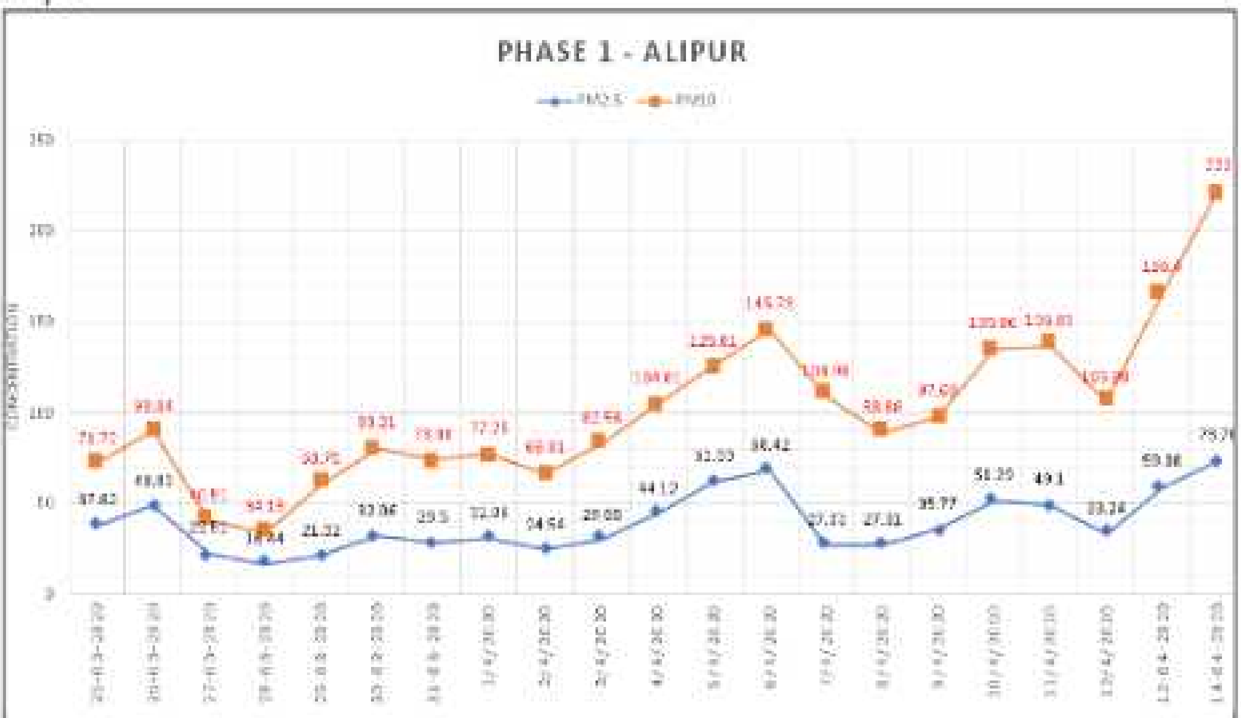


Figure 128: $PM_{2.5}$ and PM_{10} concentrations in 2020 during 24th March to 14th April

It was observed that the concentrations were very low (PM 2.5 ranging from 16 to 32 µg/m³) during the 27th to 31st March in the initial week of the phase 1. There was a major dust-storm in Delhi due to western disturbances around 15th April, and a mild dust-storm on 6th April which can also be observed in the figure with extremely high concentrations of $PM_{2.5}$ on 14th April. As a large share of open land is available in the direction of wind to the monitoring station, so the effect of wind escalated the concentrations of pollutant with the extra soil dust particles.

In the PM_{10} concentrations, it can be observed the reduction in values, during the lock-down phase with the restrictions of activities. Although peaks on 6th and 14th April can be observed, which was due to the dust-storms of western disturbances in the city.

The agricultural activities were highly effected reducing the activities emissions because the farm labours traveled back to their hometowns, arranging and bringing new labour was difficult due to police restrictions on movement of people.

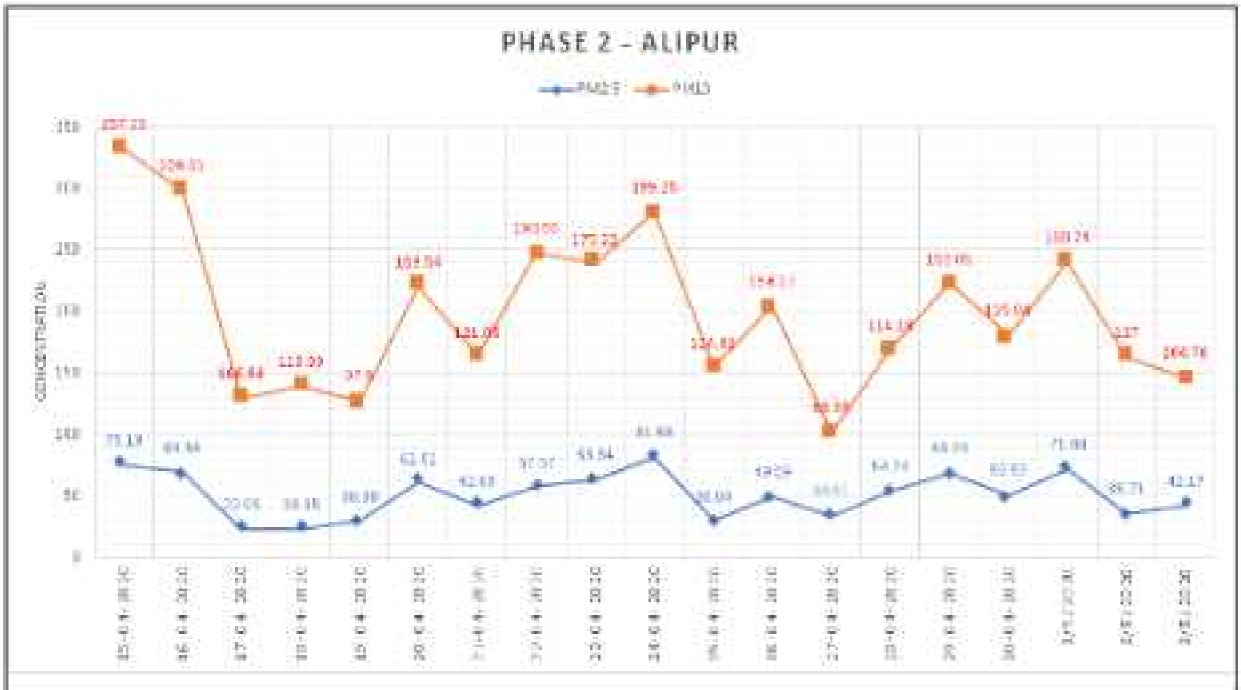


Figure 129: $PM_{2.5}$ and PM_{10} concentrations in 2020 during 15th March to 3rd May

Phase 2

During Phase 2 (mid April), which is also the peak of harvesting of wheat in Delhi, agricultural activities increased as the relaxation in movement of interstate goods and opening of repairs, market of crushers vehicles, etc. It can also be seen in the Google traffics as streets were marked orange and red even at 10 pm (Figure 130), which shows activities on loading and unloading of agricultural produce mainly.

If we compare it with the phase 1, there was an increase in concentration of $PM_{2.5}$. The initial peak around 15th and 16th April was due to the dust-storm, The PM_{10} concentrations were mostly moderately polluted throughout the phase. During the phase, in total 5 western disturbances caused the winds and mild dust-storms in the city, increasing the concentration of pollutants even when there were very little activities. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks.

So, mainly the concentrations during Phase 2 were increased due to the movement of trucks for loading & unloading and is highly influenced by meteorological conditions (dust-storms). The open areas(non-vegetative) which are surrounding the monitoring stations increased the amount of soil dust particles in the air at high wind speeds.

Figure 130: Screenshots of Google Traffic of Alipur

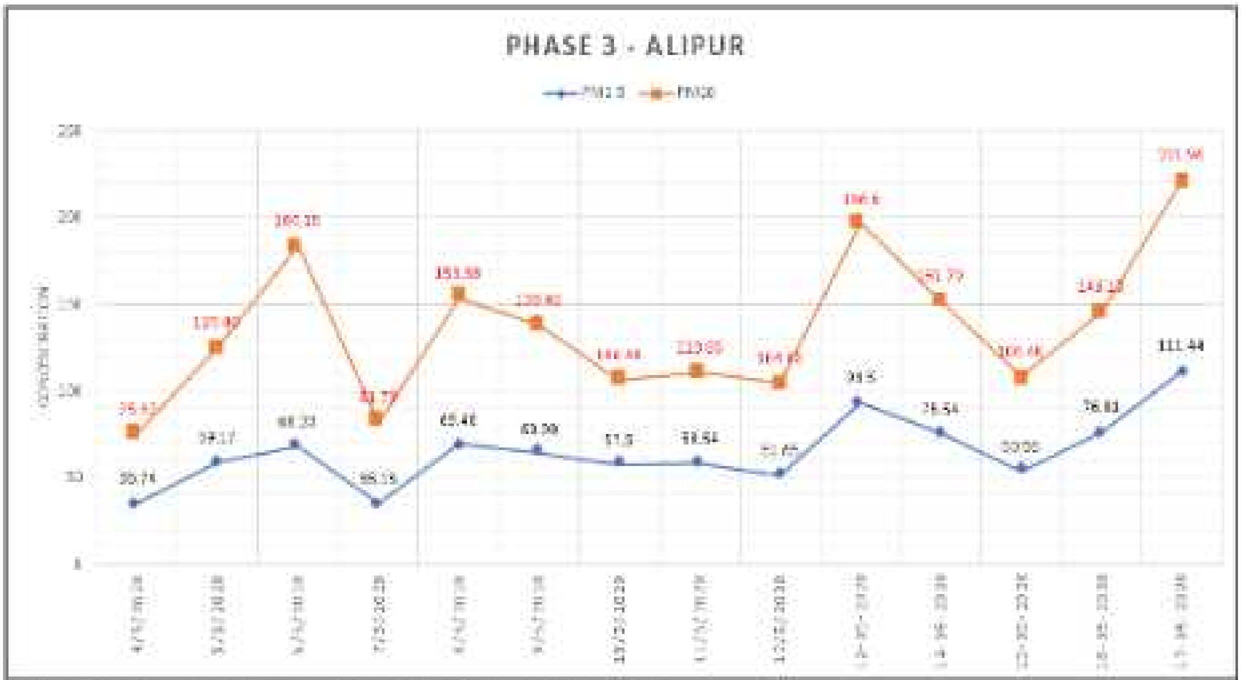


Figure 131: PM_{10} and $PM_{2.5}$ concentrations during 4th May to 17th May

Phase 3

In comparison to phase 2, significant changes in concentrations were not observed even though the relaxations were introduced in interstate bus movement. The 4 peaks in the concentrations were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

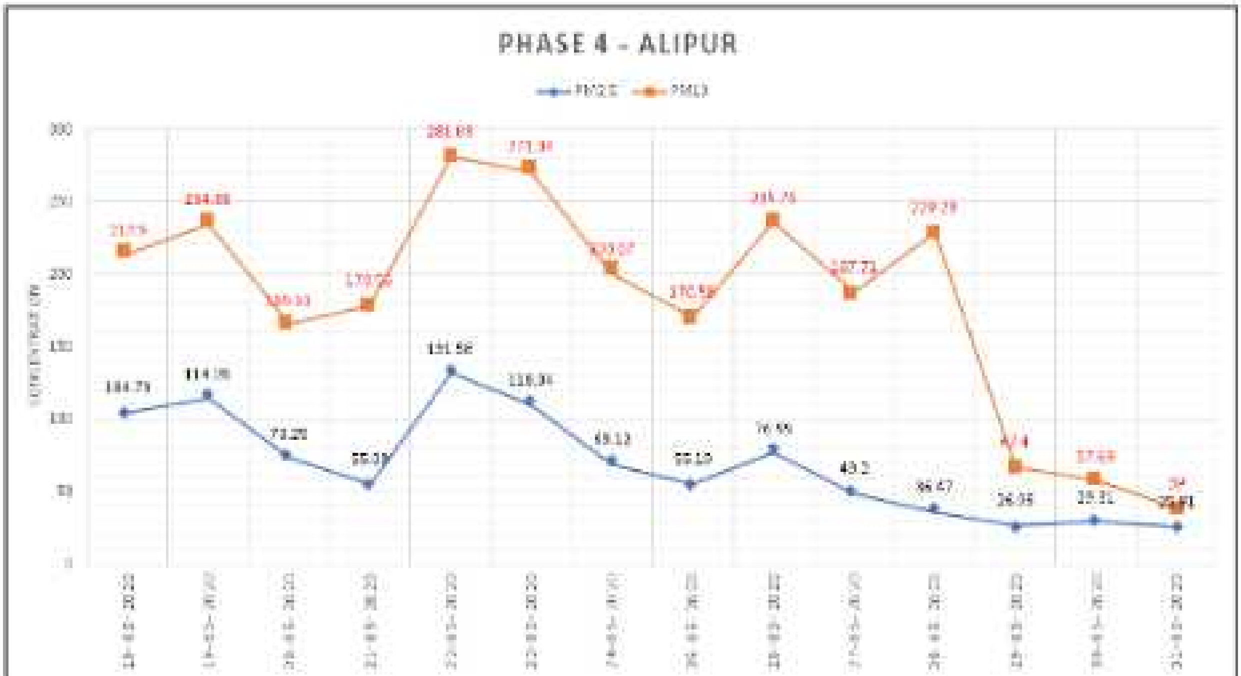


Figure 132: PM_{10} and $PM_{2.5}$ concentrations during 18th May to 31st May 2020

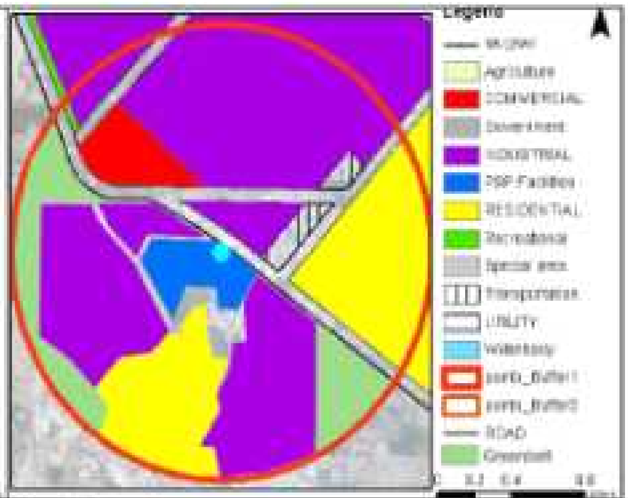
Phase 4

The PM_{10} concentrations were increased as the relaxations were made during this period for cross border traveling with passes and unobstructed movement of people/vehicles inside the city and as most shops in Delhi were made operational.

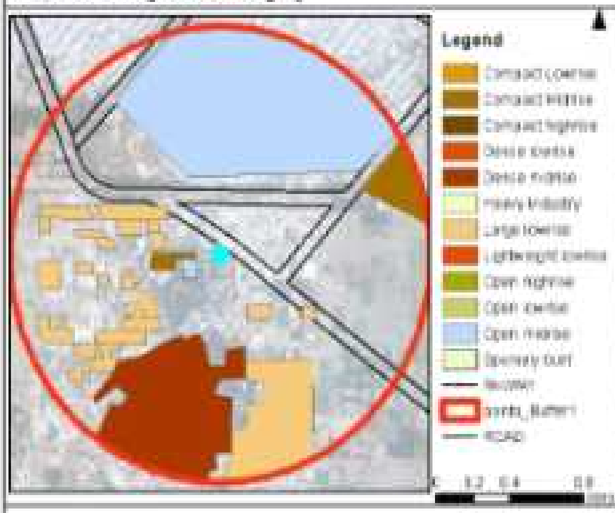
6.10.2. Bawana, DPCC

The station is located around the Bawana Industrial area in North Delhi. The predominant landuse is industrial and residential. Also it is surrounded by agricultural lands, which might influence the activities in the region.

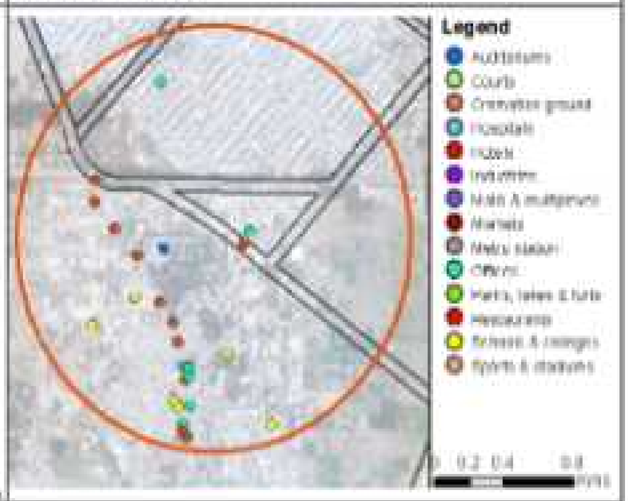
Map 193: Google earth imagery



Map 194: Land-use



Map 195: Built-form



Map 196: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)
Dense lowrise		0.00	COMMERCIAL	0	0.0	200-220
Dense midrise	0.309	9.84	INDUSTRIAL	1.2784	40.7	
Open midrise	0.830	26.33	TRANSPORTATION	0.2347	7.5	
Open highrise		0.00	RECREATIONAL	0.0042	0.1	
Open lowrise		0.00	RESIDENTIAL	0.971	30.9	
Compact Lowrise		0.00	PSP FACILITIES	0.1164	3.7	
Compact Midrise	0.068	2.16	GOVERNMENT		0.0	
Compact Highrise		0.00	UTILITY		0.0	
Large lowrise	0.339	10.78	SPECIAL AREA		0.0	
Sparsely built		0.00	WATERBODY	0.12	3.8	
Green belt	0.910	28.94	GREEN BELT	0.42	13.4	
Open area	0.300	9.55				
Waterbody	0.120	3.82				
Road	0.180	5.73				
Heavy Industry		0.00				

Table 134: Landuse and built-form percentages in the buffer zone

Figure 133: Wind direction

The predominant wind direction is from North during the months March to May. So, all the emissions by activities in this region would have a major effect on the pollution concentration in the city, as it lies in the north and wind is also from north. So, it would carry all the emissions from this region into the city core.

There were partial restrictions on the industrial units during the lock-down phases. As during the first phase of lock-down, movement of essential goods was only allowed, which was relaxed in the second phase. In second phase, manufacturing and other industrial establishments with access control in SEZS and export oriented units (EOUS), industrial estates and industrial townships were made operational.
It can be observed from the following table 135, that the concentration reduced significantly in the 1st phase of lock-down in comparison to the phase before lock-down, as we can see the concentrations of $PM_{2.5}$ reduced from poor category to moderate and satisfactory. Whereas no major reduction in PM_{10} concentrations were observed in first two phases of lock-down although it further increased in the 3rd and 4th phase. In Phase 3, inter-state movement of all types of goods/ cargo, including empty trucks were allowed, which made the industrial operations easier. The effect of which can be seen in these phases with the increase in values of the pollutants.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
	1st March	57.77	115.77	24th March	70.41	126.1	15th April	90.79	[illegible]	4th May	41.46	82.36	18th May	127.69	287.56
	2nd March	119.04	224.42	25th March	55.04	81.59	16th April	81.12	289.01	5th May	74.9	149.1	19th May	147.39	[illegible]
	3rd March	130.92	291.7	26th March	74.1	117.9	17th April	54.89	127.46	6th May	81.59	[illegible]	20th May	96.73	325.77
	4th March	101.22	216.04	27th March	36.59	58.67	18th April	38.71	136.29	7th May	47.61	113.12	21st May	75.94	232.76
	5th March	43.1	77.97	28th March	[illegible]	[illegible]	19th April	54.71	121.95	8th May	77.14	180.1	22nd May	127.31	[illegible]
	6th March	32.77	42.35	29th March	41.58	84.41	20th April	81	192.12	9th May	69.42	165.36	23rd May	91.94	370.51
	7th March	61.08	126.49	30th March	38.02	108.4	21st April	54.12	148.54	10th May	54.11	146.95	24th May	69.18	298.58
	8th March	88.5	137.3	31st March	53.65	107.2	22nd April	83.12	206	11th May	55.78	130.76	25th May	76.15	212.26
	9th March	76.54	168.44	1st April	32.14	89.86	23rd April	71.96	196.52	12th May	57.34	138.5	26th May	85.92	[illegible]
	10th March	89.55	167.56	2nd April	None	102.9	24th April	97.62	215.9	13th May	95.7	202.12	27th May	46.88	218.46
	11th March	64.42	114.56	3rd April	None	112.2	25th April	45.42	128.4	14th May	87.67	172.12	28th May	40.96	[illegible]
Bawana, Delhi - DPCC	12th March	66.79	190.75	4th April	None	131.2	26th April	53.16	187.1	15th May	68.91	149.79	29th May	38.38	78.43
	13th March	106.72	[illegible]	5th April	None	139.3	27th April	38.89	88.79	16th May	127.48	229.16	30th May	30	71.54
	14th March	53.07	375	6th April	None	160.1	28th April	90.92	179.50	17th May	143.86	[illegible]	31st May	None	67.6
	15th March	96.22	172.77	7th April	30.56	156.6	29th April	73.54	167.71						
	16th March	98.2	188.41	8th April	43.25	114.3	30th April	59.06	150.08						
	17th March	105.8	212.49	9th April	58.67	119.4	1st May	93.67	211.71						
	18th March	100	170.02	10th April	76.46	156	2nd May	44.21	155.5						
	19th March	127.8	188.84	11th April	68.28	133.7	3rd May	42.88	108.25						
	20th March	102.39	[illegible]	12th April	38.56	142.7									
	21st March	132.26	[illegible]	13th April	96.7	197.5									
	22nd March	96.9	150.85	14th April	96.17	288									
	23rd March	67.52	119.58												

Table 135: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend				Legend		
	PM2.5				PM10	
Good	30			Good	50	
Satisfactory	60			Satisfactory	100	
Moderately Polluted	90			Moderately Polluted	250	
Poor	120			Poor	350	
Very Poor	250			Very Poor	430	
Severe	>250			Severe	>430	

Legend

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019, because of the restrictions on majority of industrial activities and movement of goods and services. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

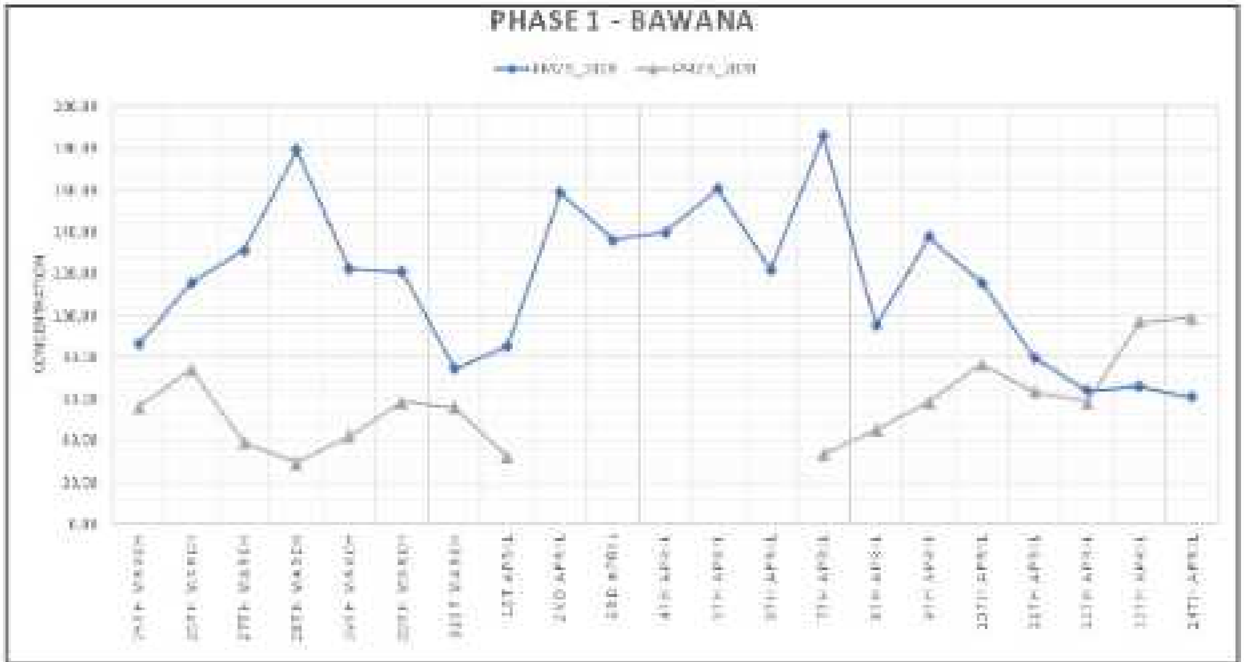


Figure 134: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at Bawana station during Phase 1: 25th March to 14th April

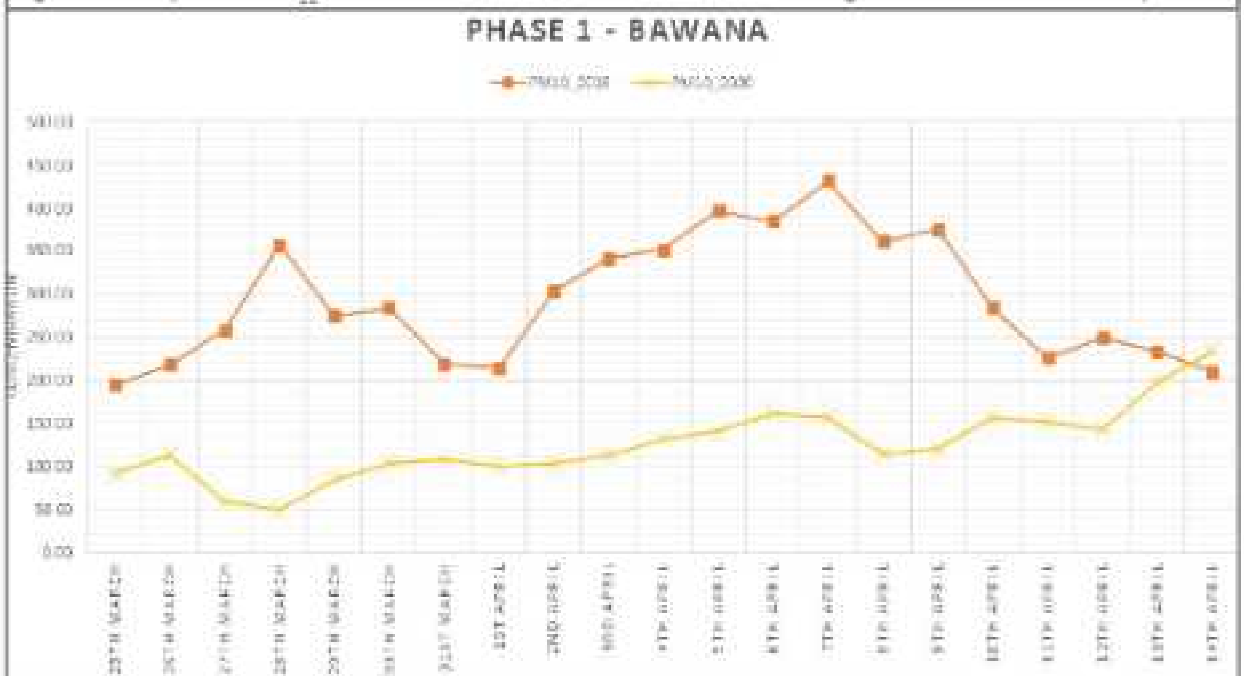


Figure 135: Comparison of PM_{10} concentrations in 2019 and 2020 at Bawana station during Phase 1: 25th March to 14th April

Phase 2

If we compare it with the phase 1, there was an increase in concentration of $PM_{2.5}$. The initial peak around 15th and 16th April was due to the dust-storm which was higher than th levels of previous year. The PM_{10} concentrations were mostly moderately polluted throughout the phase. During the phase, in total 5 western disturbances caused the winds and mild dust-storms in the city, increasing the concentration of pollutants even when there were very little activities. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks. On comparing the concentrations of 2019 and 2020, the peak of PM_{10} value was due to the dust-storm on 25th / 26th April in Delhi.

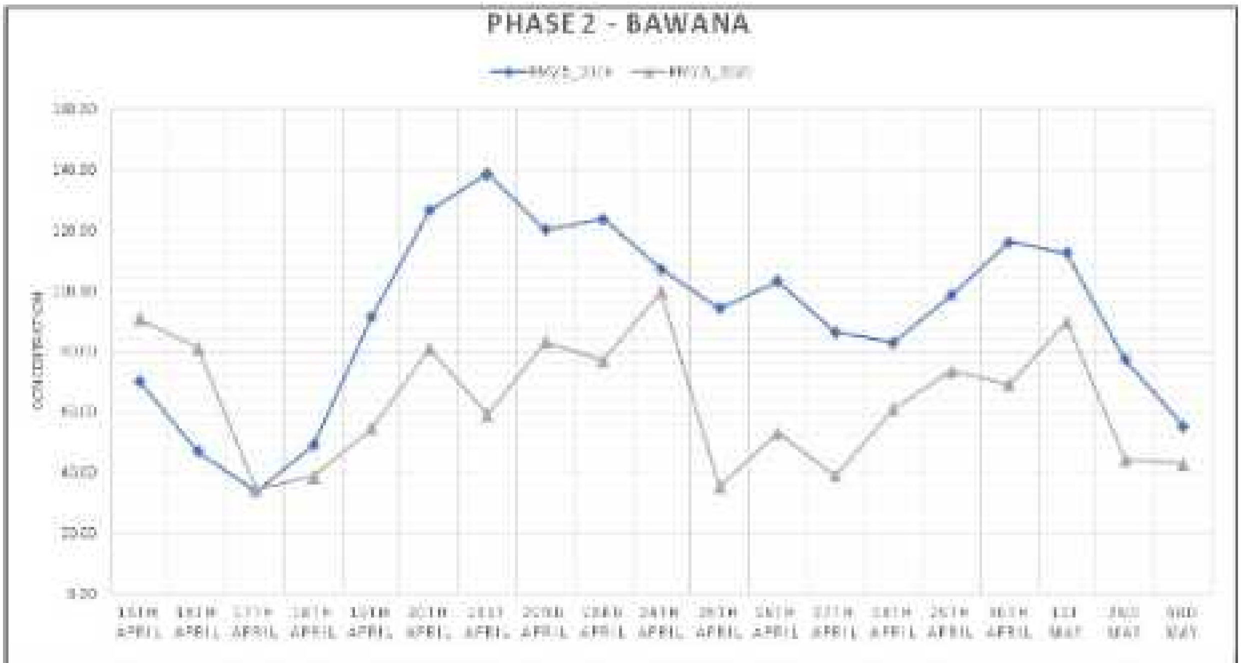


Figure 136: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at Bawana station during Phase 2: 15th April to 3rd May

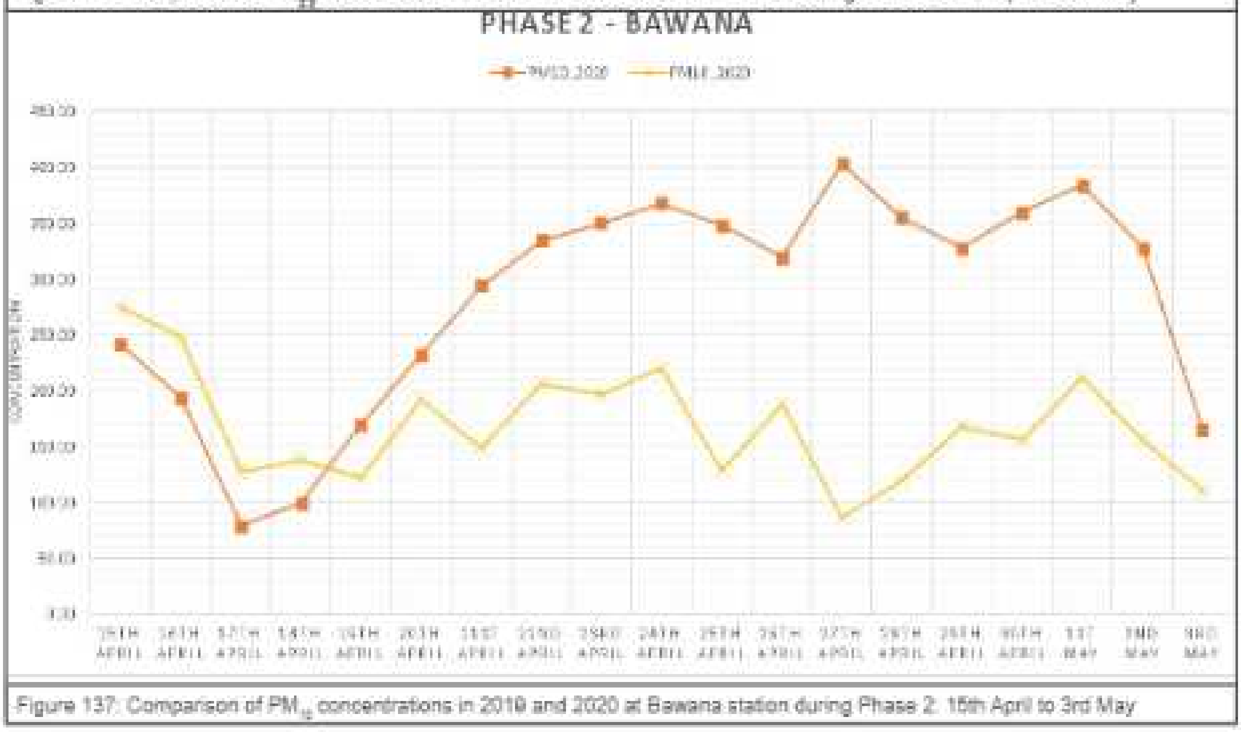


Figure 137: Comparison of PM_{10} concentrations in 2019 and 2020 at Bawana station during Phase 2: 15th April to 3rd May

Phase 3

The overall values of PM 2.5 and 10 were extremely high in 2019 due to the traffic induced by the industrial activities like loading and unloading.

In comparison to phase 2, in this phase the industrial activities in the area were permitted, so the slight increase in concentrations can attributed to it. Also, the 4 peaks in the concentrations were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

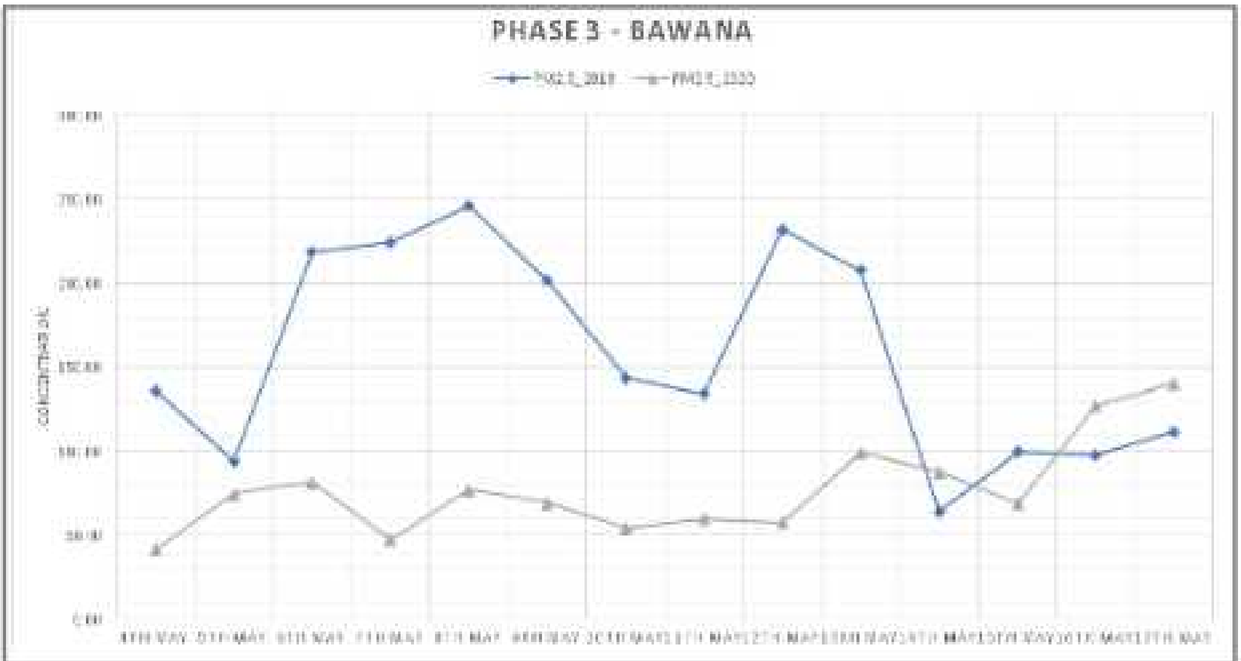


Figure 138: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at Bawana station during Phase 3: 4th May to 17th May

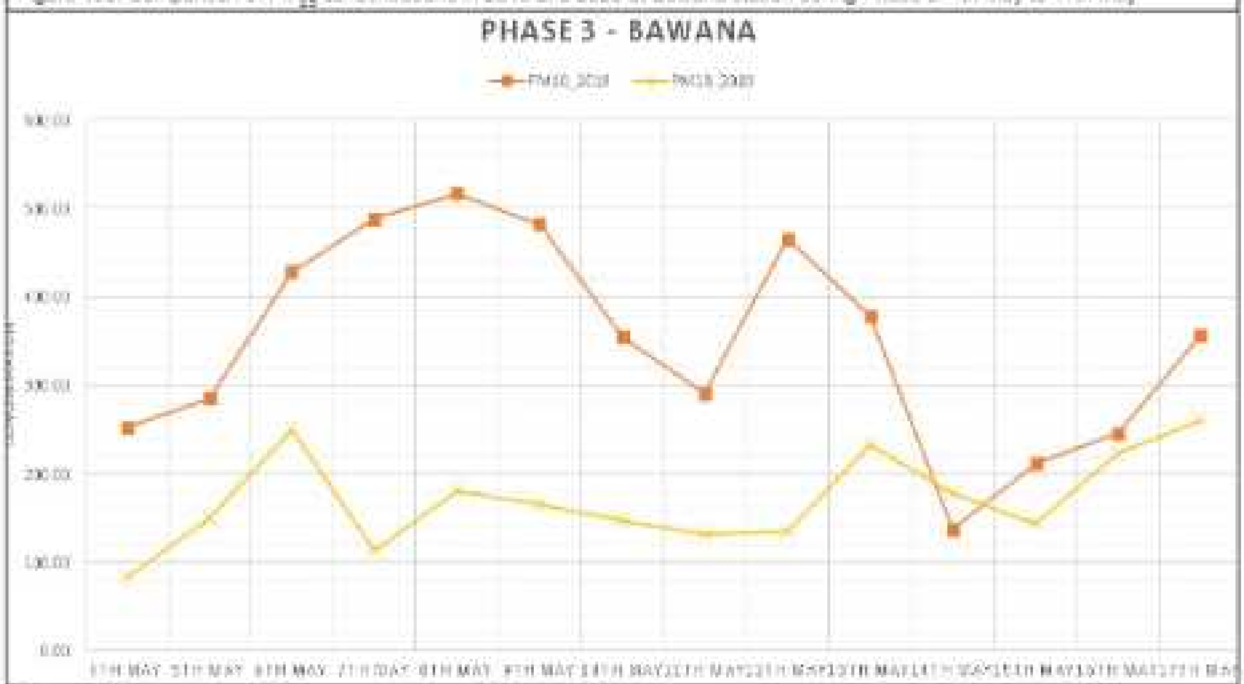


Figure 139: Comparison of PM_{10} concentrations in 2019 and 2020 at Bawana station during Phase 3: 4th May to 17th May

Phase 4

This phase brought the concentrations of both $PM_{2.5}$ and PM_{10} into the poor category in the area. With the onset of unobstructed movement of people and vehicles providing goods and services, the industrial zone at Bawana was observed to be fully functional with the concentrations of $PM_{2.5}$ and 10 surpassing even the values of 2019. The concentrations increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. It can be clearly seen how the activities in this area triggered the pollution concentrations at the monitoring station.

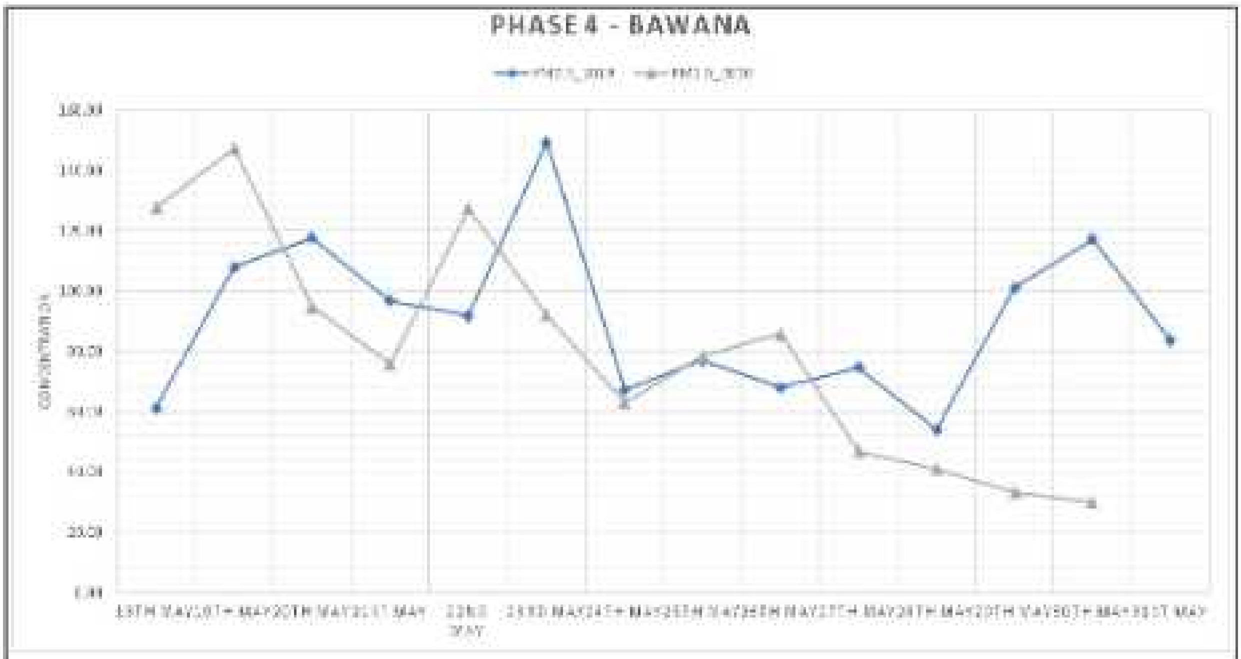


Figure 140: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at Bawana station during Phase 4: 18th May to 31st May

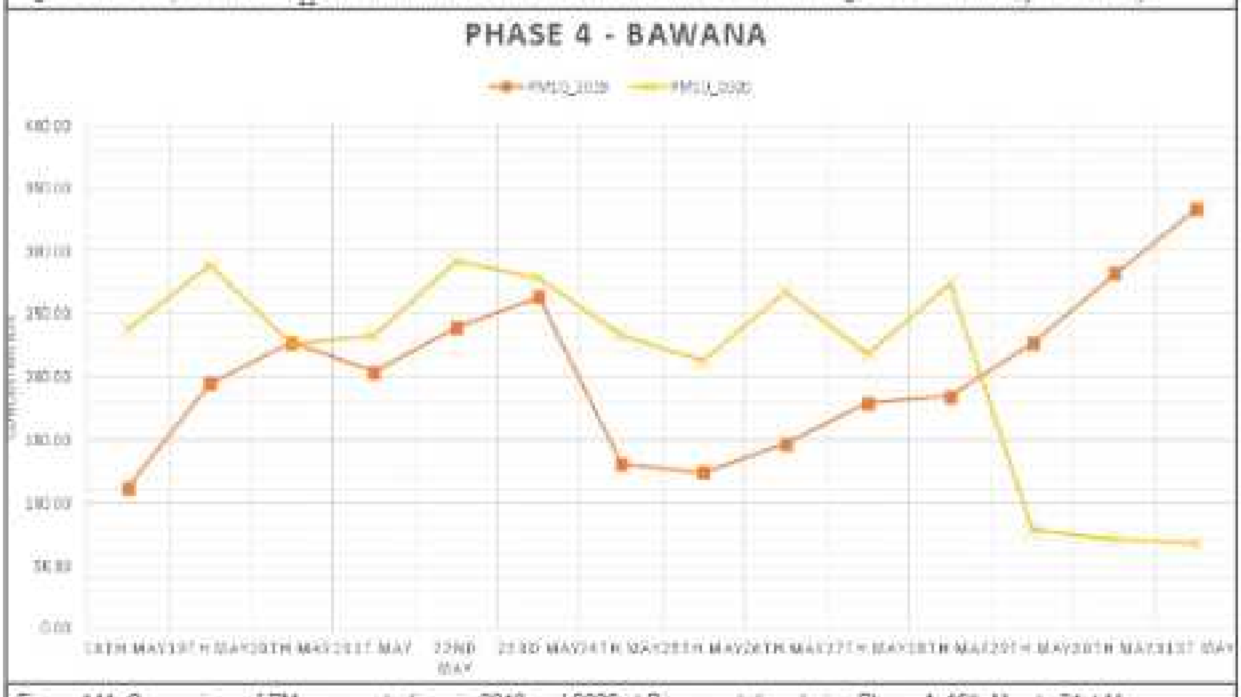
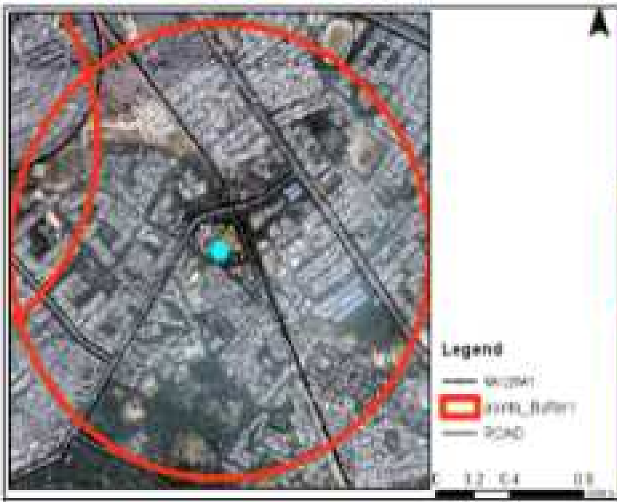


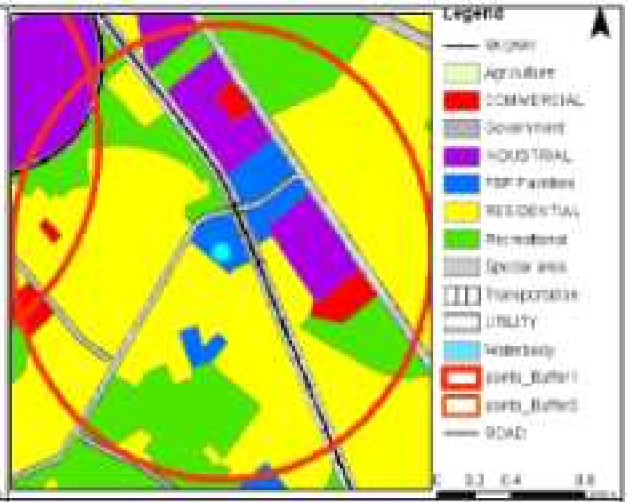
Figure 141: Comparison of PM_{10} concentrations in 2019 and 2020 at Bawana station during Phase 4: 18th May to 31st May

6.10.3. Ashok Vihar, DPCC

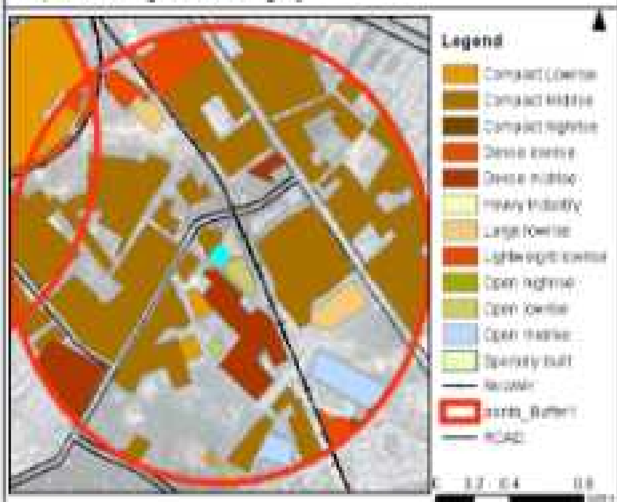
The station has residential as the predominant landuse in the buffer zone of 1km around the monitoring station. It also has significant amount of recreational and industrial landuses around it. The predominant wind direction from March to May is from North.



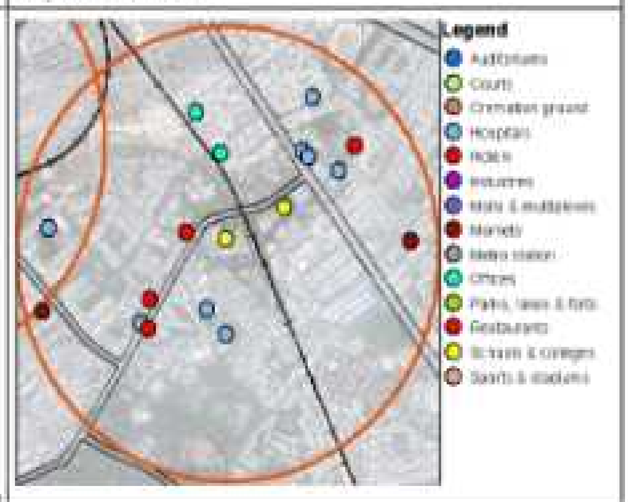
Map 197: Google earth imagery



Map 198: Land-use



Map 199: Built-form



Map 200: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)
Dense lowrise	0.122	3.66	COMMERCIAL	0.0857	2.7	200-220
Dense midrise	0.192	5.76	INDUSTRIAL	0.2864	9.1	
Open midrise	0.069	2.20	TRANSPORTATION	0.75	5.2	
Open highrise	0.000	0.00	RECREATIONAL	0.6824	21.7	
Open lowrise	0.021	0.67	RESIDENTIAL	1.6556	52.7	
Compact Lowrise	0.044	1.41	PSP FACILITIES	0.1503	4.8	
Compact Midrise	1.222	38.39	GOVERNMENT	0	0.0	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	
Large lowrise	0.044	1.40	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY		0.0	
Green belt	0.800	25.48	GREEN BELT		0.0	
Open area	0.350	11.15				
Waterbody	0.000	0.00				
Road	0.290	9.24				
Heavy Industry		0.00				

Table 136: Land use and Built-up percentages

Figure 142: Wind direction at the monitoring station

And the activities which might influence the pollution concentrations in the region could be the industrial, commercial, PSP (schools, colleges, etc) landuses and vehicular emissions from the residential sector. There is huge area (22% approx) lies under recreational sector too, which might act as pollution sink at the same time.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
Ashok Vihar, Delhi - DPCC	1st March	59.53	105.09	24th March	65.37	104.9	15th April	59.51	174.1	4th May	39.1	55.74	18th May	95.78	158.8
	2nd March	120.1	215.92	25th March	41.14	82.69	16th April	80.3	180.8	5th May	56.19	83.21	19th May	108.92	157.8
	3rd March	80.53	177.45	26th March	56.33	81.48	17th April	[illegible]	85.9	6th May	64.83	143.53	20th May	59.75	111.78
	4th March	82.71	170.8	27th March	[illegible]	44.01	18th April	29.1	65.35	7th May	36.3	65.35	21st May	44.02	118.6
	5th March	39.73	65.77	28th March	[illegible]	[illegible]	19th April	31.31	53.91	8th May	47.43	88.43	22nd May	120.97	184.87
	6th March	24.27	37.5	29th March	31.17	51.59	20th April	64.02	96.35	9th May	54.4	101.31	23rd May	63.43	150.39
	7th March	None	91.49	30th March	30.34	70.85	21st April	42.01	74	10th May	41.96	94.15	24th May	51.81	131.48
	8th March	None	177.61	31st March	37.2	65.32	22nd April	70.67	115.1	11th May	42.26	71.33	25th May	57.36	122.54
	9th March	109.18	182.98	1st April	45.29	74.19	23rd April	19.35	107.77	12th May	40.91	77.44	26th May	44.99	144.71
	10th March	96.61	152.35	2nd April	32.9	61.58	24th April	66.4	105.42	13th May	72.6	127.77	27th May	37.23	130.38
	11th March	65.47	109.88	3rd April	34.67	50.9	25th April	[illegible]	73.08	14th May	65.7	106.99	28th May	31.77	170.77
	12th March	73.84	153.06	4th April	51.68	61	26th April	42.48	101.53	15th May	49.42	79.14	29th May	23.01	44.2
	13th March	68.79	147.79	5th April	67.98	103	27th April	[illegible]	[illegible]	16th May	57.19	88.03	30th May	[illegible]	[illegible]
	14th March	35.1	72.47	6th April	70.75	122	28th April	30.33	65.08	17th May	67.66	127.85	31st May	30	[illegible]
	15th March	82.79	124.69	7th April	31.69	97.71	29th April	13.21	88.71						
	16th March	74.03	132.27	8th April	30.12	92.17	30th April	31.43	94.32						
	17th March	85.27	144.44	9th April	38.6	71.1	1st May	62.08	124.79						
	18th March	77.71	151.69	10th April	66.77	113	2nd May	32.85	50.42						
	19th March	119.73	134.58	11th April	60.79	112	3rd May	32.05	62.05						
	20th March	96.77	135.1	12th April	38.71	73.17									
	21st March	96.[illegible]	147.65	13th April	64.48	113.4									
	22nd March	88.46	134.35	14th April	57.33	121.1									
	23rd March	67.71	113.11												

Table 137: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend PM2.5		
Good	30	
Satisfactory	60	
Moderately Polluted	90	
Poor	120	
Very Poor	250	
Severe	>250	

Legend PM10		
Good	50	
Satisfactory	100	
Moderately Polluted	250	
Poor	350	
Very Poor	430	
Severe	>430	

Legend

From the table 137, it can be clearly observed that there was 50-60% reduction in the values during the first phase of the lock-down, and which were sustained till the third phase of lock-down. The possible emission source from the area can be from the vehicles of the residential sector or industrial sector and PSP sector, As PSP, commercial and residential sector were under restrictions uptill the third phase, so the concentration of $PM_{2.5}$ and PM_{10} in the area remains negligible. Although, it increased in the fourth phase, when free movement of people was permitted inside the city. The industrial area in the zone doesn't comes under SEZs nor EOUs, they also don't have any access control, so as per the guidelines these couldn't resume even under 3rd and 4th phase of lock-down, although the industries manufacturing essential commodities were operational. In 4th phase the concentrations of PM_{10} increased and quality changed to moderately polluted, whereas the $PM_{2.5}$ concentrations remained good.

Figure 143: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 1: 25th March to 14th April

Figure 144: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 1: 26th March to 14th April

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019 and 2018, because of the restrictions on majority of industrial activities and movement of goods and services. The schools and commercial centers in the region remained closed. The PM_{10} concentrations in 2018 went upto 450 µg/m³ whereas in lock-down the peak touched only 121 µg/m³ even on the day of dust-storm. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

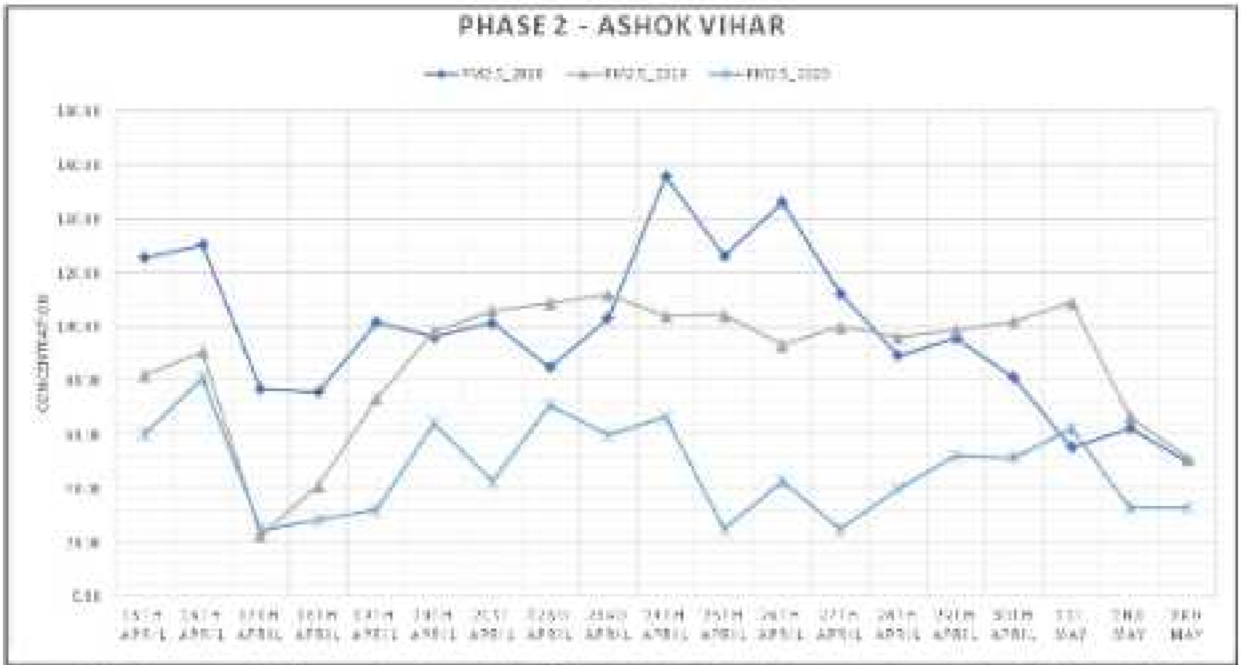


Figure 145: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 2: 15th April to 3rd May

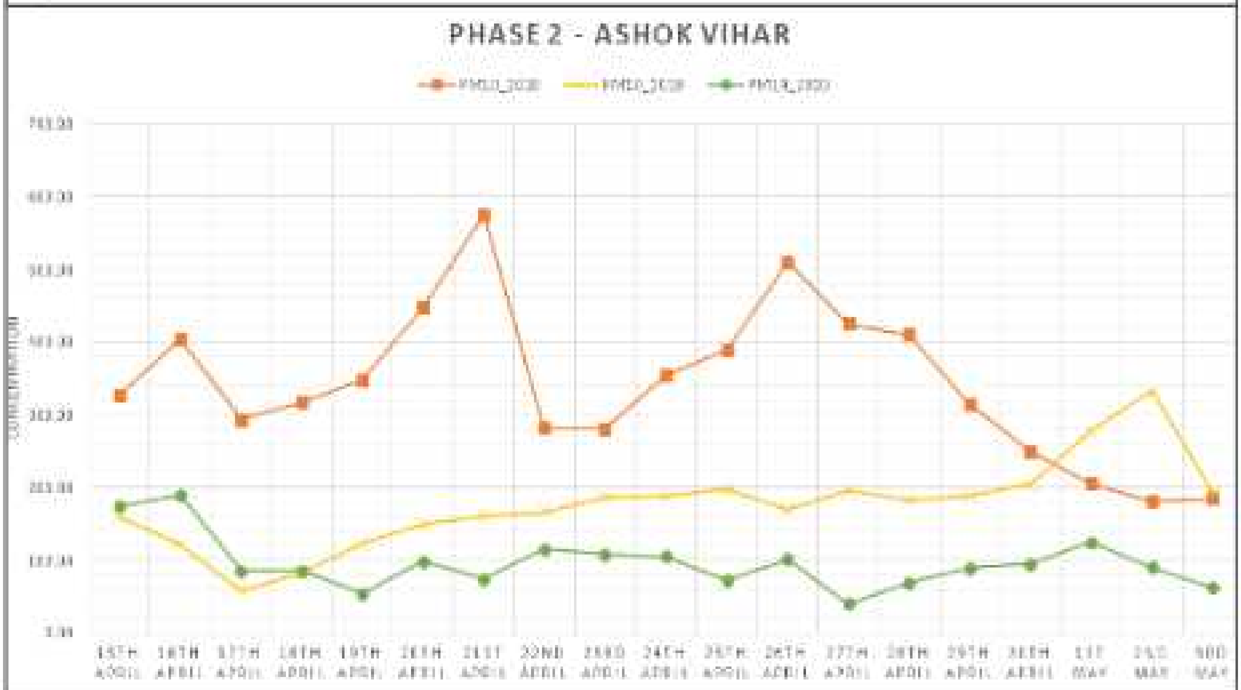


Figure 146: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 2: 15th April to 3rd May

Phase 2

The concentrations in 2020 during lock-down are three times lesser than those in the 2018. The effect of closure of activities can be seen quite evidently in the area. The concentrations of PM_{10} were maximum 120 µg/m³ even when there were in total 5 western disturbances which caused the winds and mild dust-storms in the city. So, even during the mild dust-storms the concentrations remained low as compared to the other stations in Delhi.

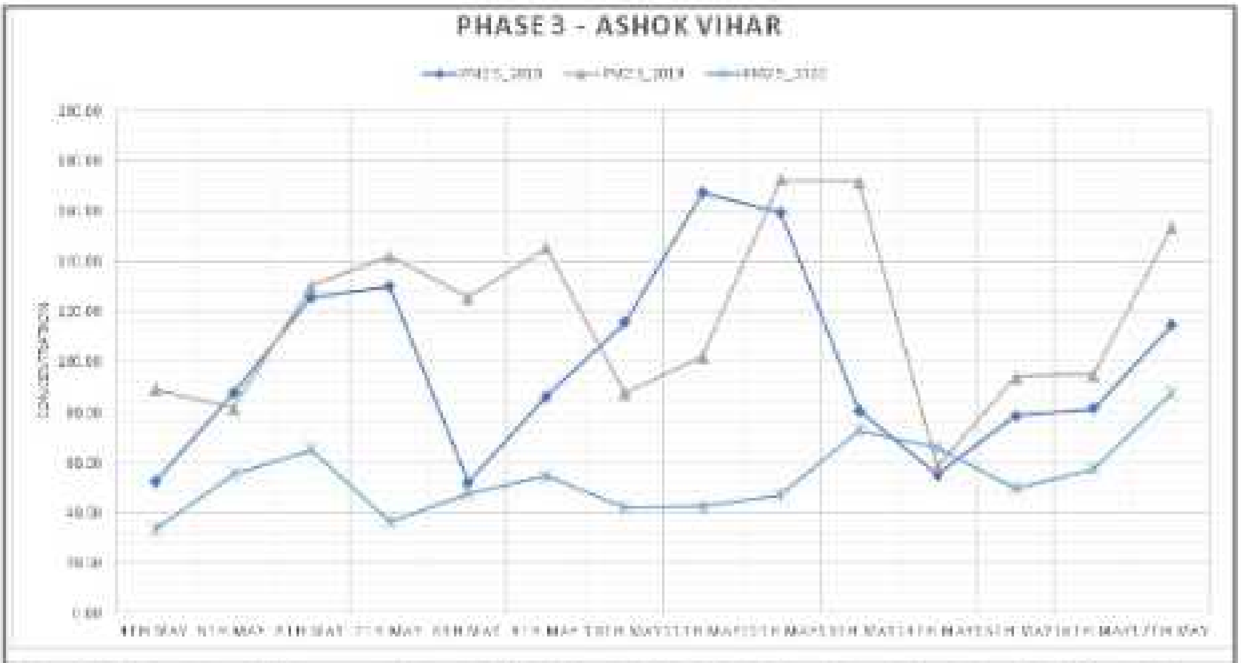


Figure 147: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 3: 4th May to 17th May

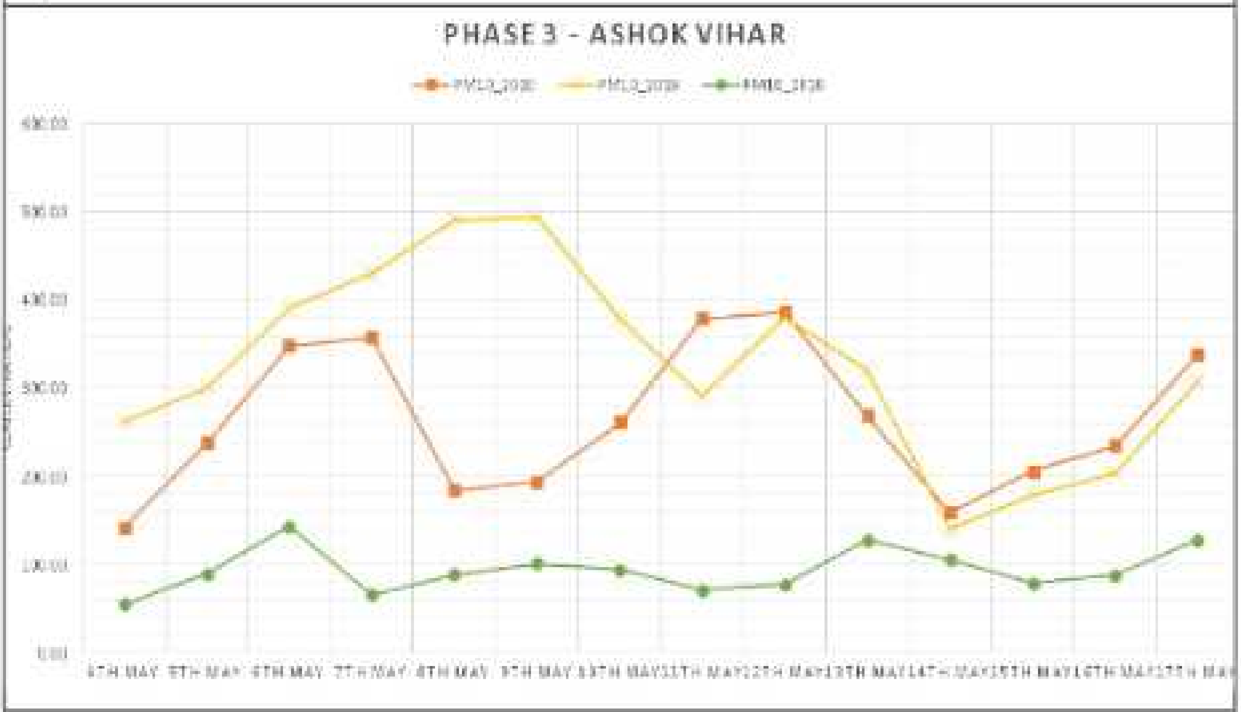


Figure 148: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 3: 4th May to 17th May

Phase 3

The overall values of PM 2.5 and 10 were extremely high in 2018 and 2019 due to the traffic induced by the industrial activities like loading and unloading and PSP sector in the zone. The maximum value of PM_{10} in 2019 went upto 480 µg/m³ which was only 140 µg/m³ in 2020. Also, the 3 small peaks in the concentrations in 2020 were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

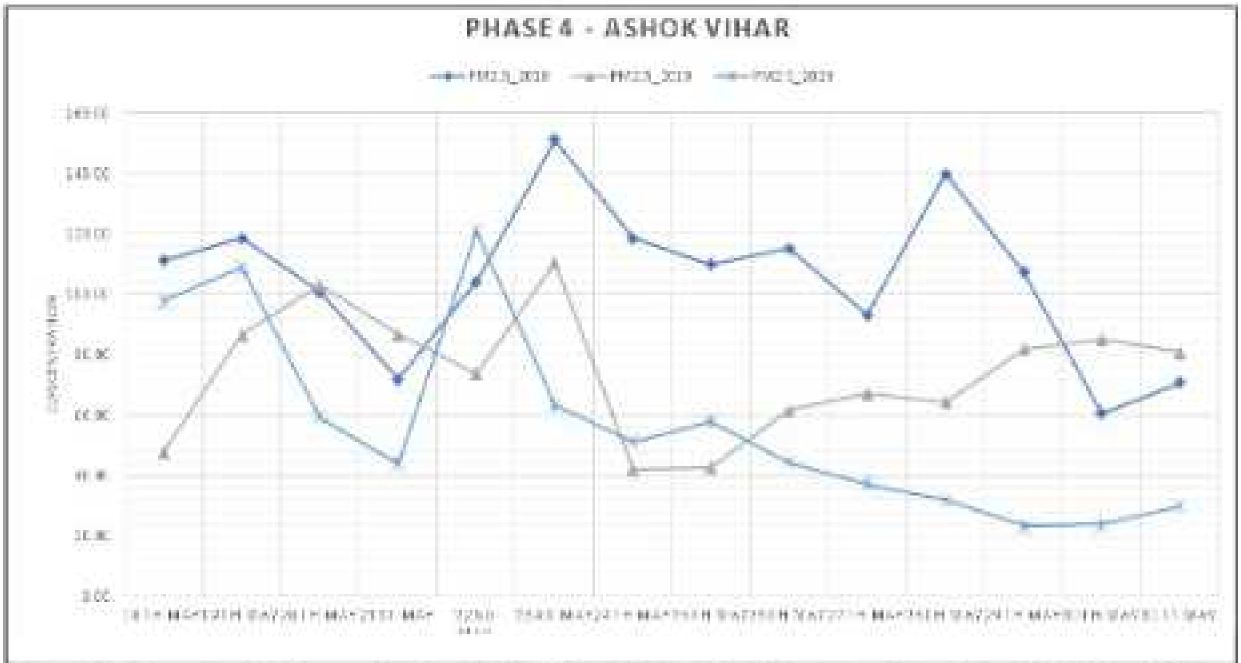


Figure 149: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 4: 18th May to 31st May

Figure 150: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at Ashok Vihar station during Phase 4: 18th May to 31st May

Phase 4

This phase brought the concentrations PM_{10} into the moderately polluted category in the area. With the onset of unobstructed movement of people and vehicles providing goods and services, the economic activities in the region were opened up to some extent.

It can be clearly seen how the activities in this area triggered the pollution concentrations at the monitoring station. The concentrations increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm, in this phase.

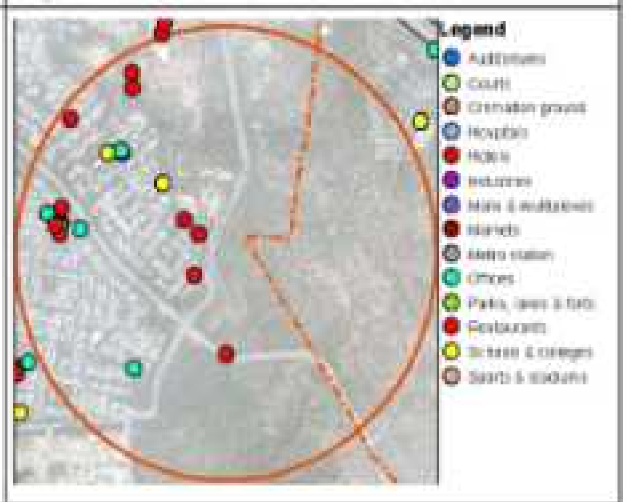
6.10.4. Aya Nagar

The station lies in the south border of Delhi with Gurugram and has recreational/ green belt as the predominant landuse in the buffer zone of 1km around the monitoring station. It also has significant amount of residential landuse in it. The predominant wind direction from March to May is from North-east.

Map 201: Google earth imagery

Map 202: Land-use

Map 203: Built-form



Map 204: Major activities

NO.	STATION NAME	LCZ Types	Area (sq. km)	%	LANDUSE Types	Area (sq. km)	%
12	Aya Nagar, Delhi - IMD	Dense lowrise	0.000	0.00	COMMERCIAL	0	0.0
		Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0
		Open midrise	0.790	25.24	TRANSPORTATION	0.24	7.6
		Open highrise	0.000	0.00	RECREATIONAL	0	0.0
		Open lowrise	0.000	0.00	RESIDENTIAL	[illegible]	[illegible]
		Compact Lowrise	0.000	0.00	PSP FACILITIES	0	0.0
		Compact Midrise	0.000	0.00	GOVERNMENT	0	0.0
		Compact Highrise	0.000	0.00	UTILITY	0	0.0
		Large lowrise	0.000	0.00	SPECIAL AREA		0.0
		Sparsely built	0.000	0.00	WATERBODY	0	0
		Green belt	2.050	65.29	GREEN BELT	1.7	54.1
		Open area	0.050	1.59			
		Water body	0.000	0.00			
		Road	0.240	7.64			
		Heavy Industry		0.00			

Table 136: Land use and Built-up percentages

Figure 151: Wind direction at the monitoring station

The station lies on an elevation of 260m which is approximately 40 m above the levels of the city, it gets benefited to some extent by it as pollutant accumulation doesn't happen here. Also, the emissions in this area can only be through either biogenic emissions from the vegetative areas, or the vehicular traffic from the residential area apart from the regional sources.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
	1st March	36.14	69.98	20th March	45.77	83.15	15th April	44.94	152.92	4th May	46.96	50.52	18th May	99.48	131.26
	2nd March	67.17	132.77	25th March	32.42	53.16	16th April	53.6	135.09	5th May	51.06	50.58	19th May	85.83	183.67
	3rd March	60.43	136.79	26th March	47.41	38.47	17th April	35.77	69.05	6th May	None	136.32	20th May	77.18	148.92
	4th March	66.3	143.75	27th March	[illegible]	[illegible]	18th April	33.13	60.12	7th May	None	73.45	21st May	82.42	150.16
	5th March	41.04	84.68	28th March	[illegible]	[illegible]	19th April	36.30	53.98	8th May	None	55.13	22nd May	111.53	182.94
	6th March	[illegible]	[illegible]	29th March	[illegible]	[illegible]	20th April	35.04	67.79	9th May	None	107.14	23rd May	64.81	159.15
	7th March	34.38	59.05	30th March	30.26	[illegible]	21st April	33.24	65.85	10th May	None	83.05	24th May	None	None
	8th March	45.43	77.36	31st March	[illegible]	52.58	22nd April	45.96	50.58	11th May	[illegible]	99.35	25th May	None	None
	9th March	43.05	98.07	1st April	25.46	51.12	23rd April	46.93	97.5	12th May	44.80	92.44	26th May	61.09	127.75
	10th March	49.13	110.32	2nd April	[illegible]	[illegible]	24th April	54.13	109.07	13th May	56.13	140.77	27th May	47.83	155.66
Aya Nagar, Delhi - IMD	11th March	69.27	91.56	3rd April	[illegible]	[illegible]	25th April	36.45	[illegible]	14th May	65.13	125.35	28th May	38.18	206.61
	12th March	39.5	128.47	4th April	37.29	60.11	26th April	37.79	85.88	15th May	56.09	98.71	29th May	[illegible]	57.6
	13th March	66.22	134.36	5th April	43.58	79.21	27th April	36.13	[illegible]	16th May	72.79	120.95	30th May	[illegible]	[illegible]
	14th March	33.99	77.88	6th April	45.55	88.38	28th April	43.88	61.09	17th May	87.88	163.45	31st May	[illegible]	[illegible]
	15th March	43.13	109.23	7th April	[illegible]	70.71	29th April	52.37	50.82						
	16th March	47.85	116.47	8th April	[illegible]	65.57	30th April	53.43	109.07						
	17th March	45.32	117.56	9th April	31.68	58.57	1st May	54.7	121.44						
	18th March	57.17	133.09	10th April	43.38	98.79	2nd May	41.71	65.41						
	19th March	62.8	142.58	11th April	50.1	98.75	3rd May	45.98	66.7						
	20th March	73.79	148.6	12th April	40.79	83.95									
	21st March	47.53	109.13	13th April	52.5	107.4									
	22nd March	68.47	130.08	14th April	42.53	118.8									
	23rd March	44.09	84.09												

Table 139: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend PM2.5			Legend PM10		
Good	30		Good	50	
Satisfactory	60		Satisfactory	100	
Moderately Polluted	90		Moderately Polluted	250	
Poor	120		Poor	350	
Very Poor	250		Very Poor	430	
Severe	>250		Severe	>430	

Legend

From the above table no. 139 it can be clearly observed that the $PM_{2.5}$ concentrations were good only even before the lock-down, and which were sustained till the third phase of lock-down. Although, PM_{10} concentrations which were moderately polluted also reduced to good quality for the next three phases. As commercial and residential sector were under restrictions uptill the third phase, so the concentration of $PM_{2.5}$ and PM_{10} in the area remains negligible. Although, it increased in the fourth phase, when free movement of people was permitted inside the city. It changed the quality from good to moderately polluted in this phase.

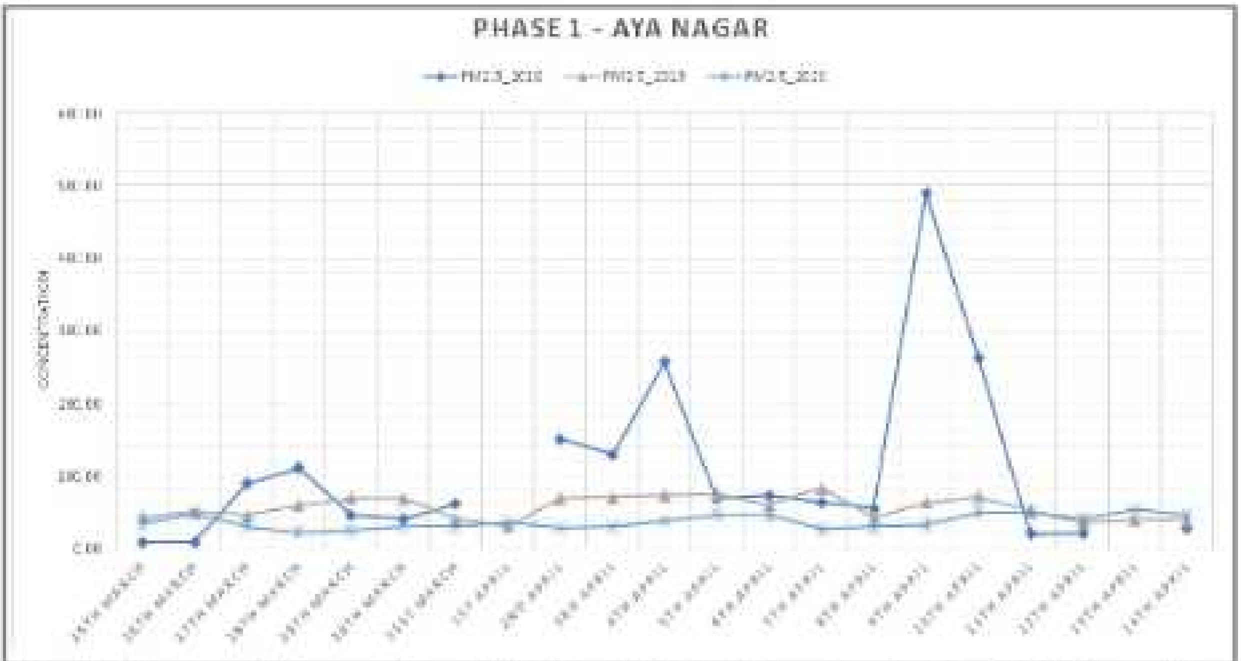


Figure 152: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Aya Nagar station during Phase 1: 25th March to 14th April

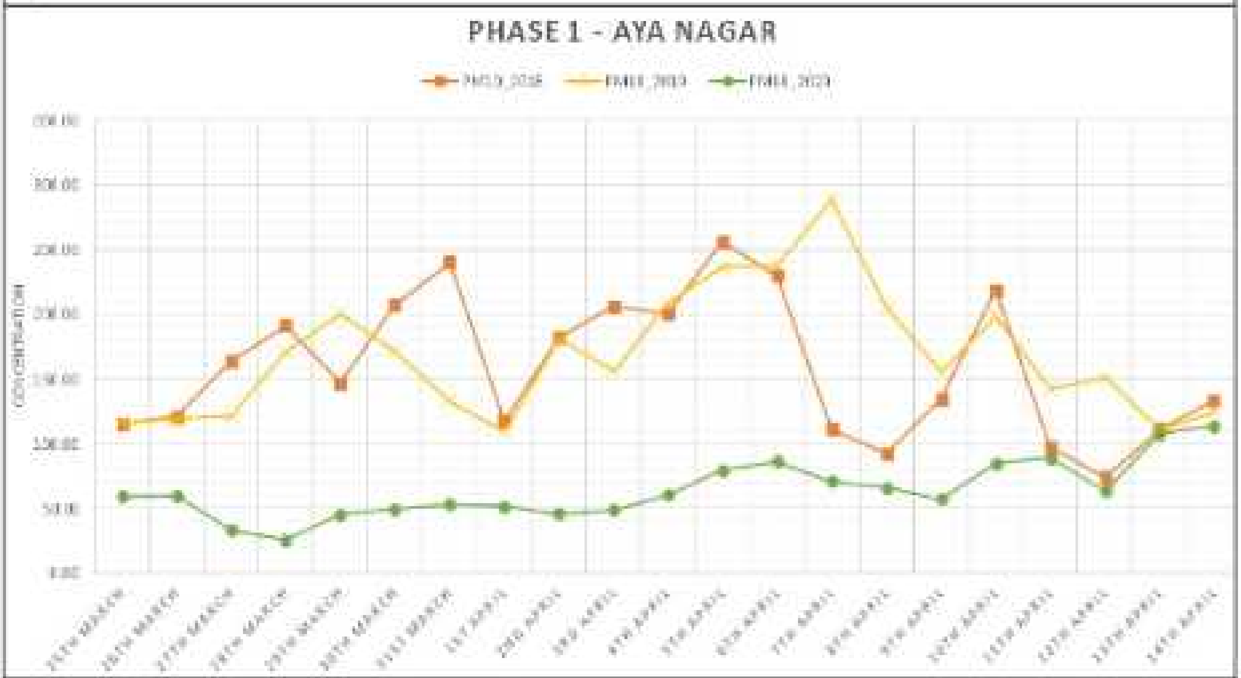


Figure 153: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at Aya Nagar station during Phase 1: 25th March to 14th April

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019 and 2018, because of the restrictions on movement of people. The PM_{10} concentrations in 2018 went upto 280 µg/m³ whereas in lock-down the peak touched only 113 µg/m³ even on the day of dust-storm. As it gets influenced by the regional pollutants to some extent, the emissions in 2018 and 2019 are higher whereas low in 2020, as the city also experienced good air quality throughout. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

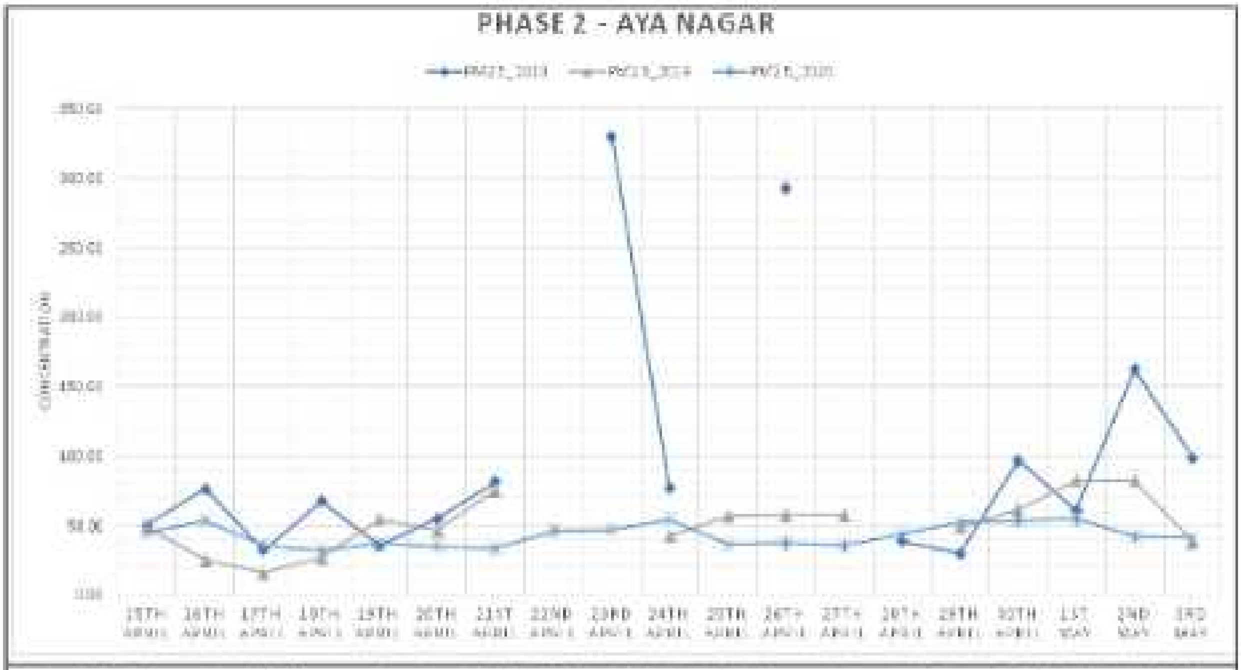


Figure 154: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Aya Nagar station during Phase 2: 15th April to 3rd May

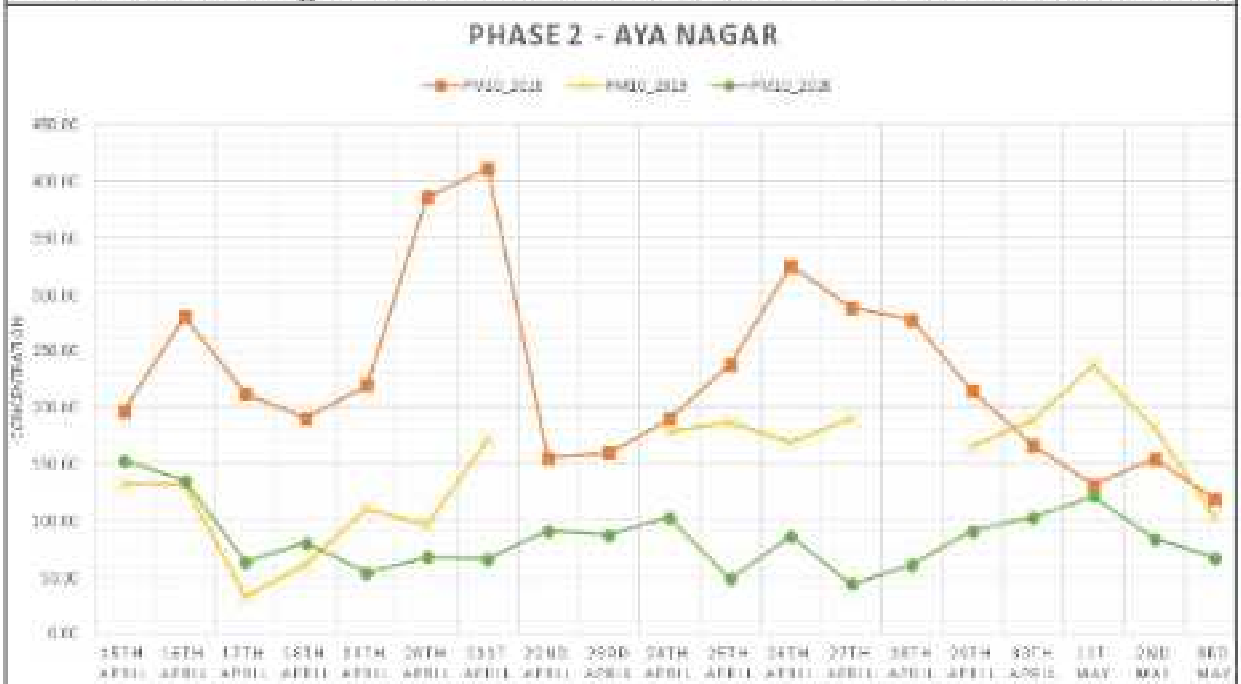


Figure 155: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Aya Nagar station during Phase 2: 15th April to 3rd May

Phase 2

The concentrations in 2020 during lock-down are three times lesser than those in the 2018. The effect of closure of activities can be seen quite evidently in the area. The concentrations of PM_{10} were maximum i.e.. 150 µg/m³ on the onset of major dust-storm on 15th April. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations in 2020 around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks. On comparing the concentrations of 2019 and 2020, the peak of PM_{10} value was due to the dust-storm on 25th / 26th April in Delhi.

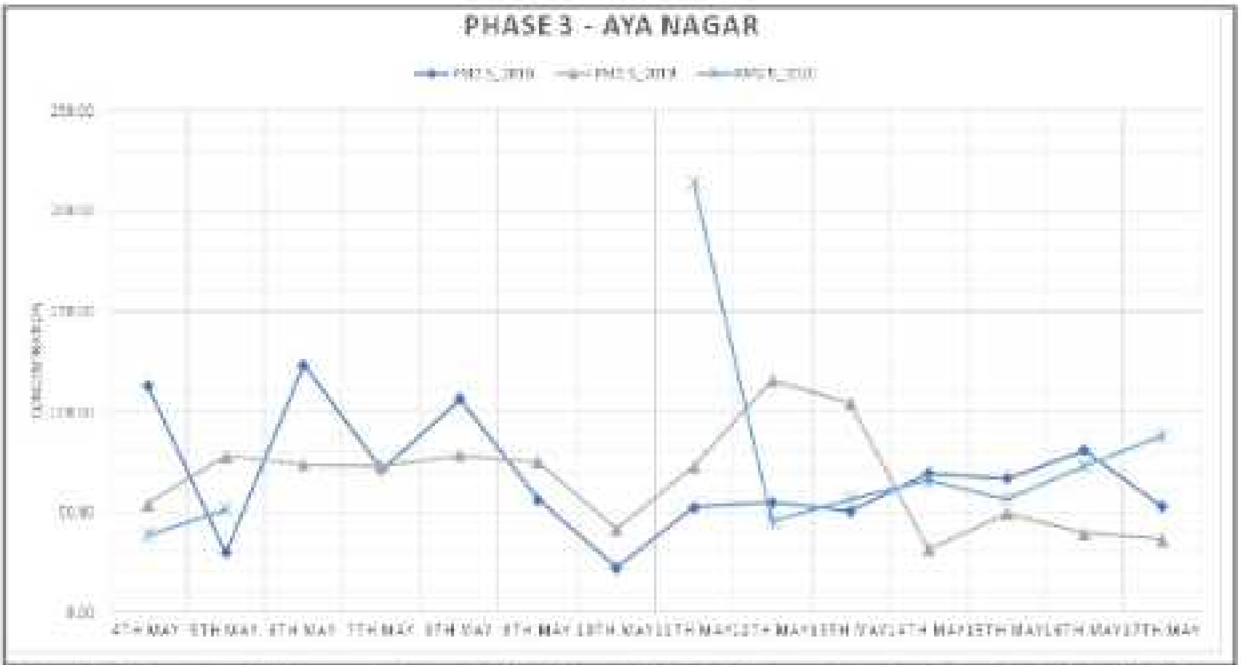


Figure 156: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at Aya Nagar station during Phase 3: 4th May to 17th May

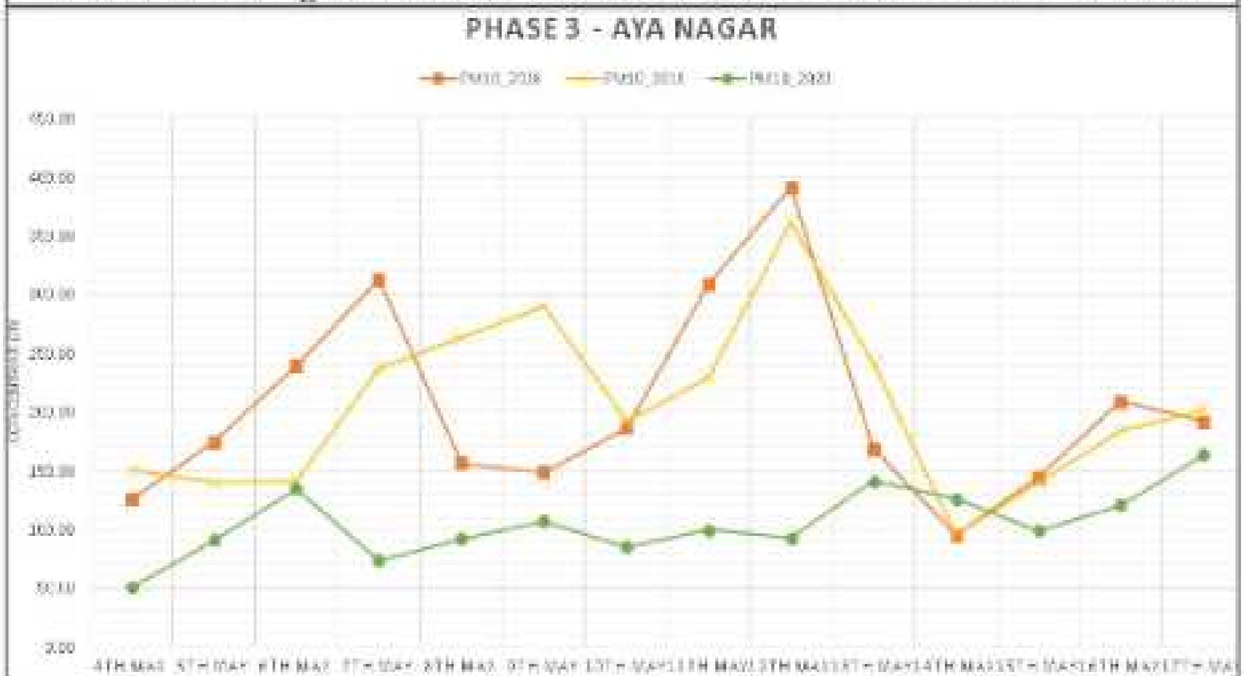


Figure 157: Comparison of PM_{10} concentrations in 2019 and 2020 at Aya Nagar during Phase 3: 4th May to 17th May

Phase 3

The overall values of PM 2.5 and 10 were extremely high in 2018 and 2019 due to the regional influences of pollutants. The maximum value of PM_{10} in 2019 went upto 370 µg/m³ which was only 165 µg/m³ in 2020.

Also, the 3 small peaks in the concentrations in 2020 were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

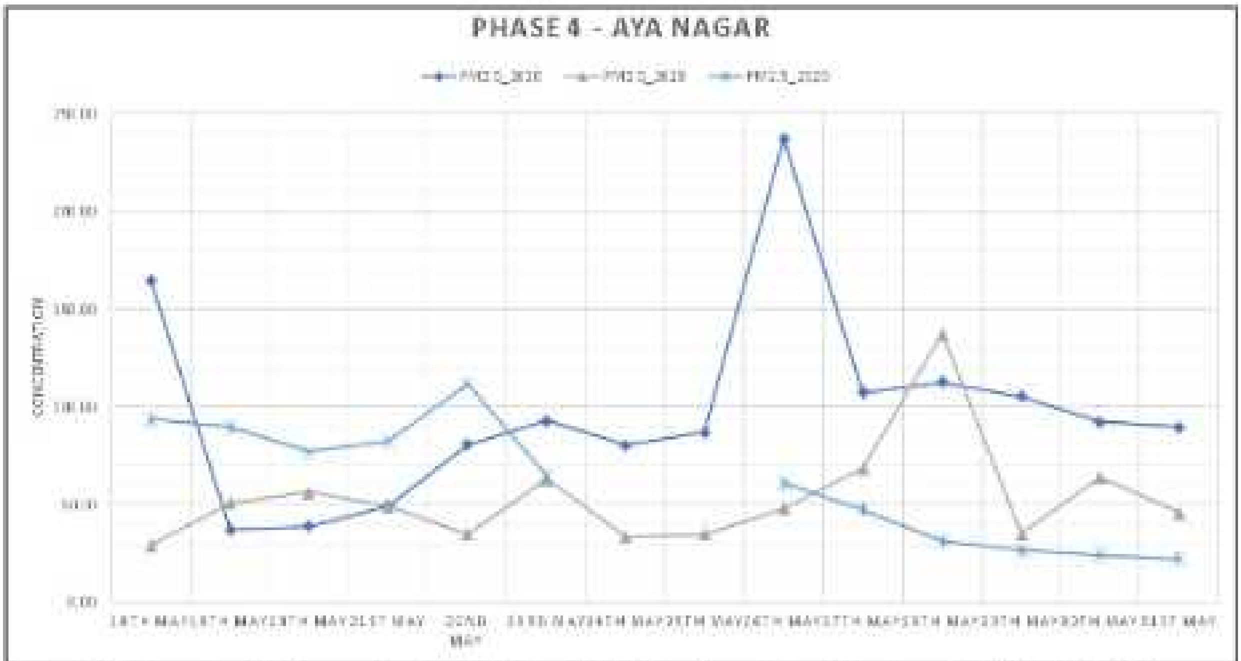


Figure 158: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at Aya Nagar station during Phase 4: 18th May to 31st May

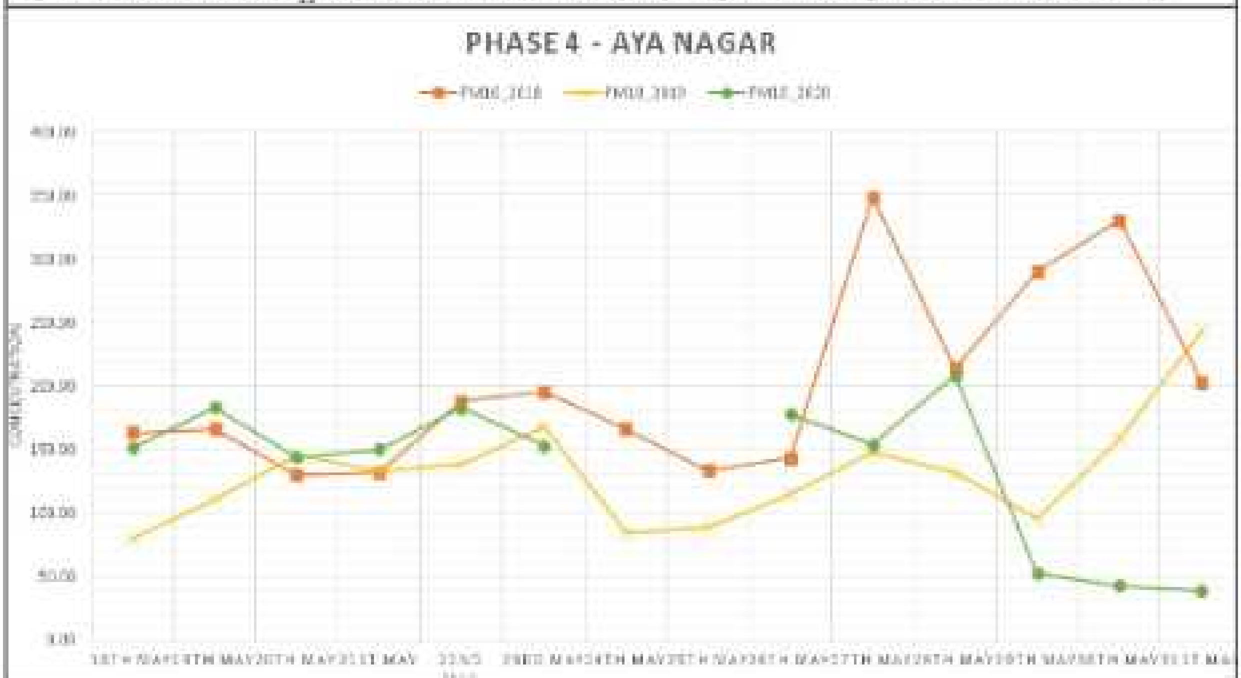


Figure 159: Comparison of PM_{10} concentrations in 2019 and 2020 at Aya Nagar station during Phase 4: 18th May to 31st May

Phase 4

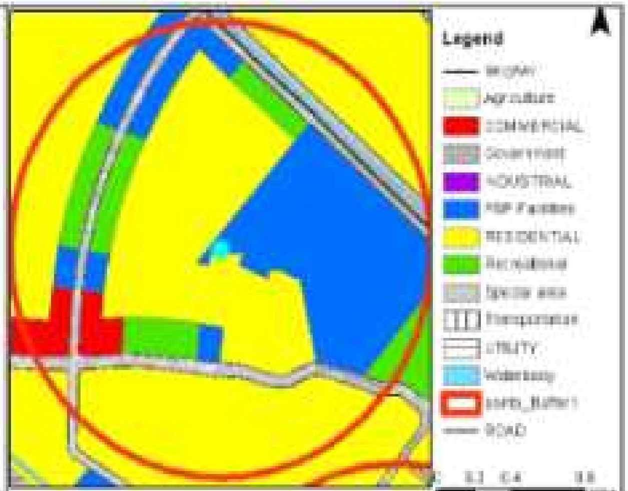
This phase brought the concentrations PM_{10} into the moderately polluted category in the area. With the onset of unobstructed movement of people and vehicles providing goods and services, the emissions in the region increased. Also, the road was used to enter/exit Delhi, when the main roads were sealed of by the state governments.

The concentrations increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm, in this phase.

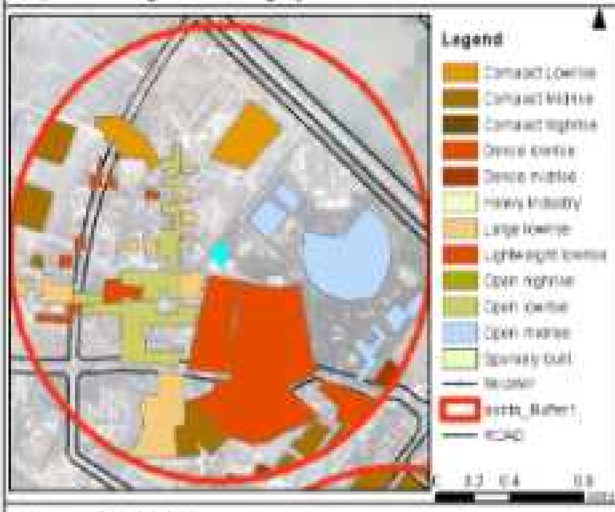
6.10.5. DTU, CPCB

The station lies in the Delhi Technical University near Rohini, and has PSP and residential as the predominant landuses in the buffer zone of 1km around the monitoring station. Although most of the area is open and without vegetation in the region and has not been developed still as per the master plan 2021.The predominant wind direction in March and April is from North-west and in May is from North-east.

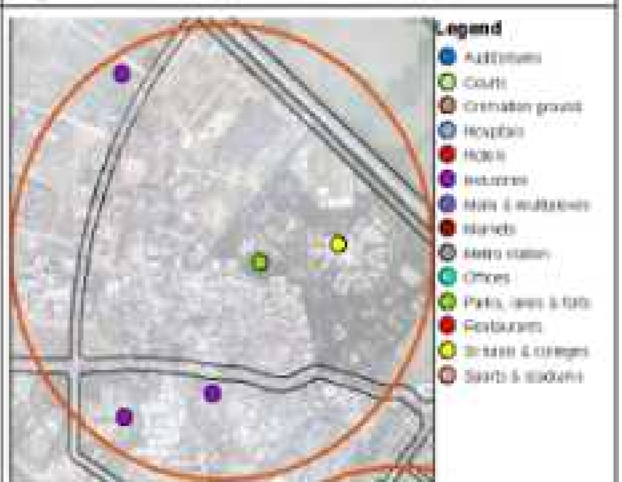
Map 205: Google earth imagery



Map 206: Land-use



Map 207: Built-form



Map 208: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	
Dense lowrise	0.404	12.67	COMMERCIAL	0	0.0	
Dense midrise	0.015	0.49	INDUSTRIAL	0	0.0	
Open midrise	0.176	5.51	TRANSPORTATION	0.23	7.3	
Open highrise	0.000	0.00	RECREATIONAL	0.3445	11.0	
Open lowrise	0.134	4.20	RESIDENTIAL	1.4567	54.8	
Compact Lowrise	0.004	2.57	PSP FACILITIES	0.7726	24.6	
Compact Midrise	0.125	3.86	GOVERNMENT	0	0.0	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	200-220
Large lowrise	0.110	3.50	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY	0.1	5.2	
Green belt	0.000	15.11	GREEN BELT		0.0	
Open area	1.260	40.15				
Waterbody	0.000	0.00				
Road	0.230	7.42				
Heavy Industry		0.00				

Table 140: Land use and Built-up percentages

Figure 160: Wind direction at the monitoring station

During the month of March and April, wheat is sown in Delhi. Agricultural practices are at peak during this period in Delhi. Paddy, Jowar and Bajra during Kharif and Wheat and Mustard crops during the Rabi seasons are the major crops in Delhi. The cultivation of vegetables is a continuous process throughout the year. Overcoming lock-down restrictions, sown area of summer crops has increased significantly, registering an increase of 36 per cent over the previous year, pushed up mainly by rice cultivation, said Ministry of Agriculture & Farmers Welfare. The possible emission sources in the area would be from the PSP and residential sector through the movement of vehicles and biogenic emissions from the agricultural areas. The first phase of lock-down brought a strict restriction while agricultural activities and traffic movement of goods and daily essential products were functional.

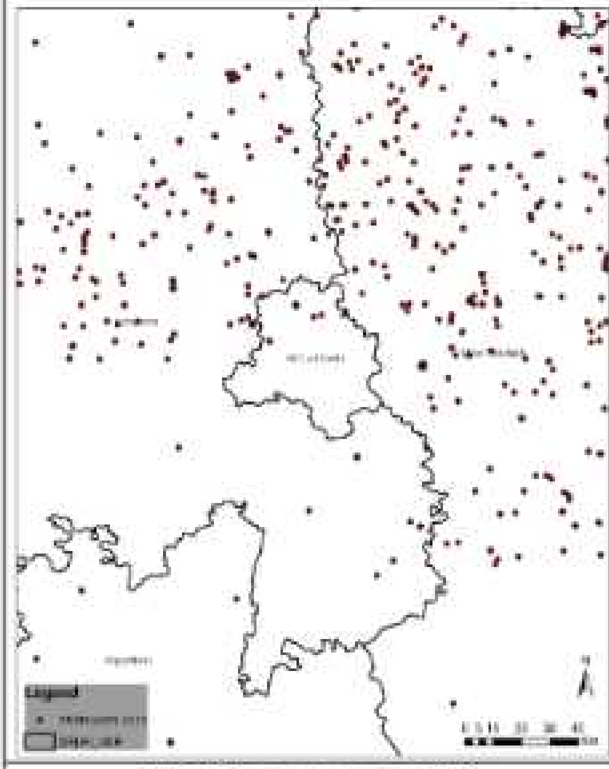
STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
DTU, Delhi - CPCB	1st March	54.28	124.50	24th March	45.77	91.49	15th April	65.86	195.10	4th May	[illegible]	58.03	18th May	126.92	[illegible]
	2nd March	106.86	220.06	25th March	42.85	78.72	16th April	83.28	208.17	5th May	56.38	127.11	19th May	130.42	[illegible]
	3rd March	109.84	238.75	26th March	65.35	96.88	17th April	25.97	109.73	6th May	71.02	204.45	20th May	77.04	212.58
	4th March	94.42	193.34	27th March	41.06	64.81	18th April	26.3	115.76	7th May	38.13	85.3	21st May	62.17	225.75
	5th March	34.56	74.99	28th March	None	85	19th April	45.08	98.75	8th May	50.43	138.78	22nd May	121.97	[illegible]
	6th March	26.62	40.28	29th March	None	82	20th April	60.84	120.05	9th May	52.1	131.52	23rd May	92.01	[illegible]
	7th March	49.97	100.09	30th March	None	95.09	21st April	42.88	107.58	10th May	43.08	121.58	24th May	64.48	287.84
	8th March	91.51	136.17	31st March	None	78.28	22nd April	70.09	156.79	11th May	45.13	102.58	25th May	77.48	282.65
	9th March	80.87	188.12	1st April	31.43	86.35	23rd April	56.8	102.00	12th May	50.24	118.72	26th May	61.30	[illegible]
	10th March	95.64	173.77	2nd April	30.72	76.61	24th April	60.15	157.42	13th May	89.78	213.89	27th May	46.6	211.22
	11th March	64.08	128.85	3rd April	42.58	86.72	25th April	[illegible]	92.94	14th May	72.14	172.85	28th May	40.13	247.17
	12th March	61.60	169.42	4th April	54.07	102.7	26th April	38.38	125.22	15th May	56.31	134.35	29th May	[illegible]	72.96
	13th March	91.04	[illegible]	5th April	65.02	113	27th April	22.4	97.08	16th May	90.09	197.12	30th May	[illegible]	58.18
	14th March	42.4	79.53	6th April	64.62	130.7	28th April	44.1	92.18	17th May	122.47	[illegible]	31st May	25.72	[illegible]
	15th March	72.53	243	7th April	38.96	121.3	29th April	51.98	119.02						
	16th March	84.72	212.17	8th April	32.25	101.4	30th April	49.8	120.50						
	17th March	96.06	245	9th April	46.16	102.5	1st May	76.88	187.65						
	18th March	98.42	[illegible]	10th April	68.57	138.4	2nd May	58	119.54						
	19th March	127.04	[illegible]	11th April	54.13	127.1	3rd May	33.36	92.76						
	20th March	108.08	[illegible]	12th April	47.09	114									
	21st March	122.77	280.38	13th April	75.66	164.3									
	22nd March	89.9	251	14th April	77.58	178.9									
	23rd March	69.49	110.03												

Table 141: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend PM2.5		Legend PM10	
Good	30	Good	50
Satisfactory	60	Satisfactory	100
Moderately Polluted	90	Moderately Polluted	250
Poor	120	Poor	350
Very Poor	250	Very Poor	430
Severe	>250	Severe	>430

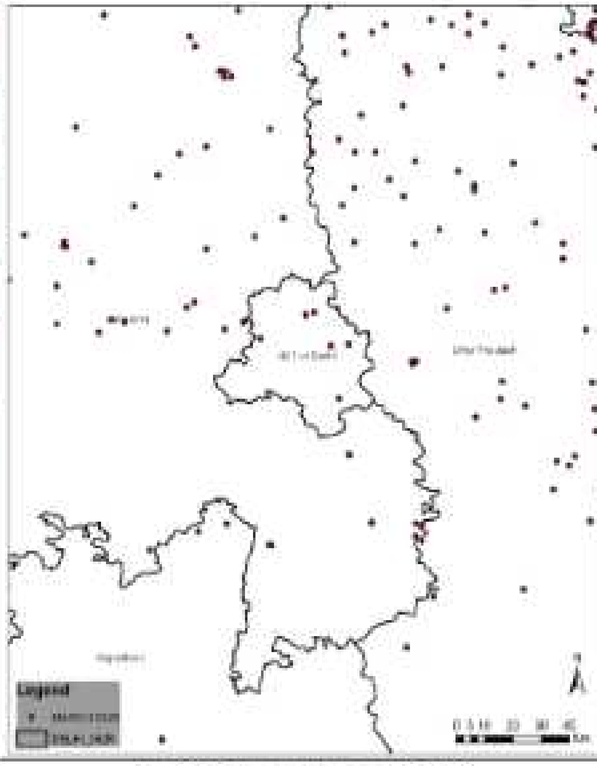
The table 141 shows how the concentration of $PM_{2.5}$ and 10 varied below and during the phases of lock-down. It was observed that the concentration reduced in the first phase of lock-down but kept on increasing during the next three phases as more and more relaxations were introduced. Before the lock-down in March 2020, the concentrations varied from good to poor quality but in the first phase, the concentrations were mainly good to satisfactory which changed to very poor by the last phase of the lock-down. It can be seen in the following maps, how the fire incidents increased in May after the harvesting of crops in agricultural areas in Delhi and nearby states.

FIRE INCIDENTS - FEBRUARY, 2020



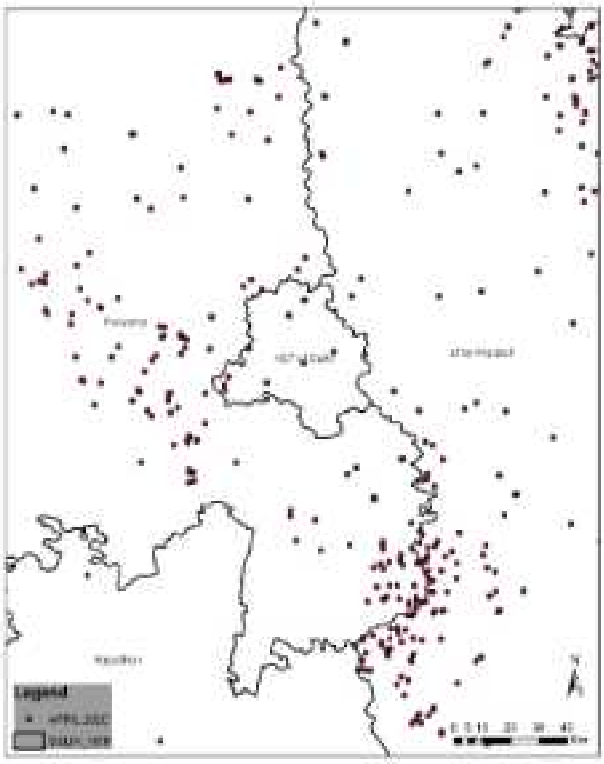
Map 209: Fire incidents in Feb 2020

FIRE INCIDENTS - MARCH, 2020



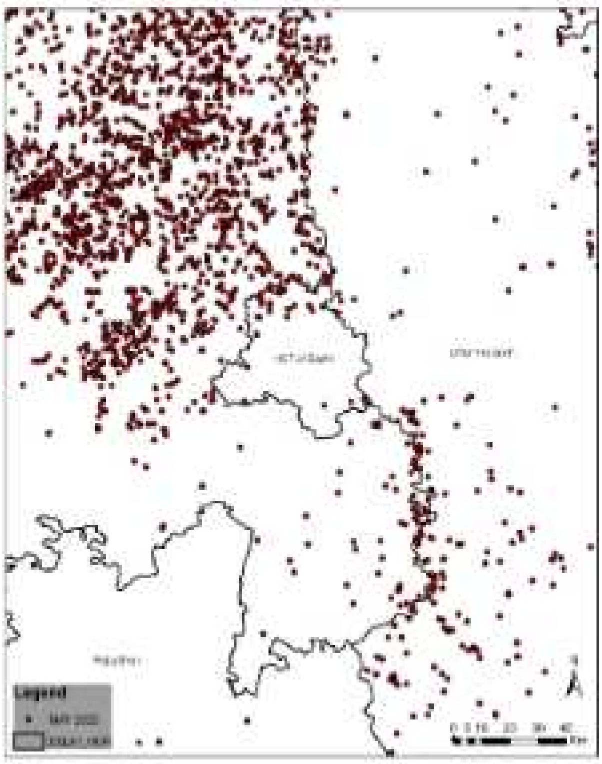
Map 210: Fire incidents in Mar 2020

FIRE INCIDENTS - APRIL, 2020



Map 211: Fire incidents in April 2020

FIRE INCIDENTS - MAY, 2020



Map 212: Fire incidents in may 2020

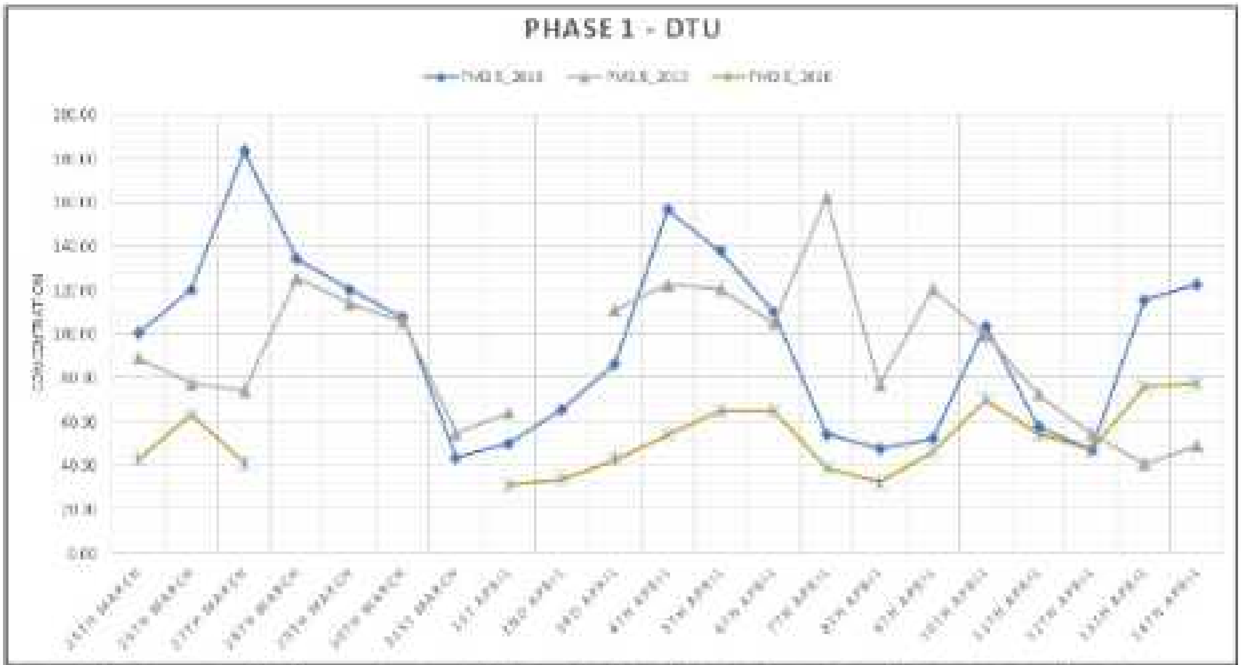


Figure 161: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at DTU station during Phase 1: 25th March to 14th April

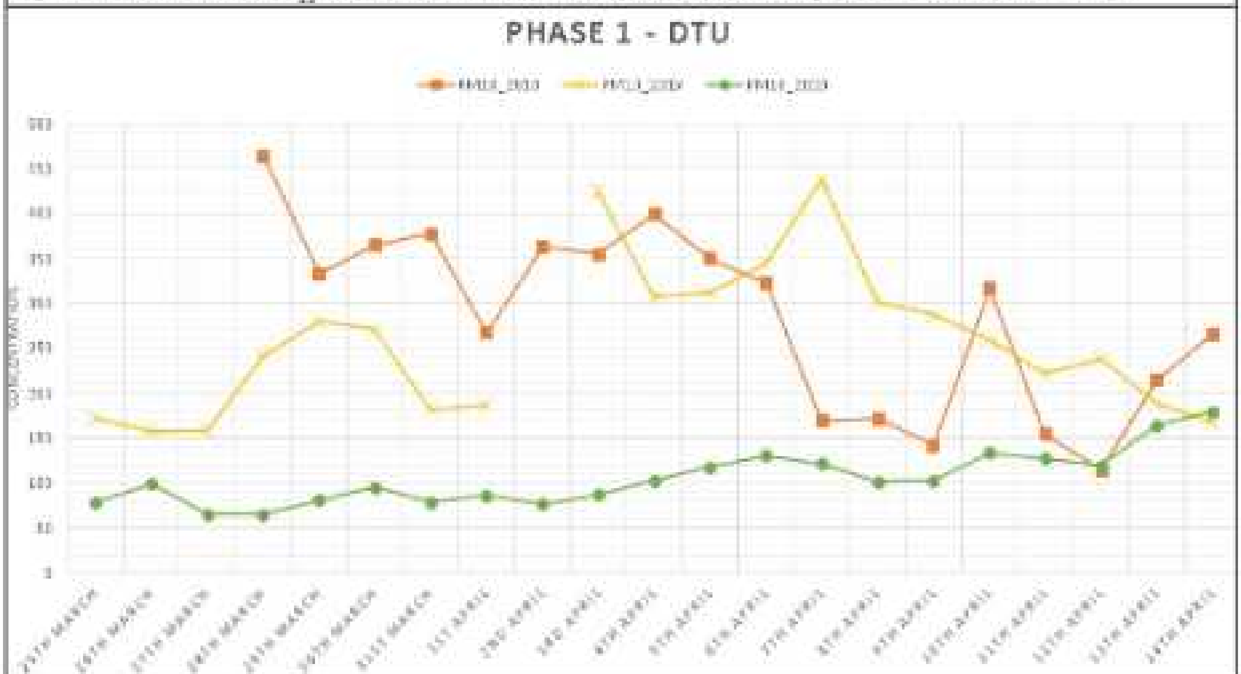


Figure 162: Comparison of PM_{10} concentrations in 2019 and 2020 at DTU station during Phase 1: 25th March to 14th April

Phase 1:

It was observed that the concentrations were very low (PM 2.5 ranging from 16 to 32 µg/m³) during the 27th to 31st March in the initial week of the phase 1. There was a major dust-storm in Delhi due to western disturbances around 15th April, and a mild dust-storm on 6th April which can also be observed in the figure with extremely high concentrations of $PM_{2.5}$ on 14th April. As a large share of open land is available in the direction of wind to the monitoring station, so the effect of wind escalated the concentrations of pollutant with the extra soil dust particles.

In the PM_{10} concentrations, it can be observed the reduction in values, during the lock-down phase with the restrictions of activities.

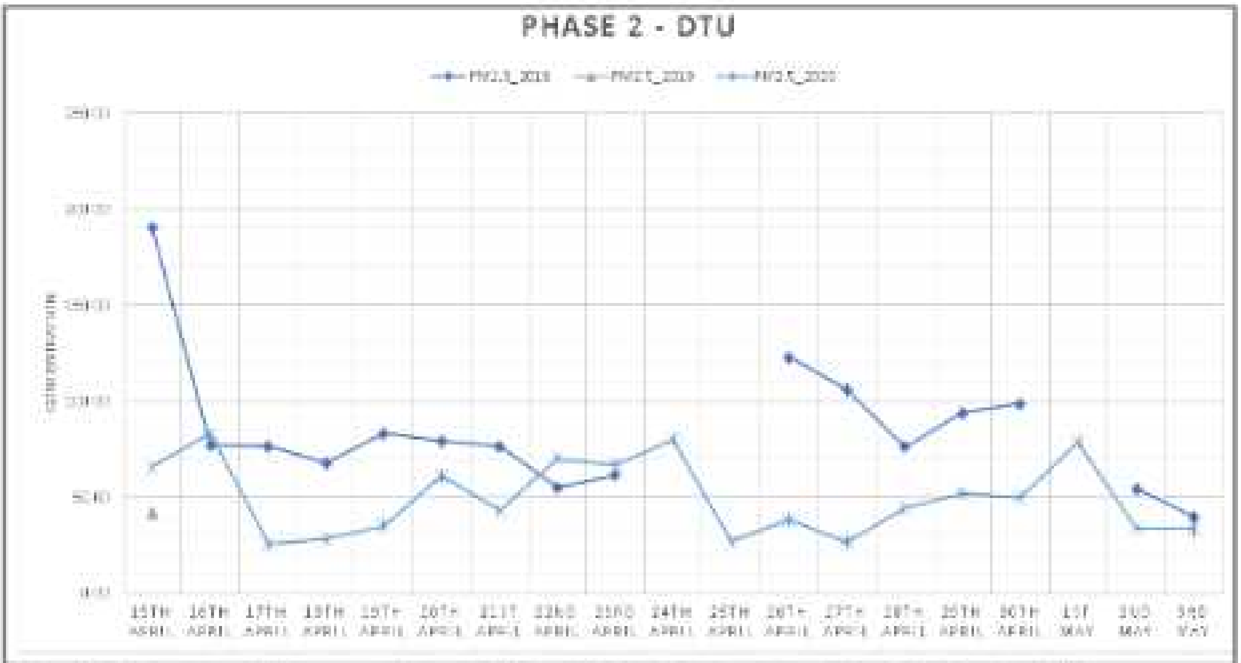


Figure 163: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at DTU station during Phase 2: 15th April to 3rd May

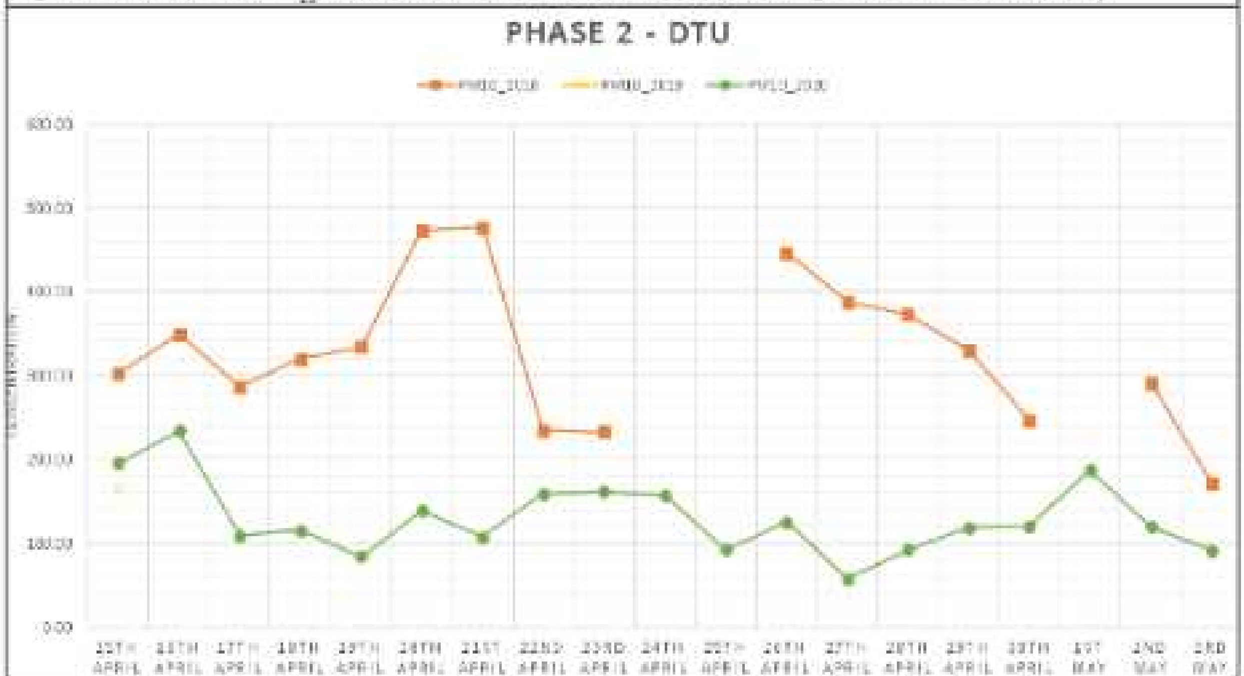


Figure 164: Comparison of PM_{10} concentrations in 2019 and 2020 at DTU station during Phase 2: 15th April to 3rd May

Phase 2

During Phase 2 (mid April), which is also the peak of harvesting of wheat in Delhi, agricultural activities increased as the relaxation in movement of interstate goods and opening of repairs, market of crushers vehicles, etc.

If we compare it with the phase 1, there was an increase in concentration of $PM_{2.5}$. The initial peak around 15th and 16th April was due to the dust-storm, The PM_{10} concentrations were mostly moderately polluted throughout the phase. During the phase, in total 5 western disturbances caused the winds and mild dust-storms in the city, increasing the concentration of pollutants even when there were very little activities. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks.

So, mainly the concentrations during Phase 2 were increased due to the movement of trucks for loading & unloading and is highly influenced by meteorological conditions (dust-storms). The open areas(non-vegetative) which are surrounding the monitoring stations increased the amount of soil dust particles in the air at high wind speeds.

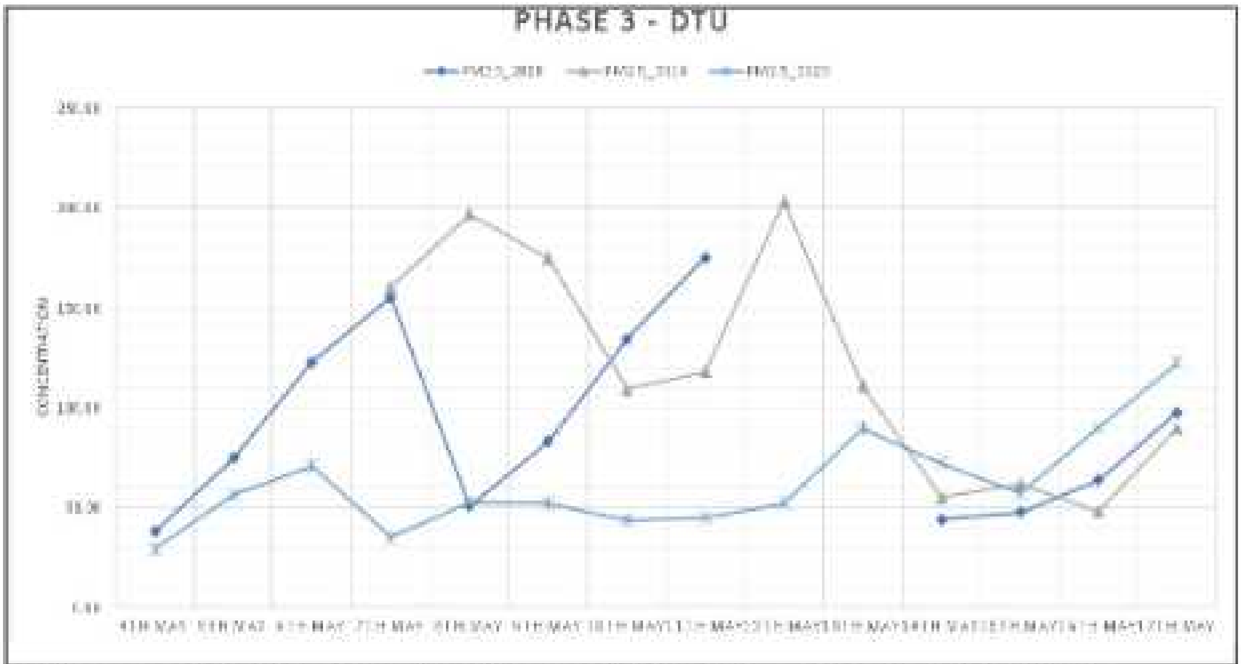


Figure 165: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at DTU station during Phase 3: 4th May to 17th May

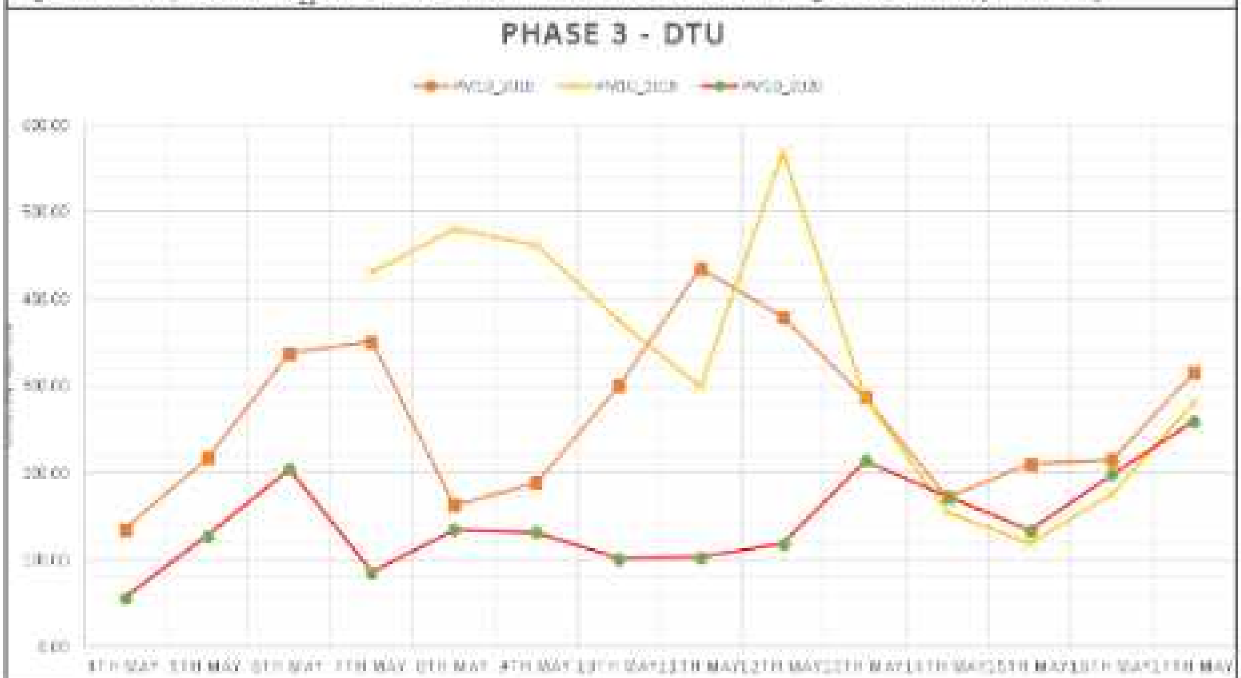


Figure 166: Comparison of PM_{10} concentrations in 2019 and 2020 at DTU station during Phase 3: 4th May to 17th May

Phase 3

In comparison to phase 2, significant changes in concentrations were not observed even though the relaxations were introduced in interstate bus movement. The 4 peaks in the concentrations were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

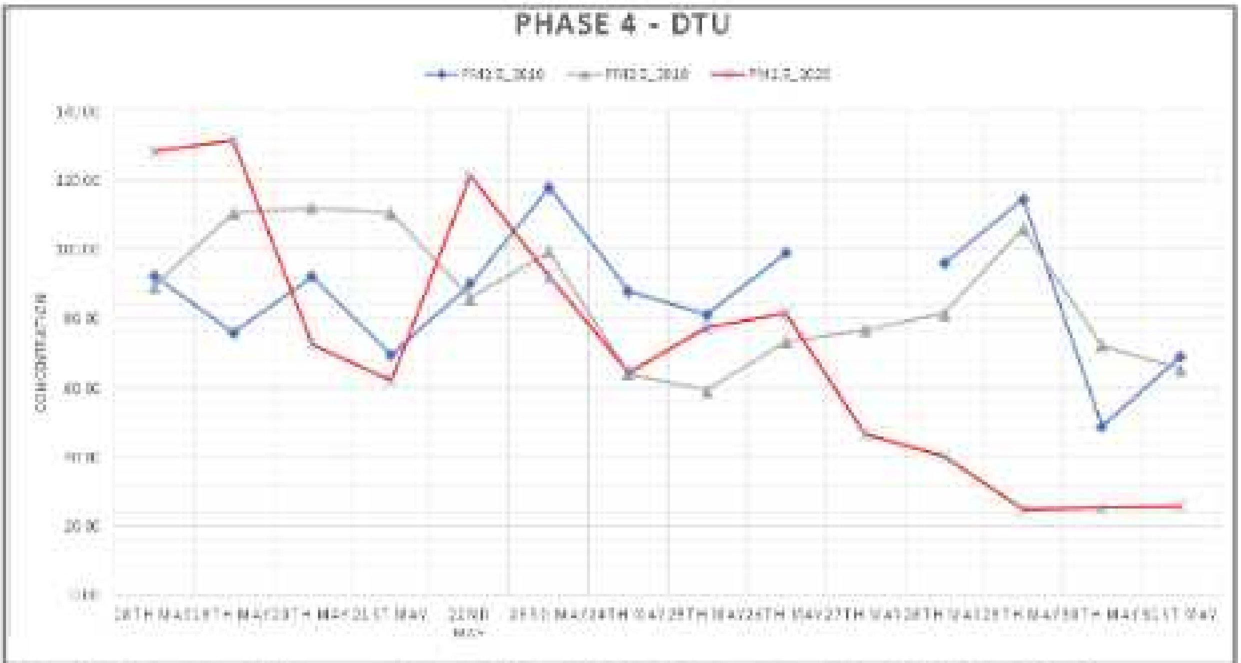


Figure 167: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at DTU station during Phase 4: 18th May to 31st May

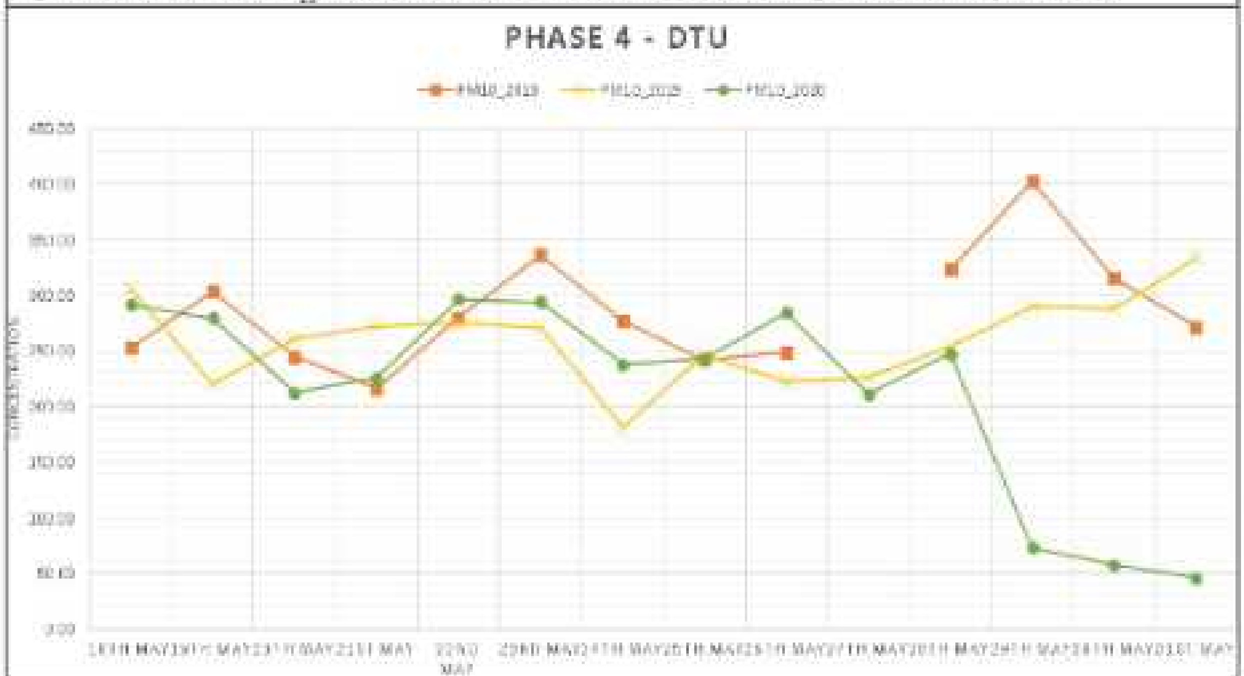


Figure 168: Comparison of PM_{10} concentrations in 2019 and 2020 at DTU station during Phase 4: 18th May to 31st May

Phase 4

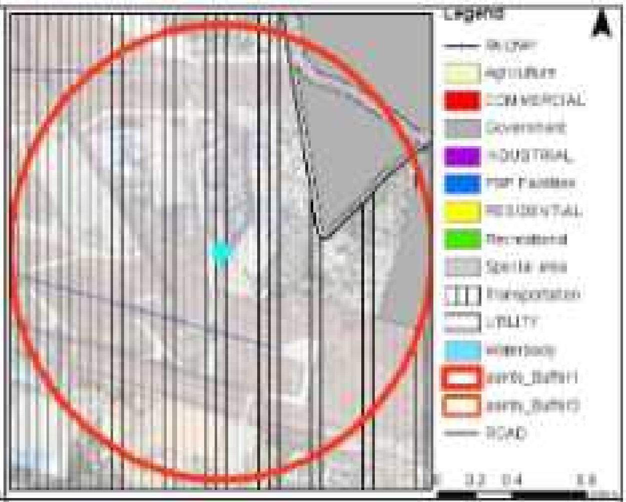
The PM_{10} concentrations were increased as the relaxations were made during this period. This phase brought the concentrations PM_{10} into the very poor category in the area. It can be attributed to the fire of the agricultural areas as discussed in the map no. 212.

With the onset of unobstructed movement of people and vehicles providing goods and services, the emissions in the region increased. The concentrations further increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm, in this phase.

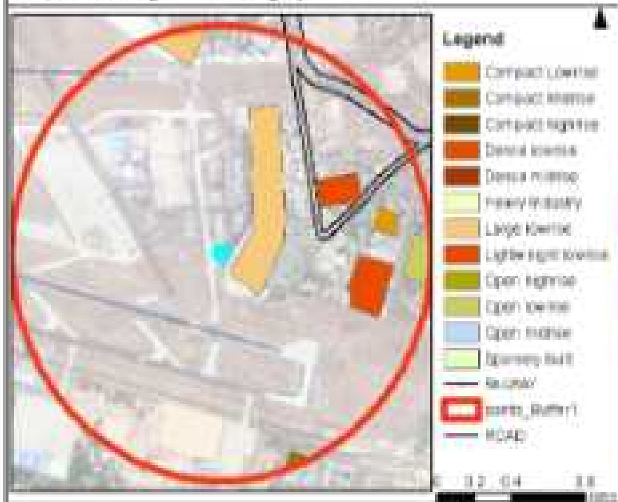
6.10.6. IGI Airport (T3), IMD

The station lies at the airport, and has transportation as the predominant landuse in the buffer zone of 1km around the monitoring station. The predominant wind direction from March to May is from North-east.

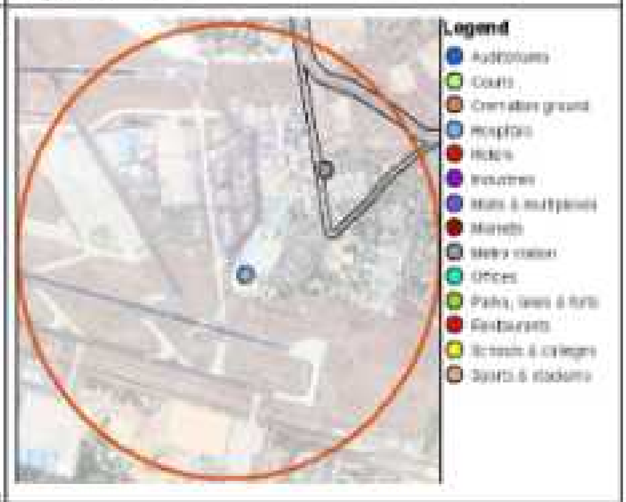
Map 213: Google earth imagery



Map 214: Land-use



Map 215: Built-form



Map 216: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)
Dense lowrise	0.065	2.08	COMMERCIAL	0	0.0	200-240
Dense midrise	0.000	0.00	INDUSTRIAL	0	0.0	
Open midrise	0.000	0.00	TRANSPORTATION	2.6703	91.4	
Open highrise	0.000	0.00	RECREATIONAL	0	0.0	
Open lowrise	0.025	0.78	RESIDENTIAL	0	0.0	
Compact Lowrise	0.010	0.32	PSP FACILITIES	0	0.0	
Compact Midrise	0.005	0.16	GOVERNMENT	0.2982	8.4	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	
Large lowrise	0.150	4.79	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY		0.0	
Green belt	0.000	0.00	GREEN BELT		0.0	
Open area	2.500	79.62				
Waterbody	0.000	0.00				
Road	0.400	12.74				
Heavy industry		0.00				

Table 142: Land use and Built-up percentages

Figure 189: Wind direction at the monitoring station

The emissions from this station are mainly due to vehicular movement in and around the airport, for picking/dropping of people and goods, and the emissions in the process are organic carbon, aromatic compounds such as Benzene and Toulene, Oxidation of SO2 and NO2. The anticipated emission load at this station would be very large due to the 24 hours operational service.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
IGI Airport (T3), Delhi - IMD	1st March	35.71	93.15	24th March	45.12	80.82	15th April	48.51	160.3	4th May	30.61	None	18th May	72.12	130.60
	2nd March	91.32	220.13	25th March	36.41	37.98	16th April	58.47	149.08	5th May	50.97	None	19th May	100.3	197.42
	3rd March	78.02	172.38	26th March	[illegible]	51.76	17th April	[illegible]	70.43	6th May	45.88	None	20th May	71.18	148.12
	4th March	71.57	188.11	27th March	[illegible]	[illegible]	18th April	[illegible]	88.24	7th May	31.24	None	21st May	58.40	140.04
	5th March	[illegible]	67.96	28th March	[illegible]	[illegible]	19th April	[illegible]	61.35	8th May	41.55	None	22nd May	65.45	160.01
	6th March	[illegible]	[illegible]	29th March	[illegible]	[illegible]	20th April	34.33	88.45	9th May	52.98	None	23rd May	54.74	161.28
	7th March	38.03	85.3	30th March	[illegible]	51.64	21st April	31.83	70.32	10th May	41.57	None	24th May	54.23	154.72
	8th March	60.47	124.30	31st March	[illegible]	51.92	22nd April	52.10	115.51	11th May	54.49	71.23	25th May	59.38	150.36
	9th March	57.37	129.02	1st April	[illegible]	51.73	23rd April	42.79	92.35	12th May	41.12	84.35	26th May	54.36	173.45
	10th March	58.21	144.21	2nd April	[illegible]	58.13	24th April	50.52	110.35	13th May	56.87	130.48	27th May	61.38	138.58
	11th March	49.97	109.76	3rd April	[illegible]	56.56	25th April	20.48	57.11	14th May	46.81	136.59	28th May	39.22	213.76
	12th March	44.44	128.70	4th April	38.22	73.13	26th April	31.13	79.5	15th May	45.30	99.79	29th May	[illegible]	70.34
	13th March	45.57	124.29	5th April	56.96	30.36	27th April	[illegible]	[illegible]	16th May	61.3	118.35	30th May	[illegible]	[illegible]
	14th March	37.51	94.37	6th April	54.2	101.3	28th April	39.2	64.4	17th May	90.28	108.69	31st May	[illegible]	[illegible]
	15th March	55.51	158.63	7th April	[illegible]	81.08	29th April	53.02	91.5						
	16th March	54.05	131.94	8th April	[illegible]	67.04	30th April	52.58	106.04						
	17th March	54.91	140.53	9th April	38.78	39.39	1st May	55.37	128.2						
	18th March	76.71	172.61	10th April	51.74	103.2	2nd May	38.12	87.59						
	19th March	69.7	182.18	11th April	44	35.06	3rd May	31.72	66.52						
	20th March	97	194.77	12th April	38.13	76.17									
	21st March	61.67	161.8	13th April	60.49	139									
	22nd March	71.15	198.57	14th April	55.36	135.3									
	23rd March	42.17	87.99												

Table 143: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend	
PM2.5	
Good	30
Satisfactory	60
Moderately Polluted	90
Poor	120
Very Poor	250
Severe	>250

Legend	
PM10	
Good	50
Satisfactory	100
Moderately Polluted	250
Poor	350
Very Poor	430
Severe	>430

The operations or airport were banned for both international and domestic travel in the starting of the lock-down and which remained till the second lock-down. Only essential services related to medical , defence were permitted. Although in Phase 3, of the lock-down Aviation ministry launched the Vande Bharat mission to bring back stranded Indians from foreign countries. And finally in phase 4, domestic air travel was given a green signal with proper SOPs and guidelines for everyone to follow.

From the above table no. 143, it can be clearly observed that the $PM_{2.5}$ and PM_{10} concentrations were upto moderately polluted levels, before the lock-down and went down to the good quality in phase 1 of the lock-down, which were sustained till the third phase of lock-down. Because of the travel ban, there were no movement of vehicles in the area, so the concentration of $PM_{2.5}$ and PM_{10} in the area remained negligible. Although, it increased in the fourth phase, when free movement of people was permitted inside the city. It changed the quality from good to moderately polluted in this phase.

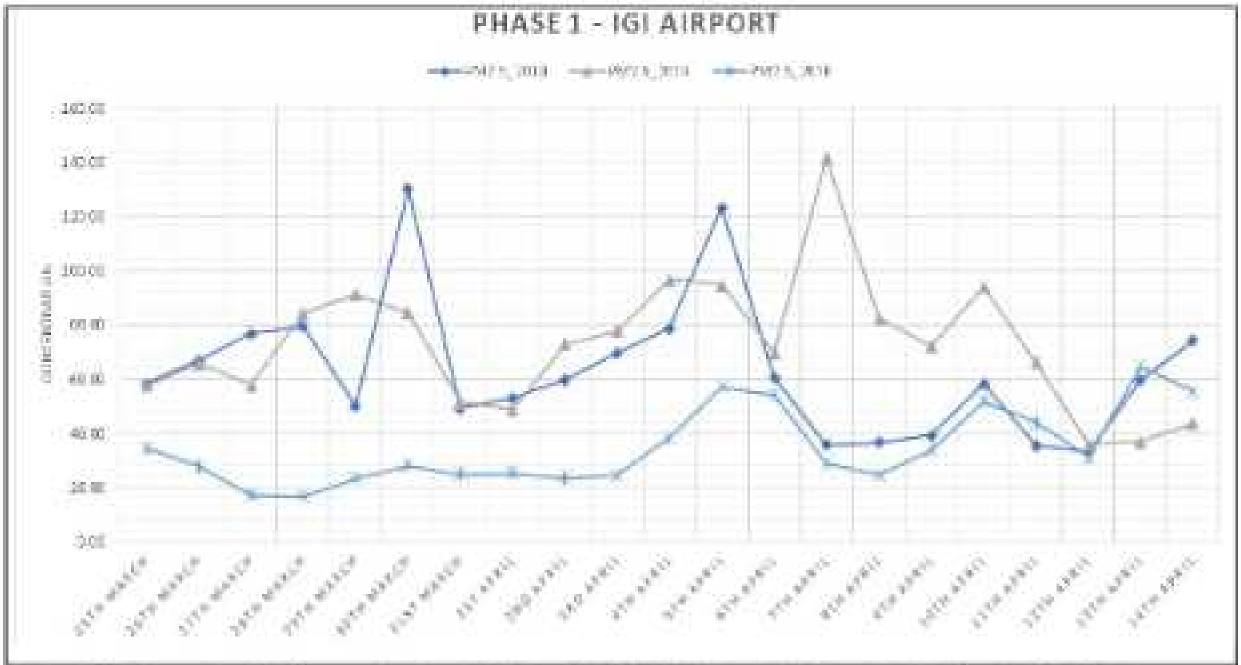


Figure 170: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at IGI station during Phase 1: 25th March to 14th April

Figure 171: Comparison of PM_{10} concentrations in 2019 and 2020 at IGI station during Phase 1: 25th March to 14th April

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019 and 2018, because of the restrictions on movement of people and air travel ban. The PM_{10} concentrations in 2019 went upto 430 µg/m³ whereas in lock-down the peak touched only 130 µg/m³ even on the day of dust-storm. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

Figure 172: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at IGI station during Phase 2: 15th April to 3rd May

Figure 173: Comparison of PM_{10} concentrations in 2019 and 2020 at IGI station during Phase 2: 15th April to 3rd May

Phase 2

The concentrations in 2020 during lock-down are three times lesser than those in the 2018. The effect of closure of activities can be seen quite evidently in the area. The concentrations of PM_{10} were maximum i.e.. 170 µg/m³ on the onset of major dust-storm on 15th April. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations in 2020 around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks. On comparing the concentrations of 2019 and 2020, the peak of PM_{10} value was due to the dust-storm on 25th / 26th April in Delhi.

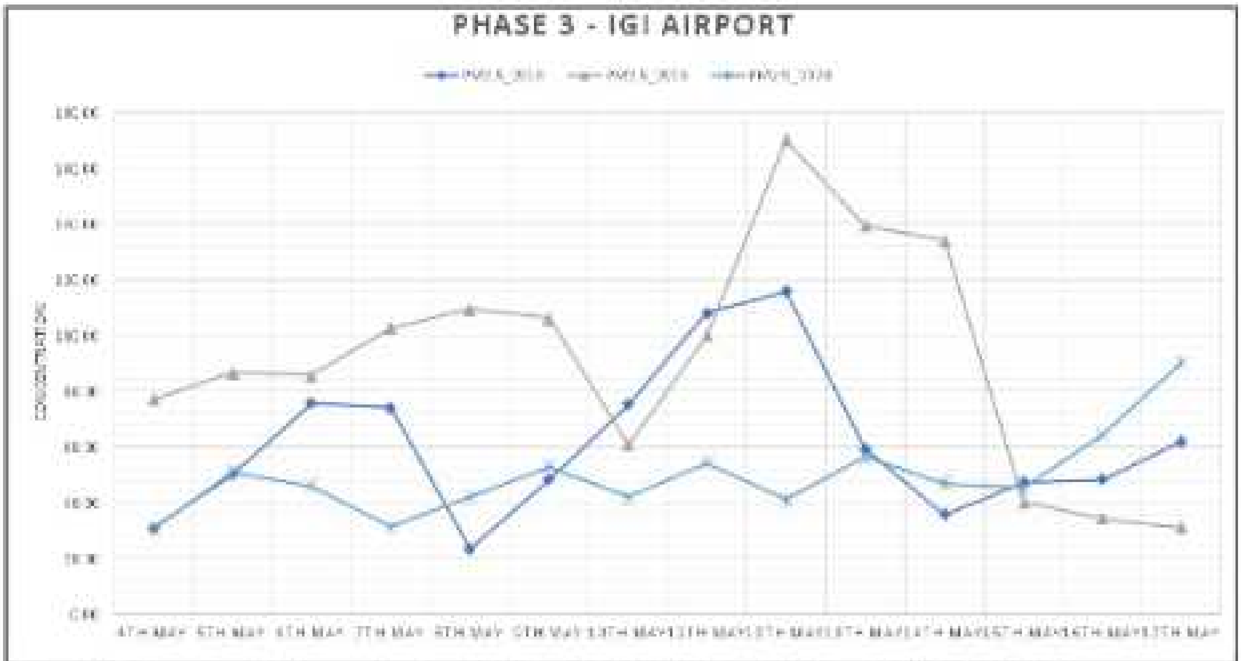


Figure 174: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at IGI station during Phase 3: 4th May to 17th May

Figure 175: Comparison of PM_{10} concentrations in 2019 and 2020 at IGI station during Phase 3: 4th May to 17th May

Phase 3

The overall values of PM 2.5 and 10 were extremely high in 2018 and 2019. The maximum value of PM_{10} in 2019 went upto 430 µg/m³ which was only 220 µg/m³ in 2020.

Also, the 3 small peaks in the concentrations in 2020 were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

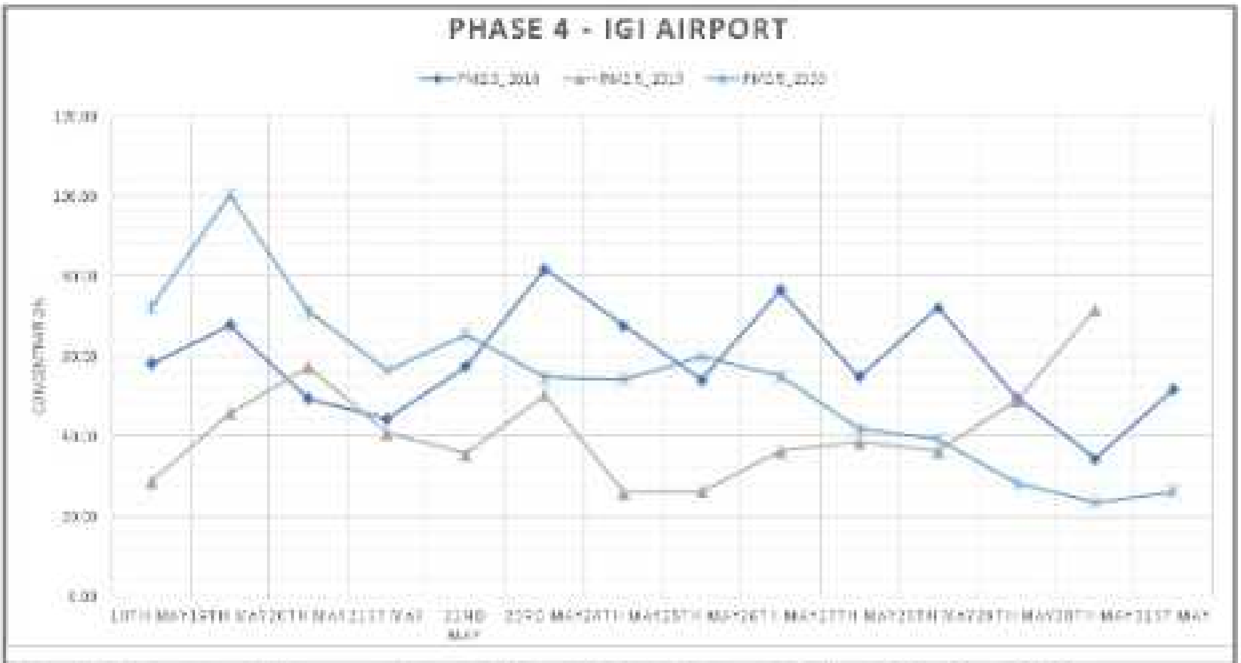


Figure 176: Comparison of $PM_{2.5}$ concentrations in 2019 and 2020 at IGI station during Phase 4: 18th May to 31st May

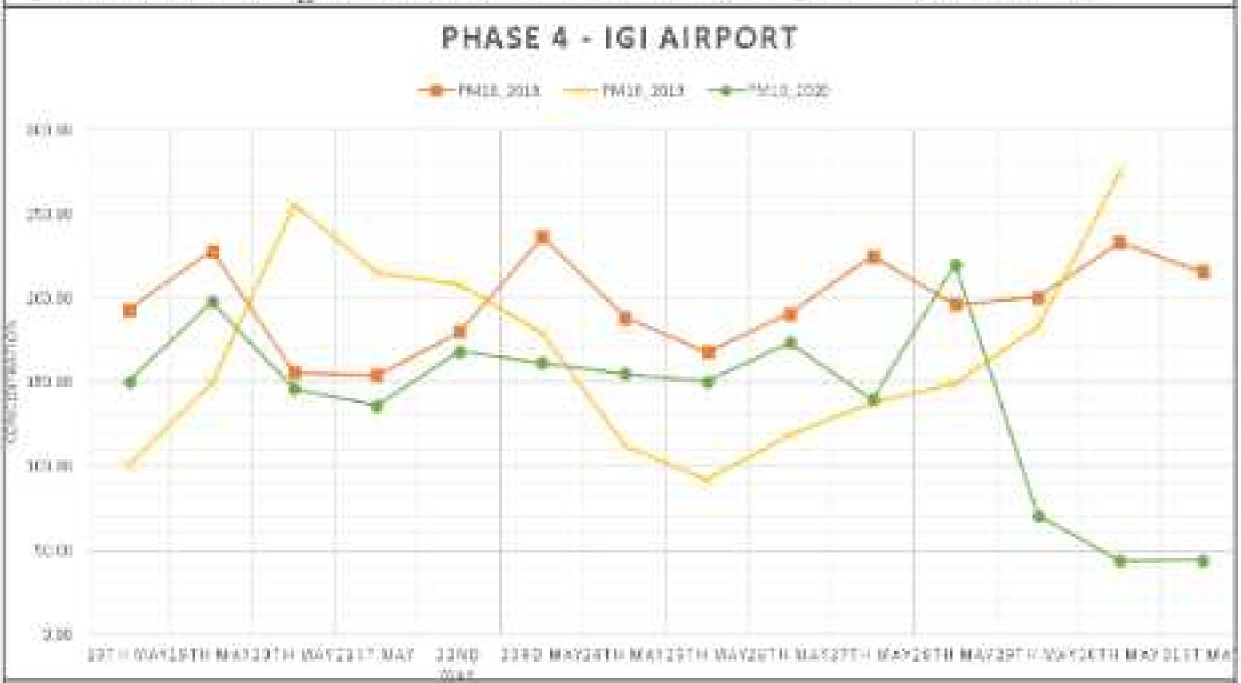


Figure 177: Comparison of PM_{10} concentrations in 2019 and 2020 at IGI station during Phase 4: 18th May to 31st May

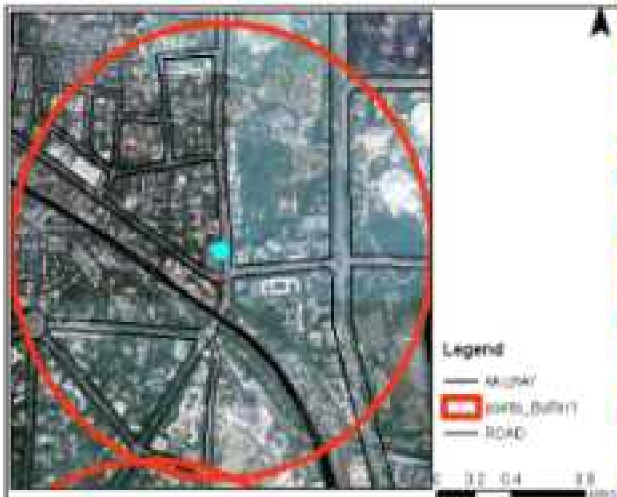
Phase 4

The PM_{10} concentrations were increased as the relaxations were made during this period. The domestic flights resumed from 22 May 2020.

This phase brought the concentrations PM_{10} into the moderately polluted category in the area. The concentrations further increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe here also like the findings at DTU monitoring station that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm and increase in movement of vehicles in and around the airport, in this phase.

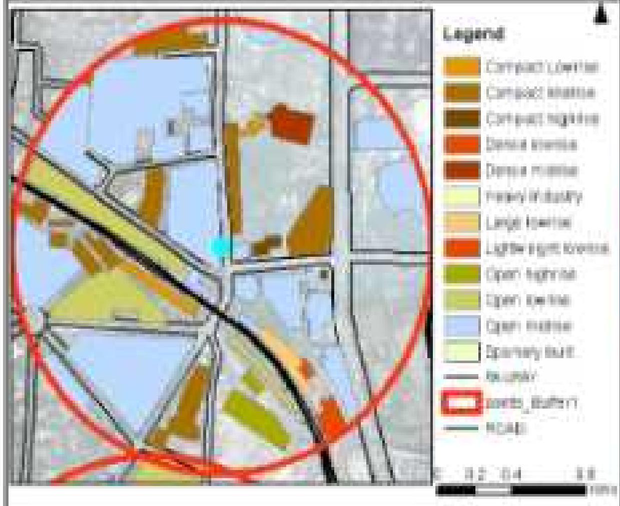
6.10.7. ITO

The station lies in the central Delhi and has PSP as the predominant landuses in the buffer zone of 1km around the monitoring station. It also has significant amount of recreational landuse in it. The predominant wind direction from March to May is from North-east.



Map 217: Google earth imagery

Map 218: Land-use



Map 219: Built-form

Map 220: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	
Dense lowrise	0.023	0.73	COMMERCIAL	0.0493	1.6	
Dense midrise	0.029	0.92	INDUSTRIAL	0	0.0	
Open midrise	0.880	28.00	TRANSPORTATION	0.3	9.6	
Open highrise	0.041	1.32	RECREATIONAL	0.3974	15.0	
Open lowrise	0.167	5.33	RESIDENTIAL	0.5974	19.0	
Compact Lowrise	0.026	0.84	PSP FACILITIES	1.0893	34.7	
Compact Midrise	0.204	6.49	GOVERNMENT	0.3462	11.0	
Compact Highrise	0.009	0.30	UTILITY	0.158	5.0	200-220
Large lowrise	0.025	0.78	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY		0.0	
Green belt	1.340	42.58	GREEN BELT		0.0	
Open area	0.100	3.18				
Waterbody	0.000	0.00				
Road	0.300	3.55				

Table 144: Land use and Built-up percentages

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
ITO, Delhi - CPCB	1st March	56.76	90.3	24th March	98	110	15th April	177.17	170.47	4th May	51.18	220.59	18th May	56.13	None
	2nd March	126.75	190.56	25th March	38.89	102.1	16th April	149.25	109.36	5th May	92.44	[illegible]	19th May	99.42	None
	3rd March	107.57	147.45	26th March	51	82.97	17th April	55.53	63.1	6th May	91.69	296.72	20th May	56.39	None
	4th March	107.18	180.56	27th March	57.9	72.54	18th April	99.54	106.13	7th May	66.76	136.13	21st May	69.82	None
	5th March	38.57	67.98	28th March	67.48	68.76	19th April	144.88	147.37	8th May	67.45	[illegible]	22nd May	117.07	None
	6th March	26.2	40.96	29th March	58.38	66.25	20th April	138.52	140.45	9th May	None	None	23rd May	89.16	None
	7th March	59.35	89.47	30th March	53.38	60.38	21st April	129.52	143.78	10th May	None	None	24th May	96.32	None
	8th March	77.26	109.67	31st March	46.62	53.51	22nd April	128.96	149.02	11th May	64.56	[illegible]	25th May	92.57	None
	9th March	53.15	88.88	1st April	51.29	68.08	23rd April	126.42	158.03	12th May	30.67	None	26th May	79.87	136.05
	10th March	83.58	127.35	2nd April	53.18	56.25	24th April	169.75	138.20	13th May	82.77	None	27th May	65.32	146.3
	11th March	76.74	112.83	3rd April	47.08	[illegible]	25th April	151.32	164.84	14th May	59.83	None	28th May	68.61	148.28
	12th March	90.35	142.56	4th April	44.73	56.11	26th April	82	88.64	15th May	85.94	None	29th May	45.07	112.14
	13th March	52.44	117.56	5th April	45.93	79.59	27th April	[illegible]	222.58	16th May	84.44	None	30th May	45.35	88.50
	14th March	56.87	84.65	6th April	46.31	78.64	28th April	120.44	106.61	17th May	85.73	None	31st May	43.25	83.3
	15th March	62.97	95.97	7th April	45.91	68.08	29th April	66.28	104.79						
	16th March	56.37	100.56	8th April	[illegible]	58.34	30th April	60.64	125.12						
	17th March	66.43	108.84	9th April	38.93	58.58	1st May	70.25	139.98						
	18th March	71.49	118.77	10th April	64.22	81.85	2nd May	42.47	156.67						
	19th March	110.2	168.61	11th April	30.76	55.61	3rd May	43.44	200.3						
	20th March	124.52	178.34	12th April	41.04	67.21									
	21st March	106.13	144.22	13th April	75.7	101.5									
	22nd March	92.95	100.99	14th April	71.43	88.69									
	23rd March	94.02	108.34												

Table 145: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend		Legend	
PM2.5		PM10	
Good	30	Good	50
Satisfactory	60	Satisfactory	100
Moderately Polluted	90	Moderately Polluted	250
Poor	120	Poor	350
Very Poor	250	Very Poor	430
Severe	>250	Severe	>430

There is 40% public and semi-public land-use in the zone, which attracts a lot of traffic in the area. Also, the share of area under roads is about 10%, with arterial roads and junctions, creating major emissions from vehicular sector in this zone.

During lock-down, most of the government offices that lie in this zone were closed for the first two phases and were resumed later with few staff in the 3rd phase. Although it was observed through google traffic, how the traffic intensity at ITO increased after phase 1 of lock-down. As it has the arterial roads and junctions, so the emissions through vehicles contributed to the increase in pollution concentration. The table 145 shows how the concentration of $PM_{2.5}$ and 10 varied below and during the phases of lock-down. It was observed that the concentration reduced in the first phase of lock-down but kept on increasing during the next three phases as more and more relaxations were introduced. Before the lock-down in March 2020, the concentrations varied from good to very poor quality but in the first phase, the concentrations were mainly good which changed to very poor by the last phase of the lock-down.

Figure 178: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at ITO station during Phase 1: 25th March to 14th April

Figure 179: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at ITO station during Phase 1: 25th March to 14th April

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019 and 2018, because of the restrictions on majority of industrial activities and movement of goods and services. Most of the offices in the region remained closed. The PM_{10} concentrations in 2018 went upto 350 µg/m³ whereas in lock-down the peak touched only 100 µg/m³ even on the day of dust-storm. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

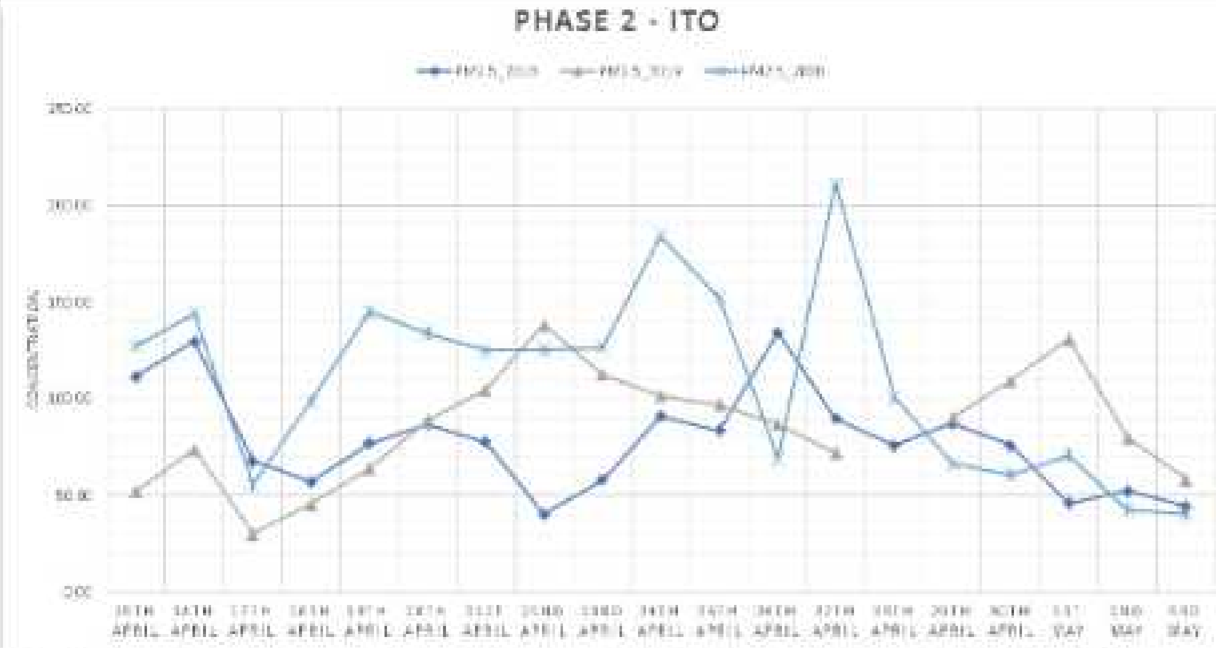


Figure 180: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at ITO station during Phase 2: 15th April to 3rd May

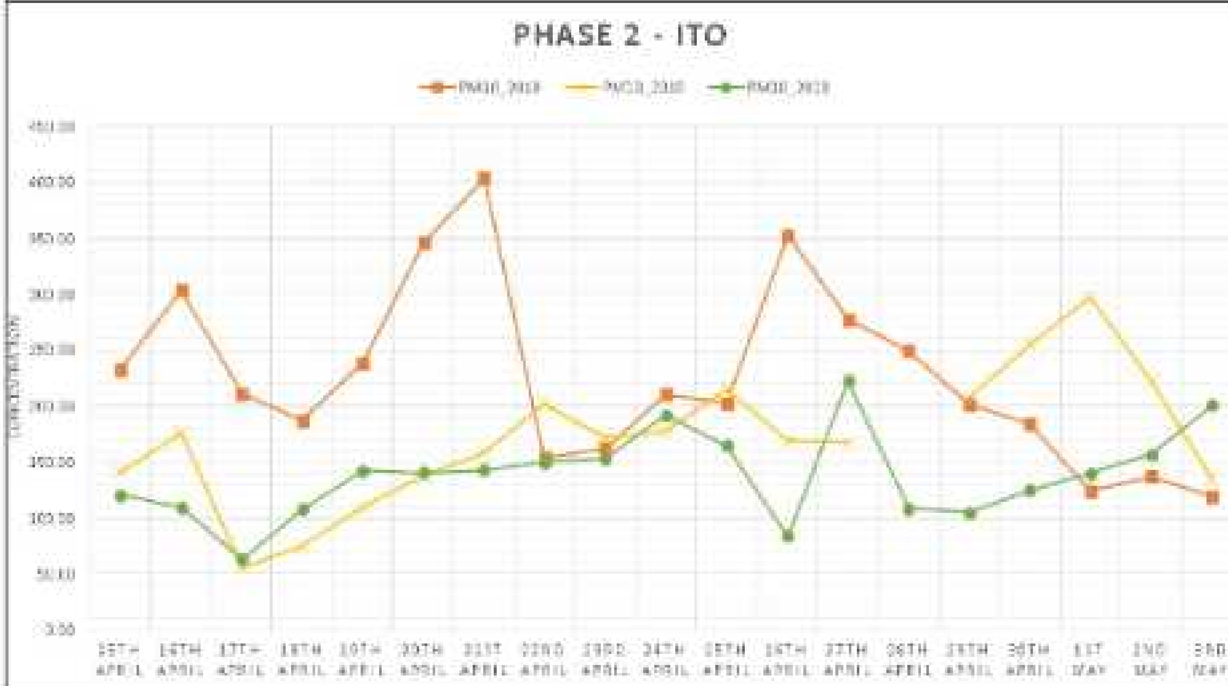


Figure 181: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at ITO station during Phase 2: 15th April to 3rd May

Phase 2

If we compare it with the phase 1, there was an increase in concentration of $PM_{2.5}$. As the lock-down was extended, the migrants came from all over and stranded in front of the railway station to go back to their states. New Delhi railway station which lies near ITO also attracted huge inflow of people during this period which created congestions on road around ITO, which could be attributed to the risen concentrations of pollutants. The initial peak around 15th and 16th April was due to the dust-storm which was higher than th levels of previous year. During the phase, in total 5 western disturbances caused the winds and mild dust-storms in the city, which further increased the concentration of pollutants. So, the peaks in PM_{10} and $PM_{2.5}$ concentrations around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks. On comparing the concentrations of 2019 and 2020, the peak of PM_{10} value was due to the dust-storm on 25th / 26th April in Delhi.

Figure 182: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at ITO station during Phase 3: 4th May to 17th May

Figure 183: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at ITO station during Phase 3: 4th May to 17th May

Phase 3:

The overall values of $PM_{2.5}$ and PM_{10} were extremely high in 2018 and 2019 due to the traffic induced by the PSP sector in the zone. Many offices were made operation during this phase in the area. There was inadequate data of PM_{10} during this phase.

The 3 small peaks in the $PM_{2.5}$ concentrations in 2020 were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

Figure 184: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 at ITO station during Phase 4: 18th May to 31st May

Figure 185: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 at ITO station during Phase 4: 18th May to 31st May

Phase 4:

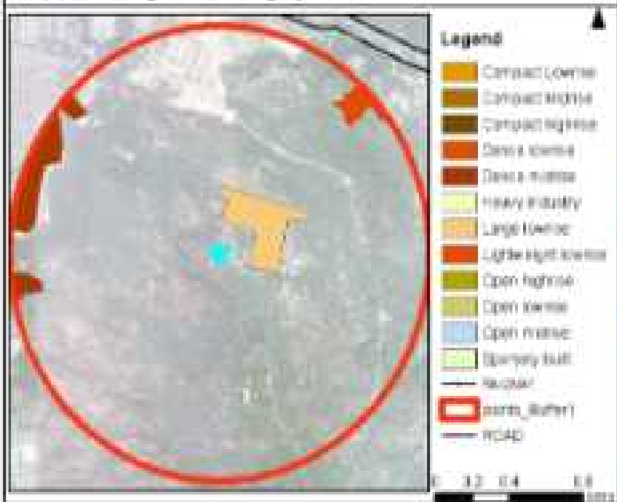
This phase brought the concentrations PM_{10} into the poor category in the area. With the onset of unobstructed movement of people and vehicles providing goods and services, the emissions in the region increased. The concentrations increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm, in this phase.

6.10.8. Dr. Karni Singh Shooting Range, DPCC

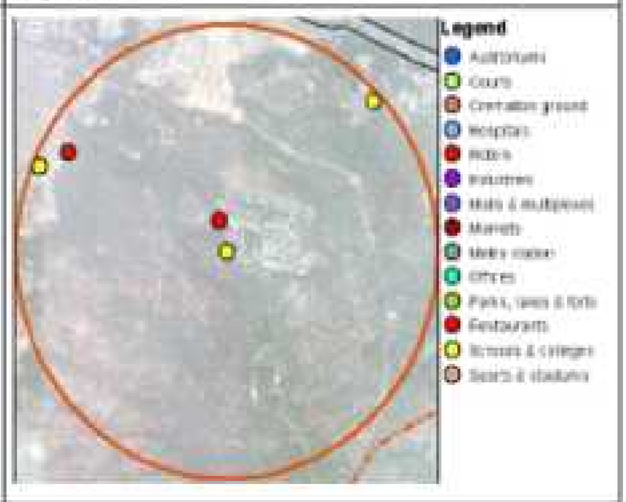
The station lies in south Delhi and has recreational/green belt as the predominant landuse in the buffer zone of 1km around the monitoring station. The predominant wind direction from March to May is from North-east.

Map 221: Google earth imagery

Map 222: Land-use



Map 223: Built-form



Map 224: Major activities

LCZ			LANDUSE			ALTITUDE
Types	Area (sq.km)	%	Types	Area (sq.km)	%	(m)
Dense lowrise	0.021	0.67	COMMERCIAL	0	0.0	210-260
Dense midrise	0.075	2.38	INDUSTRIAL	0	0.0	
Open midrise	0.000	0.00	TRANSPORTATION	0	0.0	
Open highrise	0.000	0.00	RECREATIONAL	3.0128	96.0	
Open lowrise	0.000	0.00	RESIDENTIAL	0	0.0	
Compact Lowrise	0.000	0.00	PSP FACILITIES	0.1044	3.3	
Compact Midrise	0.000	0.00	GOVERNMENT	0.0252	0.8	
Compact Highrise	0.000	0.00	UTILITY	0	0.0	
Large lowrise	0.074	2.37	SPECIAL AREA		0.0	
Sparsely built	0.000	0.00	WATERBODY		0.0	
Green belt	2.800	89.17	GREEN BELT		0.0	
Open area	0.200	6.37				
Waterbody	0.000	0.00				
Road	0.000	0.00				
Heavy industry		0.00				

Table 146: Land use and Built-up percentages

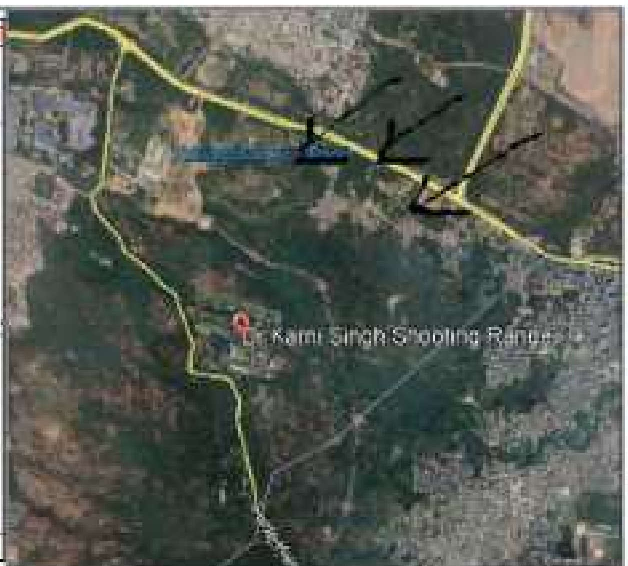


Figure 186: Wind direction at the monitoring station

The emissions in this area can only be through either biogenic emissions from the vegetative areas, apart from the regional sources. The emission loads from the activities inside the influence zone would be negligible. Although the vegetation impacts the concentration of pollutants in winters, as these have high biogenic emissions such as VOCs, which mixes with NO2 to form smog. So, there might be drastic increase in concentration of pollutants throughout the winters.

STATION NAME	Before Lockdown			Lockdown 1			Lockdown 2			Lockdown 3			Lockdown 4		
	Date	PM2.5	PM10	Dates	PM2.5	PM 10	Dates	PM2.5	PM10	Dates	PM2.5	PM10	Dates	PM2.5	PM10
Dr. Karni Singh Shooting Range, Delhi - DPCC	1st March	34.34	85.93	24th March	51.28	103.4	15th April	55.27	138.78	4th May	[illegible]	[illegible]	18th May	39	164.56
	2nd March	94.4	122.78	25th March	30.05	58.06	16th April	[illegible]	134.31	5th May	39.56	39.84	19th May	36.34	133.24
	3rd March	71.03	156.78	26th March	30.57	62.35	17th April	[illegible]	77.72	6th May	44.62	156.06	20th May	36.62	138.32
	4th March	85.18	184.77	27th March	[illegible]	[illegible]	18th April	[illegible]	84.77	7th May	[illegible]	80.4	21st May	35.74	132.16
	5th March	[illegible]	50.96	28th March	[illegible]	[illegible]	19th April	[illegible]	81.30	8th May	37.39	129.72	22nd May	41.88	162.11
	6th March	[illegible]	[illegible]	29th March	[illegible]	50.41	20th April	[illegible]	92.72	9th May	44.14	138.28	23rd May	35.65	184.15
	7th March	42.51	85.48	30th March	31	56.68	21st April	[illegible]	70.77	10th May	34.41	105.77	24th May	35.34	134.85
	8th March	47.07	208.28	31st March	[illegible]	57.39	22nd April	40.10	49.13	11th May	47.30	88.80	25th May	98.90	140.07
	9th March	66.28	250.88	1st April	[illegible]	56.31	23rd April	[illegible]	103.72	12th May	36.47	84.32	26th May	35.01	181.82
	10th March	85.85	158.22	2nd April	[illegible]	50.04	24th April	37	118.60	13th May	44.3	132.95	27th May	30.91	130.07
	11th March	52.44	96.29	3rd April	[illegible]	58.58	25th April	[illegible]	76.07	14th May	37.29	125.44	28th May	31.75	257.62
	12th March	50.09	120.80	4th April	35.47	67.5	26th April	[illegible]	111.38	15th May	31.85	97.99	29th May	[illegible]	53.42
	13th March	54.31	164.41	5th April	43.17	96.98	27th April	[illegible]	[illegible]	16th May	36.87	132.33	30th May	[illegible]	[illegible]
	14th March	34.44	79.21	6th April	46.45	95.84	28th April	61.89	85.37	17th May	41.18	154.73	31st May	[illegible]	[illegible]
	15th March	45.34	208.32	7th April	[illegible]	70.16	29th April	42.58	108.76						
	16th March	58.45	148.78	8th April	[illegible]	76.06	30th April	45.17	113.53						
	17th March	65.05	154.3	9th April	[illegible]	65.27	1st May	45.61	128.62						
	18th March	62.68	157.78	10th April	33.31	103.9	2nd May	[illegible]	101.77						
	19th March	73.45	184.74	11th April	34.73	110.2	3rd May	30.54	71.28						
	20th March	70.12	107.13	12th April	33.13	81.9									
	21st March	51.35	122.2	13th April	30.33	138.2									
	22nd March	72.9	125.29	14th April	38.22	115.6									
	23rd March	45.71	58.77												

Table 147: $PM_{2.5}$ & PM_{10} concentrations during lock-down phases

Legend	
PM2.5	
Good	30
Satisfactory	60
Moderately Polluted	90
Poor	120
Very Poor	250
Severe	>250

Legend	
PM10	
Good	50
Satisfactory	100
Moderately Polluted	250
Poor	350
Very Poor	430
Severe	>430

From the above table no. 147 it can be clearly observed that the $PM_{2.5}$ concentrations were good only even before the lock-down, and which were sustained till the forth phase of lock-down. Although, PM_{10} concentrations which were moderately polluted also reduced to good quality for the next three phases. As there are no emission sources in the zone, so the concentration of $PM_{2.5}$ and PM_{10} in the area remained negligible throughout. Although, it increased in the fourth phase, which might be due to the regional influence of pollution when free movement of people was permitted inside the city. It changed the quality from good to moderately polluted in this phase.

Figure 187: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 during Phase 1: 25th March to 14th April

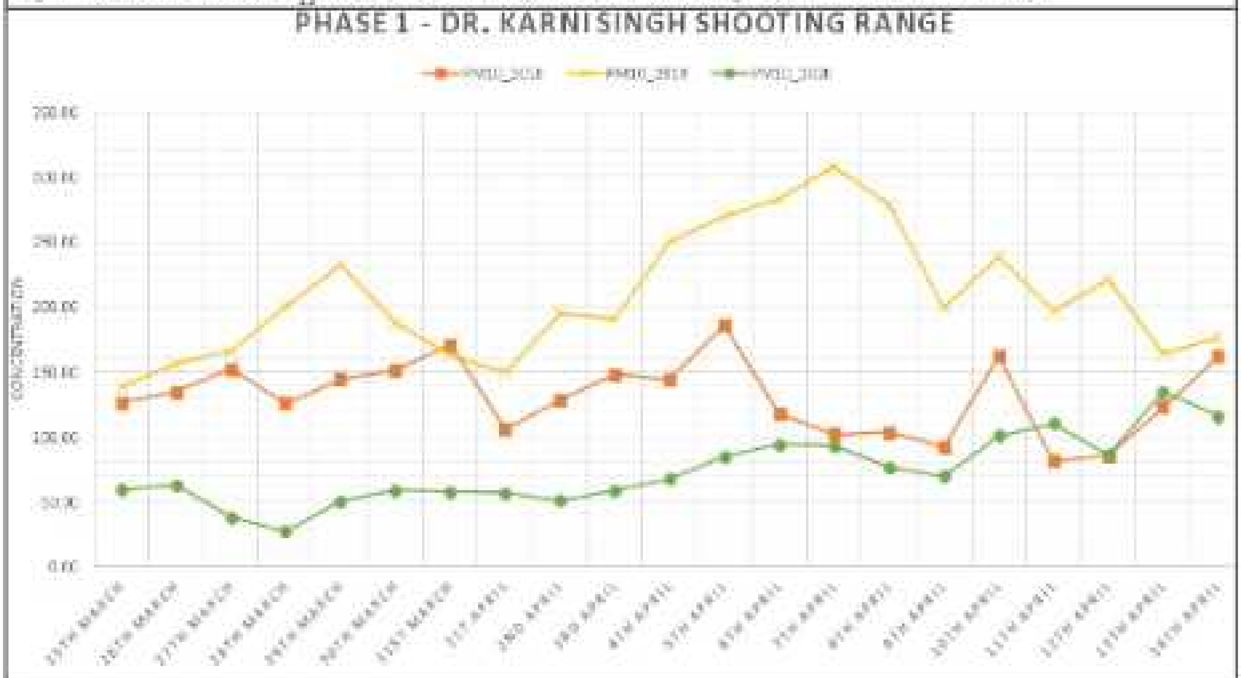


Figure 188: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 during Phase 1: 25th March to 14th April

Phase 1

The $PM_{2.5}$ and PM_{10} concentrations were significantly low when compared to the data of 2019 and 2018. The PM_{10} concentrations in 2019 went upto 310 µg/m³ whereas in lock-down the peak touched only 130 µg/m³ even on the day of dust-storm. As it gets influenced by the regional pollutants, the emissions in 2018 and 2019 are higher whereas low in 2020, as the city also experienced good air quality throughout. There was a major dust-storm in Delhi due to western disturbances around 15th April 2020, which raised the graph above the levels of 2019 concentrations at the end. A mild dust-storm on 6th April which increased the levels of PM_{10} concentrations.

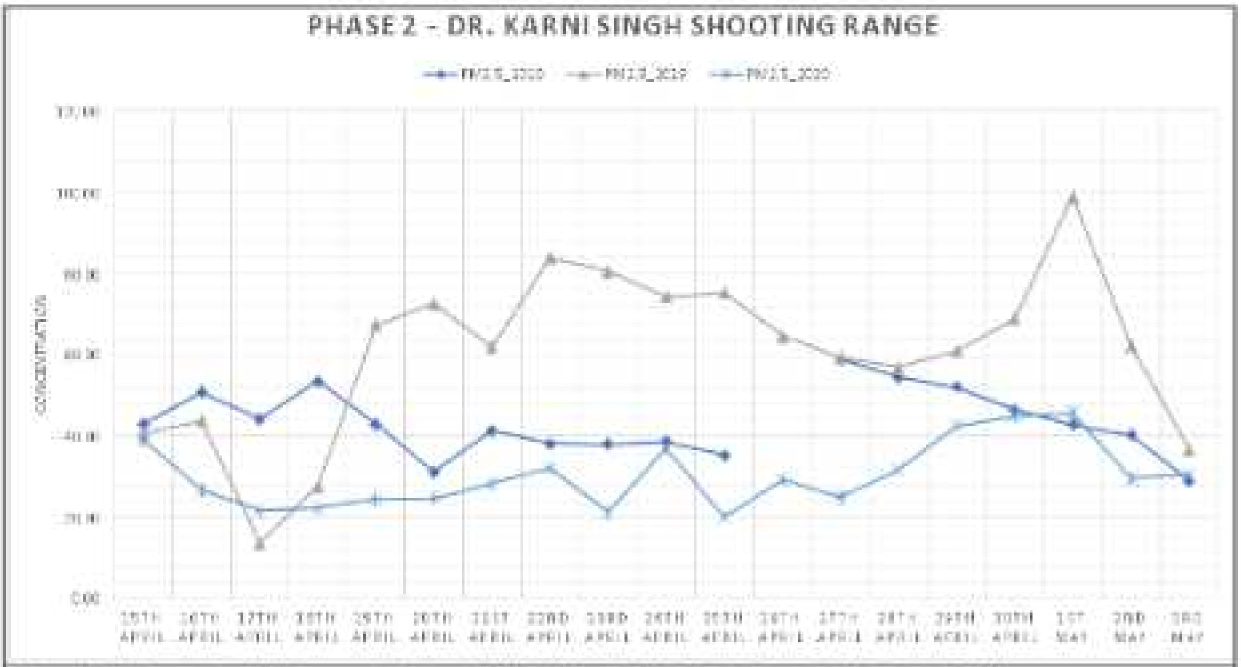


Figure 189: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 during Phase 3: 15th April to 3rd May

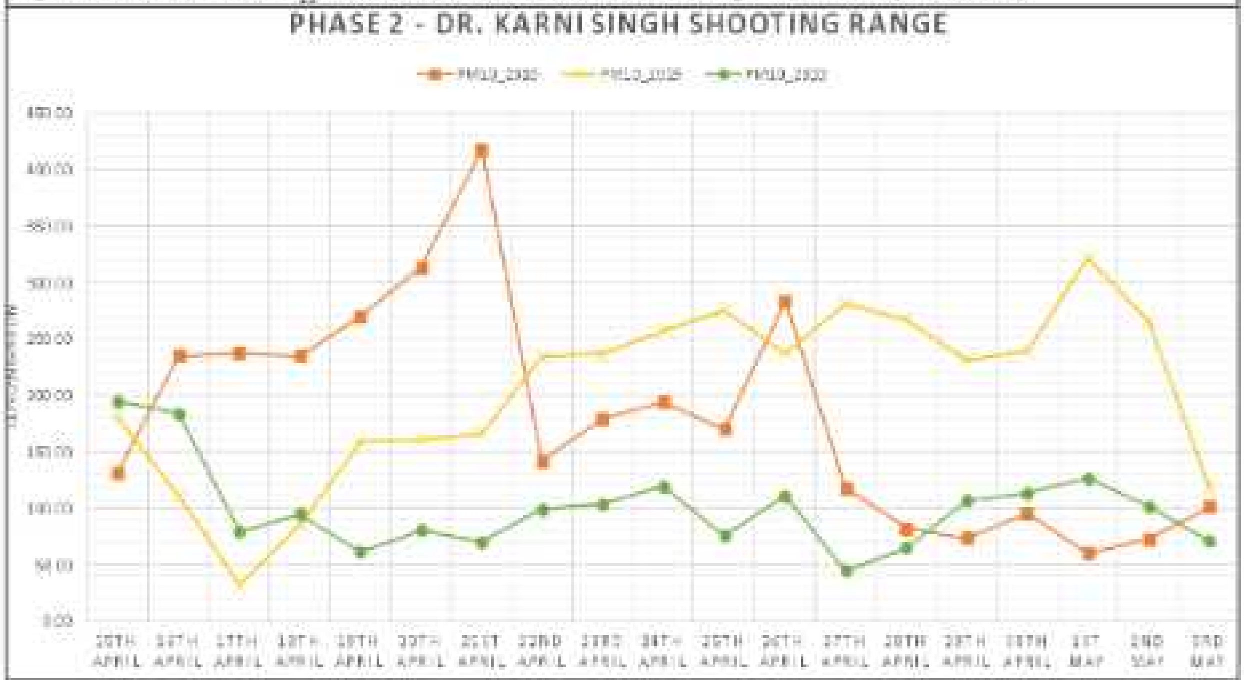


Figure 190: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 during Phase 1: 15th April to 3rd May

Phase 2

The concentrations in 2020 during lock-down are three times lesser than those in the 2018. The concentration of PM_{10} was maximum i.e.. 200 µg/m³ on the onset of major dust-storm on 15th April. The peaks in PM_{10} and $PM_{2.5}$ concentrations in 2020 around 20th, 24th, 26th, 29th April and 1st May are caused due to the winds in the region. Because few western disturbances brought rains with them, the gradual fall in concentration on some dates can be observed soon after the peaks. On comparing the concentrations of 2019 and 2020, the peak of PM_{10} value was due to the dust-storm on 25th / 26th April in Delhi.

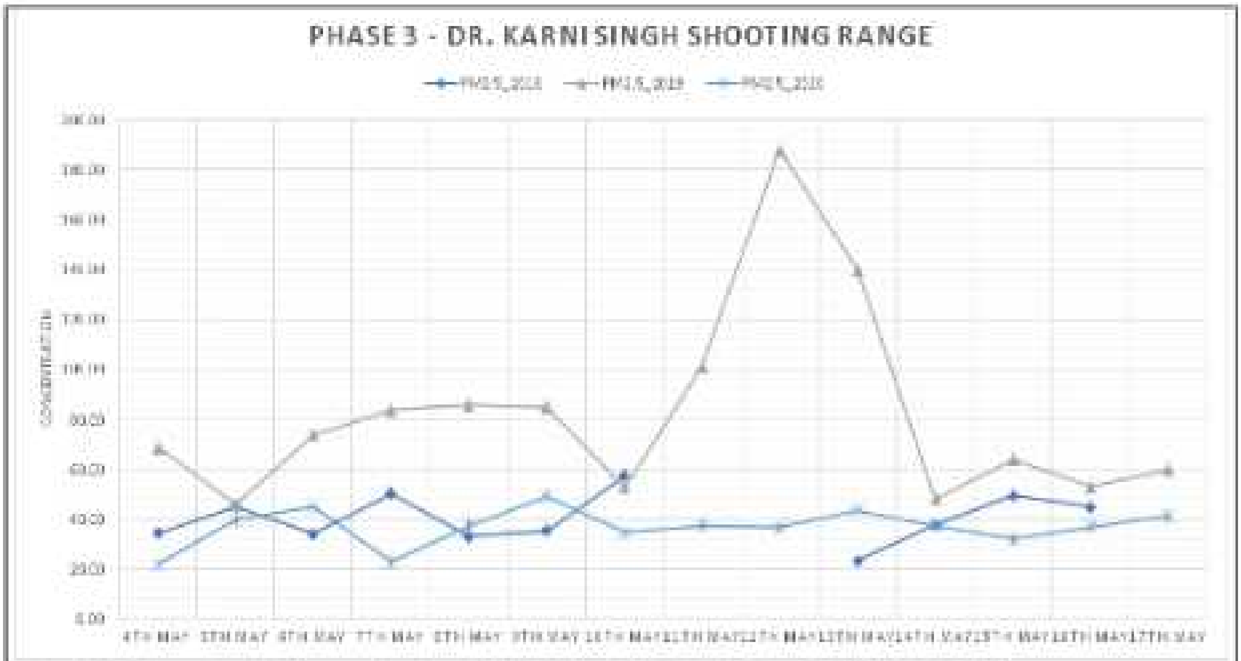


Figure 191: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 during Phase 3: 4th May to 17th May

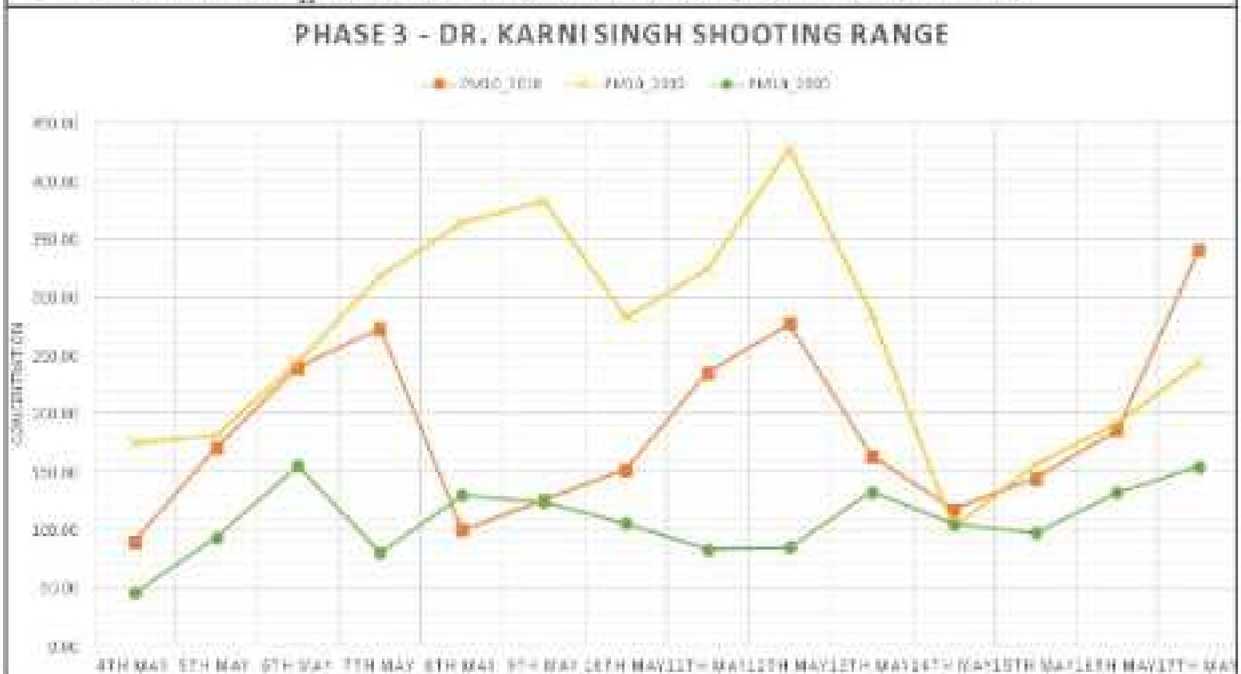


Figure 192: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 during Phase 3: 4th May to 17th May

Phase 3

The overall values of PM 2.5 and 10 were extremely high in 2018 and 2019 due to the regional influences of pollutants. The maximum value of PM_{10} in 2019 went upto 430 µg/m³ which was only 165 µg/m³ in 2020.

Also, the 3 small peaks in the concentrations in 2020 were observed due to the mild dust-storms in the city, of which some were followed by rain bringing down the temperature and pollution concentrations too, the very next day. After the dust-storms on 13th May, surprisingly hailstorm on 14th May brought the concentration down significantly.

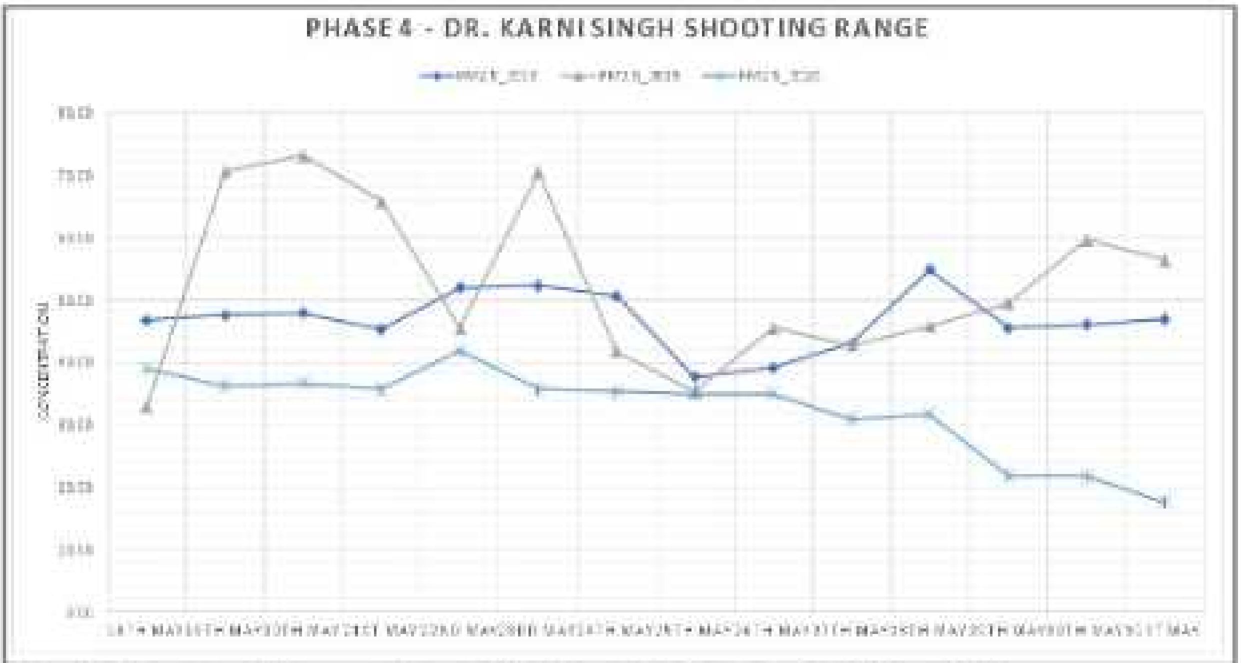


Figure 193: Comparison of $PM_{2.5}$ concentrations in 2018, 2019 and 2020 during Phase 4: 18th May to 31st May

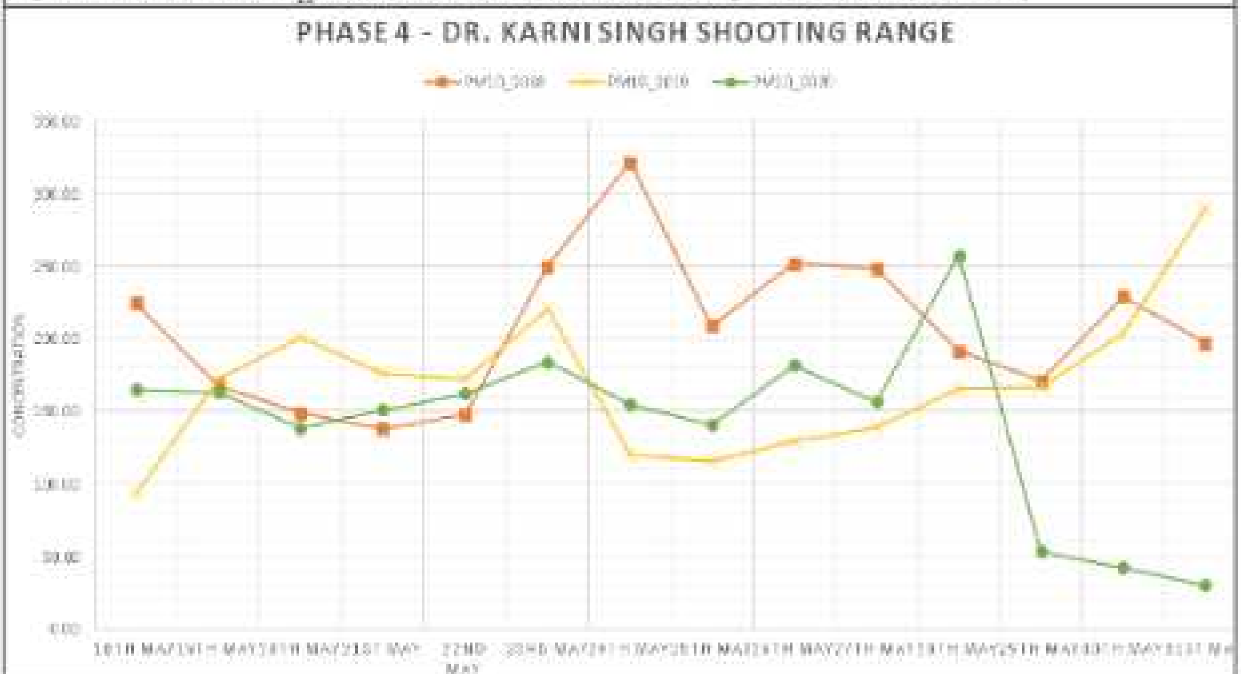


Figure 194: Comparison of PM_{10} concentrations in 2018, 2019 and 2020 during Phase 4: 18th May to 31st May

Phase 4

This phase brought the concentrations PM_{10} into the moderately polluted category in the area. With the onset of unobstructed movement of people and vehicles providing goods and services, the emissions in the region increased.

The concentrations increased due to dust-storm on 22nd may but were brought down around 29th May by the heavy rainfall in the region. Although it was strange to observe that the concentration of $PM_{2.5}$ remained in good category apart form the day of dust-storm, in this phase.

6.11. Conclusions

All the stations attributing different predominant landuses were analysed during the phases of lock-down, 2019 and 2018 , and some common observations were made. The stations on the south side of Delhi; Dr. Karni Singh Shooting Range, Aya Nagar and IGI airport mainly located on the fringes of the city, presented a common pattern. The emission loads attributed from these zones along the monitoring station were negligible as observed from the lock-down period as their concentration remained good to satisfactory in the first three phases of lock-down. It was observed that they mainly projected the concentrations arising through the influence of regional activities. $PM_{2.5}$ concentrations in all the three zones were good through out the lock-down, whereas the PM_{10} concentration was good only in first three phases and increased in the 4th phase when the regional concentrations increased of other stations in the city.

The stations located in North Delhi were DTU and Alipur, which had agricultural as the predominant landuse and activity. They both showed a gradual decline in the pollution concentration during the first lock-down phase, but the concentrations increased in the second phase after the harvesting activity begin which usually happens after Biasakhi on 14th April every year. The concentration of pollutants remained similar from 2nd and 3rd phase, as only few restrictions were lifted in phase 2 and it remained the same thereafter as no additional activities were permitted/allowed in these zones which would have made an significant impact on the emission loads in these zones. The concentration at Alipur was observed to be similar only in 4th phase just like the 2nd and 3rd at the station, but was found to be increased at DTU, because of the influence of fire incidents which brought emission loads from North east direction to the station. Although, the wind direction at Alipur was also North east only, but there weren't any fire incident observed in the north east of the station which could have influenced the concentration.

The monitoring stations at Bawana, ITO and Ashok Vihar which had different predominant landuses; Industrial, PSP and residential respectively showed diverse pattern in the concentration throughout the lock-down phases.

Ashok Vihar Station which had residential landuse had a decrease in concentration of pollutants when the lock-down was established, and thereafter remained the same (i.e., good quality) through out the 4 phases. Hence, the emission loads from the residential activities are very less.

Whereas, in Bawana industrial area, the concentrations during first three phases were similar only and increased significantly in the fourth phase when the major relaxation in movement of people, goods and services inside and outside the city were allowed. So, the pollution levels at this station depends highly on the emission load from the movement of vehicles supporting the industrial activities.

On contrary, the concentrations at ITO station increased majorly in the phase 2 itself , because of high vehicular traffic in the area. As the data of phase 3 and 4 at the station is insufficient, so nothing can be stated to analyse the pattern.

7. DEVELOPMENT OF SUITABLE FRAMEWORK FOR CARRYING CAPACITY ASSESSMENT

The development of framework for carrying capacity based planning involves, mainly, identification of the resources of the region and scope of their utilization vis-à-vis environmental impacts. The carrying capacity of air environment gives a rough estimate of the emission load (from various sources; man-made and natural) it can sustain under a set of specific conditions (release, topographic and atmospheric). We should put our efforts to explore strategies for planned and sustainable development of Delhi capital region.

7.1. Assimilative Capacity Dimensions of Air Environment

The term "assimilative capacity" of the atmosphere is believed to be used interchangeably with the "carrying capacity". The assimilative capacity of the atmosphere gives roughly an idea of the extent to which the atmosphere is capable of sustaining the pollution load from various emission sources. Thus, a thorough study of the assimilative capacity is essential for judging proper sitting of new industrial units and for regulating the operating of the industries according to the atmospheric conditions. The assimilative capacity depends on various physical parameters such as the atmospheric stability, the topography of the region etc. The atmospheric stability is a crucial parameter which is based on solar insulation, mean wind speed and temperature profile. The assimilative capacity of the atmosphere is directly proportional to the ventilation coefficient and inversely proportional to the pollution potential. Further, the ventilation coefficient is expressed as a product of the mixing height and the transport wind speed within the mixing layer. The use of atmospheric stability for the estimation of assimilative capacity is manifested in the mixing height and the transport wind. A region with large pollution potential would have less carrying capacity.

The ventilation coefficient, which is the product of mixing depth and the average wind speed, is an atmospheric condition which gives an indication of the air quality and pollution potential, i.e., the ability of the atmosphere to dilute and disperse the pollutants over a region. The higher the coefficient, the more efficiently the atmosphere is able to dispose the pollutants and better is the air quality. On the other hand, low ventilation coefficients lead to poor dispersal of pollutants causing stagnation and poor air quality leading to possible pollution related hazards. The ventilation coefficient is a function of mixing depth and the average wind speed through the mixing layer. A fluctuation in the values of either/both these quantities causes a variation in the ventilation coefficient.

The ventilation coefficient (VC) is computed as:

VC = Mixing Height × Mean wind speed

The mixing height of Delhi has been taken from CPCB CAAQM. The table below shows the mixing height of Delhi for various months.

Table 148: Ventilation coefficients, 2019

Month	Min	Max	Min_Avg	Max_Avg
January	70	2003	154.5833	1618.169
February	90	2087.8	175.1786	1768.286
March	65	2215	188.9655	1842.974
April	70	2066.6	138.6538	1609.493
May	70	4140	135.5556	1308.781
June	60	1685	131.4286	791.7793
July	120	6874.76	186.6667	1172.888
August	100	1876	193.5	1016.415
September	60	1727	129.2308	987.4815
October	80	2045	131.6129	1575.516
November	60	1749	127.8261	1405.107
December	50	1664	92.70833	1222.724

The ventilation coefficient of Delhi is low which justifies the observation of similar pattern of pollutant concentration all-round the year. The assimilative capacity of Delhi is low and as such any sort of polluting activity have a serious impact on air environment. This points out to proper management of traffic and land use allocations.

7.2. Carrying Capacity (CC) with respect to air environment

This is the 'maximum capacity of environment that can support the existing emission load by a land use and its associated activities over a particular time period". The unit of PCC is m^2/s.

It is expressed as:

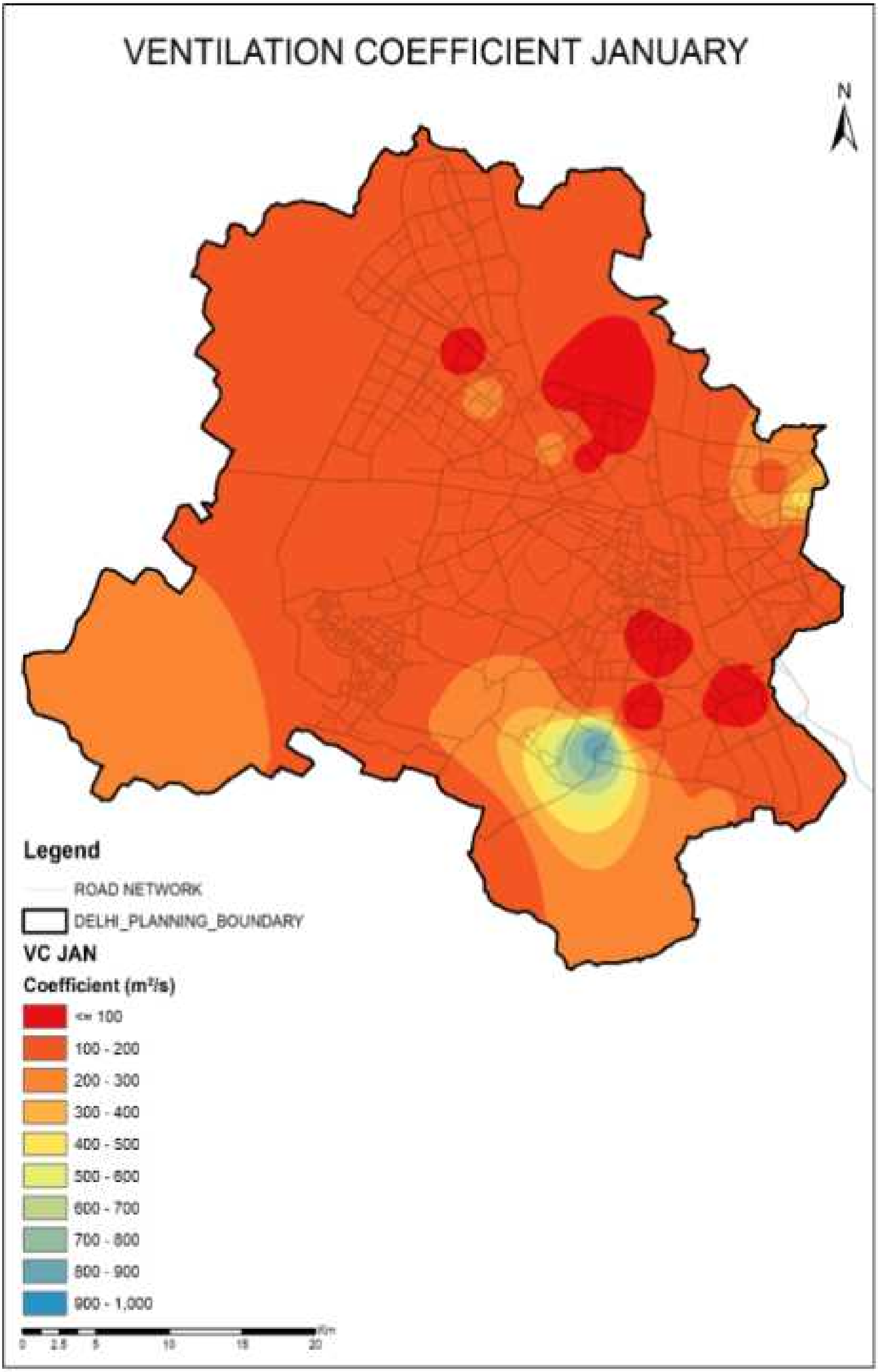
CC = (Emission Standard as per CPCB)/(Emission from Land uses) × Ventilation Coefficient; .... (1)

Table 149: Ventilation Coefficient in morning and afternoon

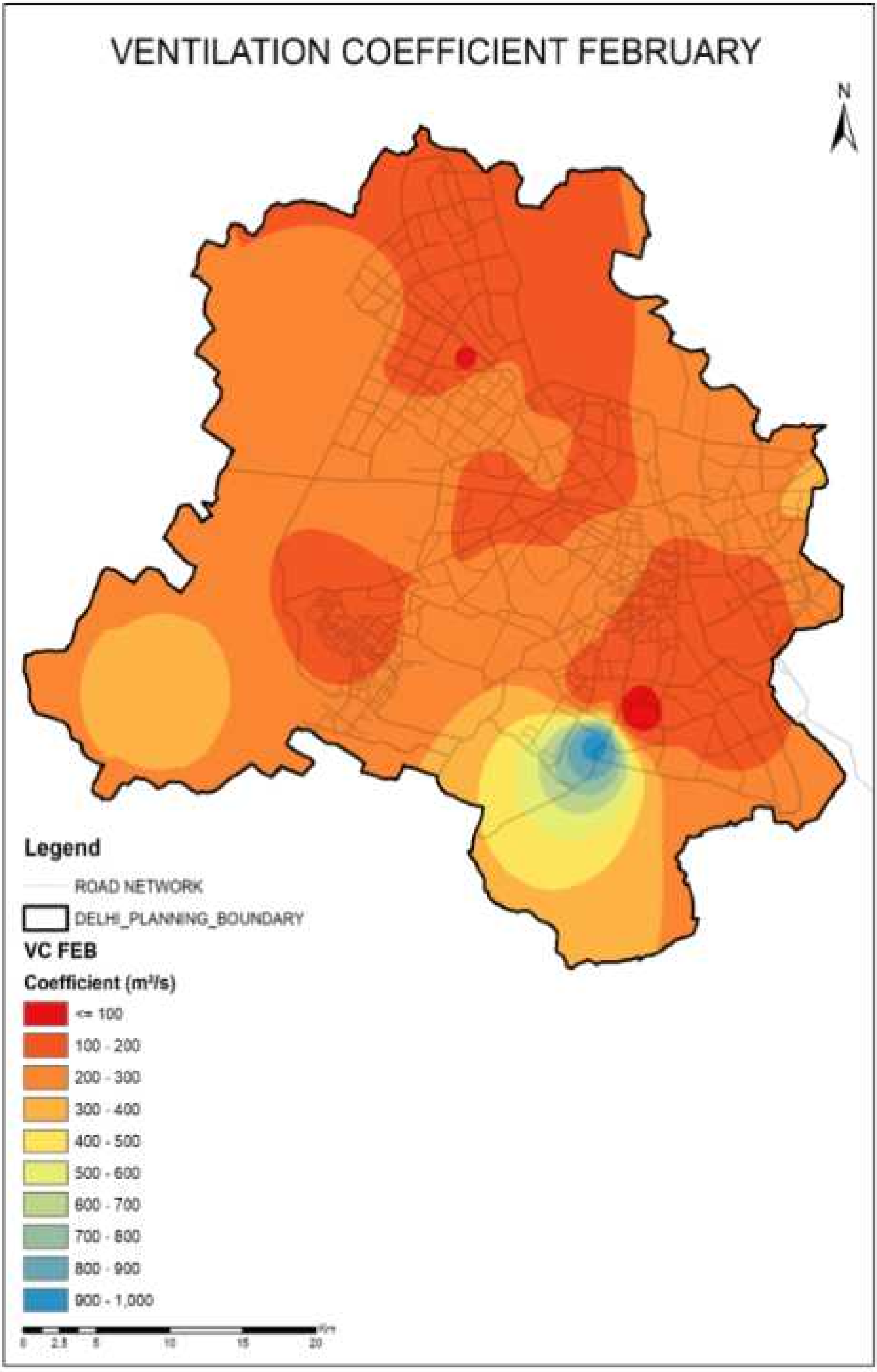
	$PM_{2.5}$	PM_{10}	Wind Speed (m/s)	Mixing Height (m)	Ventilation Coefficient*
Morning	≤ 60	≤ 100	> 4	> 500	> 2000
Afternoon			> 4	> 1500	> 6000

* The US National Meteorological Centre and Atmospheric Environment Services, Canada, has classified that, high pollution potential or low assimilative capacity occurs during afternoon, when ventilation coefficient is < 6000 m^2/s and mean wind speed does not exceed 4 m/s and during morning hours, when mixing height is < 500 m.

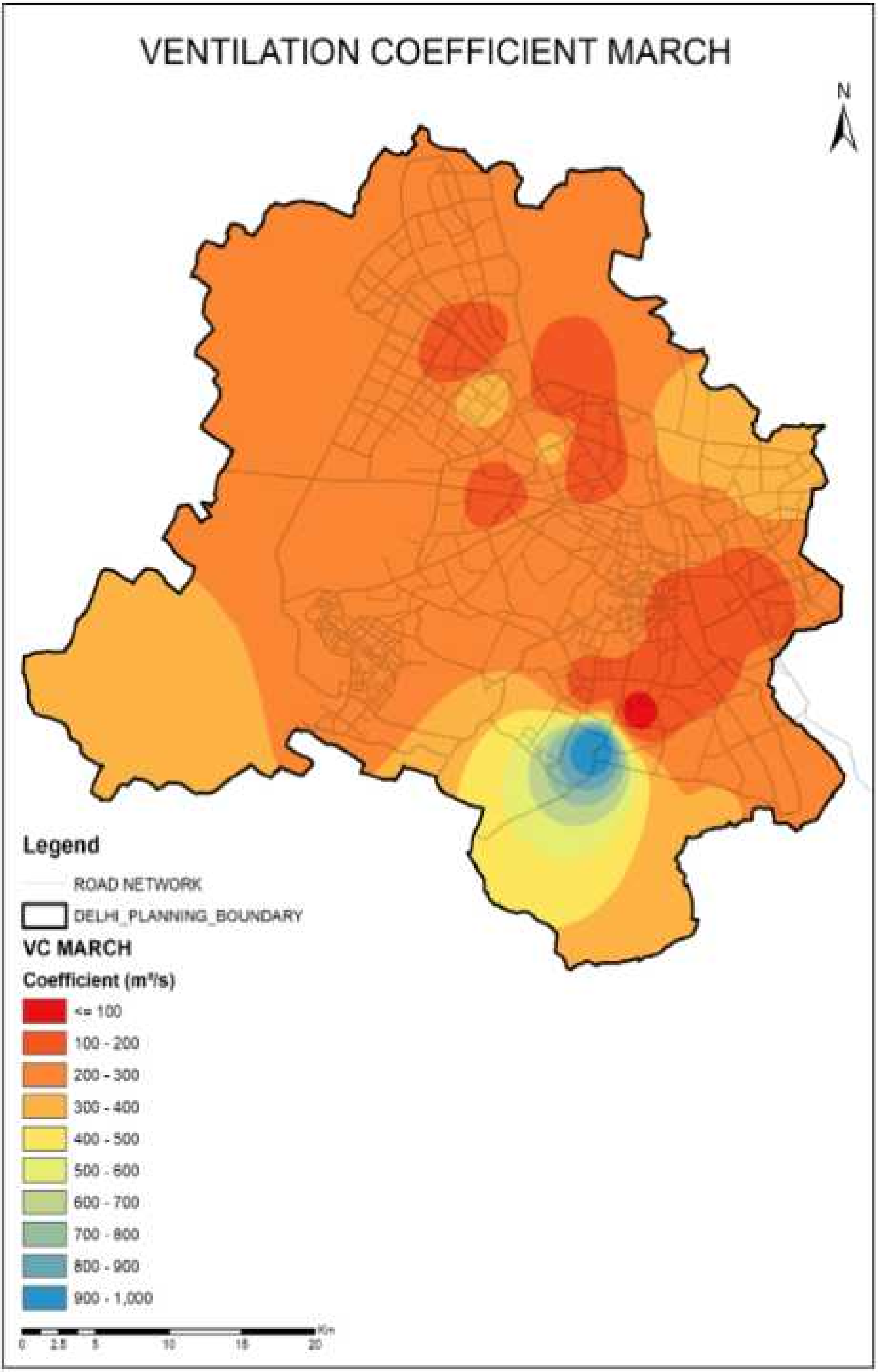
Ventilation Coefficient simply provides a broad indication of the dispersion potential in terms of low (<2000 m^2/s), medium (2000-6000 m^2/s) or high (>6000 m^2/s) of the atmosphere. But it does not give any idea about the amount of emission loads that can be assimilated in the given airshed of the region.



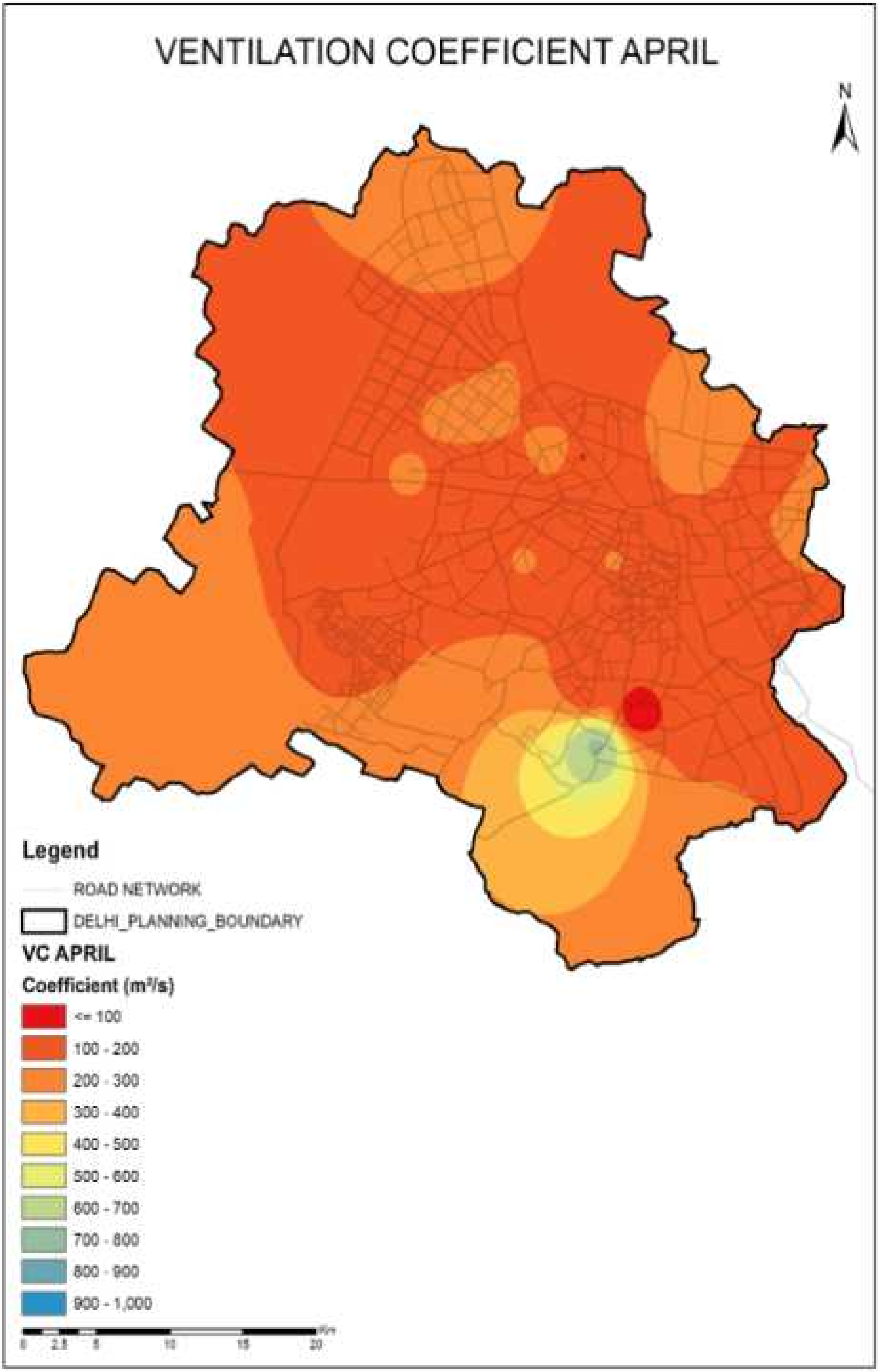
Map 225: Ventilation Coefficient,January 2019



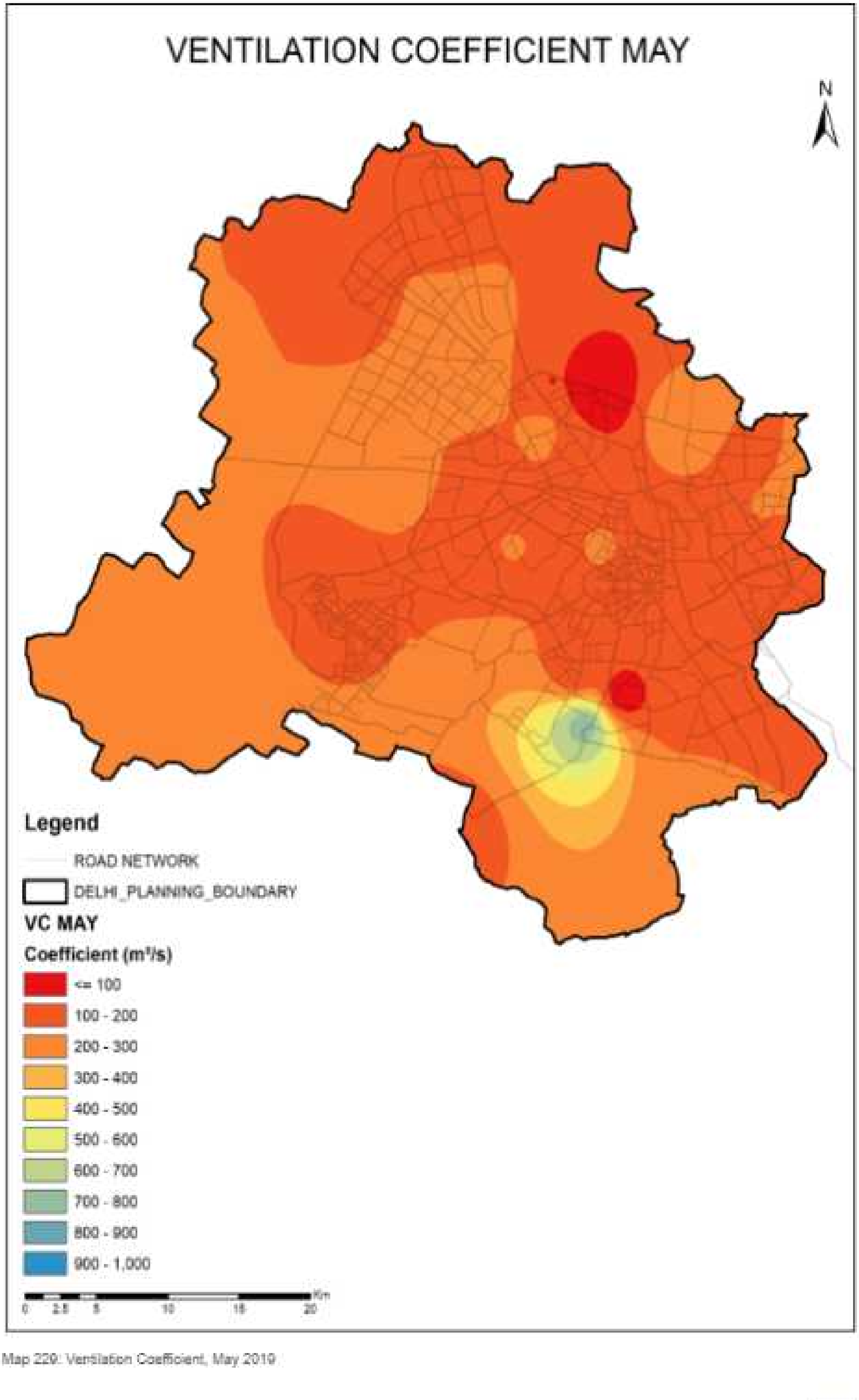
Map 226: Ventilation Coefficient, February 2019



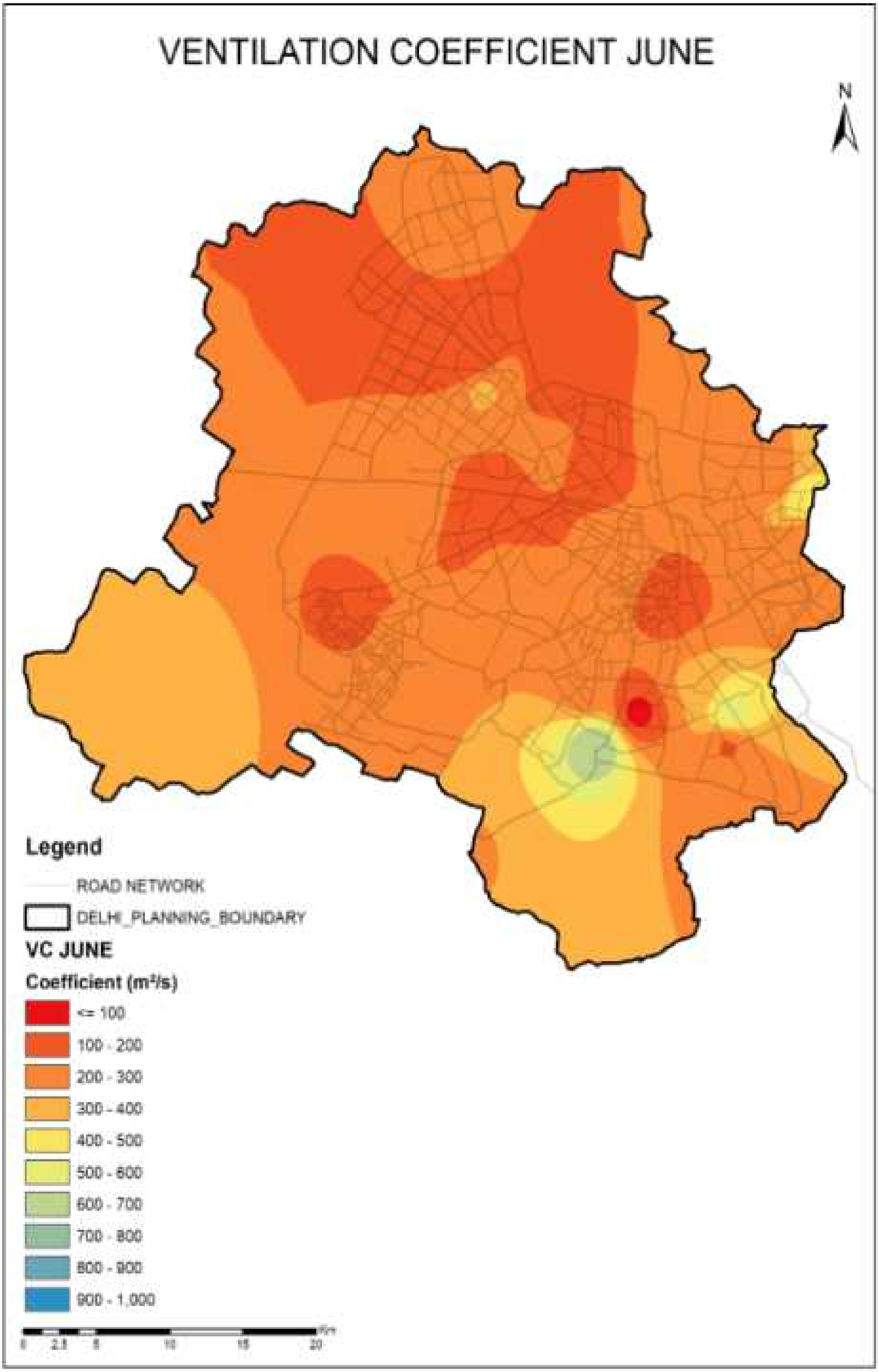
Map 227: Ventilation Coefficient, March 2019



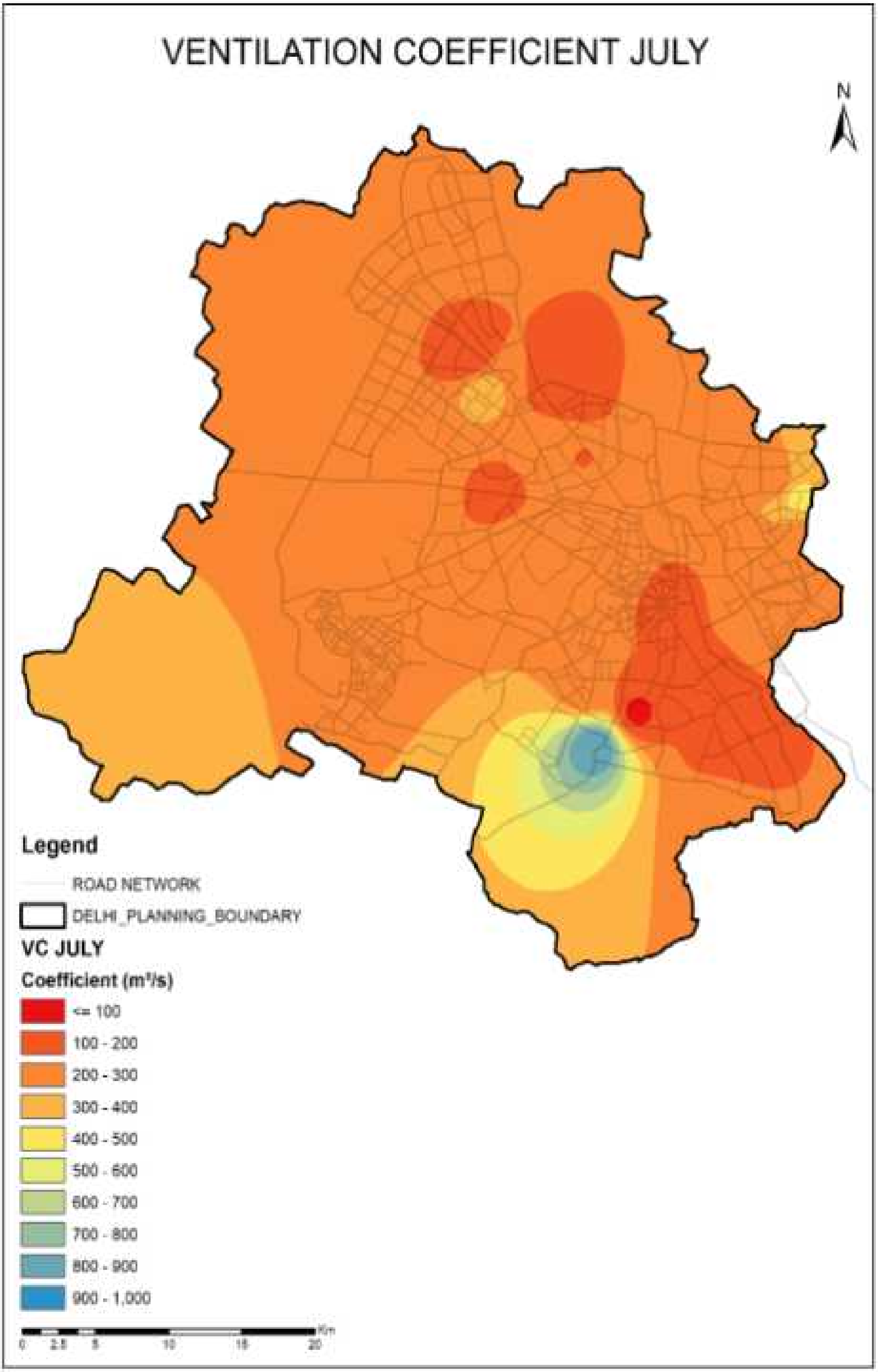
Map 229: Ventilation Coefficient, April 2019



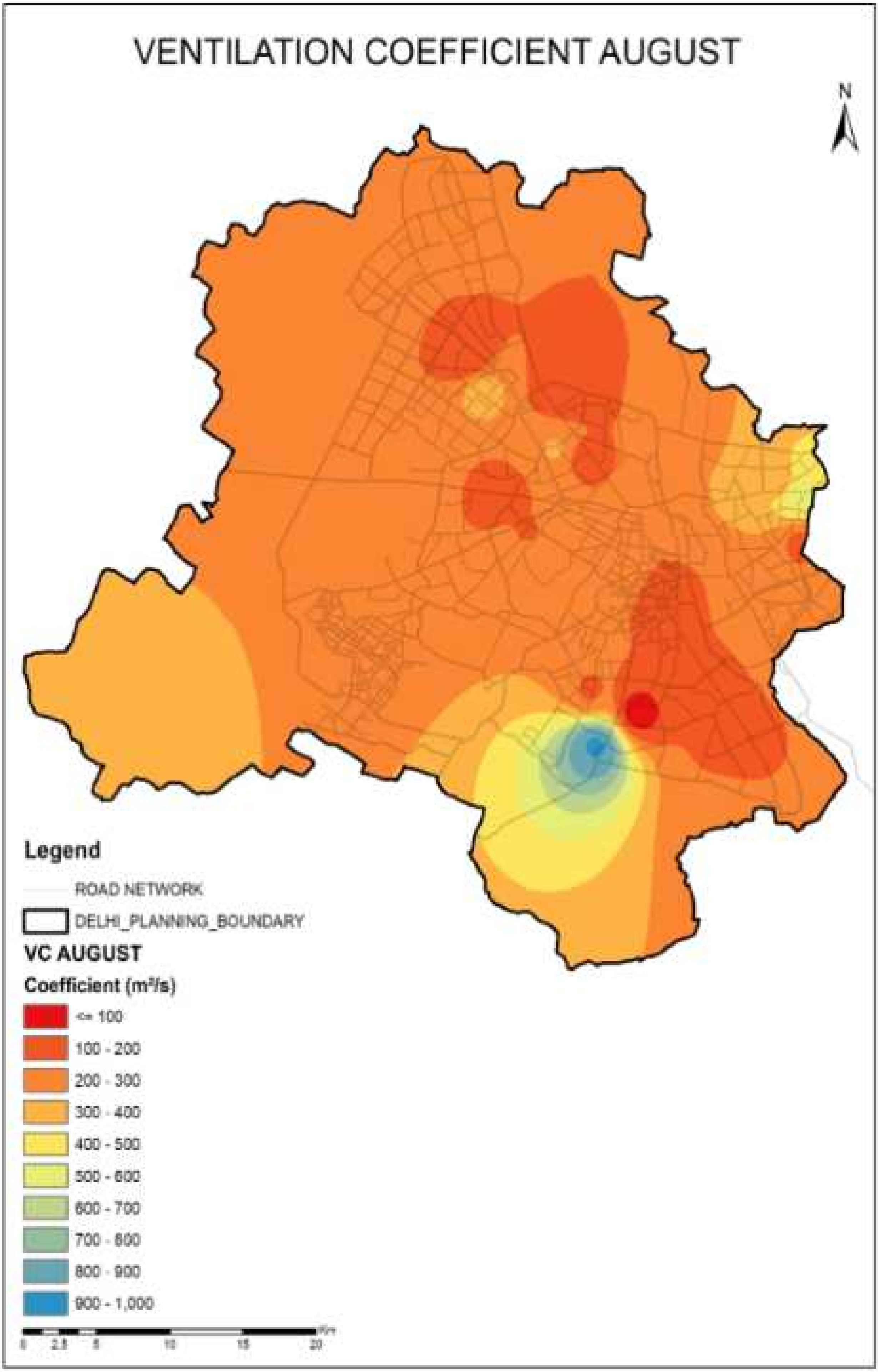
Map 229: Ventilation Coefficient, May 2019



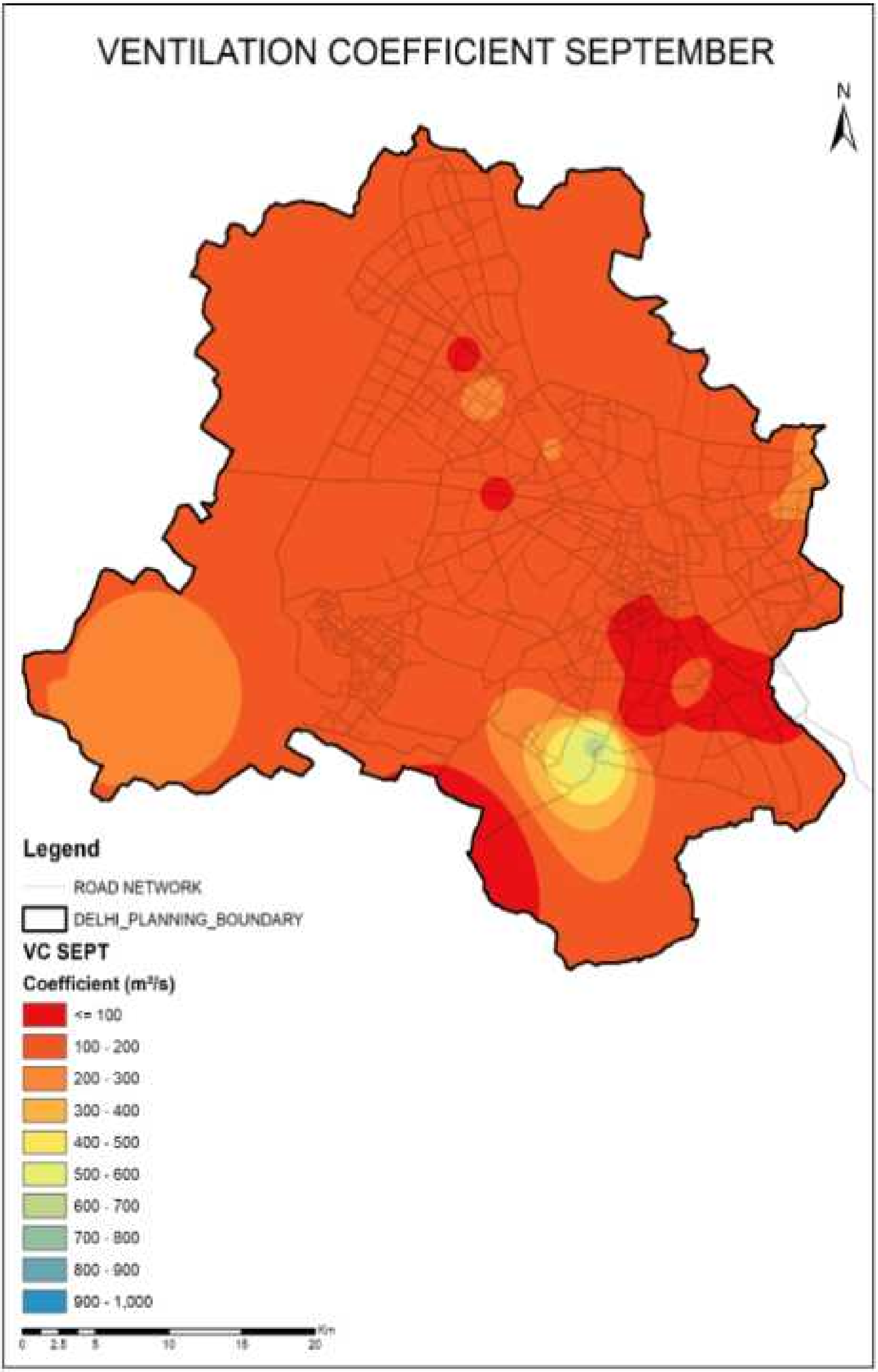
Map 230: Ventilation Coefficient, June 2019



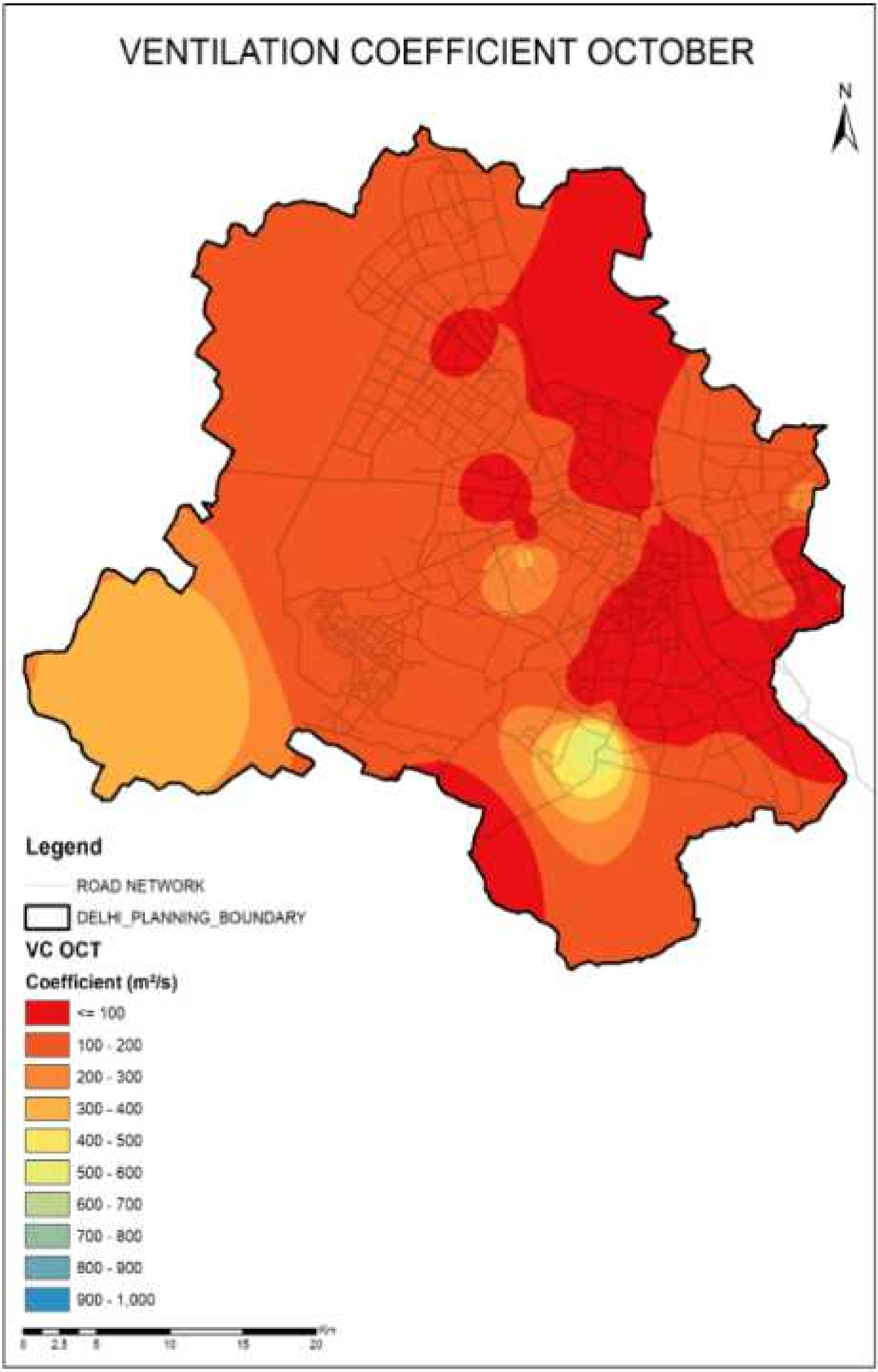
Map 231: Ventilation Coefficient, July 2019



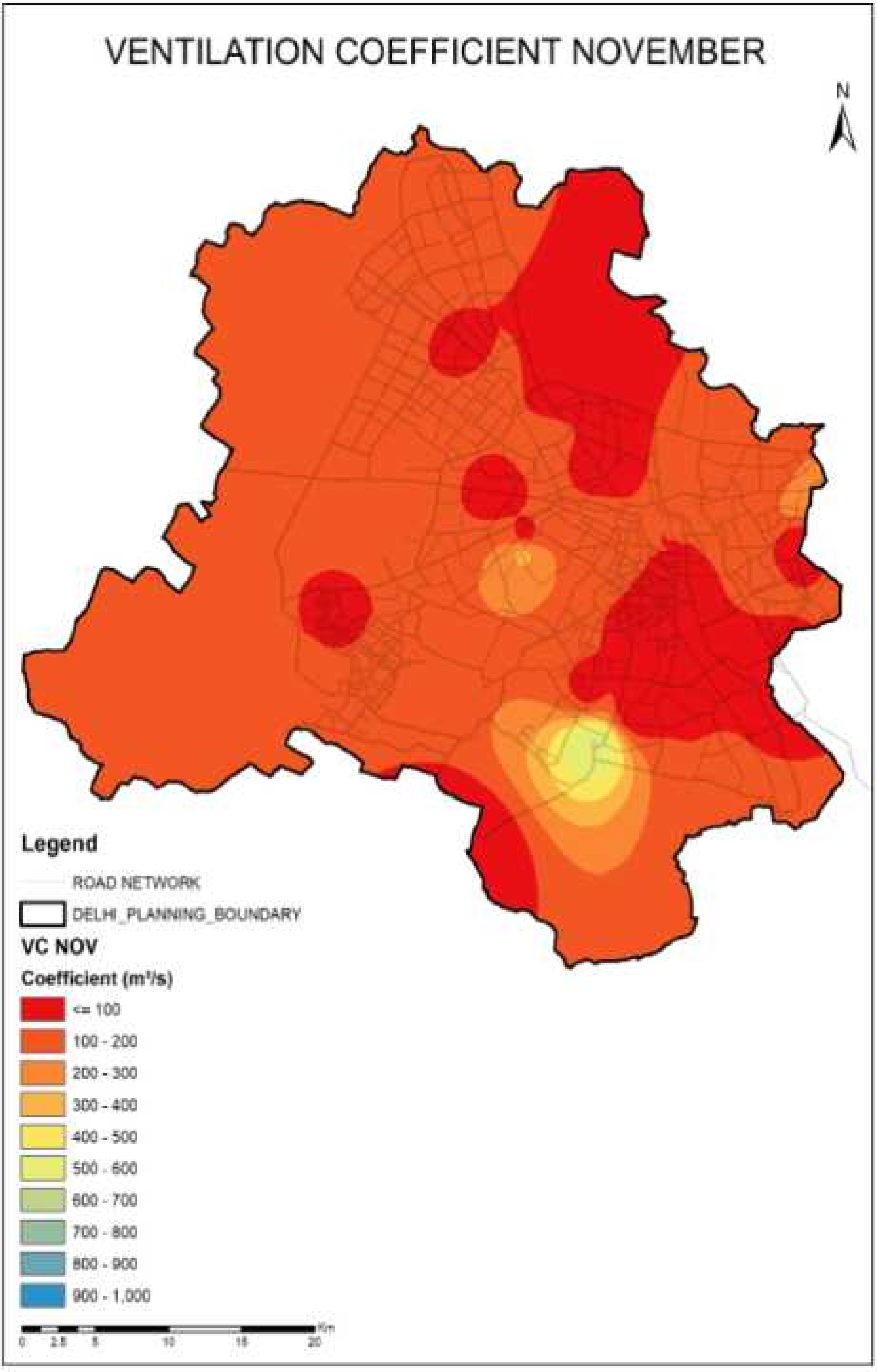
Map 232: Ventilation Coefficient, August 2019



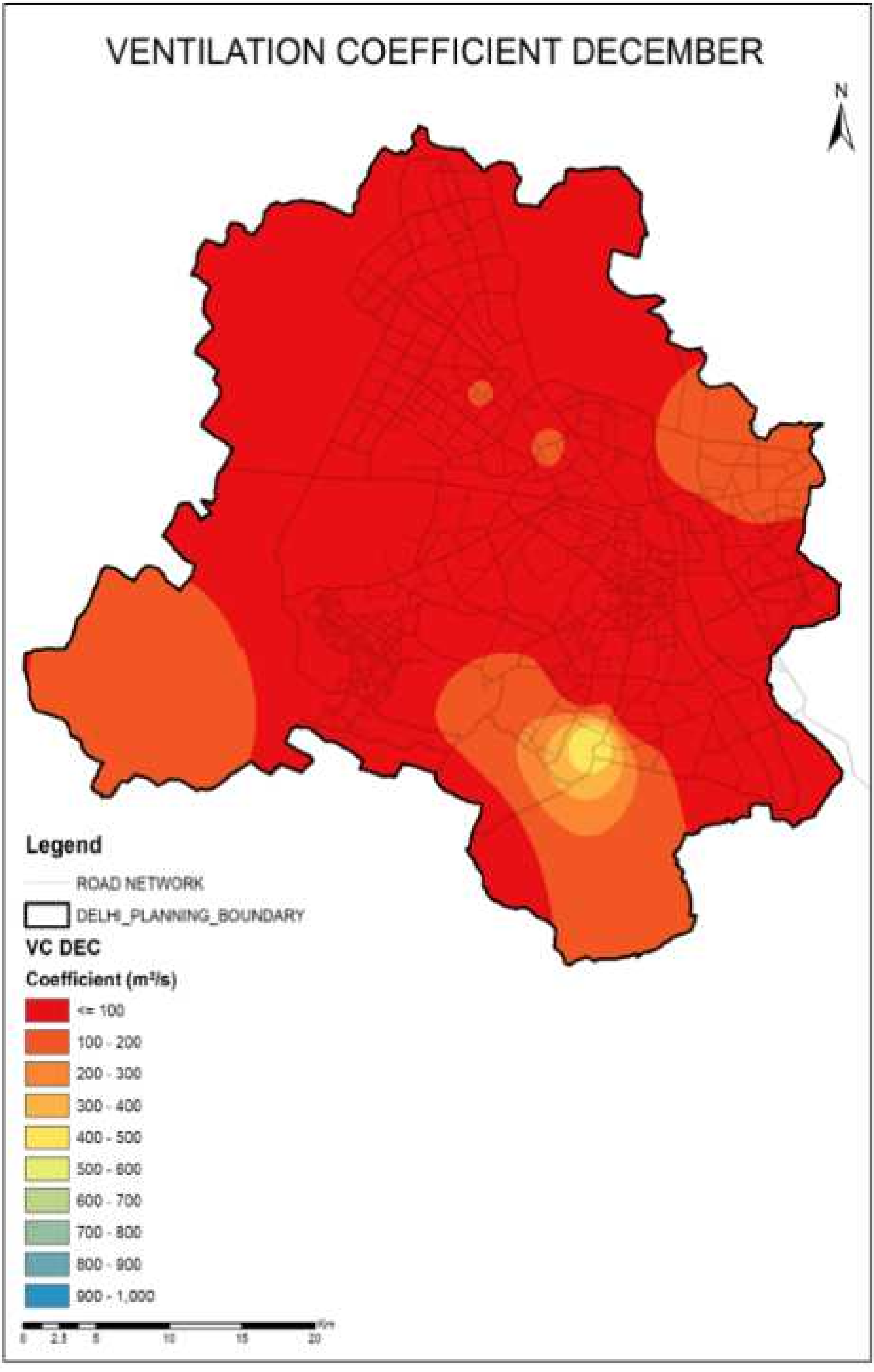
Map 233: Ventilation Coefficient, September 2019



Map 234: Ventilation Coefficient, October 2019



Map 236: Ventilation Coefficient, November 2019



Map 236: Ventilation Coefficient, December 2019

The carrying capacity changes over time as it depends on atmospheric stability and emission load over a certain period of time. However, to give an idea, monthly carrying capacity w.r.t air environment are established acknowledging the fact that meteorological factors changes over months/seasons.

The Carrying Capacity for an ideal situation where both $PM_{2.5}$ and PM_{10} is within limit, as derived from equation (1) will be 2000 m²/s in morning and 6000 m²/s in evening. The ventilation coefficient however varies w.r.t wind speed and mixing height and the values may be way lower than the given standard of 2000 m²/s or 6000 m²/s. Even at low ventilation coefficient, cities have observed clean air due to reduced emission load which is the case of lock-down where a number of activities have been prohibited including transportation.

In light of these, we can say that Ventilation Coefficient does not merely say that the cities have low or high capacities. The carrying capacity depends on both V.C. and emission loads. Reducing the emission loads at areas having low ventilation coefficient will improve air quality. The case is backed by the assessment of air quality during lock-down period. The value of mixing height has been considered the same throughout due to lack of data.

Carrying Capacity is said to be good when the estimated C.C is greater than the ventilation coefficient. Thus, the carrying capacity is dependent majorly on the emission load per day.

7.3. Methodology of carrying capacity assessment

$$\text{Emission Concentration} \propto \frac{1}{\text{Wind Speed}} \propto \frac{1}{\text{Mixing Height}} \propto \text{Land Use Activity Rate}$$

$$\text{Emission Concentration} = k \times \frac{\text{Land Use Type Engagement}}{\text{Ventilation Coefficient}}\ ;\ k - \text{activity rate or emission rate}$$

The density of dry air can be calculated using the ideal gas law, expressed as a function of temperature and pressure:

$$\rho = \frac{p}{R_{\text{specific}} T}$$

where:

ρ = air density (kg/m³)[note 1]
p = absolute pressure (Pa)[note 1]
T = absolute temperature (K)[note 1]
R_{specific} = specific gas constant for dry air (J/(kg·K))[note 1]

The specific gas constant for dry air is 287.058 J/(kg·K) in SI units. This quantity may vary slightly depending on the molecular composition of air at a particular location.

Therefore:

At IUPAC standard temperature and pressure (0 °C and 100 kPa), dry air has a density of 1.2754 kg/m³.

At 20 °C and 101.325 kPa, dry air has a density of 1.2041 kg/m³.

Humid air:

The addition of water vapor to air (making the air humid) reduces the density of the air, which may at first appear counter-intuitive. This occurs because the molar mass of water (18 g/mol) is less than the molar mass of dry air (around 29 g/mol). For any ideal gas, at a given temperature and pressure, the number of molecules is constant for a particular volume (see Avogadro's Law). So, when water molecules (water vapor) are added to a given volume of air, the dry air molecules must decrease by the same number, to keep the pressure or temperature from increasing. Hence the mass per unit volume of the gas (its density) decreases.

The density of humid air may be calculated by treating it as a mixture of ideal gases.

$$\rho_{\text{humid air}} = \frac{p_d}{R_d T} + \frac{p_v}{R_v T} = \frac{p_d M_d + p_v M_v}{RT}$$

, where:

$\rho_{\text{humid air}}$ = Density of the humid air (kg/m³)
p_d = Partial pressure of dry air (Pa)
R_d = Specific gas constant for dry air, 287.058 J/(kg·K)
T = Temperature (K)
p_v = Pressure of water vapor (Pa)
R_v = Specific gas constant for water vapor, 461.495 J/(kg·K)
M_d = Molar mass of dry air, 0.0289654 kg/mol
M_v = Molar mass of water vapor, 0.018016 kg/mol
R = Universal gas constant, 8.314 J/(K·mol)

The vapor pressure of water may be calculated from the saturation vapor pressure and relative humidity. It is found by:

$$p_v = \phi p_{\text{sat}}$$

where:

p_v = Vapor pressure of water
ϕ = Relative humidity
p_{sat} = Saturation vapor pressure

The saturation vapor pressure of water at any given temperature is the vapor pressure when relative humidity is 100%. One formula used to find the saturation vapor pressure [Pa] is:

$$p_{\text{sat}} = 6.1078 \times 10^{\frac{7.5T}{T+237.3}}$$

where T = is in degrees C. See vapor pressure of water for other equations.

Note:

This equation will give the result of pressure in hPa (100 Pa, equivalent to the older unit millibar; 1 mbar = 0.001 bar = 0.1 kPa)

The partial pressure of dry air pd is found considering partial pressure, resulting in:

$$p_d = p - p_v$$

Where p simply denotes the observed absolute pressure.

$$\textbf{Emission Concentration} \propto \text{Activity Rate} \propto \frac{1}{\text{Wind Speed}} \propto \frac{1}{\text{Mixing Height}} \propto \frac{1}{\text{Temperature}} \propto \frac{1}{\text{R.H}} \propto \text{Pressure}$$

Emission Concentration is directly proportional to the activity rate, so wherever there are industrial areas, the concentration of pollutants would be high because of constant industrial emissions and the supporting transport activities for loading/unloading activities.

Wind speed shows inversely proportional relationship with emission concentration, as low wind speeds reducing the dispersion rate of pollutants and thus increase in emission concentration will be observed. Also, it was found that built form (refer map 10) also affects the wind speed inside the city, which creates chunks of land where there is negligible wind speed when compared to the areas nearby.

Mixing height also varies inversely with the emission concentration. As explained in table 149, the mixing height is maximum in the evening and starts reducing thereafter from 6 pm to 6 am during the night. It can be seen from Table 151 & 152 that mixing height is maximum in the month of July and minimum in November and December.

Temperature is directly proportional to mixing height i.e. inversely to the emission concentrations, when temperature is high, mixing height is observed to be high and hence low pollution is observed in these areas. And when temperature is low in winters, mixing height reduces significantly, increasing the pollution in the city.

The increase of relative humidity in the atmosphere reduces the amount of solar radiation reaching the earth's surface. The heat from the solar radiation is observed by the air, resulting in minimizing atmospheric temperature nearer to the surface of earth. The air layer nearer to the surface of the earth becomes colder than the upper layers, thus reducing the upgoing currents and leading to the increase of pollutant concentrations.

Atmospheric pressure is directly proportional to the concentrations of the pollutants, as in areas where there is low atmospheric pressure, wind flows vertically upwards, increasing dispersion rate of pollutants whereas in areas where there is high pressure, downward movement of air is observed adding the concentration of pollutants from near by areas too.

Concluding all the above observations stated in the chapter, carrying capacity can be expressed as following:

It is the 'maximum capacity of environment that can support the existing emission load by a land use and its associated activities over a particular time period".

The concentrations of substances in the atmosphere are determined by: 1) transport, 2) diffusion, 3) chemical transformation, and 4) ground deposition.

Based on Anthropogenic activity:

$$\text{Emission Concentration} \propto a * K$$

Where, a – activity rate (units/hour), K – emission factor (g/unit)

Based on Meteorological factors:

$$\textbf{Emission Concentration} \propto \frac{1}{\text{Wind Speed}} \propto \frac{1}{\text{Mixing Height}} \propto \frac{1}{\text{Temperature}} \propto \frac{1}{\text{R.H}} \propto \text{Pressure}$$

Therefore, we can say that;

$$\textbf{Emission Concentration} \propto \frac{\text{Activity Rate} * \text{Emission Factor}}{\text{Wind Speed} * \text{Mixing Height}} \propto \frac{1}{\text{Temperature}} \propto \frac{1}{\text{R.H}} \propto \text{Pressure}$$

It is expressed as:

Carrying Capacity = (Emission Standard as per CPCB)/(Pollutant Concentration) × Ventilation Coefficient; .... (1)

$$\textbf{Carrying Capacity} = \left(\frac{\textbf{Emission Standard as per CPCB}}{\textbf{Pollution Concentration at monitoring station}} \times \textbf{Ventilation Coefficient} \right) - \textbf{Ventilation Coefficient}$$

i.e.,

(this formula is being used for estimating carrying capacity further in the study)

8. CARRYING CAPACITY ASSESSMENT

Using the formula of carrying capacity derived in chapter 7, the estimated carrying capacity for both $PM_{2.5}$ and PM_{10} were concluded month-wise for the monitoring stations across Delhi NCT. All the carrying capacity assessment maps (Maps 237-260) were developed through raster (factor) analysis using GIS, based on the categories mentioned in table 152.

Table 150: Carrying Capacity estimation of Delhi for 2018

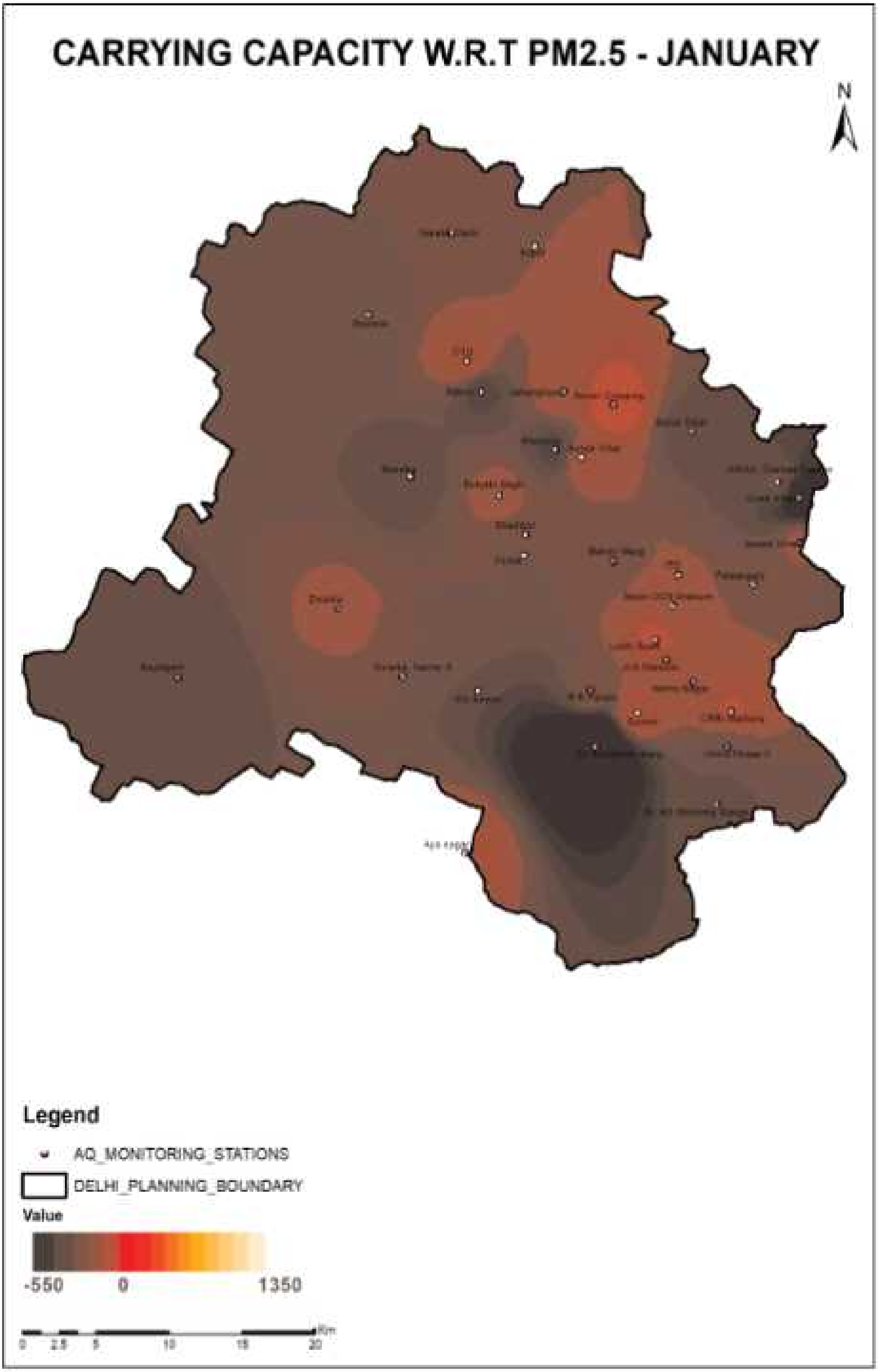
Month	Mean Wind Speed (m/s)	Min Mixing Height (m)	Max Mixing Height (m)	V.C. (m^2/s)		Avg. VC (m^2/s)	Avg. $PM_{2.5}$ conc. ($\mu g/m^3$)	Avg. PM_{10} conc. ($\mu g/m^3$)	Estimated CC (m^2/s) PM 2.5	Estimated CC (m^2/s) PM 10
				Min	Max					
January	0.81	70	2003	56.6444	1620.84	838.741	195.514	320.731	257.3953	261.50905
February	1.14	90	2087.8	102.759	2383.77	1243.26	137.025	274.476	544.895	452.9586
March	1.26	65	2215	81.9051	2791.07	1436.49	99.6783	238.741	864.6751	601.69297
April	1.36	70	2066.6	95.0054	2804.83	1449.92	90.1323	264.759	965.193	547.63992
May	1.49	70	4140	104.35	6171.57	3137.96	87.5763	248.602	2149.92	1262.2422
June	2.27	60	1685	136.377	3829.91	1983.14	81.0935	237.037	1067.301	816.63785
July	1.94	120	6874.76	232.315	13309.2	6770.77	42.258	105.268	9613.486	6431.9326
August	1.49	100	1876	149.488	2804.39	1476.94	41.7192	121.387	2124.115	1216.2203
September	1.40	60	1727	84.0987	2420.64	1252.37	45.9776	116.765	1634.32	1072.5536
October	1.22	80	2045	97.615	2495.28	1296.45	137.082	303.364	567.4865	427.35832
November	1.08	60	1749	64.8214	1889.54	977.182	199.614	345.045	293.7236	283.20383
December	0.99	50	1664	49.2958	1640.56	844.93	228.739	382.097	221.6313	221.12954

Table 151: Carrying Capacity estimation of Delhi for 2019

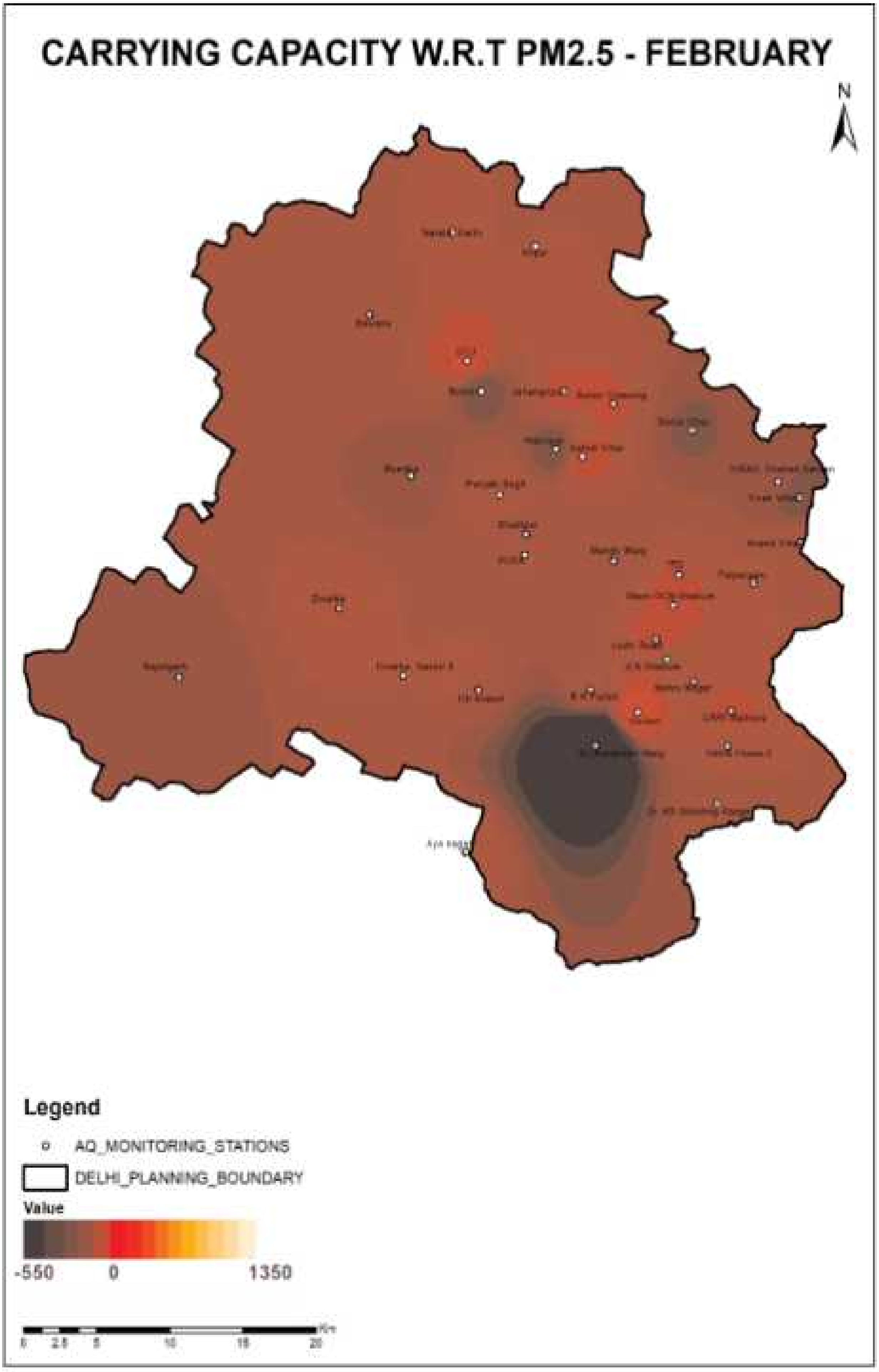
Month	Mean Wind Speed (m/s)	Min Mixing Height (m)	Max Mixing Height (m)	V.C. (m^2/s)		Avg V.C	Avg. $PM_{2.5}$ conc. ($\mu g/m^3$)	Avg. PM_{10} conc. ($\mu g/m^3$)	Estimated CC (m^2/s) PM 2.5	Estimated CC (m^2/s) PM 10	PM 2.5 C.C = E.C.C-V.C	PM 10 C.C = E.C.C-V.C
				Min	Max							
January	1.29	70	2003	76.3	2183.77	1129.785	203.89	324.26	332.409	348.4195	[illegible]	[illegible]
February	1.31	90	2087.8	117.9	2735.08	1426.49	140.96	240.42	607.1893	593.3375	[illegible]	[illegible]
March	1.38	65	2215	89.7	3056.7	1573.2	88.48	186.48	1066.817	843.6293	[illegible]	[illegible]
April	1.43	70	2066.6	100.1	2955.74	1527.67	89.77	238.87	1075.571	645.4853	[illegible]	[illegible]
May	1.46	70	4140	102.2	6044.4	3071.3	85.96	244.91	2145.161	1254.818	[illegible]	[illegible]
June	1.9	60	1685	114	3201.5	1657.75	82.96	208.18	1579.813	796.3061	[illegible]	[illegible]
July	1.37	120	6874.76	164.4	9418.42	4791.41	46.63	141.26	6165.228	3391.909	1373.81859	[illegible]
August	1.53	100	1876	133	2495.08	1314.04	34.87	85.85	2277.366	1576.533	963.325087	262.492093
September	1.16	60	1727	69.6	2003.32	1036.46	40.11	98.46	1550.426	1052.671	513.966328	16.3111335
October	0.98	80	2045	78.4	2004.1	1041.25	123.44	241.74	506.1163	430.7314	[illegible]	[illegible]
November	1.01	60	1749	60.6	1766.45	913.545	204	315.76	268.6827	282.2373	[illegible]	[illegible]
December	0.91	50	1664	45.5	1514.24	779.87	203.42	310.48	229.8016	251.182	[illegible]	[illegible]

Table 152: Categorization of Carrying Capacity

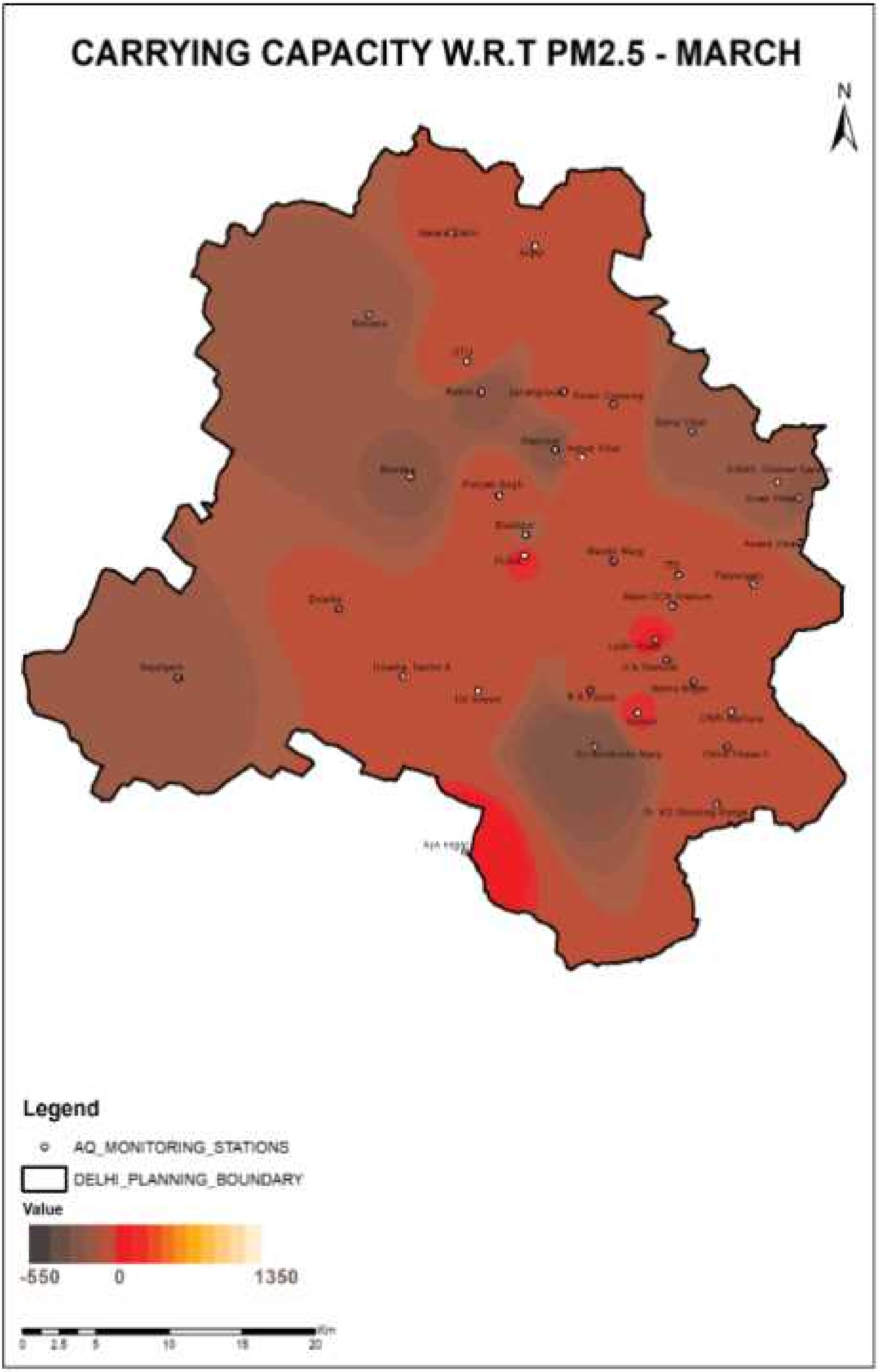
Category	Condition	Code
High	Carrying Capacity > Ventilation Coefficient	
Moderate	Carrying Capacity = Ventilation Coefficient	
Low	Carrying Capacity < Ventilation Coefficient	



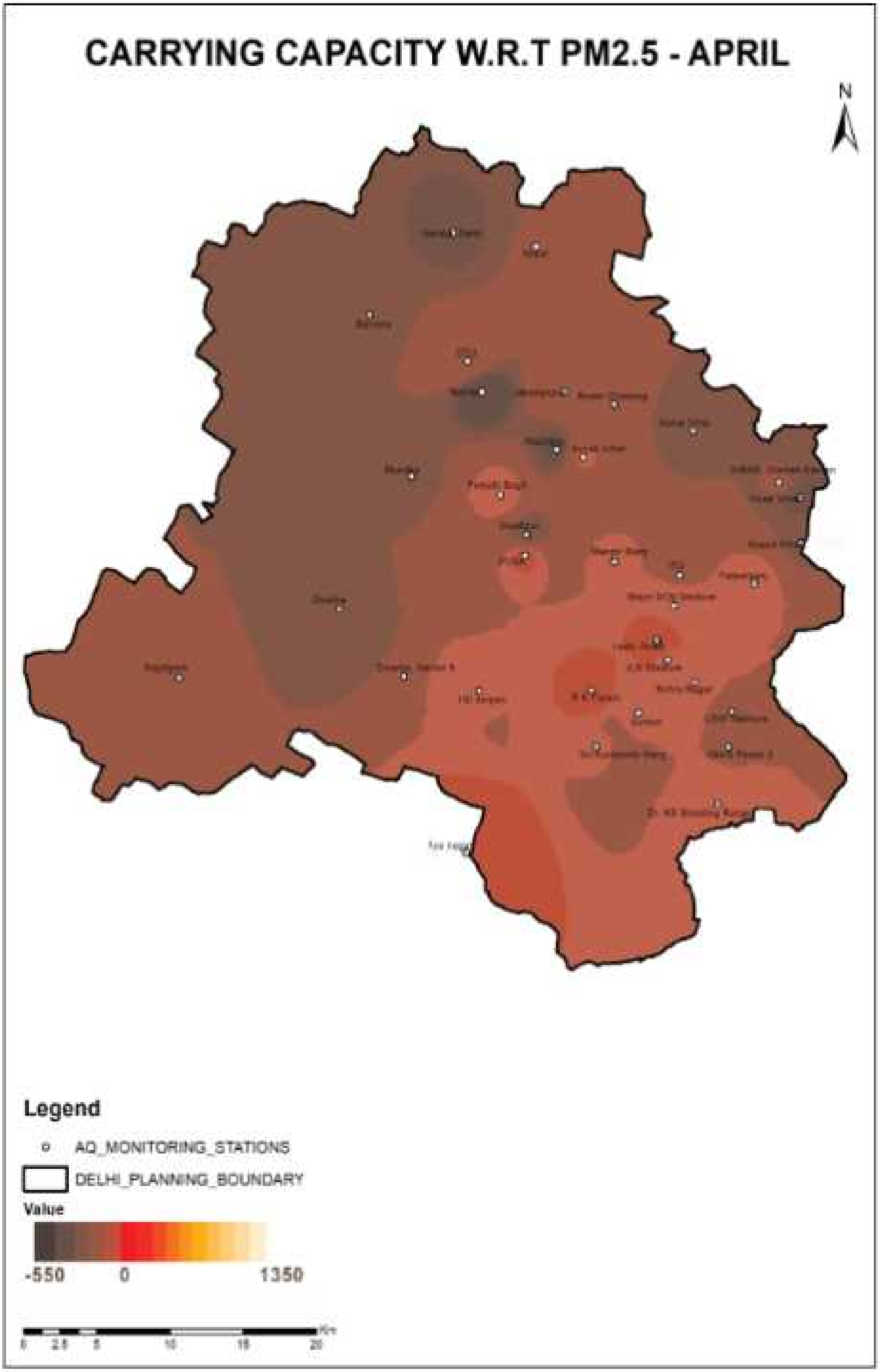
Map 237: Carrying Capacity w.r.t $PM_{2.5}$, January



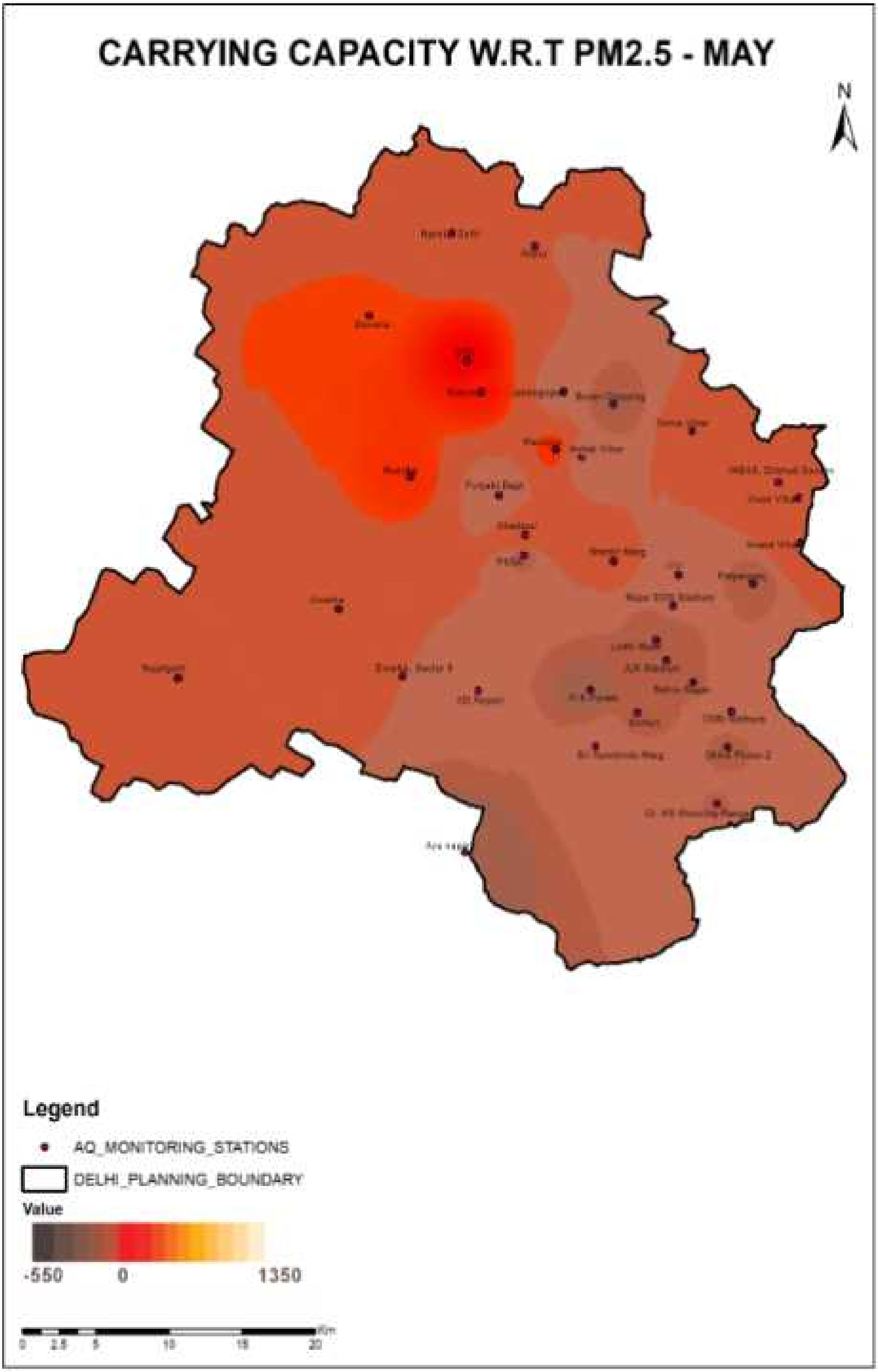
Map 238: Carrying Capacity w.r.t $PM_{2.5}$ February



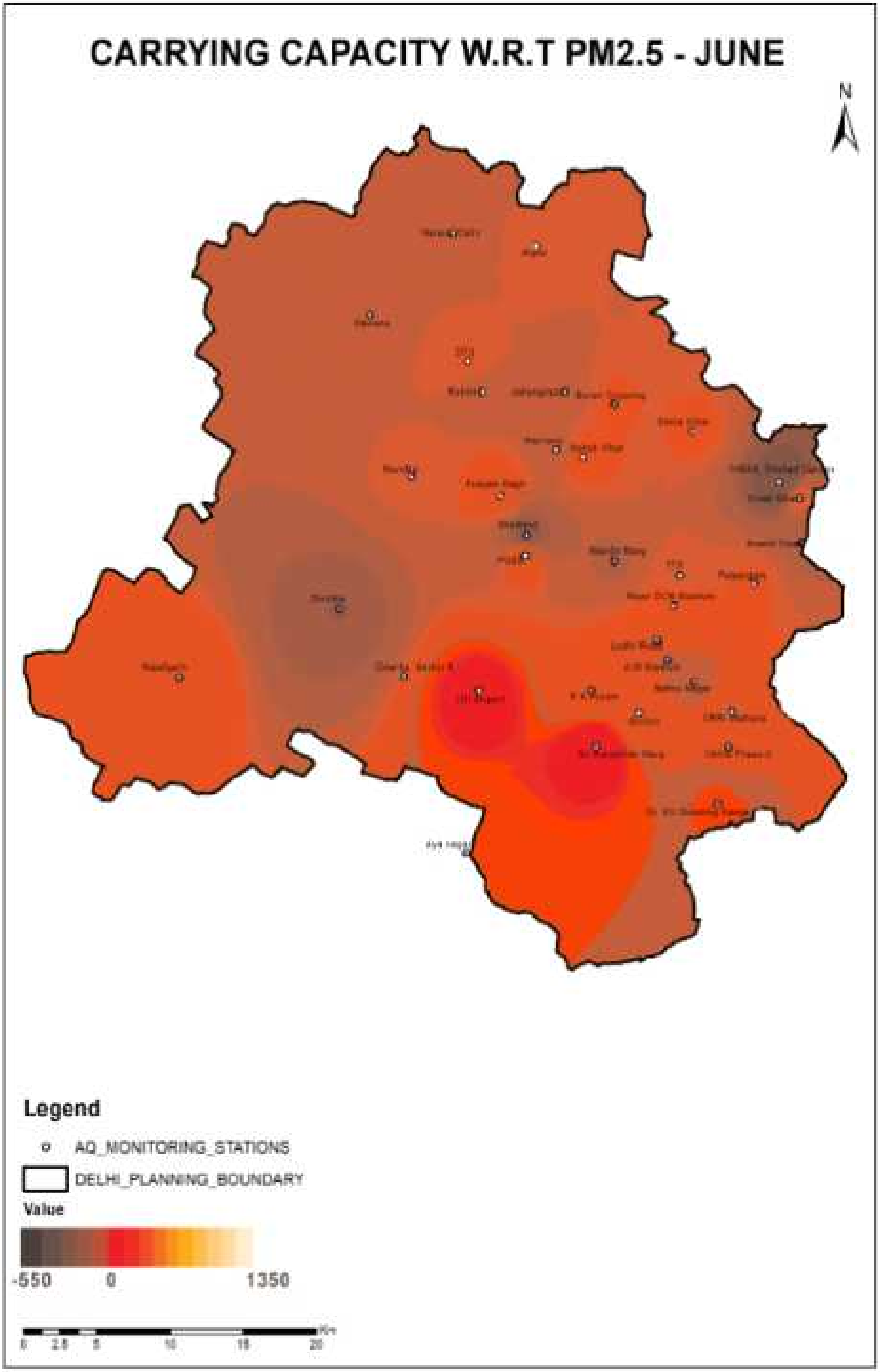
Map 239: Carrying Capacity w.r.t $PM_{2.5}$, March



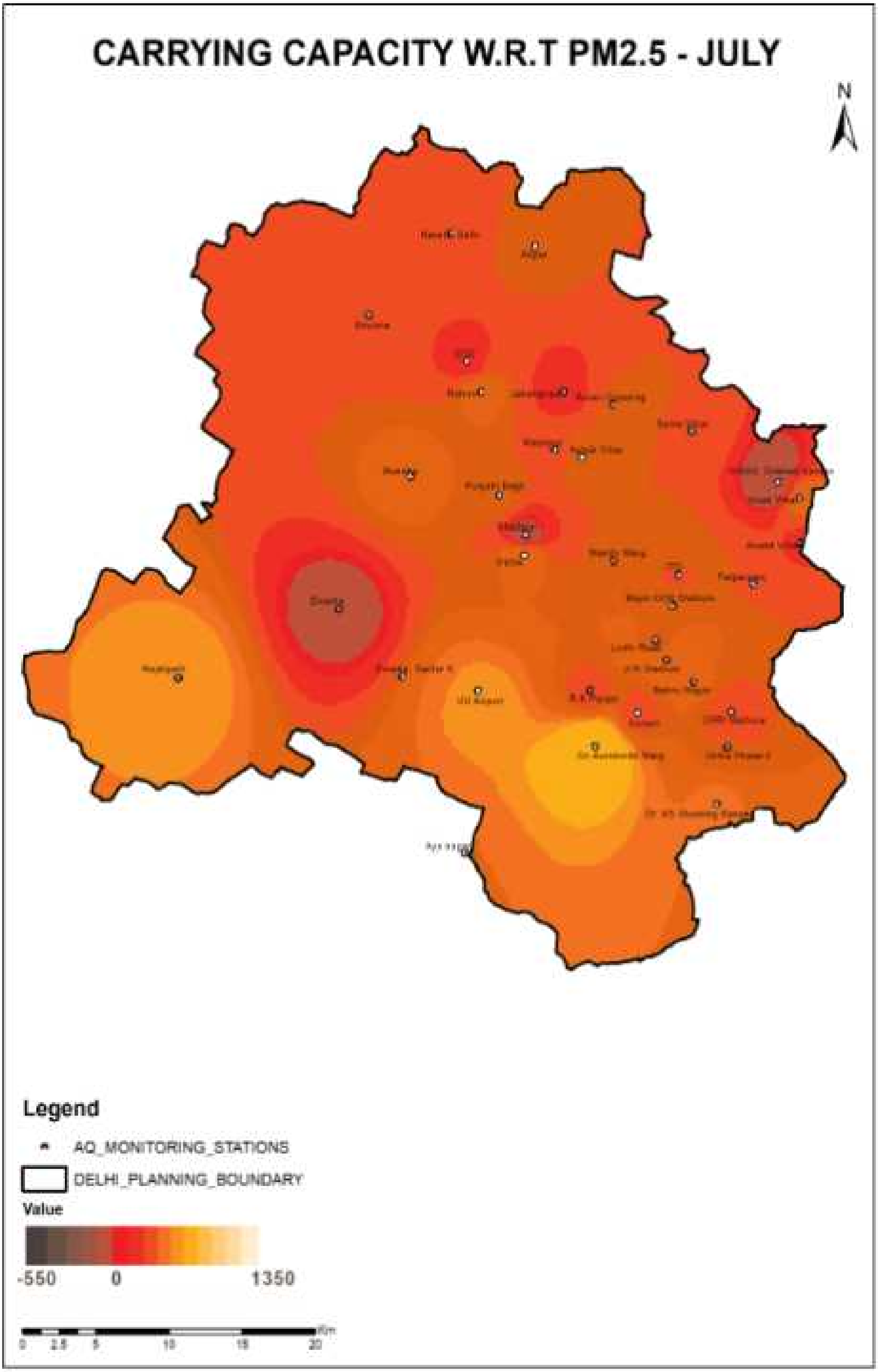
Map 240: Carrying Capacity w.r.t $PM_{2.5}$- April



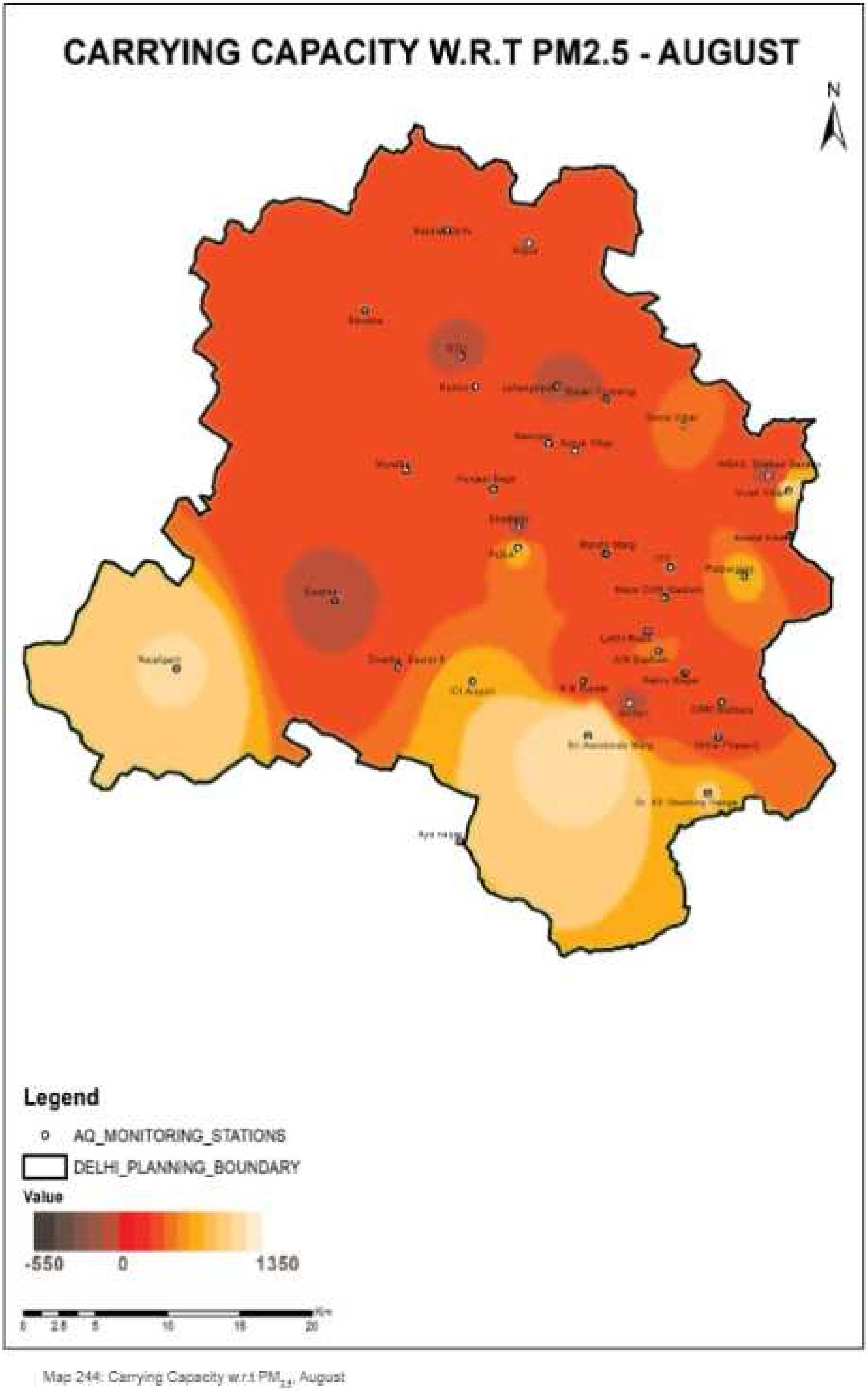
Map 241: Carrying Capacity w.r.t $PM_{2.5}$, May



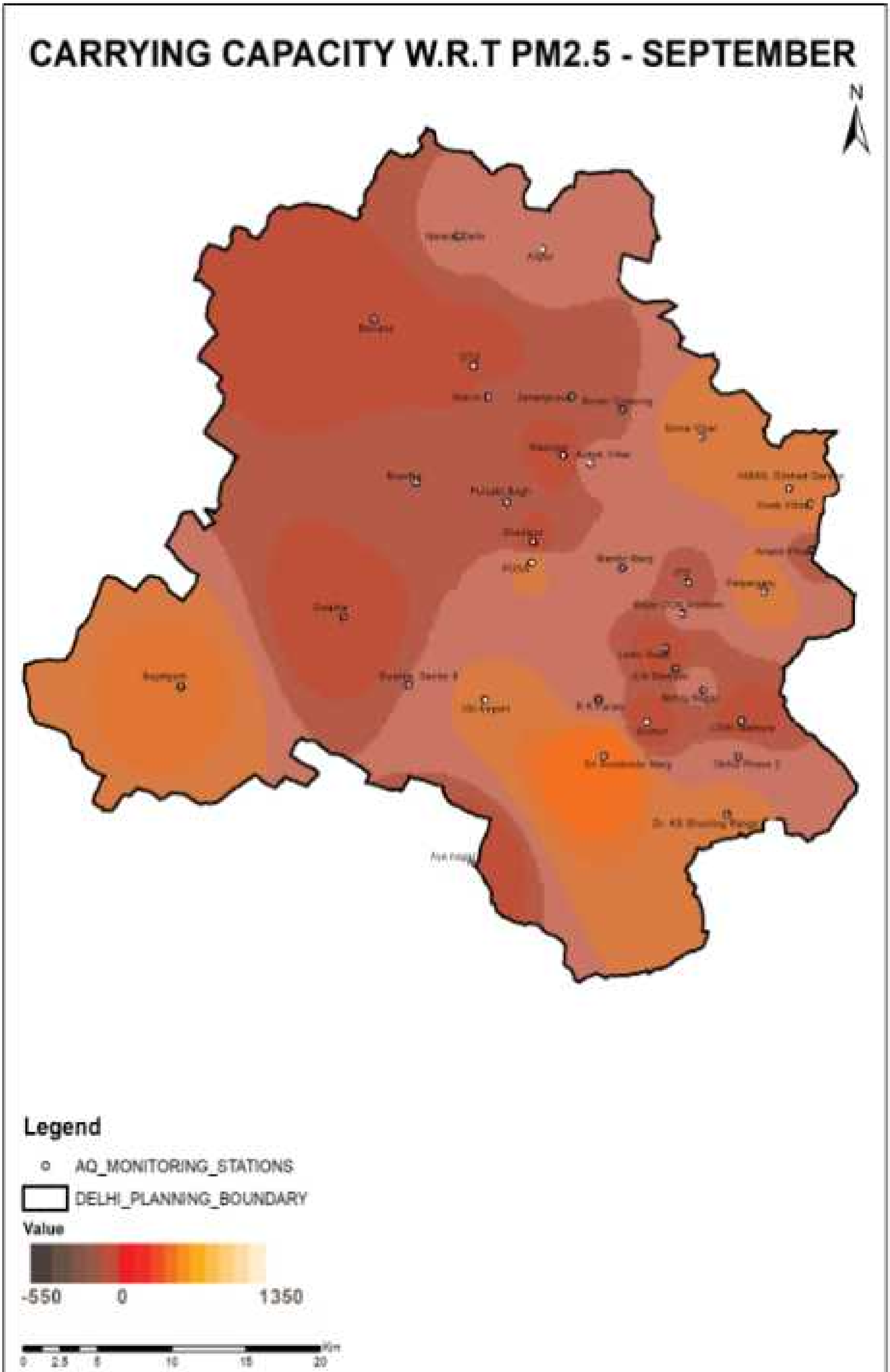
Map 242: Carrying Capacity w.r.t $PM_{2.5}$, June



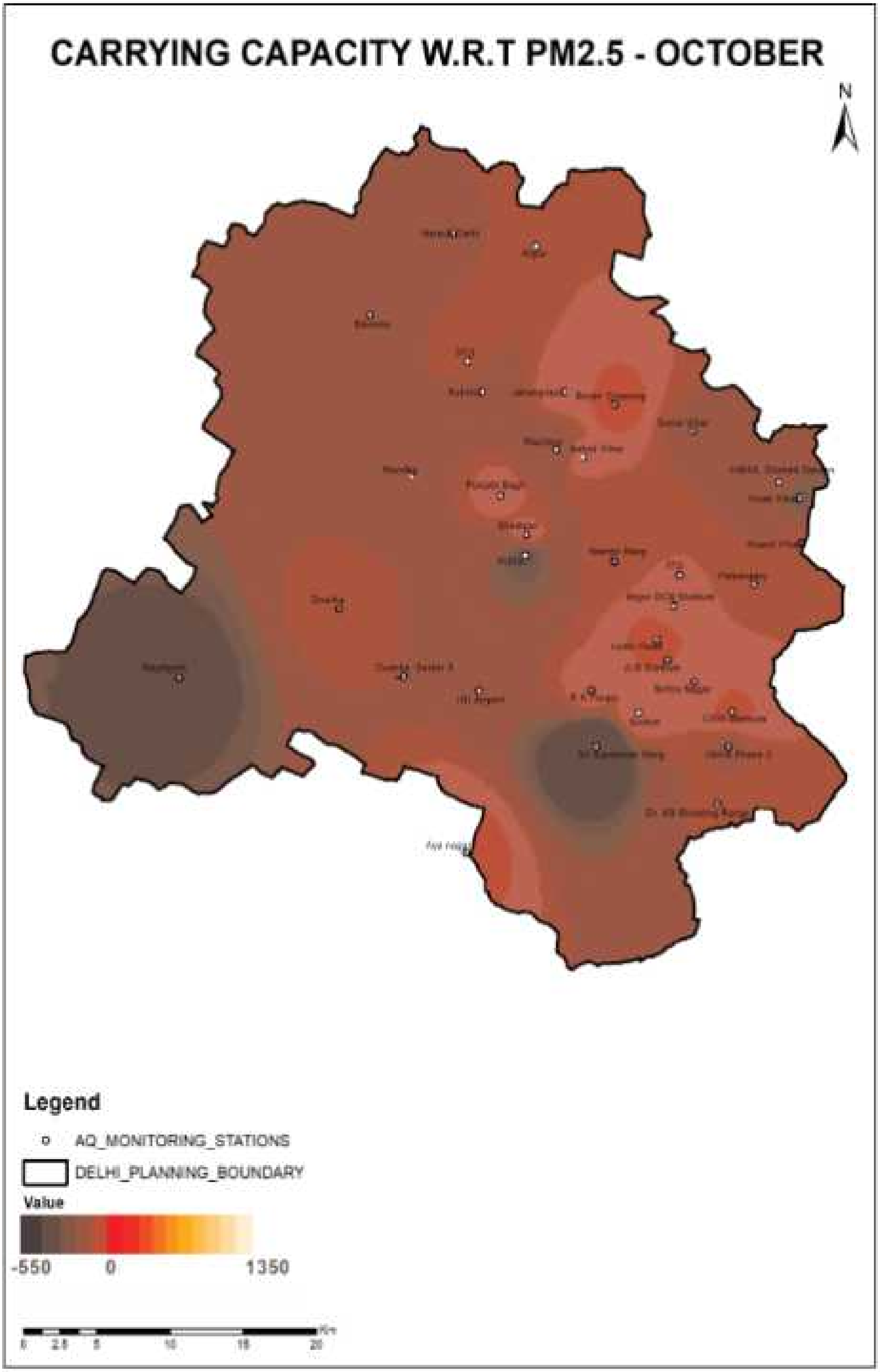
Map 243: Carrying Capacity w.r.t $PM_{2.5}$, July



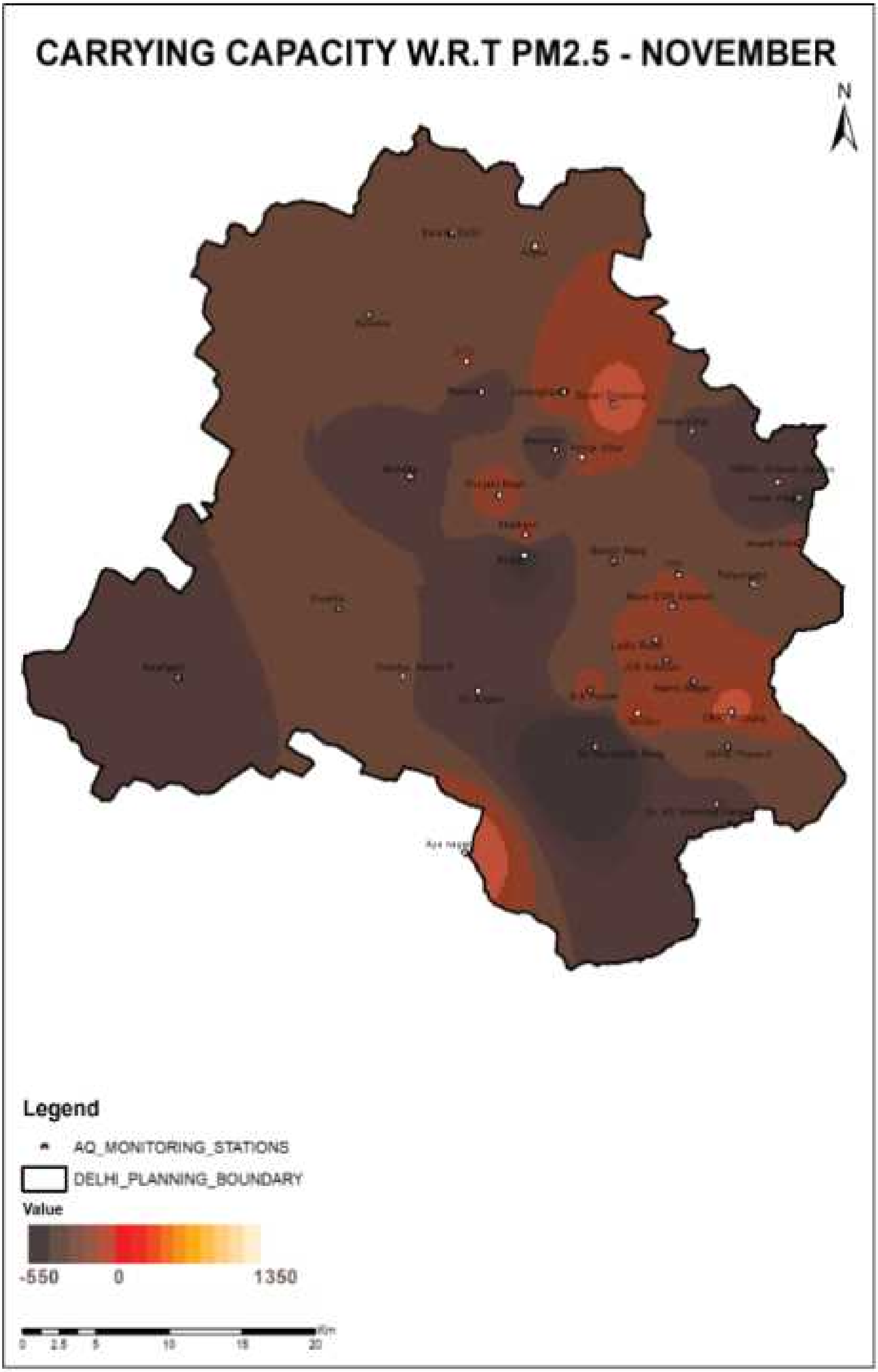
Map 244: Carrying Capacity w.r.t $PM_{2.5}$, August



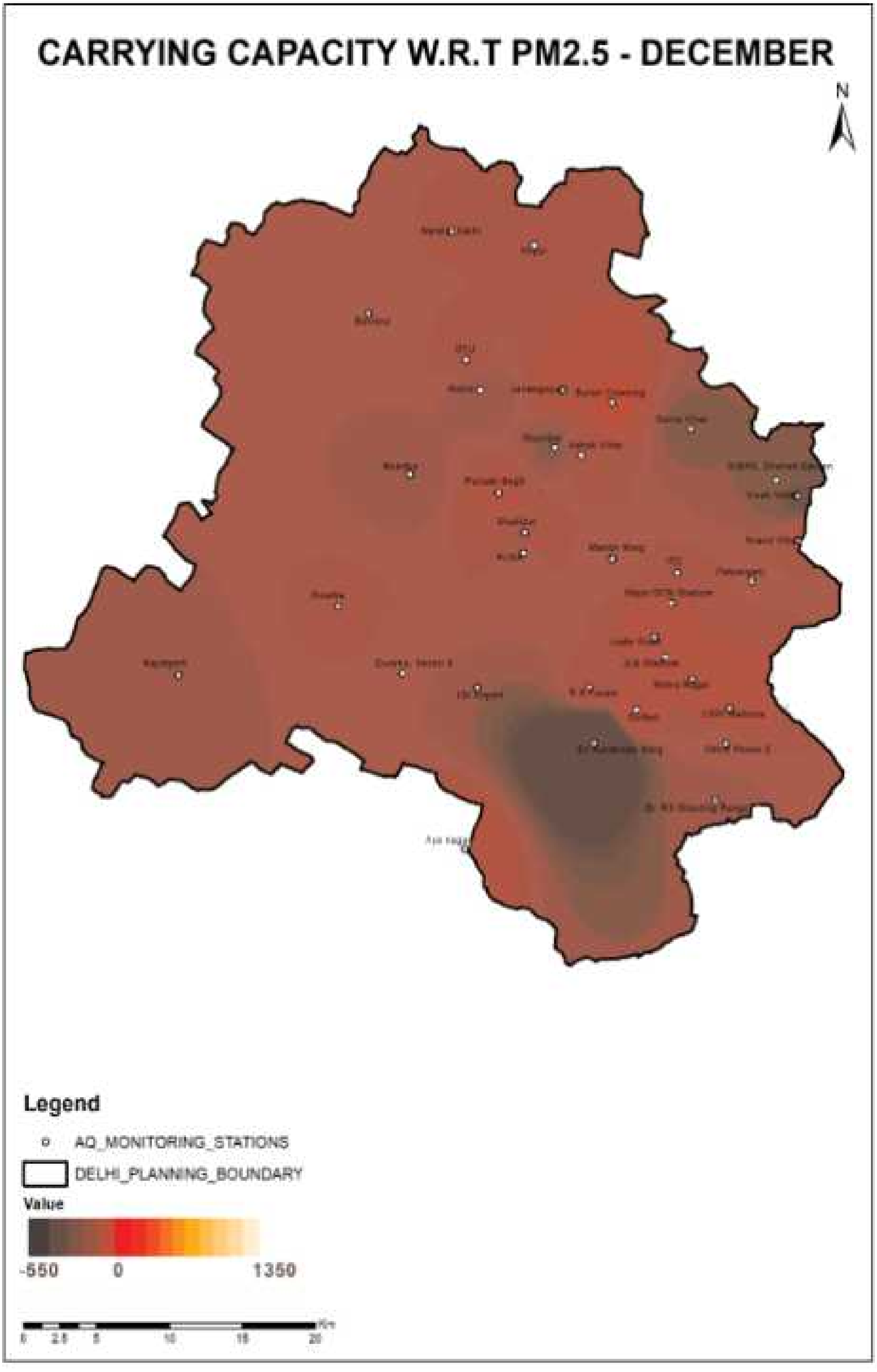
Map 245: Carrying Capacity w.r.t $PM_{2.5}$, September



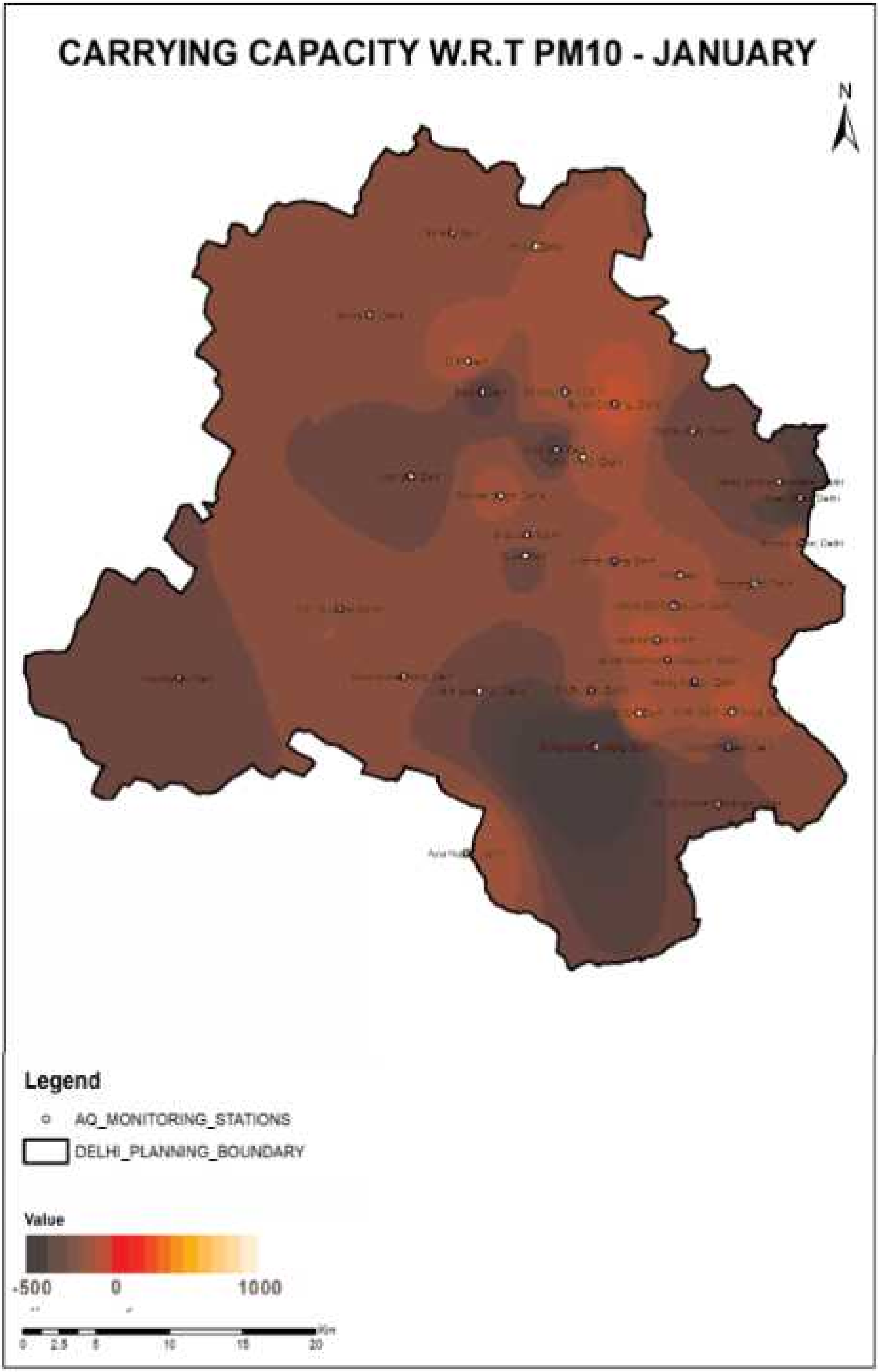
Map 246: Carrying Capacity w.r.t $PM_{2.5}$- October



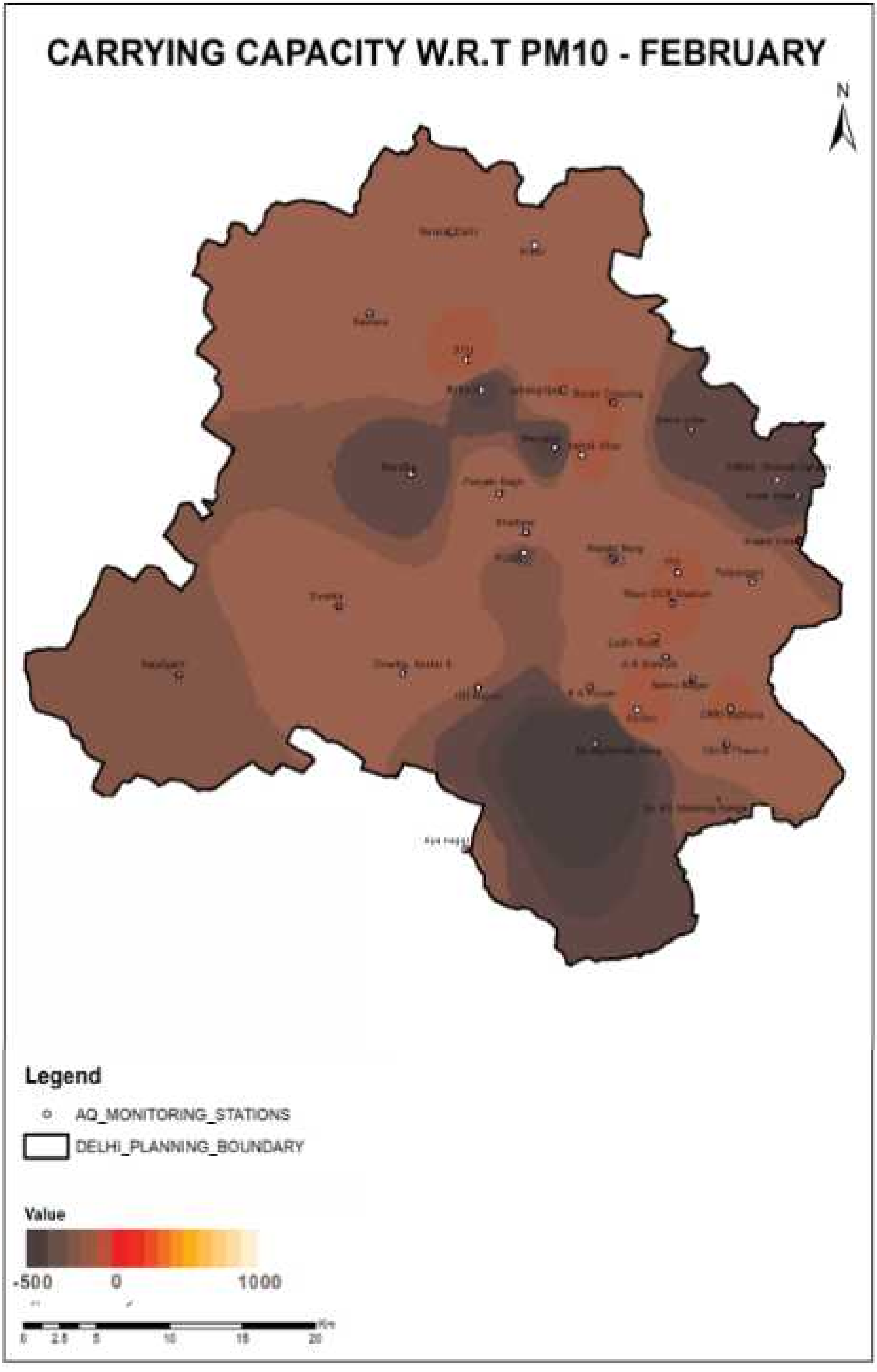
Map 247: Carrying Capacity w.r.t $PM_{2.5}$, November



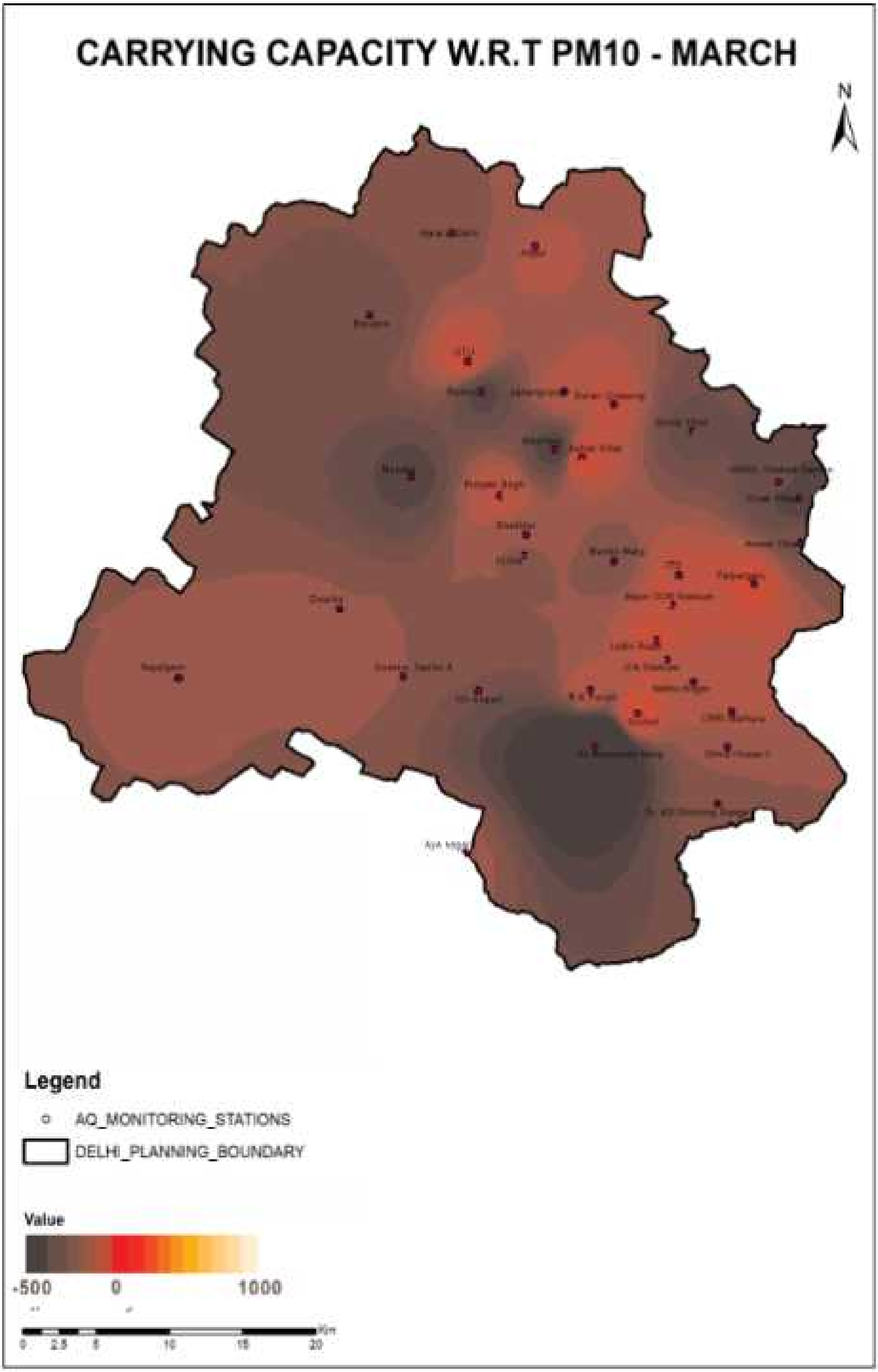
Map 248: Carrying Capacity w.r.t $PM_{2.5}$, December



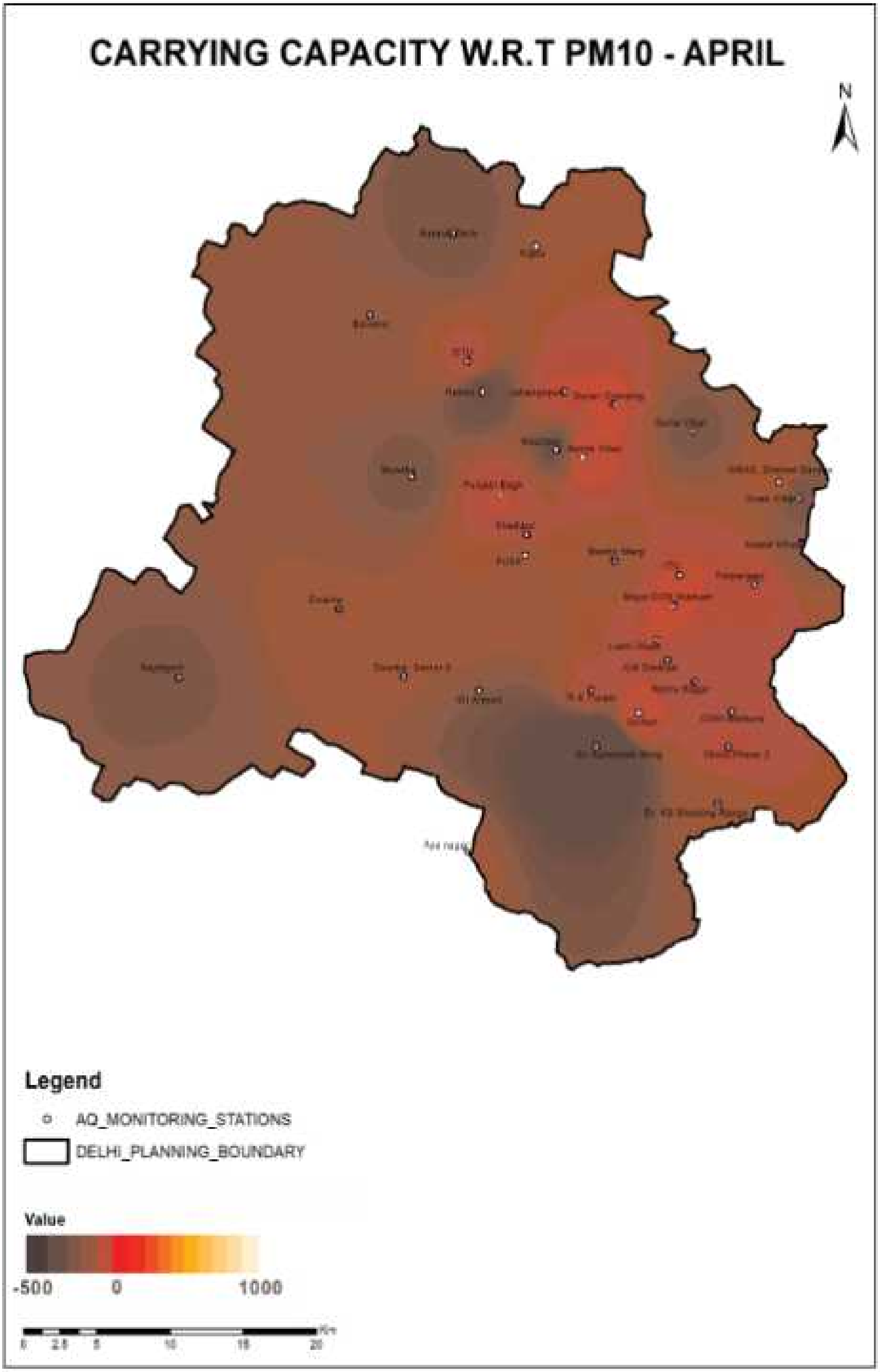
Map 249: Carrying Capacity w.r.t PM_{10}, January



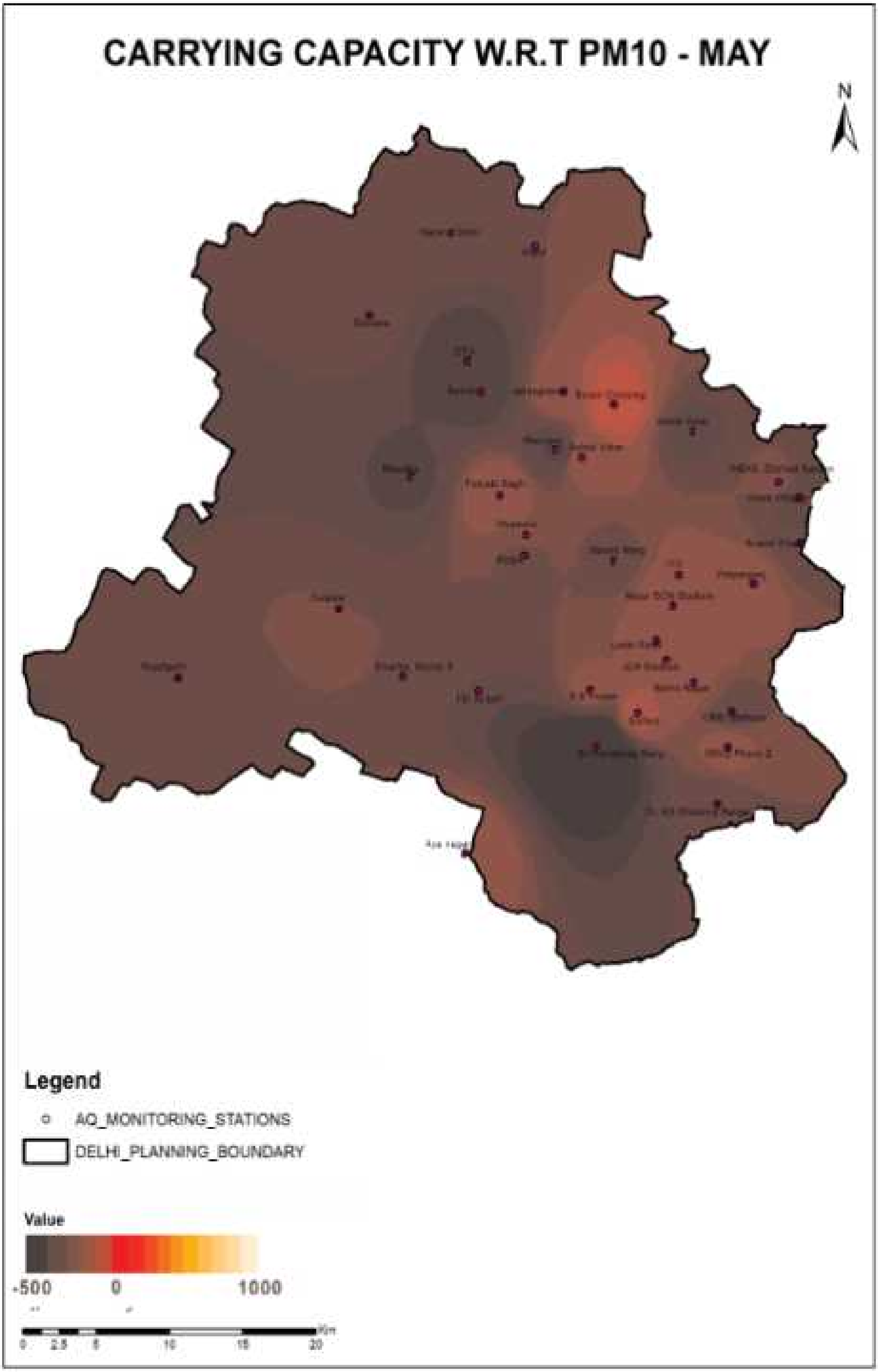
Map 250: Carrying Capacity w.r.t PM_{10} February



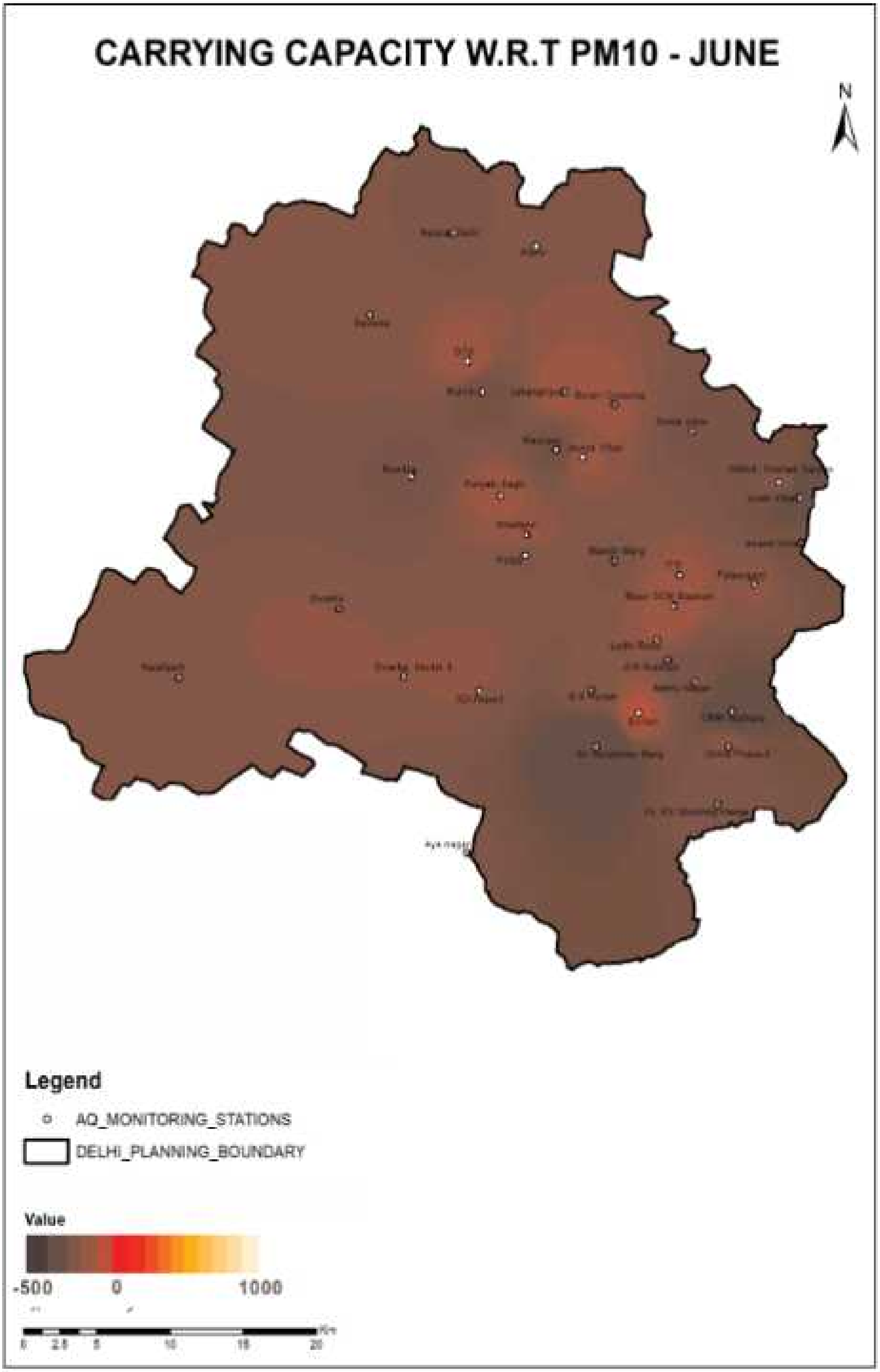
Map 251: Carrying Capacity w.r.t PM_{10}, March



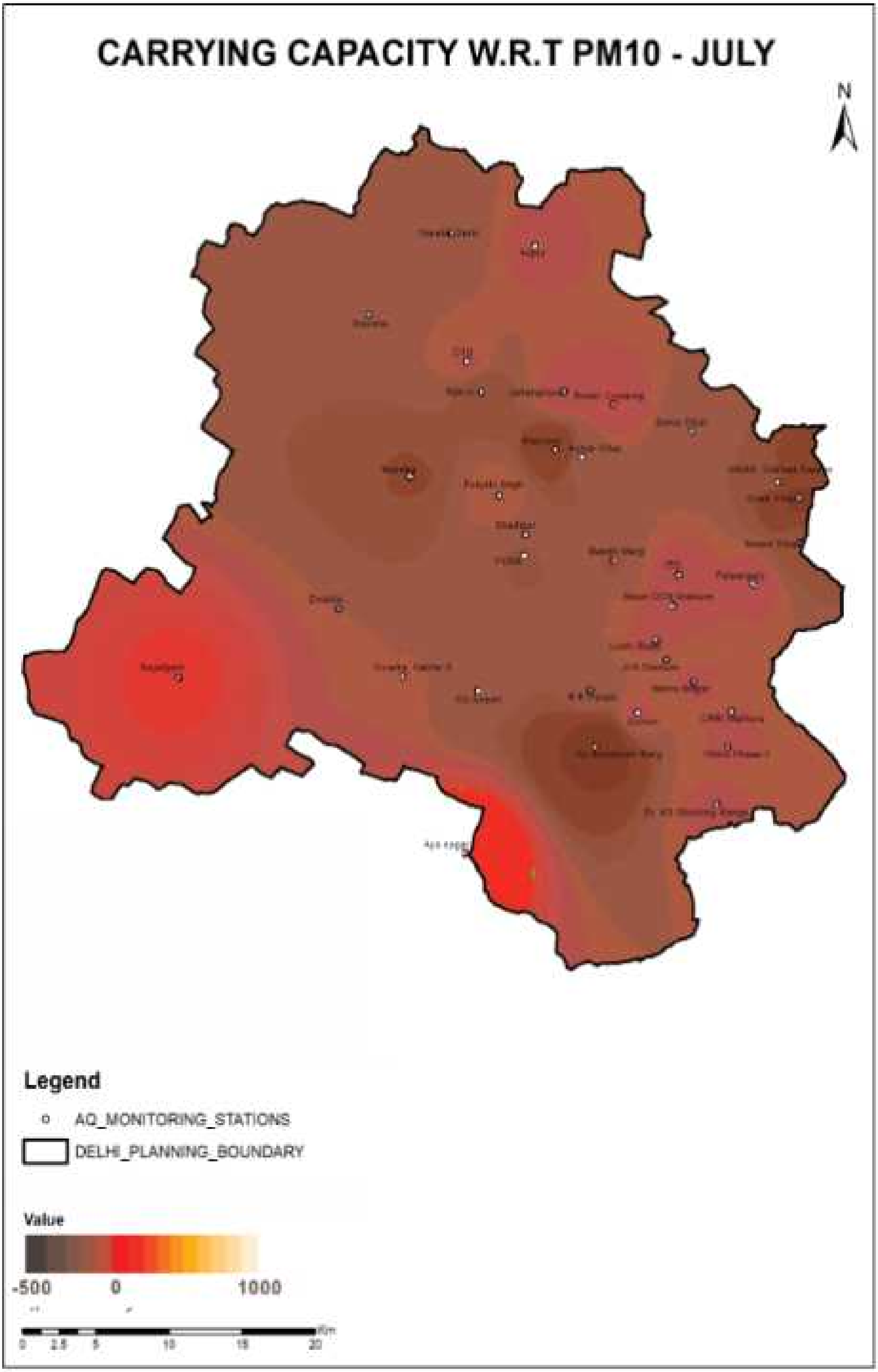
Map 252: Carrying Capacity w.r.t PM_{10} April



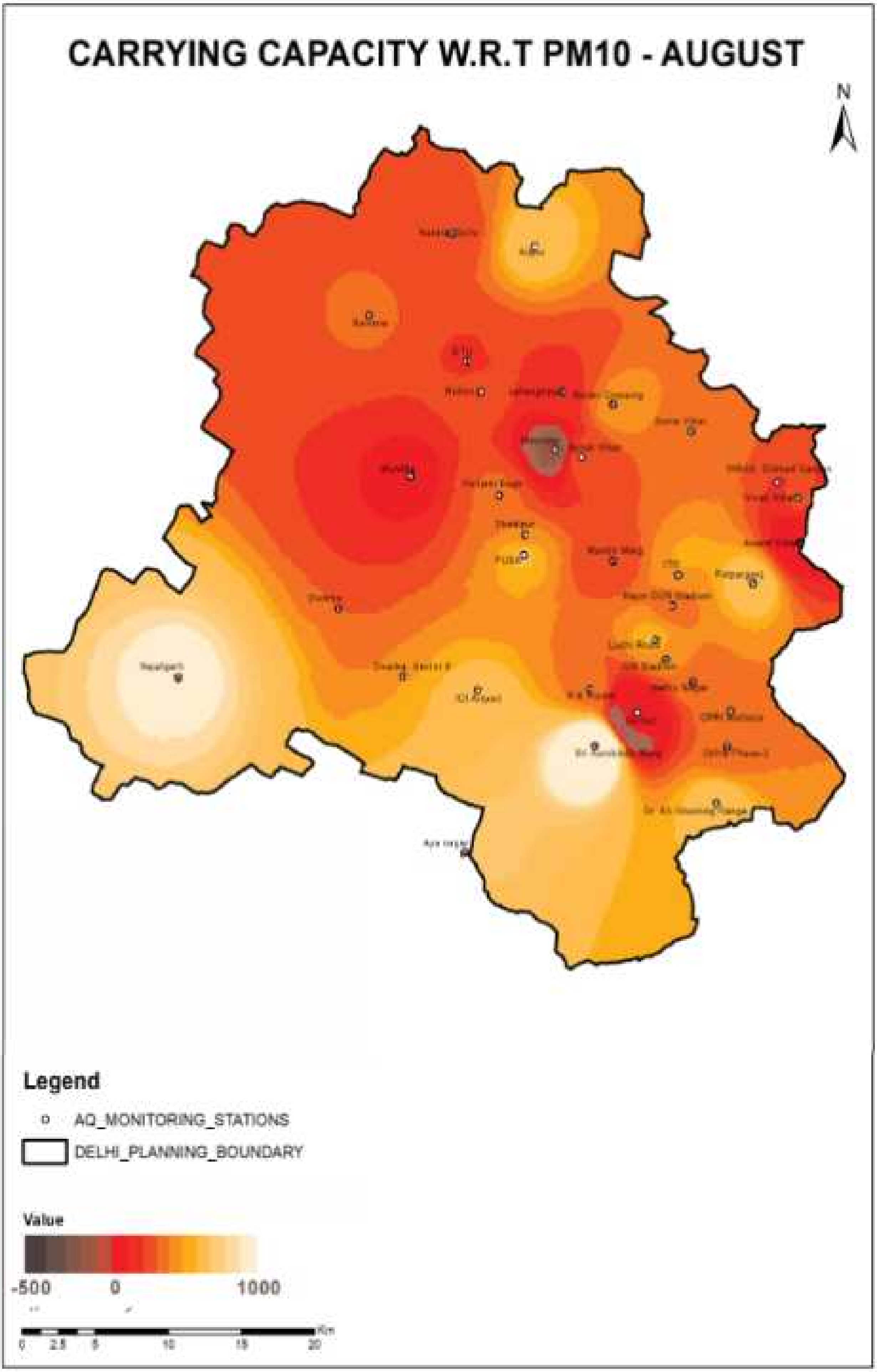
Map 253: Carrying Capacity w.r.t PM$_{10}$, May



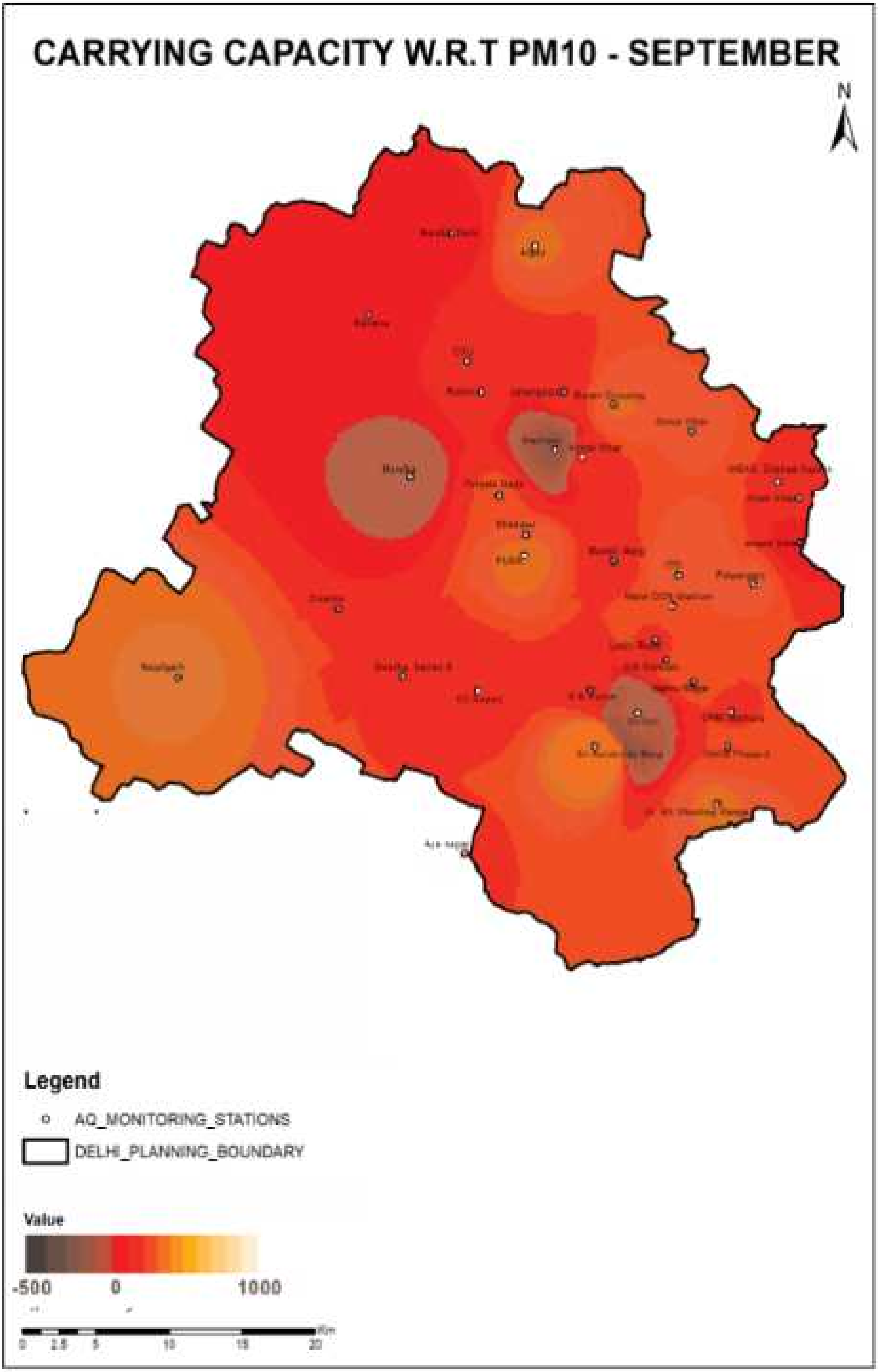
Map 254: Carrying Capacity w.r.t PM_{10}, June



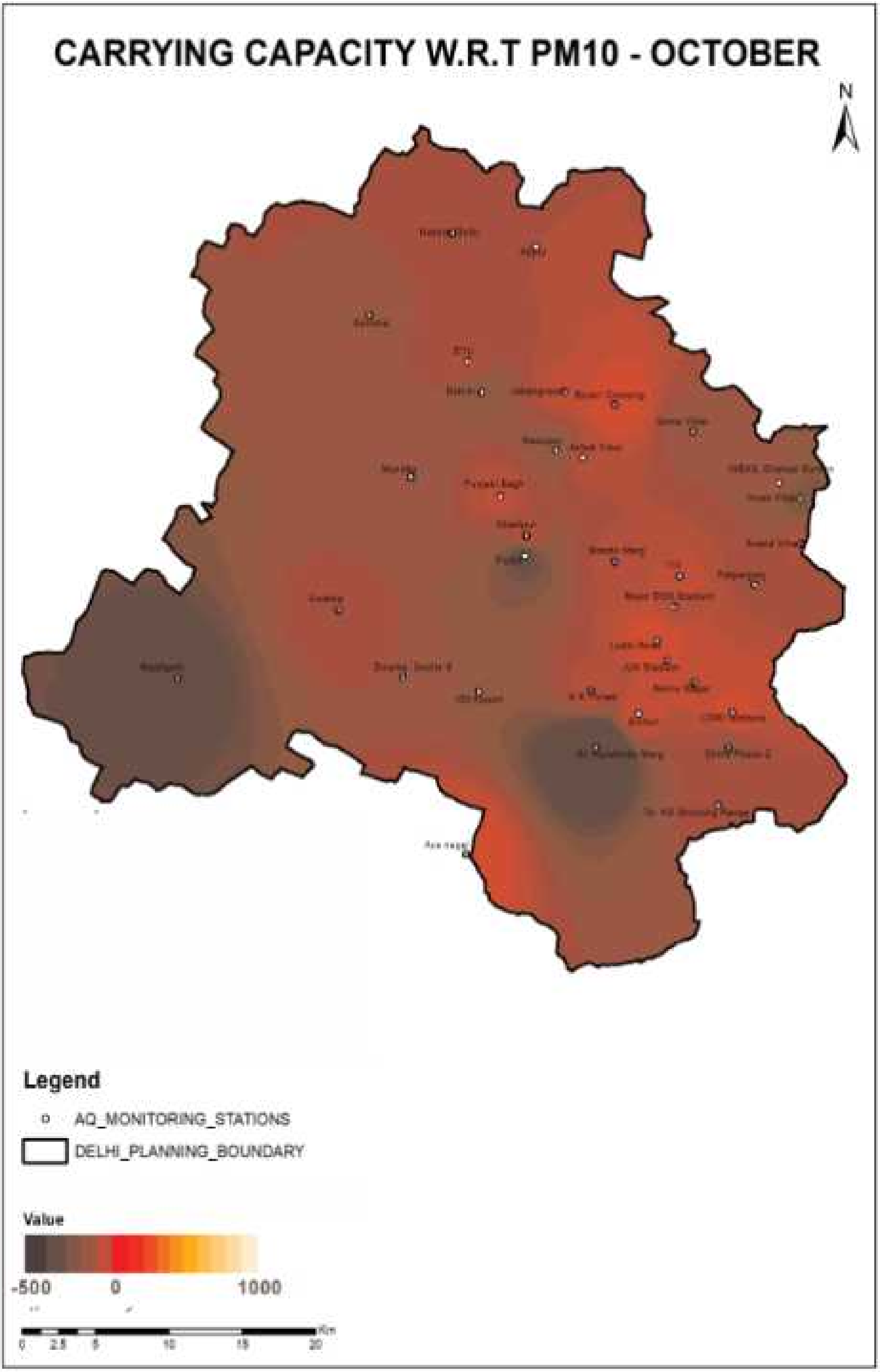
Map 255: Carrying Capacity w.r.t PM_{10}, July



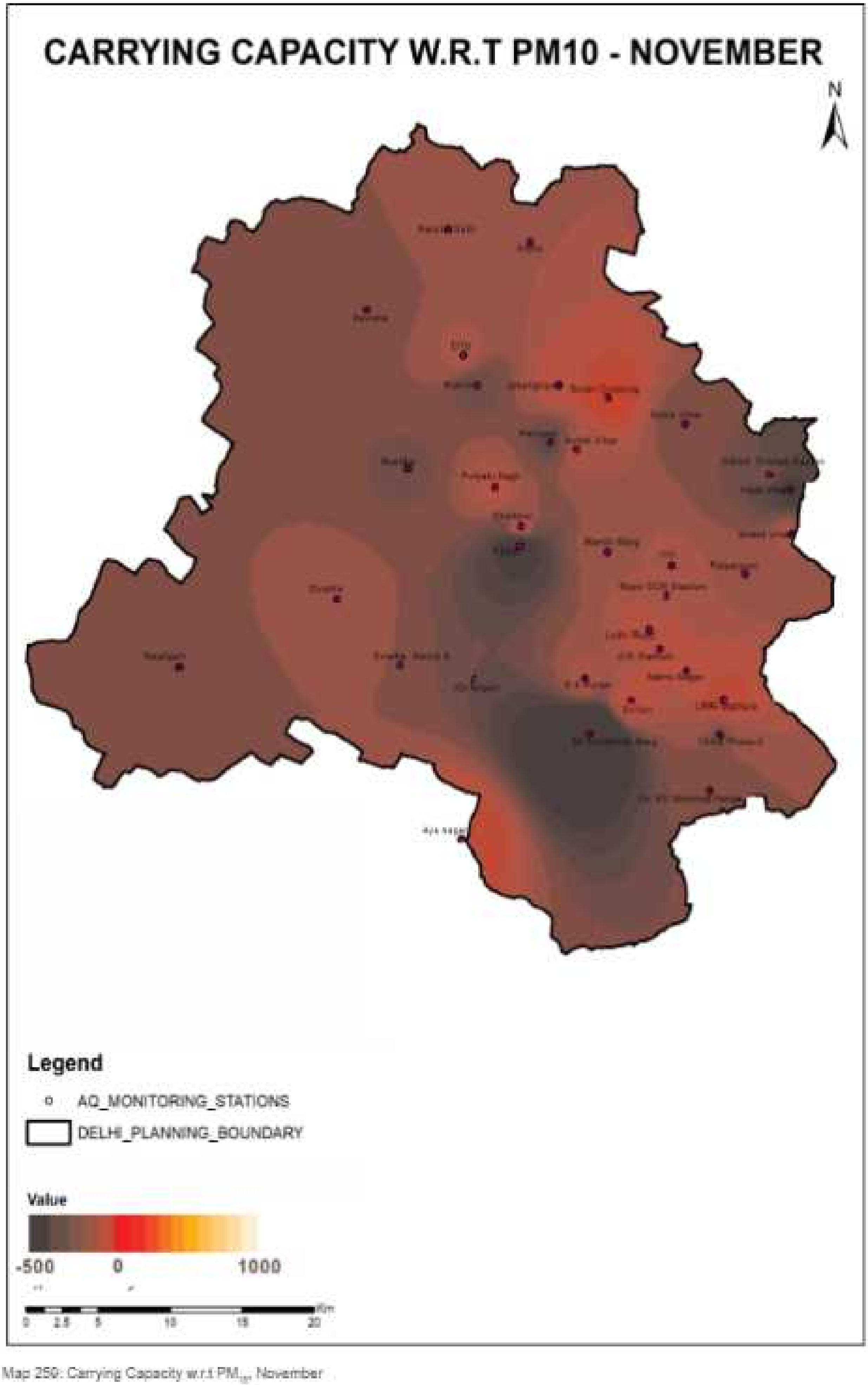
Map 256: Carrying Capacity w.r.t PM_{10} August



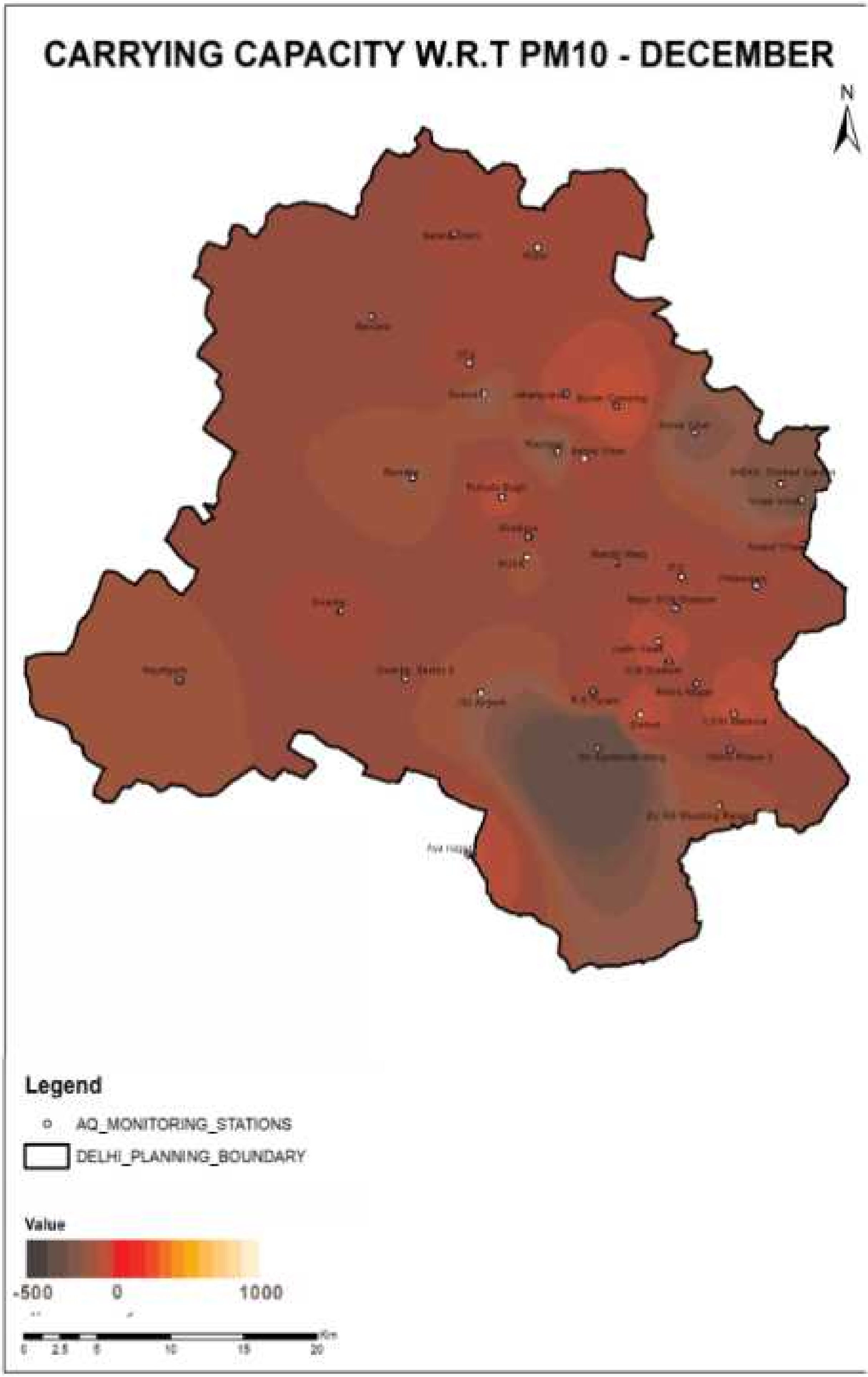
Map 257: Carrying Capacity w.r.t PM_{10}, September



Map 258: Carrying Capacity w.r.t PM_{10}, October



Map 259: Carrying Capacity w.r.t PM_{10}, November



Map 260: Carrying Capacity w.r.t PM_{10}: December

9. STRATEGIES & RECOMMENDATIONS

9.1. STRATEGIES TO ENHANCE CARRYING CAPACITY

Carrying Capacity can be enhanced given the management capacity (MC) is available.

Table 153: Rainfall pattern observed in 2019

Month	Rainfall (in mm)	Rainy Days	Min Mixing Height (m)	Max Mixing Height (m)	Wind Speed	Stubble Burning
January	42.3	6	70	2003	1.09	
February	85.3	11	90	2087.8	1.31	
March	15.4	6	65	2215	1.38	
April	112.3	4	70	2066.6	1.43	
May	10.6	10	70	4140	1.46	
June	8.3	5	60	1685	1.9	
July	271	28	120	6874.76	1.37	
August	99.9	29	100	1876	1.33	
September	54.1	21	60	1727	1.16	
October	3.5	5	80	2045	0.98	high
November	30.2	7	60	1749	1.01	high
December	35.5	3	50	1664	0.91	

Management Capacity:

Factors if properly managed will increase the capacity further such as

(i) Biomass Burning:

a. Increase in LPG penetration in city

b. Zero open burning and

c. Use of residue briquettes in power plants

(ii) Transport:

a. Public transportations system on electric vehicles followed by private vehicles

b. Fleet modernization – all vehicles to BS-VI

c. Reducing emissions from vehicles by congestion management

d. Shift of cars and 2w to shared commuter transport.

(iii) Industries:

a. Power plant controls with continuous monitoring

b. Strict PM control on all industries

c. Fuel switch to gas from solid fuels

(iv) Road Dust and Construction:
a. Vacuum cleaning of roads
b. control of dust from construction activities

(v) Other
a. Use of refuse in WTE – reducing emissions from refuse burning in WTE plants fitted with controls
b. 24 x 7 electricity supply – reduce DG set emissions
c. Control of burning of waste in landfill sites

Effective strategies month wise needs to be developed based on given meteorological conditions and recurring anthropogenic activities observed in the past such as stubble burning.
The study done by TERI and IIT K provides the emission load per year. However, the question still remains unanswered such as to what quantity of emissions (in kgs/day) needs to be maintained in order to achieve the NAAQ standard for $PM_{2.5}$ and PM_{10}? The receptor modeling of some locations in TERI Report provides a glimpse of contributing sources based on winter and summer seasons and such receptor modeling outputs needs to be prepared for all the monitoring stations in Delhi for all the months in order to fully capture the emission sources at that particular location.
Pollution Control Efficiency [%] = capture efficiency [%] x destruction (or collection) efficiency [%]
Maximum controlled emissions rate [Kgs/hr] = Emission rate [Kgs/hr] x ([100 - Pollution control efficiency] ÷100)
Max. controlled emissions [Kgs/year] = Max. uncontrolled emissions [Kgs/year] x ([100 - Pollution control efficiency] ÷100)

Table 154: Strategies and their pollution control efficiency

Sl. no.	Strategies	Description	Pollution Control Efficiency (%)	
			$PM_{2.5}$	PM_{10}
	Biomass burning			
1	Increase in LPG penetration in residential sector in NCR by 75% in 2025- 100% in 2030	Convert 75% and 100% biomass to LPG in 2025 and 2030, respectively.	10	9
2	Supply and use improved biomass cook-stoves	Supply improved biomass cook-stoves to 75% and 100% of households using biomass in 2025 and 2030, respectively.	7	5
3	Supply and use improved induction cook-stoves	Supply improved induction cook-stoves 75% and 100% to households using biomass in 2025 and 2030, respectively.	10	8
4	Use of agricultural residues in WTE	Zero open burning through WTE plants (With adequate tail-pipe controls)	12	9
5	Use of agricultural residues in power plants (NCR)	Zero-open burning and use of residue briquettes in power plants	15	11
6	Use of agricultural residues in local households	Zero-open burning and use of residues briquettes in local households	15	12

Sl. no.	Strategies	Description	Pollution Control Efficiency (%)	
			$PM_{2.5}$	PM_{10}
	Transport			
7	Electrification of vehicular fleet	Bus (25-50%), two (20-40%) and three wheelers (100%), and cars (20-40%) in 2025 - 2030	1.4	0.6
8	Public transportation- Buses	25% and 50% electric buses in 2025 and 2030		
9	Electric vehicles- 2/3 wheelers	20% in 2025 and 40% in 2030 electric two-wheelers, and 100% three-wheelers		
10	Electric vehicles - Cars	20% in 2025 and 40% in 2030 electric cars		
11	Fleet modernization - Restricted entry/movement of pre-BS-VI vehicles	All vehicles to be BS-VI equivalent	1	0.4
12	Banning entry of pre BS-IV trucks and buses	All old trucks and buses to be modernised to BS-VI equivalent		
13	Improved inspection and maintenance system	High emitter emissions go down from 25% to 10% (2025) and 25% to 5% in 2030	1	0.3
14	Reducing real world emissions from vehicles by congestion management	Reduce real world emissions to 50% in both 2025 and 2030		
15	Shift of 50% cars and 2-w to shared commuter vehicles	Shift 50% of personal transport on shared commuter transport on EV in 2025 and 2030	0.4	0.2
16	Increased penetration of biodiesel	12% penetration by 2025 and 20% by 2030	0.3	0.6
17	Increased penetration of hybrid and EV cars	35% hybrid and 15% EV cars by 2025 and 70% hybrid and 30% EV by 2030	0.1	0.3
	Industries			
18	Power plant controls with continuous monitoring	Implement stricter NOx and SO2 standards	50	10
19	Stricter enforcement of standards in industries through continuous monitoring	In industries, reduce real world emissions by 50% in both 2025 and 2030	10	9
20	Introduction and enforcement of new SO2 and NOx standards	75% and 100% enforcement of SO2/NOx standards in other industries in 2025 and 2030, respectively.		
21	Enforcement of Zig-Zag brick kiln technology (NCR)	75% and 100% enforcement of Zig-Zag brick kiln technology in 2025 and 2030, respectively	3	4
22	Fuel switch to gas from solid fuels	50% and 100% fuel switch to gas from solid fuels in 2025 and 2030, respectively.	23	24
23	Strict PM control on stone crushers	Increase PM_{10} control efficiency to 80% and $PM_{2.5}$ to 40% in both 2025 and 2030	3	6
24	Introduce stringent PM_{10} and $PM_{2.5}$ norms	Introduce and implement stricter PM standards in industries through installations of wet scrubbers	9	18
	Road dust and construction			
25	Vacuum cleaning of roads	Silt load reduction 25% and 50% (in 2025 and 2030, respectively)	7	12
26	Wall to wall paving	Silt load reduction 25% and 50% (in 2025 and 2030, respectively)	7	12
27	Control of dust from construction activities	Barriers and water based controls -30% and 60% in 2025 and 2030, respectively.	1	2

Sl. no.	Strategies	Description	Pollution Control Efficiency (%)	
			$PM_{2.5}$	PM_{10}
	Others			
28	Full ban on refuse burning activities and use of refuse in Waste to Energy (WTE)	Reduced emissions form refuse burning in Waste to Energy (WTE)	5	3
29	Landfill fire control	Zero landfill emissions	0.4	0.2
30	DG sets controls using innovative technologies	PM and NOx controls at DG sets (80% reduction in PM and NOx emissions in 2030)	0.3	0.1
31	Supply 24x7 electricity	Supply 24x7 electricity, DG set emissions falls to 10% and 5% in 2025 and 2030, respectively	0.4	0.2

It can be derived that air pollution is influenced by:
• Regional Factors (Macro-Level)
• Local Factors (Micro-Level)

At regional level, the factors include:
• Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
• Topography
• Land Use and Land Cover
• Activities around the city limits and its location.

At Local level, the factors include:
• Climate: Temperature, Precipitation, Relative Humidity, Pressure, Wind Direction and wind speed
• Land Use: Primary activity and Secondary activity (Travel Demand)
• Location of Activities – Industries, Power Plants, Commercial Centres, etc.
• Building Heights: Local Climatic Zones

As observed in the analysis, the buffer zones around the monitoring stations which have industrial areas shows high concentration of both PM_{10} & $PM_{2.5}$ pollutants in comparision to other landuses, because of the supporting activities of industrial zones like vehicular traffic for loading/ unloading of goods, etc. So recommendations are proposed to further reconside the location of indutrial estates.

9.2. Recommendations for zoning industrial estates

Industrial Estate Planning Approach in India:
Central Pollution Control Board (CPCB)
CPCB's Zoning Atlas for siting of industries program aims to support and simplify decision-making process on siting of industries based on environmental considerations. This is an attempt to identify suitable areas district wise for planned industrial development in various states. Using the Zoning Atlas, one can identify environmentally sound sites for setting up

an IE. These sites can be reviewed from economic considerations such as availability of raw materials, transportation network, water supply and electricity, waste disposal facilities, etc., to identify the probable sites for which detailed micro-level investigations can be carries out to select final sites.

State Industrial Development Corporation (SIDC)

SIDC identifies the potential sites for industrial development. The industrial sites are selected mainly on the basis of socio-economic considerations in accordance with the regional/state master plan. SIDCs approach the development authorities for Notification of the proposed sites for land use conversion. SIDC also monitors the development of Industrial Estates (IE) within the stipulated timeframe in order to prevent artificial escalation in land prices.

Development Authorities (DA)

The DA plans the physical and infrastructural development of an IE. In many regions instead of the SIDCs, DA identifies the sites as well. The DA also notifies the land use conversion once the site is selected. There are other institutions and government agencies that have stated addressing various aspects of IE planning, but the attempts are in isolation.

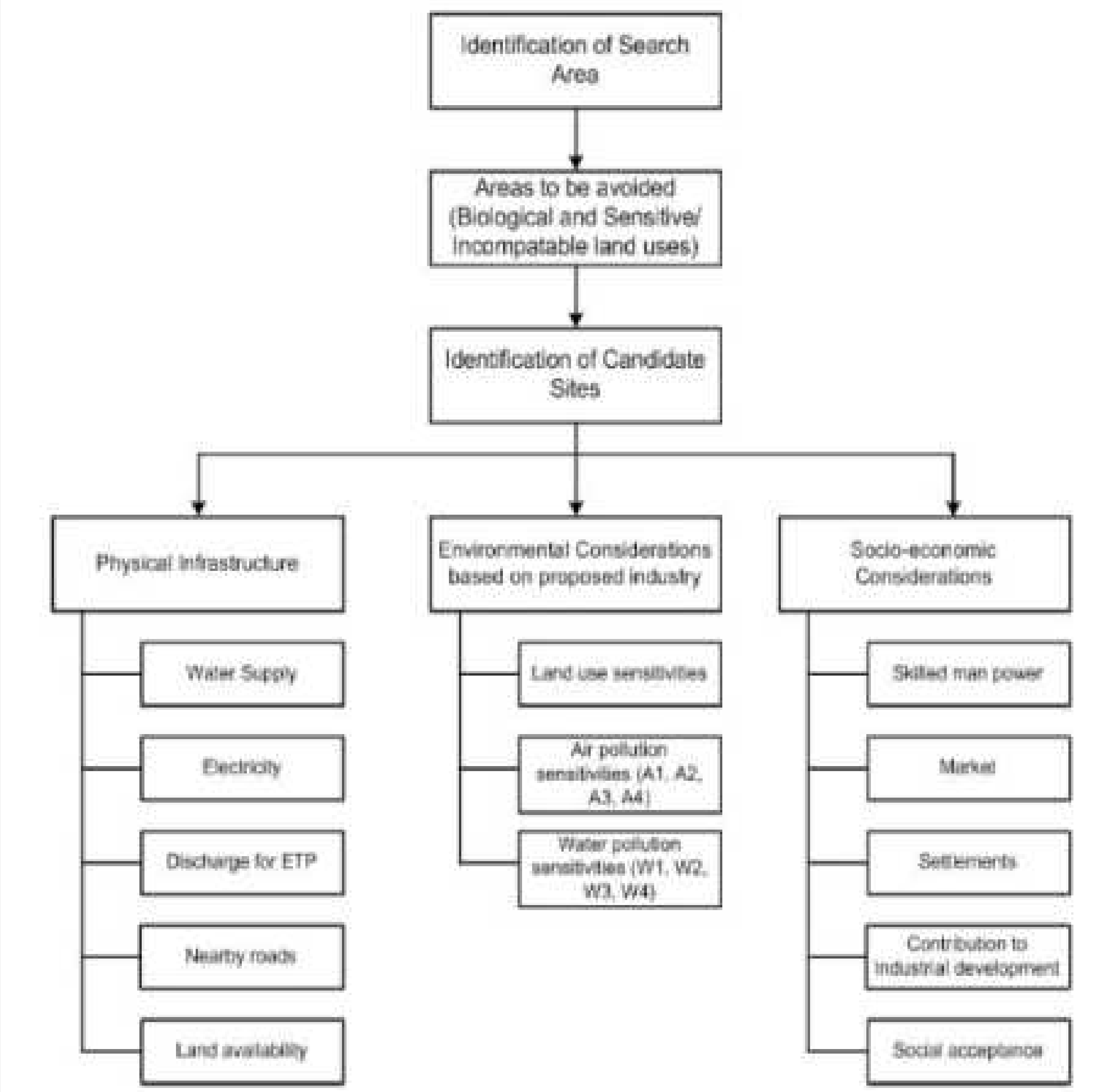


Figure 195: Site Suitability Approach for Industries

Source: Technical EIA Guidance Manual for Industrial Estates, MoEF&CC, GoI, October 2009

Environmental Guidelines for Industries

1. Areas to be avoided

In siting industries, care should be taken to minimize the adverse impact of the industries on the immediate neighbourhood as well as distant places. Some of the natural life sustaining systems and some specific land uses are sensitive to industrial impacts because of the nature and extent of fragility. With a view of protection such an industrial site shall maintain the following distances from the areas listed:

Table 155: Distance of Different Areas from Industrial Site

S. No.	Areas	Distance
1	Ecologically and/or otherwise sensitive areas	At least 25 km, depending on the geo-climatic conditions the requisite distance have to be increased by the appropriate agency.
2	Coastal areas	At least 1/2 km from High Tide Line.
3	Flood Plain of the Riverine Systems	At least 1/2 km from flood plain or modified flood plain affected by dam in the upstream or by flood control systems.
4	Transport/Communication System	At least 1/2 km from highway and railway.
5	Major settlements (3,00,000 population)	Distance from settlements is difficult to maintain because of urban sprawl. At the time of siting of the industry if any major settlement's notified limit is within 50 km, the spatial direction of growth of the settlement for at least a decade must be assessed and the industry shall be sited at least 25 km from the projected growth boundary of the settlement.

Source: Environmenal Guidelines for Industries,MOEFCC

2. Siting criteria

Economic and social factors are recognized and assessed while siting an industry. Environmental factors must be taken into consideration in industrial siting. Proximity of water sources, highway, major settlements, markets for products and raw material resources is desired for economy of production, but all the above listed systems must be away for environmental protection. In such a selected site, the following factors must be recognized:

- No forestland shall be converted into non-forest activity for the sustenance of the industry (as per the Forest Conservation Act, 1980).
- No prime agricultural land shall be converted into industrial site.
- Within the acquired site the industry must locate itself at the lowest location to remain obscured from general sight.
- Land acquired shall be sufficiently large to provide space for appropriate treatment of wastewater still left for treatment after maximum possible reuse and recycle. Reclaimed (treated) wastewater shall be used to raise green belt and to create water body for aesthetics, recreation and if possible, for aquaculture. The green belt shall be 1/2 km wide around the battery limit of the industry. For industry having odour problem it shall be a kilometer wide.
- The green belt between two adjoining large-scale industries shall be one kilometer.
- Enough space should be provided for storage of solid wastes so that these could be available for possible reuse.
- Layout and form of the industry that may come up in the area must confirm with the landscape of the area without affecting the scenic features of that place.

- Associated township of the industry must be created at a space having physiographic barrier between the industry and the township.
- Each industry is required to maintain three ambient air quality measuring stations within 120-degree angle between stations.

3. Guidelines for Buffer Zones

Buffer zones are areas created around the conservation area, often peripheral to it, inside or outside to enhance its protection. Within Buffer zones, certain legal and/or customary restrictions are placed upon resource use and/or is managed to reduce the negative impacts of restrictions on the neighbouring communities. Based on various activities, important buffer zones have been identified in Table 156.

Table 156: Activities and their Buffer zones

S.No.	Activities	Recommended Buffer
1	Ecosensitive zones[23]	• As per National Wildlife Action Plan (NWAP) 2002-2016, "All identified areas around Protected Areas and wildlife corridors are to be declared as ecologically fragile under the Environment (Protection) Act, 1986." • As general principle the width of the eco-sensitive zone could go up to 10kms around a Protected area as provided in the Wildlife Conservation Strategy, 2002. In case where sensitive corridors, connectivity and ecologically important patches, crucial for landscape linkage, are even beyond 10 kms width; these should be included in the Eco-sensitive zones. • Further, even in context of a particular Protected Area, the distribution of an area of Eco-sensitive Zone and the extent of regulation may not be uniform all around and it could be of variable width and extent.
2	Railway land	RoW includes no development zone in itself.
3	Aviation related infrastructure	• As per Airport Authority of India (AAI), the buffer zone is applicable within 20 km radius of Airport on the height of the buildings, for which NOC is required from AAI for any construction activity. • Aviation imposes height restrictions only. Other DCR norms such as ground coverage, setbacks etc. of the local municipality are applicable. • The airport should be 20 km away from green area such as wildlife sanctuaries/ zoos/ bird sanctuaries and should not have restricted activities such as butcheries, sewage and no garbage storage around airports.
4	Communication and Transmission facilities such as satellite towers[24]	Installation of telecom towers should not be allowed on and around (100 Meters) the buildings where educational, religious and health care institutions are functioning.
5	Industrial area / SEZ[25]	• No SEZs may be planned in the sensitive areas such as the forests, mangroves, coral reefs, archeologically important sites, sensitive ecosystems, etc. A buffer zone of 1000 m shall be maintained from such sensitive areas and a greenbelt with tree density of 1000 trees/ acre shall be developed in the said buffer zone. • Major settlements (of 3,00,000 population) to maintain a buffer of 50-25 kms from the settlement's notified limit and projected growth boundary respectively

23 Guidelines for declaration of Eco□Sensitive Zones around national parks and wild life sanctuaries, MoEF, 2011

24 Draft Special Regulation For Installation Of Telecom Towers In Urban Areas, Government of Orissa, 2013

25 SEZ guidelines, Industries Commissionerate, Government of Gujarat

S.No.	Activities	Recommended Buffer
6	Mining and quarrying[26]	Buffer zone in case of Mining Lease (ML) area up to 25 ha is to be considered as 5 km all around the periphery of the core zone and for ML area above 25 ha- an area 10 km all around the periphery of the core zone.
7	Petrochemical and Gas industries[27]	No Gas pipeline should be located within 15.0 meters of any private dwelling or any industrial building or place of public assembly in which persons work, congregate or assemble, unless it is provided with at least 300 mm of cover over and minimum cover as specified Petroleum And Natural Gas Regulatory Board Notification, 2009. • No Gas or Oil well shall be drilled at any point, within a minimum distance, to be prescribed by the Central Government, of any railway, pipeline or other right of way, surveyed road, dwellings, industrial plant, air-craft runway, buildings used for military or public purposes, or within three kilometres of any mine, whether active or abandoned, unless the special permission of the Central Government is obtained in advance. • About 90m x 90m buffer to be maintained along the active oil wells, petroleum storage tanks, encompassing all the safety norms for precautions against fire[28]
8	Heritage related areas[29,30]	Every area, beginning from the limit of the protected area/monument, extending to a distance of 100 meters in all directions shall be the 'protected areas' and extending up to a distance of 200 meters in all directions shall be 'regulated area'. The protected zone is a no construction zone. The building regulations in the regulated zone to be prepared by the Heritage Conservation Committee in consultation with ASI.
9	Natural hazard zonessuch River flood plainsand water bodies including wetlands[31]	• The basic concept of flood plain zoning is to regulate land use in the flood plains to restrict the damage caused by floods. Flood plain can be identified based on last 50 or 100 year flooded area of water bodies or river. There can be different considerations for regulations. For example, the area likely to be affected by floods up to a 10-year frequency should be kept reserved only for gardens, parks, playgrounds, etc. Residential or public buildings, or any commercial buildings, industries, and public utilities should be prohibited in this zone. • In area liable to flooding in a 25-year frequency flood, residential buildings could be permitted with certain stipulation of construction on stilts (columns), minimum plinth levels, prohibition for construction of basements and minimum levels of approach roads, etc. In urban areas there should be double storeyed buildings. Ground floors could be utilised for schools and other non-residential purposes.
10	Coastal Regulation Zone	Coastal land up to 500 m from the High Tide Line (HTL) landward side and a stage of 100 m along banks of creeks, estuaries, backwater and rivers subject to tidal fluctuations is called the Coastal Regulation Zone, which is regulated for developmental activities.

26 Proforma For Environmental Appraisal Of Mining Projects, MOEF
27 The Petroleum and Natural Gas Rules, 1959
28 Oil Mines Regulations, 1984
29 Model Building Byelaws, TCPO
30 Ancient Monuments and Archaeological Sites and Remains Act, 2010 (AMASR)
31 National Disaster Management Guidelines Management of Floods, NDMA

S.No.	Activities	Recommended Buffer
11	Manmade hazard zones such as radioactive, chemical and gas treatment / processing/ distribution lines[32]	Chemical industry - The development of buffer zones all around the industry in an effective manner and establish Off-Site responding agencies at an appropriate distance from the new installations. Nuclear Plants[33] • 500 Ha is needed to be in the control of power station as an exclusion zone. This is maintained as a vacant space and developed as a green belt area. • Sterilised Zone: the plant as sterilized zone maintains Area of 5 km radius. No restriction is imposed by the plant on organic development activities of population in the annulus between 1.5 and 5 kms. Administrative actions ensure that there is no influx of large population in this area • Population Restriction: – Population density within 10 km radius: Less than two-third of state average; – Population within sterilised zone (5Km radius) Less than 20,000; – Population centres with more than 10,000 persons more than 10 km away; – Population centres with more than 100,000 person) more than 30 km away;
12	High density/ high activity zones	Areas around high density, mixed land use or residential areas along dense commuter's zones/ arterial and sub-arterial roads to be buffered with trees and plantations, flexible building material for attenuation/reflection.

4. Eco-Sensitive zones

Due to rapid urbanization and its impact on protected zone, there is a need to conserve protected areas. The MoEF&CC has developed guidelines for declaration of eco-sensitive zones around protected areas, national parks and wildlife sanctuaries. These guidelines provide the framework to states/UTs to develop specific buffer zones around National Parks, Wildlife Sanctuaries, Sanctuaries, important migratory corridors, etc. with a view of minimizing and preferably eliminating any negative impact on protected areas and sanctuaries. The recommended procedure to be adopted by states is mentioned below:

• Prepare an inventory of the different land use patterns and the different types of activities, types and number of industries operating around each of the Protected Area (National Parks/ Sanctuaries) as well as important Corridors be made with the help of range officers.

• A small committee comprising the concerned Wildlife Warden, Warden, an Ecologist and an official of the Revenue Department of the concerned area, could be formed whose function is to provide recommendation on requirement and extent of eco sensitive zone. Further, the committee can also suggest the methods of management of zone and thematic activities, which can be included in the Development Plan/ Master Plan of the region.

9.3. Zoning Atlas for Siting of Industries[34]

CPCB prepared a zoning atlas for industries, some major factors are discussed below:

As per the District Atlas, Zoning Atlases are to be prepared with following themes:

- Areas to be avoided (Biological diversity and Incompatible Landuse) – Environmentally Sensitive Zones
- Air Pollution Sensitivity (Sites for air polluting Industries)

32 National Disaster Management Guidelines Chemical Disasters (Industrial), NDMA

33 http://www.npcil.nic.in/pdf/news_12oct2011_01.pdf (National Power Corporation of India Limited)

34 Anand Kumar, CPCB, 29-08-2018

- Surface Water Pollution Sensitivity (Sites for water polluting Industries)
- Suitability of sites/zones for industrial location

Areas to be avoided- Sensitive Zones/ Biological Diversity /Incompatible Land Uses-

- Biological Diversity: Sanctuaries National parks Game reserve Tiger reserve/elephant Sensitive Zones Sanctuaries, parks, reserve, reserve/turtle nesting ground, breeding grounds Core areas of Biosphere reserves, Wet lands, Areas with threatened (rare, vulnerable, endangered) flora/fauna, protected corals, Reserved/Protected Forest and any other locally specified.
- Sensitive/Incompatible Land Uses: Public water supply areas (river, reservoir) monuments, Flood prone areas, CRZ, World Heritage Site, Religious places, Tourist places, Protected tribal settlements, Agriculture Research Stations, Air Port and any other specified by State or local government.

9.3.1. Air Pollution Sensitivity Assessment

An assessment for Delhi has been carried out based on the guidelines introduced by the Zoning Atlas.

Industry Category	Impact Potential*
A1	> 7 km
A2	5 to 7 km
A3	2 to 5 km
A4	< 2 km

* Impact potential considered without pollution control equipment in operation

Figure 196: Categorization of industries

Source: http://cdn.cseindia.org/userfiles/CEPI.pdf

3. Land Use Sensitivity

Feature	Zone – 1	Zone – 2	Zone – 3	Zone – 4
National Parks /Sanctuaries/ Mangrove area/ Wetlands	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Tiger reserve/elephant reserve/turtle nesting ground, breeding grounds/ Game reserve	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Core zone of biosphere reserve	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Notified protected tribal settlements/ Critical'/'high' air polluted areas/ Agricultural research stations/Air Port	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Areas with threatened (rare, vulnerable, endangered) flora/fauna, protected corals/ Habitat for migratory birds	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Botanical gardens, Zoological gardens, Gene Banks	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Monuments of national significance/ World Heritage Sites	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Any other closed/protected area under the Wild Life (Protection) Act, 1972	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Core areas of scenic areas/tourism areas/hill resorts/ religious places/pilgrim centres with more than 5 lakh visitors/tourists/pilgrims per year	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Hilly stretches that act as barriers for dispersion of emissions, areas with frequent inversion conditions	< 2 km	2 to 5 km	5 to 7 km	> 7 km
Any other feature as specified by the State or local government/or locally applicable	< 2 km	2 to 5 km	5 to 7 km	> 7 km

Figure 197: Land use Sensitivity

Source: http://cdn.cseindia.org/userfiles/CEPI.pdf

4. Site Suitability to Air Polluting Industries (without considering water pollution)

Air pollution sensitivity / Industry category	Env. Sensitive Zones/ Areas to be avoided	Zone-1 (<2 km)	Zone-2 (2 to 5 km)	Zone-3 (5 to 7 km)	Zone-4 (> 7 km)
A1 (> 7km)	Not Suitable	Not Suitable	Not Suitable	Not Suitable	Possible
A2 (5 to 7 km)	Not Suitable	Not Suitable	Not Suitable	Possible	Suitable
A3 (2 to 5 km)	Not Suitable	Not Suitable	Possible	Suitable	Suitable

Industries with impact potential less than 2 km (A4 category) may be considered for siting anywhere in the district based on micro-level conditions, except in the areas that are to be avoided . However, in all the cases micro-level assessments are essential before taking final decision on site suitability. Also, 'consent to establish' is required in all cases.

Figure 198: Site Suitability to Air Polluting Industries (without considering water pollution)

Source: http://cdn.cseindia.org/userfiles/CEPI.pdf

9.3.2 Possible Alternate Sites for Industrial Siting

1. Zoning of the District

- Sensitive zones
- Zone –1 High risk zone for air polluting industries (Z1)
- Zone-2 High risk zone for air polluting industries (Z2)
- Zone-3 Medium risk zone for air polluting industries (Z3)
- Zone-4 Low risk zone for air polluting industries (Z4)

A1 category - industries with emission from combustion of fuels using coal 125 t/hr or equivalent fuel, or industries having process emission emitted through organized let out system (stack) or having fugitive emission or odour nuisance, or industries generating noise levels of 90 dBA and above

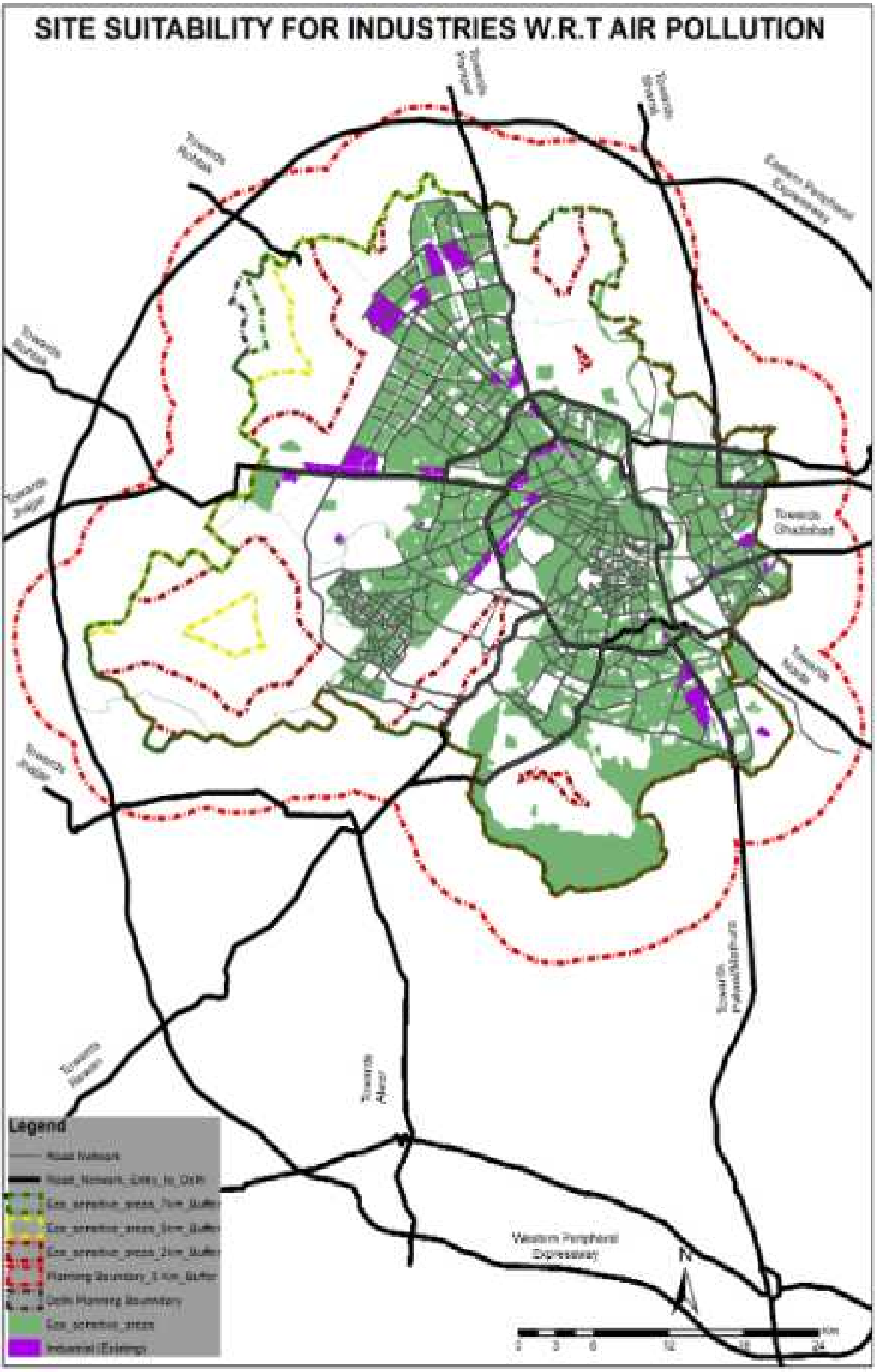
A2 category - industries with combustion emission from usage of coal 125 t/hr or equivalent, or generating noise levels between 70-90dBA, or having diesel generator sets 50 KVA

A3 category - industries having emission only from boilers of steam generation capacity less than 2t/hr but not using coal, or noise of FdBA, or using DG sets upto 50 KVA

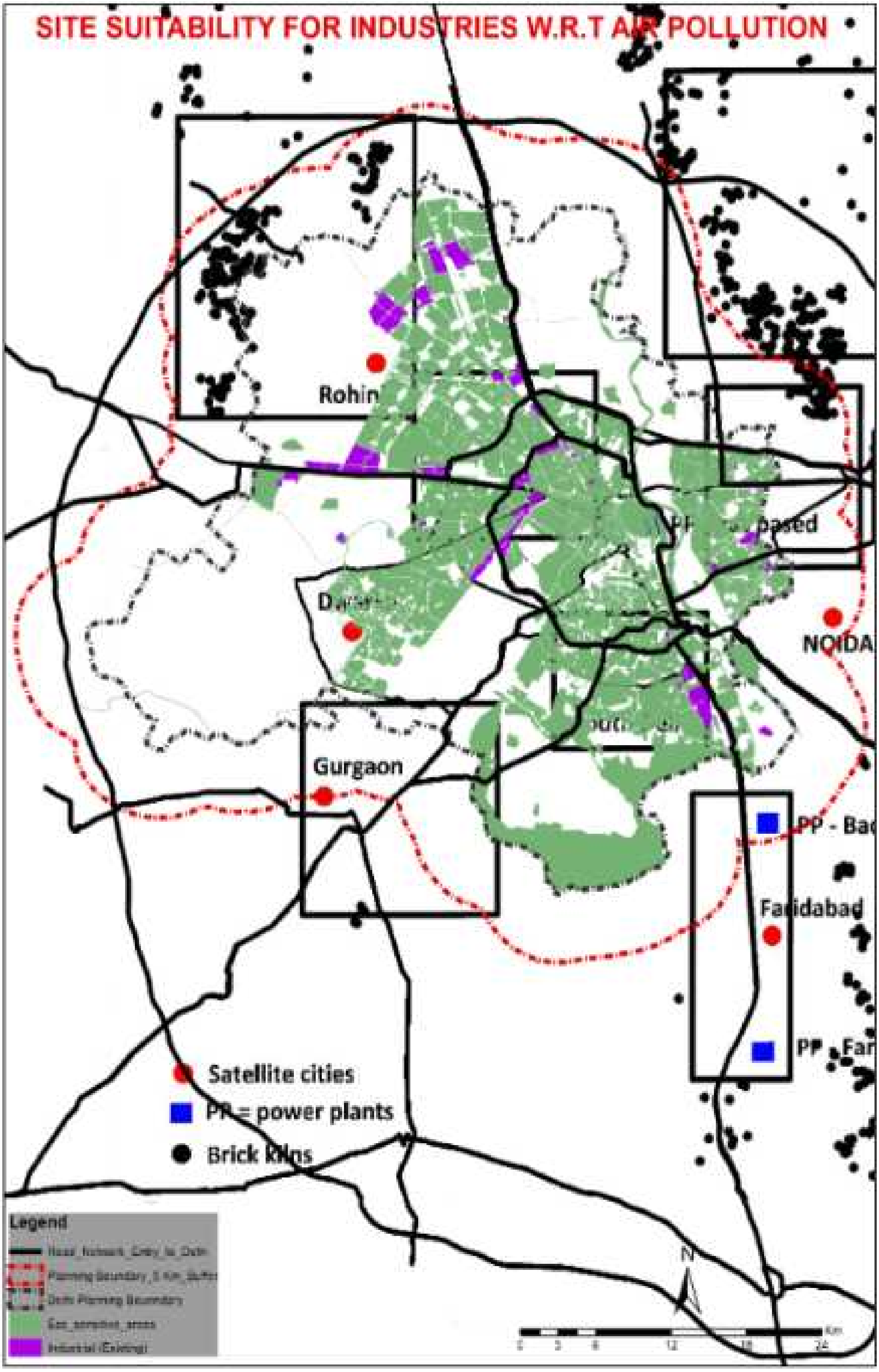
A). Site Suitability for Industries with respect to air pollution

The area lying within Eco_sensitive_areas_2km_Buffer (Zone 1) are not suitable for any type of industries (A1, A2 & A3). The areas lying between Eco_sensitive_areas_2km_Buffer and Eco_sensitive_areas_5km_Buffer (Zone 2) is not suitable for industries A1 & A2. The siting of A3 industries is possible in this zone. The areas lying between Eco_sensitive_areas_5km_Buffer and Eco_sensitive_areas_7Km_Buffer (Zone 3) is not suitable for A1 type industries where as there is possibility for A2 and is most suitable for A3 type industries. The areas lying beyond Eco_sensitive_areas_7km_Buffer (Zone 4) is possible for siting of A1 type industries and is most suitable for A2 and A3 type industries.

Industries with impact potential less than 2 km (A4 category) may be considered for siting anywhere in the district based on micro-level conditions, except in the areas that are to be avoided. However, in all the cases micro-level assessments are essential before taking final decision on site suitability. Also, 'consent to establish' is required in all cases.



Map 260: Site suitability for industries



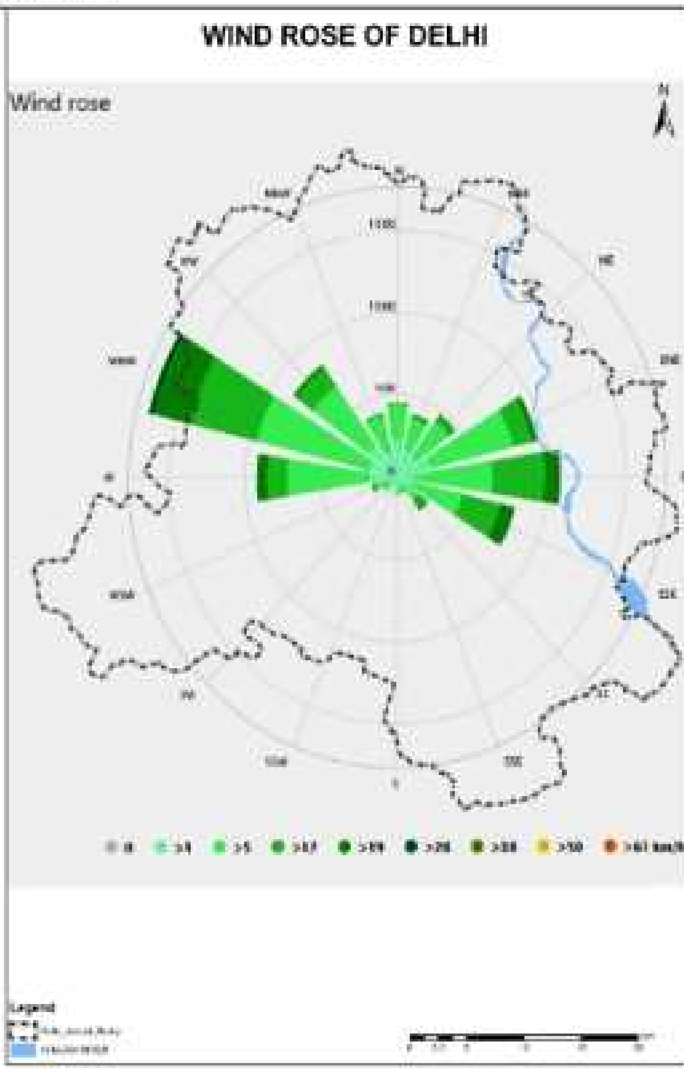
Map 261: Location of brick kniis with respet to the site suitability

According to a research paper released by the Centre for Science and Environment on March 11 at the Anil Agarwal Dialogue in Delhi, India is the second largest producer of bricks in the world and manufactures nearly 200 billion bricks a year. The paper states that 65 per cent of these bricks are produced in the Indo-Gangetic plains, which have one of the world's most fertile alluvial plains.

Brick kiln shall be established at least 500 m away from residential area having a minimum population of 100-150 people or 20 houses including both kachcha and pucca houses, 1.0 km from a residential area having a population more than 150 or more than 20 houses including both kachcha and pucca houses. However, the distance from notified municipal area will be 5.0 km.

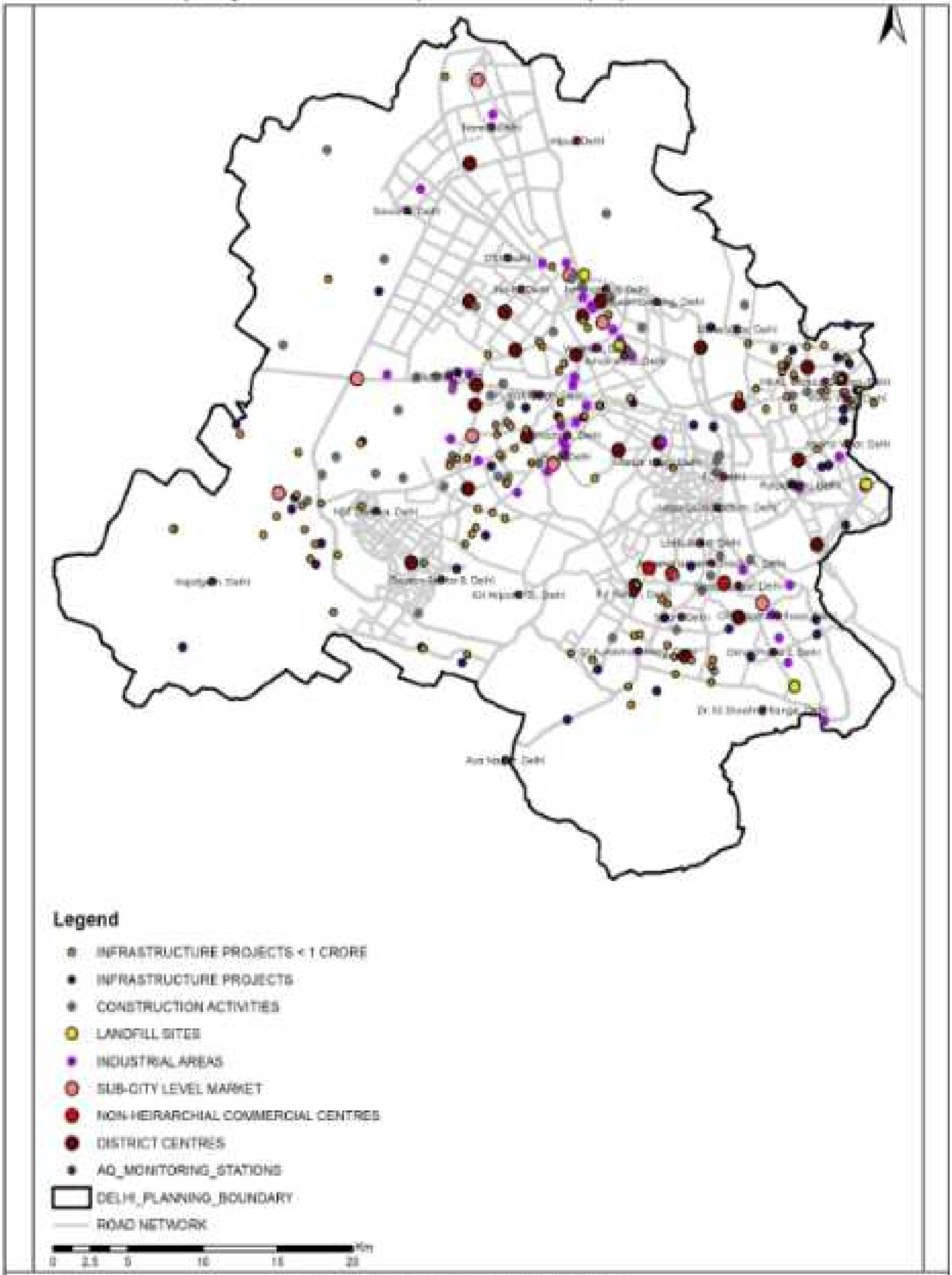
9.4. Observations:

Given the predominant wind direction of Delhi and observing monthly wind directions, the possibly suitable locations lies towards South West. The area has various locational advantages w.r.t access to road network (expressway, highways) and airport connectivity. The existing locational setting of industries favors large inflow of vehicles (trucks) for transport of finished goods and procurement of raw materials. The wind direction being predominant from NW, W, E & SE direction is unfavourable for industries located within that region. The existing industries near Bawana, Mundka, Alipur, Rohini, Jahangirpuri, Wazirpur and Anand Vihar thus poses a huge problem of air pollution.



Map 262: Wind rose diagram of Delhi

The Emission Inventory prepared by TERI and IIT Kanpur have accounted for fuel usage in industries while the emission from the process itself within those industries and secondary activities (procurement of raw materials and transportation of goods) were not accounted. The existing zoning of industries in Delhi (as per Master Plan of Delhi, 2021) does not support to betterment of air quality. 10.1.3 Phase 1 (25 March – 14 April)



Map 263: Major Activity Locations in Delhi

On observing the daily mixing height data and wind speed, we also see the location advantage of siting industries towards south-west region of Delhi. The modeled mixing height is shown below.

The MoEF&CC and URDPFI Guideline Vol 1 states the use of Zoning Atlas for Siting of Industries prepared by CPCB for allocation of industrial areas where as no such relevance have been found in Master Plan of Delhi, 2021.

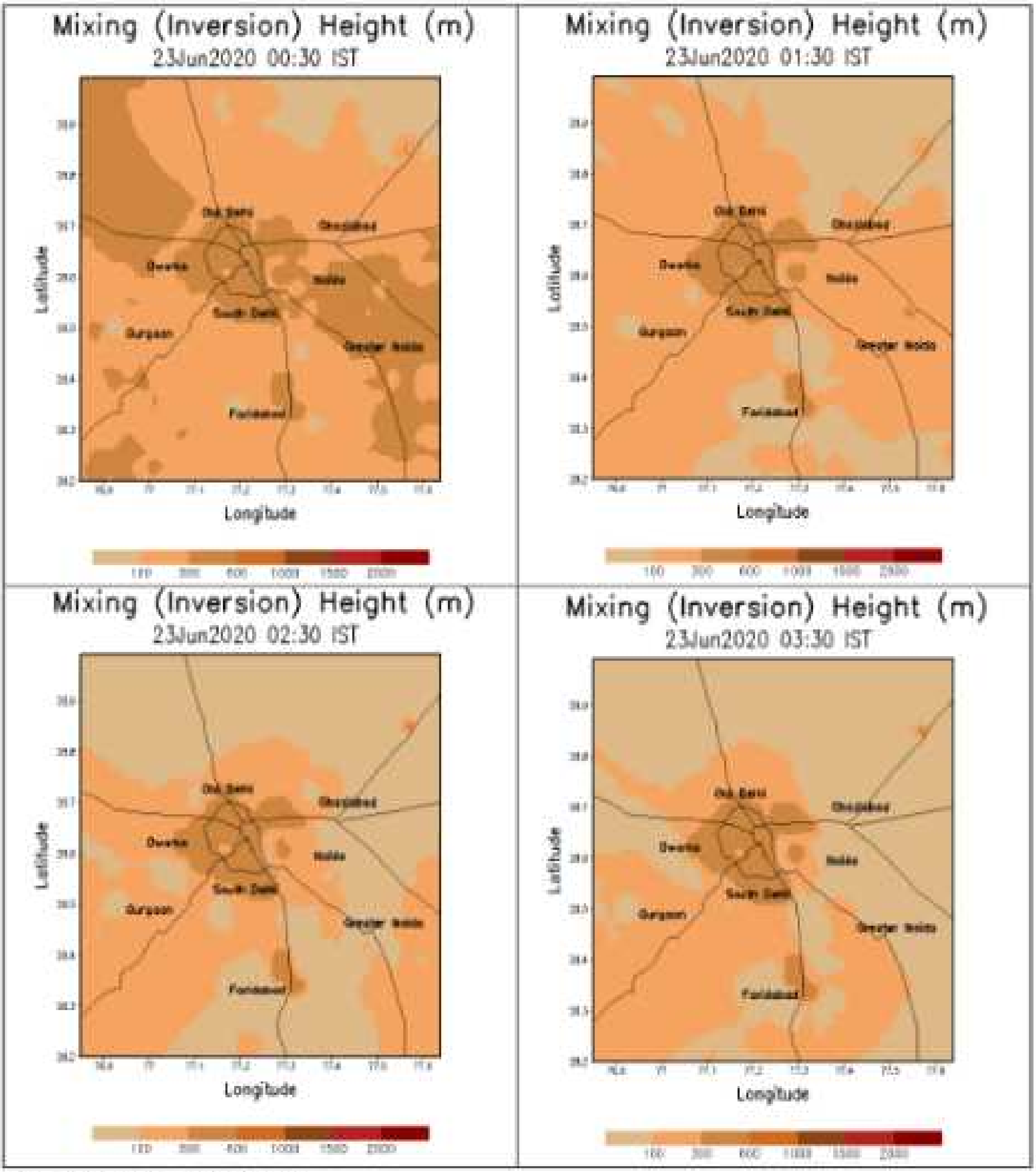
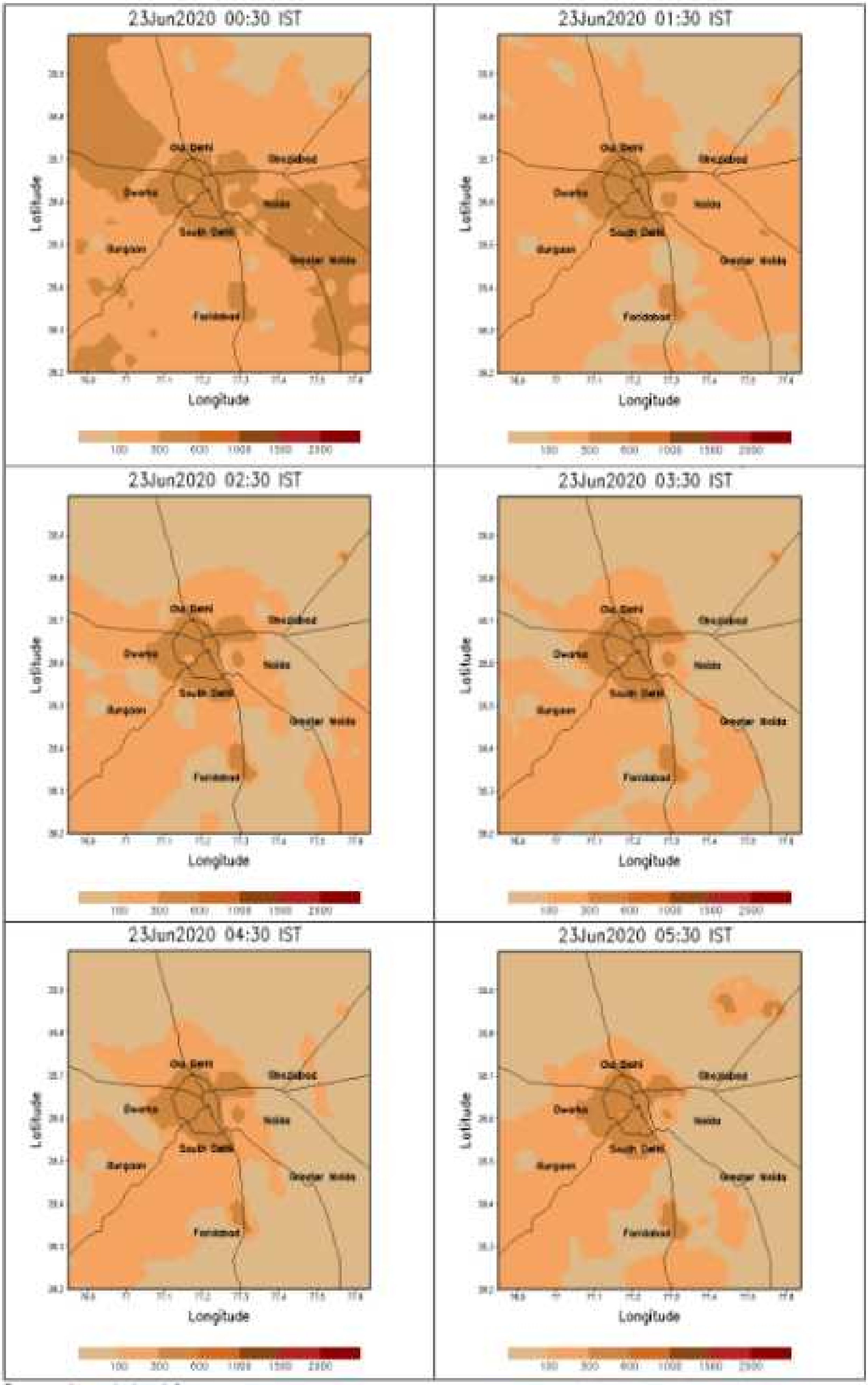
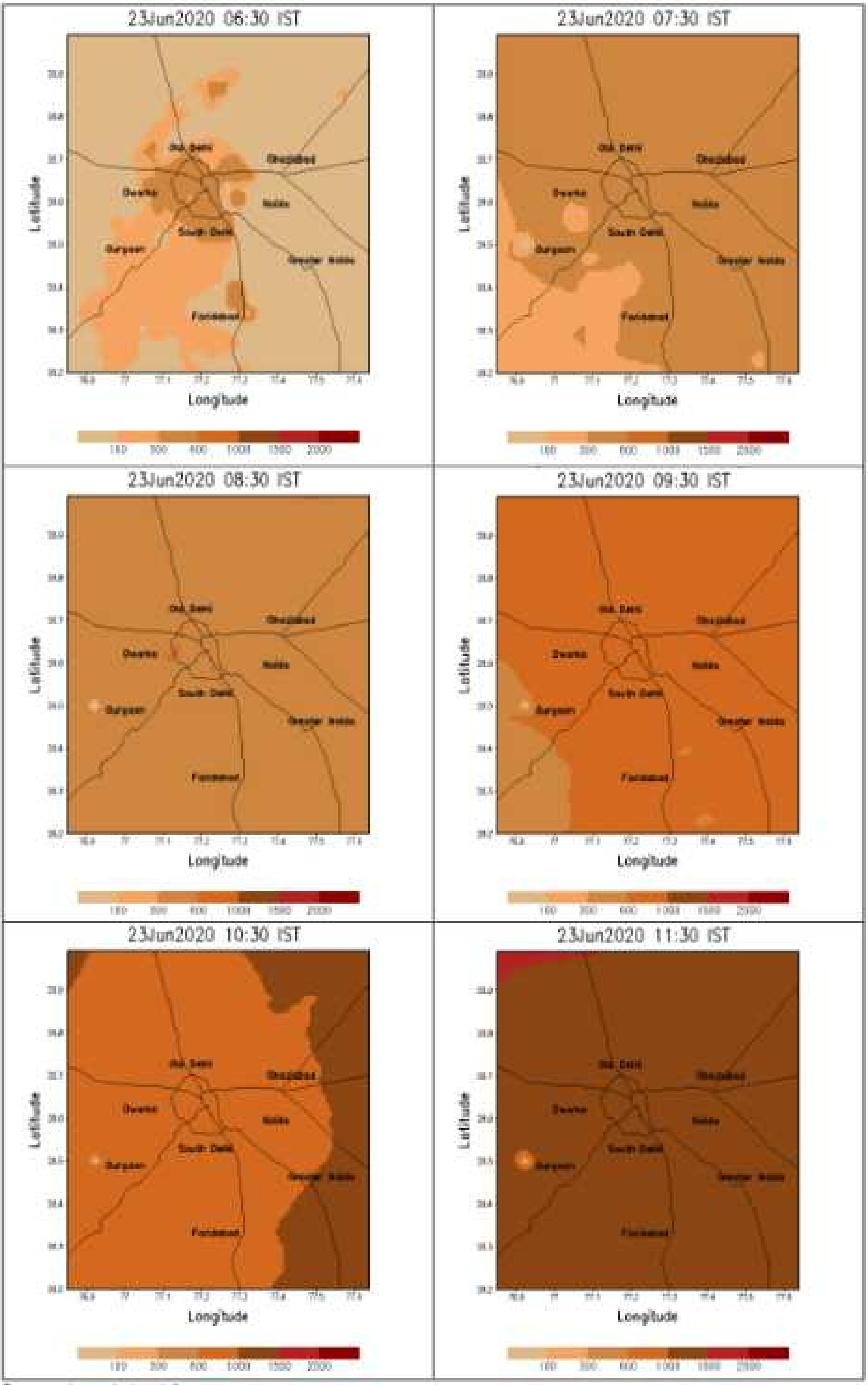


Figure 109: Mixing Height around Delhi

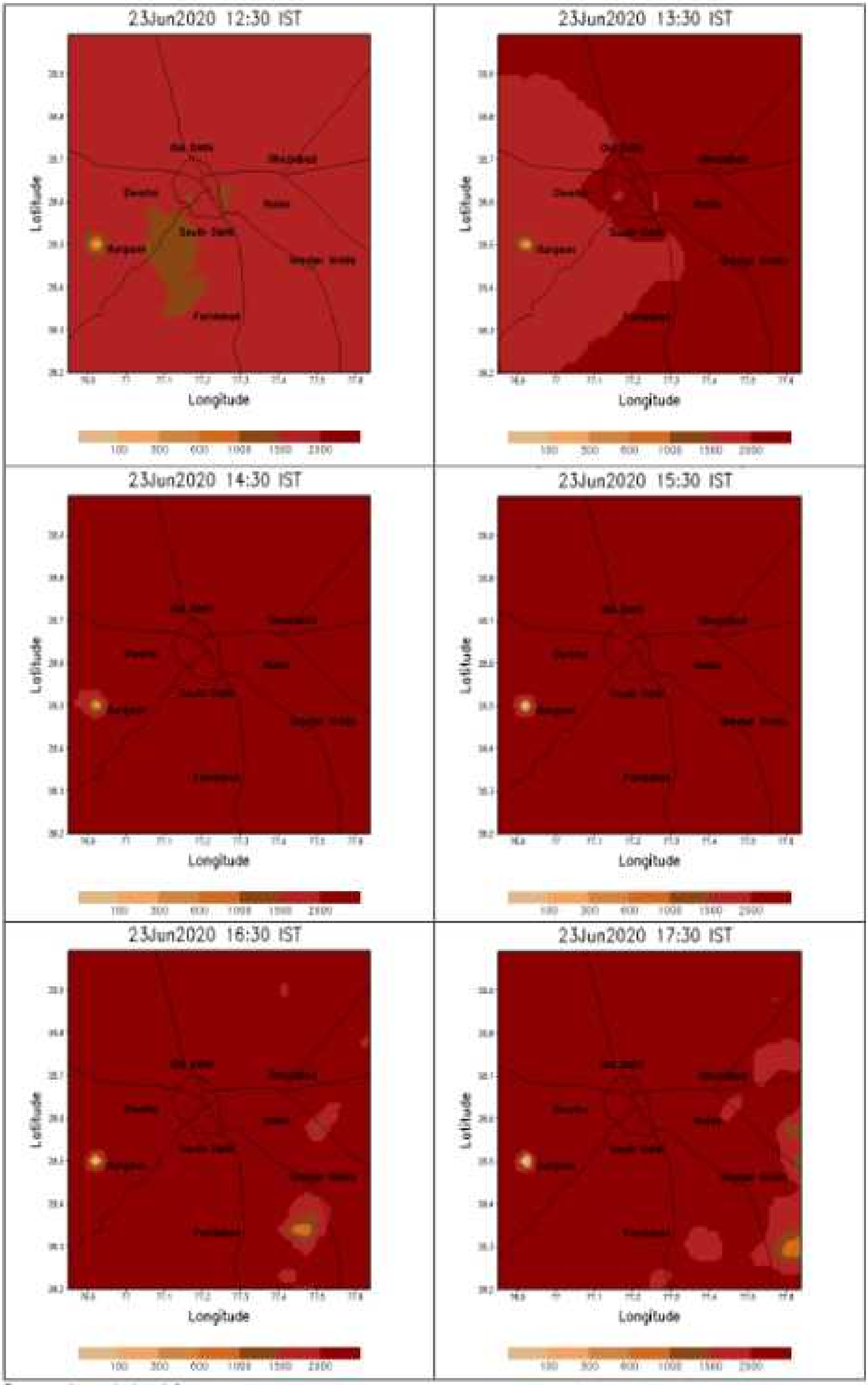
Source: urbanemissions.info



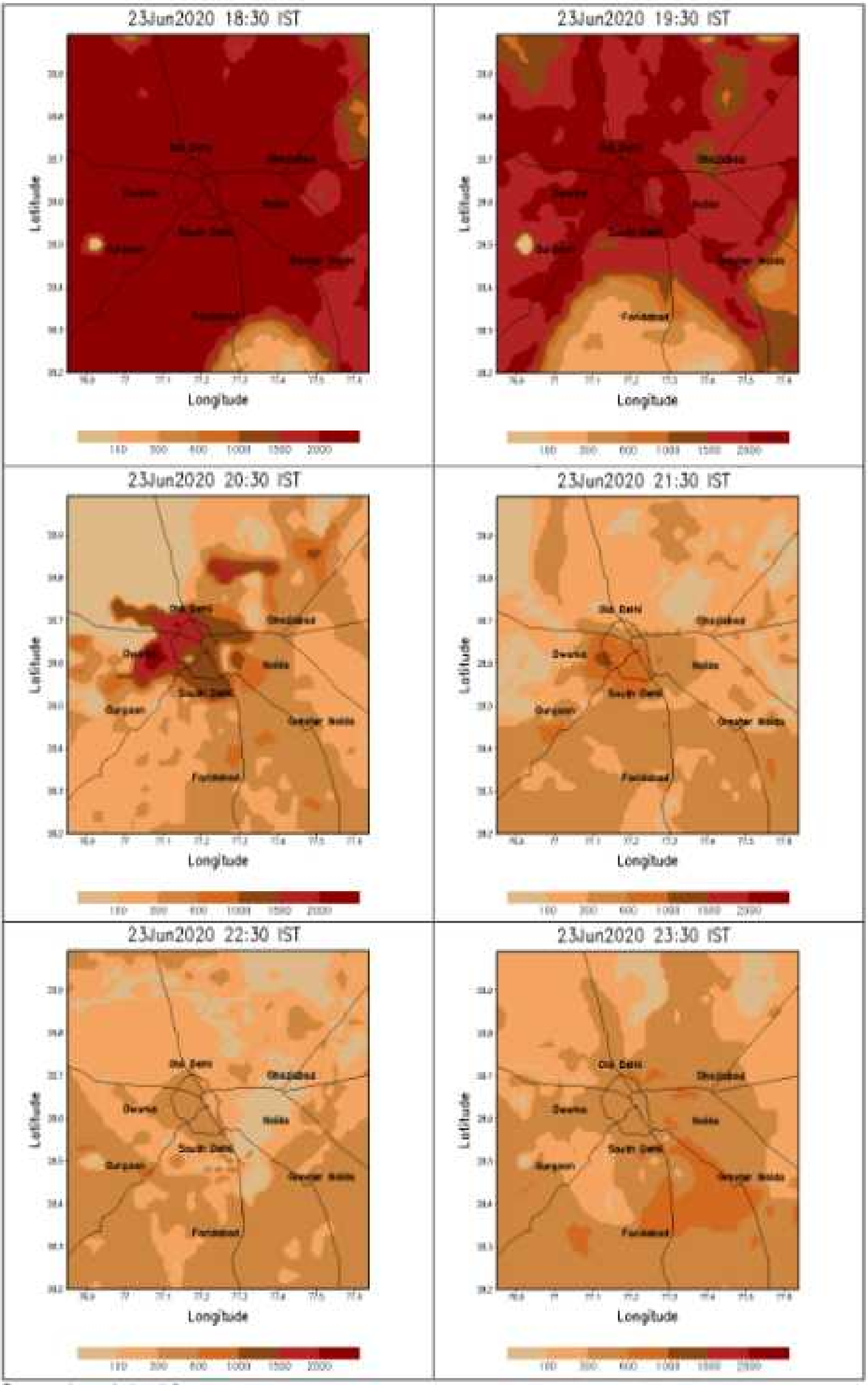
Source: urbanemissions.info



Source: urbanemissions.info



Source: urbanemissions.info



Source: urbanemissions.info

10. SCALES OF INTERVENTIONS

The following recommendations are provided based on the scale of influence:

10.1. Control on landuse based activities

A. Regional Level

It has been observed that regional influence in terms of operating brick klins, fires, stubble burning especially fro north -east and north west have an influence on the level of air pollution in NCT Delhi. Hence for a distance of 5 to 8 kms beyond the NCT boundary there should be a control of sources of air pollution. Some of the suggestions are as follows

;

- The growth trajectories as specified in the Delhi Master Plan 2021 and NCR Plan should include considerations of Environmental Management w.r.t air quality. -
- Developments & Development controls governed by FAR should incorporate study of wind movement towards city and should help in better pollutant dispersion potential.
- Transport corridors connecting Delhi with nearby cities should be managed in such that heavy traffic volumes are diverted away from the observed monthly wind direction pattern.
- Goods movement into the city via HCVs and LCVs should be controlled via limiting movement to city limits. This would mean relocating a better site for warehouses.
- Comprehensive Transportation Management Plan based on latest year study should be prepared.
- Management Plan for solid waste & agricultural waste should be brought with focus on discouraging burning of waste.
- Management of desertification– vegetation/green cover and urban wetlands should be developed in the green belt and peri-urban areas of Delhi.

B. City & Local Level

The built form of the City modifies the air flow pattern and pockets of air stagnation prevent the dispersion of pollutants . Activity build up due to corresponding landuse and increase in pollution levels need to be addressed. It is therefore suggested ;

- Developments & Development controls governed by FAR should incorporate study of wind movement within city and should help in better pollutant dispersion potential. Height restrictions should be enforced based on fluid dynamics/air movement.
- Standard Operating Procedures should be identified for organized and unorganized activities (as observed during lockdown period).
- Landuse based activities should be controlled based on its scale of trip generation & attraction.

- Efficiency of public transport should be increased thus reducing dependencies on personal vehicles for daily trips. The focus should be on minimizing vehicular kilometer travel (VKT) of each individual.
- Strategies for encouraging cycles as mode of travel to work should be introduced.
- Dedicated bicycle lane, elevated bicycle corridors or shaded bicycle corridors should be identified to encourage more bicycle users.
- Restricted vehicular entry to major work centres encouraging use of last mile connectivity should be enforced.
- Green cover should be maintained based on its influence over air quality. It should not act as a barrier.
- Location of landuse which attracts high levels of activities should be discouraged in North West, North East and Souh East Delhi which show high level of air pollution
- Proposed industries should not be located in areas around sensitive landuses.
- The growth direction of Delhi is towards West spreading over North West and South West region. The holding capacities have been increased significantly in order to accommodate the existing and future population. As such efforts should be made to ensure land use zoning aligns with promoting good air quality rather than degrading the situation. Also land use implications on air quality can be estimated in hand for new development zones in order to provide sustainable solution without hampering the development process and air quality.
- Preparation of existing land-use plan. The have been cases where proposed master plan of city and existing scenarios differ and Delhi is no exception. And GIS based master plan shape files should be made publicly available from Development Authorities and Air pollution Data including the mixing height values from Air Quality Monitoring Agencies in order to encourage better R&D in the field of air pollution.

10.2. Acknowledgment of Variables and Independent Factors

A. Regional, City & Local Level

- Strategies should focus on controlling land use based activities and should not entirely depend on ventilation coefficient which primarily signifies assimilative capacity of air environment.
- Mixing heights increases and decreases with time and as such strategies should be independent of these variables i.e., wind speed and mixing height should be kept in mind.
- Air Pollution Studies i.e., called Source Apportionment Study / Emission Inventory should be done in conjunction with Land Uses and Development Authorities and Air Pollution Management Agencies should work together to device effective and appropriate zoning mechanism for controlling air pollutant concentration.

10.3. Setting emission budget for each activity

A. Regional Level, City & Local Level

- Emission budget (allowable emissions in kgs/day) should be identified based on various observations. The case of lockdown can be taken in such case and emission limits from various activities highlighted in emission inventory should be prepared.
- Emission budget should acknowledge the growing population, increase in personal vehicle users and demand of goods.

10.4. Identification of appropriate zoning mechanisms

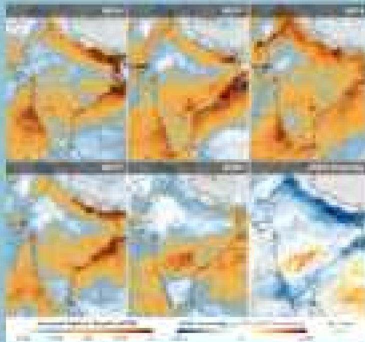
A. Regional Level, City and Local Level

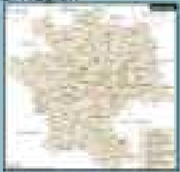
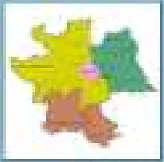
- Zoning of Land uses should be done only with detail study on the implications of land use and its associated activities on air quality. Long term average meteorological conditions or climate simulation modeling should be taken into consideration.
- The Master Plan of Delhi should incorporate land use implications on air quality and device appropriate land use mix.

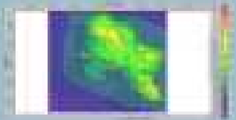
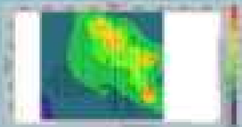
10.5. Improving management capacity

A. Regional Level City and Local Level

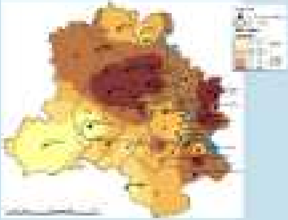
- To enforce air pollution controls, strategies such as emission standards, economic incentive, cost benefit and air quality standards can only be achieved with adequate management capacity.
- Operational & Management capacity of air pollution mitigation strategies should be increased.
- Routine checks and disposal of activity-based strategies should be done in frequent interval every month.

ECOLOGICAL SETTING OF NCT DELHI & ASPECTS TO BE ADDRESSED TO CONTROL POLLUTION		
ECOLOGICAL ZONES	**OBSERVATIONS**	**RECOMMENDATIONS**
Biogeographic Zone  NCT Delhi is located in Semi-Arid Bio -Geographic Region and is characterised by low rainfall, thorny and open forests, wetlands.	- Located in the bowl like Ganga Plains, the dust laden winds predominantly from west get trapped around and within NCT Delhi contributing to almost 65 percent of the pollution here (IITM, 2018) - AOD (Aerosol optical depth) measurements over India during March 31 to April 5 period for each year from 2016 through 2020. The 6th map (anomaly) shows how AOD in 2020 compared to the average for 2016-2019.  This indicates the suspension of dust in the air due to physiographic reasons	- It is important to incorporate dust mitigation measures by planting the appropriate trees, maintaining moisture in urban and rural areas. Incase of NCT Delhi measures for propagating greenery and maintaining waterbodies at both the Regional i.e National Capital Region Level (NCR) and NCT Delhi level - Studies on appropriate vegetation to be propagated need to be undertaken
Agro-climatic Zones  NCT DELHI and NCR lie in V- Upper Gangetic plain region -Uttar Pradesh & VI- Trans Gangetic plain region- Chandigarh, Delhi, Haryana, Punjab, Rajasthan		

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi		
REGIONAL LEVEL	OBSERVATIONS	RECOMMENDATIONS
National Capital Region 	Fire incidents during lockdown 	NCR PLAN TO INCLUDE Demarcation of Air shed in Sub-Regional Plans of Uttar Pradesh, Rajasthan and Haryana and regulating air polluting activities -burning of garbage, agricultural wastes etc -relocation of brick kilns / change to clean fuel -control of industrial pollution especially in identified CEPI areas (Critically Environmentally Polluted Industrial Areas) -preparation of Clean Air Action Plan (CAP) for the identified Non Attainment Cities (NAC
Sub Regions – NCT Delhi, Uttar Pradesh, Haryana and Rajasthan 	Brick Kilns around Delhi 	
Proposed Landuse around NCT Deli as per Master Plans 	Western and Eastern peripheral highways  Proposed developments Loni, Gaziabad, Noida and Greater Noida, Faridabad, Gurugram and Sonipat indicates a spurt in activities and traffic movement around NCT Delhi in the Region	Green belt along highways to be maintained inorder to ensure trapping of dust and control of pollution by planting the right type of tree species Delineation of airshed to identify sources of pollution outside NCT Delhi which impact the air pollution Levels in Delhi

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi		
NCT DELHI	OBSERVATIONS	RECOMMENDATIONS
Landcover of NCT Delhi, 2017 	Percentage change in Landcover class during 1977-2017  Source: BHUVAN There is significant reduction in green cover and increase in built up areas	The growth and development of NCT Delhi has resulted into substantial increase in built up area. And associated built form and activities such as transportation and construction
Isopleths of highest 24-hr values of PM10  Isopleths of highest 24-hr values of PM2.5 	Airpollution levels Based on the Source Apportionment Studies, there are high pollution levels especially w.r.t. PM levels in Delhi, the hot spot from PM level point of view is Shahdara, East Delhi, Badarpur, Rithala and Badli Samaypur	PM 2.5 and PM 10 are above permissible limits almost all year round and certain areas are emerging as hotspots. As per SUPPORTIVE CAPACITY estimates the Carrying Capacity of NCT Delhi has been surpassed.

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
SPATIAL PLANNING SCALES – Regional Plan, Master Plan, Zonal Plans and Local Area Plans of NCT Delhi		
	Recommendations of MPD 2021 	While the Master Plan Delhi recognized the rising air pollution levels the recommendations are primarily regulatory in nature. However long term landuse and built form, etc. control measures need to be formulated to control the impact on rising health problems.

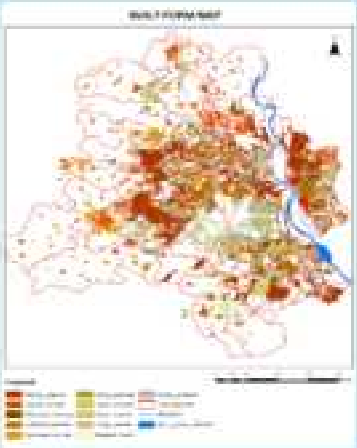
SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
PLANNING ZONES	OBSERVATIONS	RECOMMENDATIONS
(Existing) Air pollution hotspots and Planning Zones 	**VERY-POOR AQI [360-400] in January- ZONE E** •High density areas (425-745 pph) **Landuse** •Industrial –Shahdara, Gandhi Nagar, Shastri Nagar •Residential-Trilokpuri, KaLyanpuri, Seemapuri •Mixed Landuse- Laxmi Nagar •Transport Terminal- Anand vihar	The Master Plan NCT Delhi 2041 should discourage development in Zones E and H , and high density parts of Zones C, M,B and F as the AQI levels are very poor .

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
PLANNING ZONES	**OBSERVATIONS**	**RECOMMENDATIONS**
Density of Planning Zones 	**VERY POOR AQI (360-400) in January -ZONE H, C, M & B** - High density areas (425-745 pph) **Landuse** - **Industrial** –Mundka, Jahangirpuri, Wazirpur, Burari, Ashok Vihar, Bawana - **Slums**-Bhalswa, Jahangirpuri, Kirtinagar, Kathputli Colony - **Mixed Landuse**-Parts of Punjabi Bagh, Shadipur **VERY-POOR AQI (346-398) in January-ZONE F** - High density areas (425-745 pph) **Landuse** - **Industrial** –Okhla - **Residential**- Khirki Village - **Slums**- Sangam Vihar, Sanjay Colony - **Mixed Landuse**- Urban villages Hauz Rani, Chirag Delhi, Shahpur Jat	The Master Plan NCT Delhi 2041 should discourage development in Zones E and H , and high density parts of Zones C, M,B and F as the AQI levels are very poor .
Planning Zones (Proposed) Master Plan Delhi 2021 and planning zones	Zone L is slated for future growth as per Zonal Development Plan for Zone L with a parallel grouping of public and semi-public landuse 	The Public-SemiPublic and Commercial areas proposed should be so planned that they allow for dispersion of air pollution. The built form and air flow should be studied before finalizing the building heights. AdequateGreen infrastructure to be planned to address the need for air pollution sinks.

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION

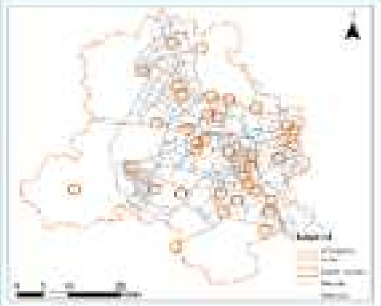
PLANNING ZONES

Local Climatic Zones (LCZs) as proposed by Stewart and Oke in 2012 were used to study the urban built forms affecting the mechanism of dispersion processes in urban neighborhoods.



OBSERVATIONS

Local Level - Activities: The local level assessment was done for 38 monitoring stations present in Delhi. For this a buffer of 1Km (influence area/zone) around the monitoring stations was earmarked and accordingly the broad land uses, activities and LCZs were mapped.



IMPLICATIONS OF ACTIVITY DIPDURING LOCKDOWN AND CORRESPONDING POLLUTION LEVELS INDICATED A COR-RELATION

RECOMMENDATIONS

Detailed scientific studies need to be undertaken to arrive at the landuse , built form, activity and air pollution linkage.

The carrying capacity changes over time as it depends on atmospheric stability and emission load over a certain period of time.

Carrying Capacity = (Emission Standard as per CPCB/Emission load from Land uses mix *

Ventilation Coefficient) – Ventilation Coefficient

i.e.,

Category	Condition	Code
High	[illegible]	
Moderate	[illegible]	
Low	[illegible]	

The Ventilation coefficient shows only the dispersion potential. So to capture the Real Carrying Capacity (RCC), the parameters such as diffusion, chemical transformation and ground deposition needs to factored in the calculations.

SCALE OF INTERVENTION TO CONTROL LEVEL AND EXPOSURE TO AIR POLLUTION		
PLANNING ZONES	OBSERVATIONS	RECOMMENDATIONS
Local level 	Based on the studies carried out for 1km radius around monitoring stations it is observed. Location specific observations indicated landuse, activity and traffic impacting pollution levels.	Less percentage of greens, more are other activities causing more polluted days in a year. Location and pattern of greens impact level of pollution. Intensity of traffic movement impacts level of pollution. Need for a detailed scientific study to enable formulation of specific recommendations.

11. ACTION PLAN

Based on the outcomes of the study, certain strategies have been proposed which can be taken as important ingredients to the action plan for managing the development activities based on air pollution in the city. All the aspect wise strategies proposed by previous studies have been added to those proposed by this study.

Table 137: Strategies for Action Plan

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
1	Hotels/ Restaurants	Stop use of Coal			Eliminate use of coals which are still used for barbeques
2	Domestic Cooking	LPG to all		Eliminate use of solid fuels in households	Slum settlements continue to use solid fuels which needs to be replaced by LPG
3	MSW Burning	Stop MSW burning: improve collection and disposal (landfill and waste to energy plants)		Scaling up of implementation of waste management—solid waste and construction and demolition waste	Management Plan for solid waste & agricultural waste should be brought with focus on discouraging burning of waste
4	Construction and Demolition	Vertically cover the construction area with fine screens			Height restrictions should be enforced based on fluid dynamics/air movement
		Handling and Storage of Raw Material: completely cover the material			City infrastructure under construction should prevent congestion of traffic caused by it
		Water spray and wind breaker			
		Store the waste inside premises with proper cover			
5	Concrete Batching	Water Spray			
		Wind Breaker			
		Bag Filter at Silos			
		Enclosures, Hoods, Curtains, Telescopic Chutes, Cover Transfer Points and Conveyor Belts			

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
6	Road Dust and Soil dust	Vacuum Sweeping of major roads (Four Times a Month)	Vacuum cleaning of roads		All the open areas (exposed to soil) should be covered with vegetation.
		Carpeting of shoulders			
		Mechanical sweeping with water wash	Wall to wall paving of roads		
		Plant small shrubs, perennial forages, grass covers in open areas	Control of dust from construction activities		
7	Vehicles	Electric/Hybrid Vehicles: 2% of 2-Ws, 10% of 3-Ws and 2% 4Ws wef July 2017. New residential and commercial buildings to have charging facilities	Public transportation system on electric vehicles; followed by private vehicles	Transform public transport at scale and enforce vehicle restraint measure in Delhi–NCR	Efficiency of public transport should be increased. The focus should be on minimizing vehicular kilometer travel (VKT) of each individual.
		Retrofitment of Diesel Particulate Filter: wef July 2018	Setting up OBD/remote sensing based and advanced I&M centres	BS-VI ready. Physical checks of advanced emissions control systems to prevent tampering; integration of remote sensing measurements with on-road emissions inspection to address gross polluters, and characterization of emissions of the fleet must be ensured.	Strategies for encouraging cycles as mode of travel to work should be introduced. Dedicated bicycle lane, elevated bicycle corridors or shaded bicycle corridors should be identified to encourage more Bicycle users.
		Implementation of BS – VI for all diesel vehicles including heavy duty vehicles (non-CNG buses and trucks) and LCVs (non-CNG): wef January 2018	All vehicles to be BS-VI		Transport corridors connecting Delhi with nearby cities should be managed in such that heavy traffic volumes are diverted away from the observed monthly wind direction pattern.
		Inspection/ Maintenance of Vehicles	Reduce real world emissions by 50% by congestions management strategies	efforts must be made to leapfrog to electric mobility to cut down exposures	
		Ultra Low Sulphur Fuel	Shift 50% of personal transport on shared taxis in 2025 and 2030		

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
	Vehicles	2-Ws with Multi Point Fuel Injection (MPFI) system or equivalent wef January 2019			
8	Industry and DG Sets	Reduce sulphur content in Industrial Fuel (LDO, HSD) to less than 500 PPM	Power plant controls with continuous monitoring	Approved fuel lists to eliminate coal and dirty fuel streams, and new NOx and SOx standards to tighten PM emissions limits at industrial boilers need to be enforced.	Relocating warehouses for minimizing goods movement into the city via HCVs and LCVs.
		Minimize uses, uninterrupted power supply. Banning 2- KVA or smaller DG sets	Introduction and enforcement of new SO2 and NOx standards	Strong hotspot monitoring and localized action also needs to be ensured.	Restricted vehicular entry to major work centres encouraging use of last mile connectivity should be enforced.
			Enforcement of zig-zag brick kiln technology		Proposed industries should not be located in areas around sensitive landuses.
			Strict PM control on stone crushers		
			Supply 24x7 electricity		
			Fuel switch to gas from solid fuels		
9	Secondary Particles	De-SOx-ing at Power Plants within 300 km of Delhi	Use of refuse in WTE	Regional action on power plants to implement new emissions standards and move to natural gas.	Vegetation/green cover and urban wetlands should be developed in the green belt and peri-urban areas of Delhi.
		De-NOx-ing at Power Plants within 300 km of Delhi			
10	Secondary Organic Aerosols	Controlling Evaporative emissions: Vapour Recovery System at petrol pumps (Fuel unloading and dispensing)			

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
11	Biomass Burning	Managing crop residue burning in Haryana, Punjab and other local biomass burning. Potential alternatives: energy production, biogas generation, commercial feedstock for cattle, composting, conversion in biochar. Raw material for industry wef July 2018	Convert 75% and 100% biomass to LPG in 2025 and 2030 respectively		Use of residue briquettes in power plants
			Zero-open burning and use of residue briquettes in power plants		Zero open burning
12	Fly Ash	Wind Breaker, Water Spraying, plantation, reclamation			
13	Air Pollution Management			Local solutions will have to be implemented not only to reduce the high local level of pollution but also to reduce exposure of local communities	Standard Operating Procedures should be identified for organized and unorganized activities (as observed during lockdown period).
					The Master Plan of Delhi should incorporate land use implications on air quality and device appropriate land use mix.
					Zoning of Land uses should be done only with detail study on the implications of land use and its associated activities on air quality. Long term average meteorological conditions or climate simulation modeling should be taken into consideration.
				Ensure enforcement, incentivization, deterrence and compliance	Emission budget (allowable emissions in kg/day) should be identified based on various observations.
14	Further researches				Preparation of existing land-use plan.
					Comprehensive Transportation Management Plan based on latest year study should be prepared.

STRATEGIES FOR ACTION PLAN					
Sno.	Aspects	IITk 2016	TERI 2018	CSE 2019	SPA 2020
	Further researches				Air Pollution Studies i.e. called Source Apportionment Study / Emission Inventory should be done in conjunction with Land Uses and Development Authorities
					Controlling land use based activities and it should not entirely depend on ventilation coefficient which primarily signifies assimilative capacity of air environment.

An action plan has been proposed phase wise for short term, medium term and long term strategies

SHORT TERM (2025)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Relocating warehouses for minimizing goods movement into the city via HCVs and LCVs.	Goods movement into the city via HCVs and LCVs should be controlled via limiting movement to city limits. This would mean relocating a better site for warehouses.	3-4 years	DDA, MoUD and states urban development and transport departments
2	SOP for organized and unorganized activities	Standard Operating Procedures should be identified for organized and unorganized activities to minimize the emissions (as observed during lockdown period).	1 year	Municipal corporations
3	Vehicular Restrictions in clusters of Public & Semi-Public (PSP) landuse	Restricted vehicular entry to major work centres encouraging use of last mile connectivity should be enforced.	1-2 year	DDA, MoUD and states urban development and transport departments
4	Elevated bicycle corridors, dedicated cycle lanes	Strategies for encouraging cycles as mode of travel to work should be introduced. Dedicated bicycle lane, elevated bicycle corridors or shaded bicycle corridors should be identified to encourage more bicycle users.	3-4 years	DDA, MoUD and states urban development and transport departments
5	Fuel switch to gas from solid fuels	Eliminate use of coals which are still used for barbeques	2 years	DPCC, Municipal corporations
6	Increase in LPG penetration in residential sector	Slum settlements continue to use solid fuels which needs to be replaced by LPG	2-3 years	DPCC, Municipal corporations

SHORT TERM (2025)				
Sno.	Strategies	Description	Time frame	Responsible Agency
7	Better alternate routes during infrastructure development	City infrastructure under construction should prevent congestion of traffic caused by it.	as per project	DDA, MoUD and states urban development and transport departments
8	Covering open areas (non-vegetative) through proper plantation or green cover	All the open areas (exposed to soil) should be covered with vegetation.	1 year	DDA, Cantonment Board, Municipal corporations
Emission Budget				
1	Limiting emissions from various activities	Emission budget (allowable emissions in kg/day) should be identified based on various observations. The case of lockdown can be taken in such case and emission limits from various activities highlighted in emission inventory should be prepared.	1 year	DPCC and CPCB

MEDIUM TERM (2030)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Identification of corridors where pollution builds up due to micro climatic factor	Transport corridors connecting Delhi with nearby cities should be managed in such that heavy traffic volumes are diverted away from the observed monthly wind direction pattern.	Study needs to be done within 2-3 years and actions can be implemented after pilot testing of the strategy.	"State transport departments NCR(Delhi, UP, Haryana, Rajasthan), MoRTH, State transport departmentsNCR(Delhi, UP, Haryana, Rajasthan)"
2	Use of agricultural residues in power plants	Management Plan for solid waste & agricultural waste should be brought with focus on discouraging burning of waste.	It should be brought into practice within 2 years and should be 80% implemented by 2030	DPCC, Municipal corporations
3	Limiting building heights in certain areas based on air pollution simulation studies	Height restrictions should be enforced based on fluid dynamics/air movement.	5-8 years	DDA, MoUD and states urban development and transport departments
4	Controlling land use based activities	Landuse based activities should be controlled based on its scale of trip generation & attraction	Control mechanism should be brought in place within next 5-10 years	DDA, MoUD and states urban development and transport departments

MEDIUM TERM (2030)				
Sno.	Strategies	Description	Time frame	Responsible Agency
8	Public transportation system based on last mile connectivity	Efficiency of public transport should be increased thus reducing dependencies on personal vehicles for daily trips. The focus should be on minimizing vehicular kilometer travel (VKT) of each individual.	Within 6-7 years it should be efficiently brought down to practice.	Transport department
Appropriate zoning mechanisms				
1	Incorporation of landuse implications on air quality into master plan	The Master Plan of Delhi should incorporate land use implications on air quality and device appropriate land use mix.	Should be incorporated into the 2041 master plan and efforts on enforcement should be initiated within next 2-3 years.	DDA, MoUD and states urban development and transport departments
2	Improved inspection and maintenance system	Routine checks and disposal of activity-based strategies should be done in frequent interval every month.	Full implementation by 2030	Municipal corporations

LONG TERM (2040)				
Sno.	Strategies	Description	Time frame	Responsible Agency
Land Use Based Activities				
1	Developments & Development controls based on wind movement towards city	Developments & Development controls governed by FAR should incorporate study of wind movement towards city and should help in better pollutant dispersion potential.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments.
2	Plantation in green belt and peri-urban areas of Delhi	Management of desertification – vegetation/ green cover and urban wetlands should be developed in the green belt and peri-urban areas of Delhi.		Municipal corporations
3	Green cover inside city should be properly maintained based on the wind directions	Green cover should be maintained based on its influence over air quality. It should not act as a barrier.	Should be part of the Zonal plans and implemented widely within next 10-15 years.	Municipal corporations
4	Discourage allocation of landuse of high levels of activities in areas which already shows high level of pollution	Location of landuse which attracts high levels of activities should be discouraged in North West, North East and South East Delhi which show high level of air pollution.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments.

LONG TERM (2040)				
Sno.	Strategies	Description	Time frame	Responsible Agency
5	Siting of industries should be away from sensitive landuses.	Proposed industries should not be located in areas around sensitive landuses.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development departments
Appropriate zoning mechanisms				
1	Proper zoning of landuse based on implications of its associated activities on air quality.	Zoning of Land uses should be done only with detail study on the implications of land use and its associated activities on air quality. Long term average meteorological conditions or climate simulation modelling should be taken into consideration.	It should be incorporated as part of 2041 master plan	DDA, MoUD and states urban development and transport departments

FURTHER RESEARCH			
1	GIS based land-use plan	Preparation of existing land-use plan. (only proposed MPD2021 is in public domain right now)	DDA, MoUD and states urban development departments
2	Air pollution studies should be done alongwith Development authorities	Air Pollution Studies i.e., called Source Apportionment Study / Emission Inventory should be done in conjunction with Land Uses and Development Authorities	DPCC and CPCB
3	Land use & Activities Correlation	Controlling land use based activities and it should not entirely depend on ventilation coefficient which primarily signifies assimilative capacity of air environment.	DPCC and CPCB
4	Comprehensive Transportation Management Plan	Comprehensive Transportation Management Plan based on latest year study should be prepared.	MoUD and states urban development and transport departments
5	Conduct Air pollution model simulation with respect to urban fabric	Study on Air pollution model simulation for Delhi needs to be done to understand the effect of flow of pollutants influenced by the urban fabric and meteorological factors.	DPCC, CPCB, DDA, MoUD
6	Air Pollution Tolerant Species	Study to identify air pollution tolerant native species for Delhi	CPWD, DPCC, CPCB, DDA, MoUD

12. FUTHER STUDIES

The chapter suggests all the further studies that needs to be carried out related to landuse, built form, vegetation for control of air pollution in NCT Delhi.

NCT Delhi spread over an area of 1483 sq. kms. with a population of 16.75 million (Census 2011) and a density of 11,297 persons per sq.km is proposed to grow to 230 lakhs by 2021 and as per best fit curve model of population projection could reach upto 250 lakhs by 2030. The major environmental issue in the city is the high levels of pollution especially $PM_{2.5}$ and PM_{10} .

The urban sprawl, builtform density need to be studied to control local level increase in pollution levels. The Source Apportionment Studies and Carrying Capacity Analysis has identified zones reporting high pollution levels or hotspots. Detailed scientific studies need to be undertaken both in the hotspot areas and the other areas to arrive at patterns of landuse, built form and vegetation types that would help to contain the rise an air pollution levels .

12.1. Scientific study to correlate land use activities and air pollution

The study would include identification of planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green,recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Landuse typology**- Residential, Commercial, Industrial, Public-Semipublic, Mixed use (types of mix), recreation, waterbodies etc and trends as per the MPD,1962, PDP 1980 and MPD 2021 and proposed interventions as per MPD 2041.
- **Flooruse** – Building use and flooruse in select landuses alongwith and heights to understand the existing patterns in the selected area.
- **Study of Byelaws and Development controls**- as applicable to the landuse size of building to understand violations if any
- **Identification of activities w.r.t to Landuse –** Activity listing to arrive at air polluting activities such as traffic composition, volume, street vending, cooking, manufacturing, waste disposal etc.and identification of air polluting activoties
- **Location and spread of activities w.r.t landuse and seasons -** appropriate mapping to understand the spread and intensity of the activities
- **Preparation of emission inventory based on the air polluting activities through primary surveys**

- **Estimation of air pollution load due to the polluting activities based on appropriate emission factors**
- **Identification of aspects of landuse and built form that impact air pollution and suggestions for their management and control**

12.2. Built- form characteristics, air flow and ventilation coefficient

The study would include identification of planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green,recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Study of Byelaws and Development controls-** as applicable to the landuse, size of building to understand the applicable FloorArea Ratios, Ground Cover, setbacks etc. and violations if any
- **Built form Characteristics –** building heights, building density, open to built ratio, predominant orientation
- **Ground Level Concentration of pollution –** for $PM_{2.5}$ and PM_{10} based on GIS or applicable models
- Estimation of air pollution load due to the polluting activities based on appropriate emission factors
- **Simulation of wind flow movement seasonwise –** by application of appropriate models to arrive at areas which trap pollution
- **Suggestions for building heights, orientation etc to e included in the bye laws to enable dispersal of air pollution**

12.3. Air Pollution and Tolerant Vegetation

The study would include study of existing tree, shrub, climbers and ground cover in identified planning zones, sub zones or wards which fall into hotspot and non-hotspot areas w.r.t $PM_{2.5}$ and PM_{10} and record the air pollution trends as available from the monitoring stations in the area and study the following in the area followed by:

- **Overview of the selected area** to arrive at population, density predominant landuse, green,recreation and waterbodies, traffic characteristics, infrastructural status etc.
- **Literature study on guidelines for greenbelt development for mitigating airpollution –** species suggested for various agroclimatic zones in India and suggestions for propogation, location w.r.t air pollution source, density and width of plantations in the case of NCT Delhi
- **Pattern of existing vegetation –** location, spread and species typology along roads of various hierarchy, parks of various hierarchy, residential, institutional, commercial, industrial areas, along waterbodies and within urban /city forests w.r.t – type of species, height spread, canopy size (large shrubs and trees), evergreen/deciduous, leaf characteristics,

condition etc

- **Air Pollution Tolerance Index –** estimation of the APTI of existing vegetation based on laboratory analysis of samples from the area
- **Suggestion for selection of the right vegetation to enhance air pollution exposure/ mitigation for study area–** type of species mix, propogation, location and maintenance for existing area
- **Suggestion for selection of the right vegetation to enhance air pollution exposure/ mitigation for NCT Delhi–** type of species mix w,r.t. various transport corridors Industrial, Commercial, Instititional, Residential landuses including propogation, location and maintenance guidelines

12.4. Delineation of Air Shed of NCT Delhi

Airshed is roughly analogous to the concept of the watershed and considers air basins as geographical areas that share the same air because of topography, meteorology and climate. To address the problem of air pollution comprehensively, Sagnik Dey, Associate Professor at IIT-Delhi and Coordinator for the Centre for Excellence for Research for Clean Air (CERCA), said, **"We need to delineate airsheds based on wind flows and their pollutant reach. The city action plans should be integrated with the larger airshed management strategy to deal with the problem".**

An approach of delineating Airshed can been developed with focus on inflows and outflows. The quality of air is influenced by the intensity of activity(ies). Cities are dependent on each other for goods, raw materials, employment opportunities, etc. Therefore, identifying the intensity of flows will help in building a functional relationship between the dominant centre (focus area) and the surrounding cities/towns

- **Gravitation Analysis between cities adjoining NCT Delhi in NCR** – Ghaziabad, Noida, Greater Noida, Faridabad, Gurugram, Jhajjar, Sonepat, Baghpat etc. to understand the intensity of activities and flows between these cities and implication on air pollution load.
- **Sources of Pollution in NCR –** Identification of sources of pollution based on latest Source Apportionment studies conducted for NCR
- **Estimation of Ground Level Concentrations of air pollutants pollutants -** based on appropriate models w.r,t identified sources
- **Delineation of Airshed of NCT Delhi-**guidelines for development and recommendations for regulation of landuse and acivities in the Delineated region.

References

DPCC, 2020. Delhi Pollution Control Committee. [Online]
Available at: http://www.dpcc.delhigovt.nic.in/indexup.php

Census, 2020. District Statistical Handbook, 2011. [Online]
Available at: https://censusindia.gov.in/

CPCB, 2014-15. National Air Quality Index, New Delhi: CPCB.

CPCB, 2020. Central Pollution Control Committee. [Online]
Available at: https://cpcb.nic.in/

CPCB, 2020. National Ambient Air Quality Data. [Online]
Available at: https://app.cpcbccr.com/ccr/

CPCB, 2020. Source Apportionment Studies. [Online]
Available at: https://cpcb.nic.in/source-apportionment-studies/

Aleem, Z., 2020. India takes a small step toward relaxing its strict lockdown. [Online]
Available at: https://www.vox.com/2020/4/25/21236183/india-coronavirus-lockdown-small-business
[Accessed 25 April 2020].

Clarke, P., 2020. Planting more trees could backfire, warn government advisers. [Online]
Available at: https://www.fwi.co.uk/news/environment/planting-more-trees-could-backfire-warn-government-advisers

Anuja, 2020. Taking cues from Odisha, Punjab extends lockdown till 1 May. [Online]
Available at: https://www.livemint.com/news/india/taking-cues-from-odisha-punjab-extends-lockdown-till-1-may-11586520697517.html
[Accessed 10 April 2020].

Aristodemou, E. et al., 2018. How tall buildings affect turbulent air flows and dispersion of pollution within a neighbourhood. Environmental Pollution, Science Direct, 35(15), pp. 2679-2695.

Banerjee, A., 2020. Coronavirus lockdown extended till 31 May, says NDMA. [Online]
Available at: https://www.livemint.com/news/india/covid-19-lockdown-4-0-coronavirus-lockdown-extended-till-31-may-says-ndma-11589715203633.html
[Accessed 17 May 2020].

BBC News, 2020. Coronavirus lockdown guidelines: What has India changed under new rules?. [Online]
Available at: https://www.bbc.com/news/world-asia-india-52290761
[Accessed 15 April 2020].

BBC News, 2020. India coronavirus: All major cities named Covid-19 'red zone' hotspots. [Online]
Available at: https://www.bbc.com/news/world-asia-india-52306225
[Accessed 16 April 2020].

Bhaskar, U., 2020. India to remain closed till 3 May, economy to open up gradually in lockdown 2.0. [Online]
Available at: https://www.livemint.com/news/india/pm-modi-announces-extension-of-lockdown-till-3-may-11586839412073.html
[Accessed 14 April 2020].

CSE, 2020. Breathing Space: How to Track and Report Air Pollution Under the National Clean Air Programme, New Delhi: CSE.

Dutta, P. K., 2020. In coronavirus lockdown extension, Modi wields stick, offers carrot on exit route. [Online]
Available at: https://www.indiatoday.in/coronavirus-outbreak/story/in-coronavirus-lockdown-extension-modi-wields-stick-offers-carrot-on-exit-route-1666741-2020-04-14
[Accessed 14 April 2020].

Garg, A., Bhattacharya, S., Shukla, P. & Dadhwal, V., 2001. Regional and Sectoral Assessment of Greenhouse Gas Emissions in India. Atmospheric Environment, Science Direct, 35(10.1016/S1352-2310(00)00414-3), pp. 2679-2695.

Gettleman, J. & Schultz, K., 2020. Modi Orders 3-Week Total Lockdown for All 1.3 Billion Indians. [Online]
Available at: https://www.nytimes.com/2020/03/24/world/asia/india-coronavirus-lockdown.html
[Accessed 24 March 2020].

Ghosh, D., 2020. "Unlock1": Malls, Restaurants, Places Of Worship To Reopen June 8. [Online]
Available at: https://www.ndtv.com/india-news/lockdown-extended-till-june-30-malls-restaurants-can-reopen-from-june-8-except-in-containment-zones-2237910
[Accessed 30 May 2020].

Ghosh, D., 2020. Lockdown For 2 More Weeks. What Will Be Different Now: 10 Points. [Online]
Available at: https://www.ndtv.com/india-news/nationwide-lockdown-over-coronavirus-extended-for-two-weeks-beyond-may-4-2221782
[Accessed 2 May 2020].

Grover, A. & Singh, R. B., October 2019. Urban Health and Wellbeing. Springer Nature Singapore Pte Ltd. 2020: Springer, Singapore.

Gupta, S., 2020. Covid hasn't gone viral in India yet, but some in the world & at home can't accept the truth. [Online]

Available at: https://theprint.in/national-interest/covid-hasnt-gone-viral-in-india-yet-but-some-in-the-world-at-home-cant-accept-the-truth/404178/
[Accessed 18 April 2020].

Guttikunda, S., 2010. Role of meteorology on Urban Air Pollution Dispersion: A 20yr analysis for Delhi, New Delhi: UrbanEmission.Info.

Guttikunda, S., 2019. Primer on Pollution Source Apportionment. [Online]
Available at: https://urbanemissions.info/publications/primer-on-pollution-source-apportionment/
[Accessed 1 March 2020].

Guttikunda, S. K. & Gurjar, B. R., 2012. Role of meteorology in seasonality of air pollution in megacity Delhi. Environmental Monitoring and Assessment, Springer, 184(https://doi.org/10.1007/s10661-011-2182-8), pp. 3199-3211.

Hindustan Times, Bengaluru, 2020. Covid-19: Karnataka extends lockdown by 2 weeks, throws in some relaxations. [Online]
Available at: https://www.hindustantimes.com/india-news/covid-19-karnataka-extends-lockdown-by-2-weeks-throws-in-some-relaxations/story-03KKPWk1Hu6Xe2ThcFhBWI.html
[Accessed 11 April 2020].

ID, S., 2011. Local Climate Zone Classification System,. In: Redefining the Urban Heat Island. Vancouver, Canada: University of Columbia.

IHME, 2016. The Cost of Air Pollution, Strengthening the Economic Case for Action, 1818 H Street NW, Washington, DC 20433: International Bank for Reconstruction and Development/ The World Bank.

India Today, 2020. Day 1 of coronavirus lockdown: India registers 101 new cases, 3 deaths; Govt says working to deliver essential services. [Online]
Available at: https://www.indiatoday.in/india/story/day-1-of-coronavirus-lockdown-india-registers-88-new-cases-3-deaths-govt-says-working-to-deliver-essential-services-1659742-2020-03-25
[Accessed 25 March 2020].

India Today, 2020. Rs 2.3 trillion for 1.3 billion: Govt to announce stimulus package to fight coronavirus, says report. [Online]
Available at: https://www.indiatoday.in/india/story/coronavirus-stimulus-package-for-businesses-poor-modi-govt-1659698-2020-03-25
[Accessed 26 March 2020].

India Today, 2020. What is Janata Curfew: A curfew of the people, by the people, for the people to fight coronavirus. [Online]
Available at: https://www.indiatoday.in/india/story/janata-curfew-to-fight-coronavirus-pm-modi-

urges-citizens-to-stay-off-roads-from-7-am-to-9-pm-on-sunday-1657581-2020-03-19
[Accessed 19 March 2020].

Industries and Mines Department, 2015. GUJARAT INDUSTRIAL POLICY 2015, Gujarat: Industries Commissionerate, Government of Gujarat.

Jayasinghe, A., Sano, K. & Rattanaporn, K., 2017. Application for developing countries: Estimating trip attraction in urban zones based on centrality. Journal of Traffic and Transportation Engineering, Science Direct, 4(5), pp. 464-476.

Kumar, A., 2016. Zoning g Atlas for Siting of Industries. [Online]
Available at: http://cdn.cseindia.org/userfiles/CEPI.pdf
[Accessed 5 April 2020].

MoEF&CC, 2011. Guidelines for declaration of Eco-senstive Zones around National Parks and Wildlife Sanctuaries, New Delhi: MoEF&CC.

MoEF&CC, 2018. Proforma for Environmental Appraisal of Mining Projects. [Online]
Available at: http://moef.gov.in/wp-content/uploads/2018/04/q-min.pdf
[Accessed 1 May 2020].

MoHFW, 2020. Latest Updates, Ministry of Health and Family Welfare. [Online]
Available at: https://www.mohfw.gov.in/
[Accessed 29 March 2020].

MoHUA, 2016. Model Buyilding Bye-Laws, 2016. [Online]
Available at: http://mohua.gov.in/upload/uploadfiles/files/MBBL.pdf
[Accessed 2 April 2020].

NCRPB, 2020. Functional Plan on Transport for National Capital Region, New Delhi: National Capital Region Planning Board.

NEgi, M. S., 2020. Close schools, all religious activities, extend lockdown: States tell Centre. [Online]
Available at: https://www.indiatoday.in/india/story/close-schools-all-religious-activities-extend-lockdown-states-tell-centre-1664354-2020-04-07
[Accessed 7 April 2020].

News 18, 2020. PM Modi Speech on Coronavirus Highlights: Janata Curfew on Sunday, Avoid Panic Buying. [Online]
Available at: https://www.news18.com/news/india/pm-modi-speech-on-coronavirus-highlights-janata-curfew-on-sunday-avoid-panic-buying-2543315.html
[Accessed 19 March 2020].

Oke, T., 1987. Boundary Layer Climates, Second Edition. s.l.:Tylor & Francis Group.

Ramesh, S. & Basu, M., 2020. R0 data shows India's coronavirus infection rate has slowed, gives lockdown a thumbs up. [Online]
Available at: https://theprint.in/science/r0-data-shows-indias-coronavirus-infection-rate-has-slowed-gives-lockdown-a-thumbs-up/399734/
[Accessed 14 April 2020].

RITES, April 2010. Transport Demand and Forecast and Development of Public Transport Network, New Delhi: RITES.

Sabnavis, M., Kansara, D. & Mishra, M., 2019. Indian Hotel Industry - Review & Prospects, Mumbai: CARE Ratings Limited.

Sankrit, R., 2015. SEWA Bharat and Street Vendors in Delhi, Delhi: Inclusive Cities Project.
Sharma, N. C., 2020. India lacks transparency in sharing air quality data, says report. [Online]
Available at: https://www.livemint.com/news/india/india-lacks-transparency-in-sharing-air-quality-data-says-report-11594272281071.html

Sharma, V., 2018. Delhi civic agencies find easy solution for waste problem by burning it. [Online]
Available at: https://www.hindustantimes.com/delhi-news/delhi-civic-agencies-find-easy-solution-for-waste-problem-by-burning-it/story-C2K5Uk6twSmL55vDouBWnK.html
[Accessed 1 March 2020].

Singh, K. D., Goel, V., Kumar, H. & Gettleman, J., 2020. India, Day 1: World's Largest Coronavirus Lockdown Begins. [Online]
Available at: https://www.nytimes.com/2020/03/25/world/asia/india-lockdown-coronavirus.html
[Accessed 25 March 2020].

Stewart, I. D. & Oke, T. R., 2012. Local Climate Zones for Urban Temperature Studies. Bulletin of the American Meteorological Society, 93(12), pp. 1879-1900.
Thakur, J., 2020. Pollutants enter Delhi via three distinct air corridors during winters: Study. [Online]
Available at: https://www.hindustantimes.com/india-news/scientists-identify-three-distinct-corridors-through-which-pollutants-enter-delhi-during-winters/story-QSqsDYU2kDQyRSAScGwjiL.html

The Economic Times, 2020. Covid-19: People flock to wholesale markets in UP, West Bengal amid lockdown. [Online]
Available at: https://economictimes.indiatimes.com/news/politics-and-nation/covid-19-people-flock-to-wholesale-markets-in-up-west-bengal-amid-lockdown/videoshow/74787095.cms
[Accessed 24 March 2020].

The Economic Times, 2020. Lockdown 4.0 guidelines: Nationwide lockdown extended till May 31, with considerable relaxations. [Online]
Available at: https://economictimes.indiatimes.com/news/politics-and-nation/centre-extends-

nationwide-lockdown-till-may-31-with-considerable-relaxations/articleshow/75790821.cms
[Accessed 21 May 2020].

The Hindu, 2020. India lockdown 4.0 guidelines | What's allowed and what's not?. [Online]
Available at: https://www.thehindu.com/news/national/lockdown-40-guidelines-whats-allowed-and-whats-not/article31609394.ece
[Accessed 18 May 2020].

The Tribune, 2020. Centre extends nationwide lockdown till May 31, new guidelines issued. [Online]
Available at: https://www.tribuneindia.com/news/nation/centre-extends-nationwide-lockdown-till-may-31-new-guidelines-issued-86042
[Accessed 17 May 2020].

Times, H., 2020. Covid norms to shape Delhi's next Master Plan. [Online]
Available at: https://m-hindustantimes-com.cdn.ampproject.org/c/s/m.hindustantimes.com/cities/covid-norms-to-shape-delhi-s-next-master-plan/story-tnXtX2PBuYzPxW3JPEzmqJ_amp.html

UN News, 2020. COVID-19: Lockdown across India, in line with WHO guidance. [Online]
Available at: https://news.un.org/en/story/2020/03/1060132
[Accessed 24 March 2020].

Vishnoi, A., 2019. IIT Kanpur had warned CPCB about pollution in early Oct. [Online]
Available at: https://economictimes.indiatimes.com/news/politics-and-nation/iit-kanpur-had-warned-cpcb-about-pollution-in-early-oct/articleshow/71915105.cms
[Accessed 1 March 2020].

Voices, E., 2020. Satellite images: Air pollution in India plummets. [Online]
Available at: https://go.shr.lc/3cOrwds

Weng, Q. & Yang, S., 2006. Urban Air Pollution Patterns, Land Use, and Thermal Landscape: An Examination of the Linkage Using GIS. Springer, 117(10.1007/s10661-006-0888-9), pp. 463-489.