(Integrated M.Tech X Semester Dissertation Presentation)

Evaluating the impact of COVID-19 induced lockdown on the environment of major settlements in India

INTEGRATED MASTER IN TECHNOLOGY IN GEOINFORMATICS

By
Shashank Bhaskar
CUJ/I/2016/IGEO/26

Under the supervision of
Dr. Amit Kumar
Assistant Professor & Coordinator, DGI

Department of Geoinformatics
(School of Natural Resource Management)
Central University of Jharkhand
Ranchi - 835205

Introduction

- Coronavirus disease (COVID-19) caused by SARS-CoV-2 first reported in Wuhan, China in late December 2019 (Chen et al., 2020). Subsequently, it spreads to the larger parts of the globe very rapidly through human transmission (**WHO, 2020**).
- In India, the first positive case of COVID-19 was reported on 30 January 2020 in Kerala, when a student arrived from China (**Reid, 2020**), and later a set of cases was recorded across Delhi with a tourist group of 14 Italian, and 01 Indian on 03 March 2020 (**Perappadan, 2020**).
- To interrupt the infection cycle in India, a nation-wide lockdown was implemented from March 25 to April 14, 2020, and it was then extended until May 31, 2020, i.e. Phase 1 (March 25 to April 14), Phase 2 (15 April to 3 May), Phase 3 (4–17 May), and Phase 4 (18–31 May). As the number of COVID-19 cases rises every day in its second wave, governments are implementing strict restrictions on people's movements in order to prevent the disease from spreading further.
- It is the biggest lockdown in history with a ~1.3526 billion population under the direct impact. This lockdown led to the shutdown of all industries, businesses, parks, educational institutions, rail, road, and air transportations, and other crucial social interactions. Very essential activities and services including medical, security, and food supply remained out of shutdown implementation.

Source: AFP

OBJECTIVES

1. To deduce the impact of the COVID-19 pandemic induced lockdown on atmospheric pollution in the urban and peri-urban environment (CO, NO_2 , SO_2, PM2.5) of major Indian cities.
2. To assess the changes in vegetation cover using different biophysical parameters.
3. To analyse the implications of COVID-19 induced lockdown on various urban function
4. To analyze and to verify the change in the quality of water of Yamuna river due to lockdown.
5. To analyse the impact of COVID-19 in regions of major inequality during the major disaster events.

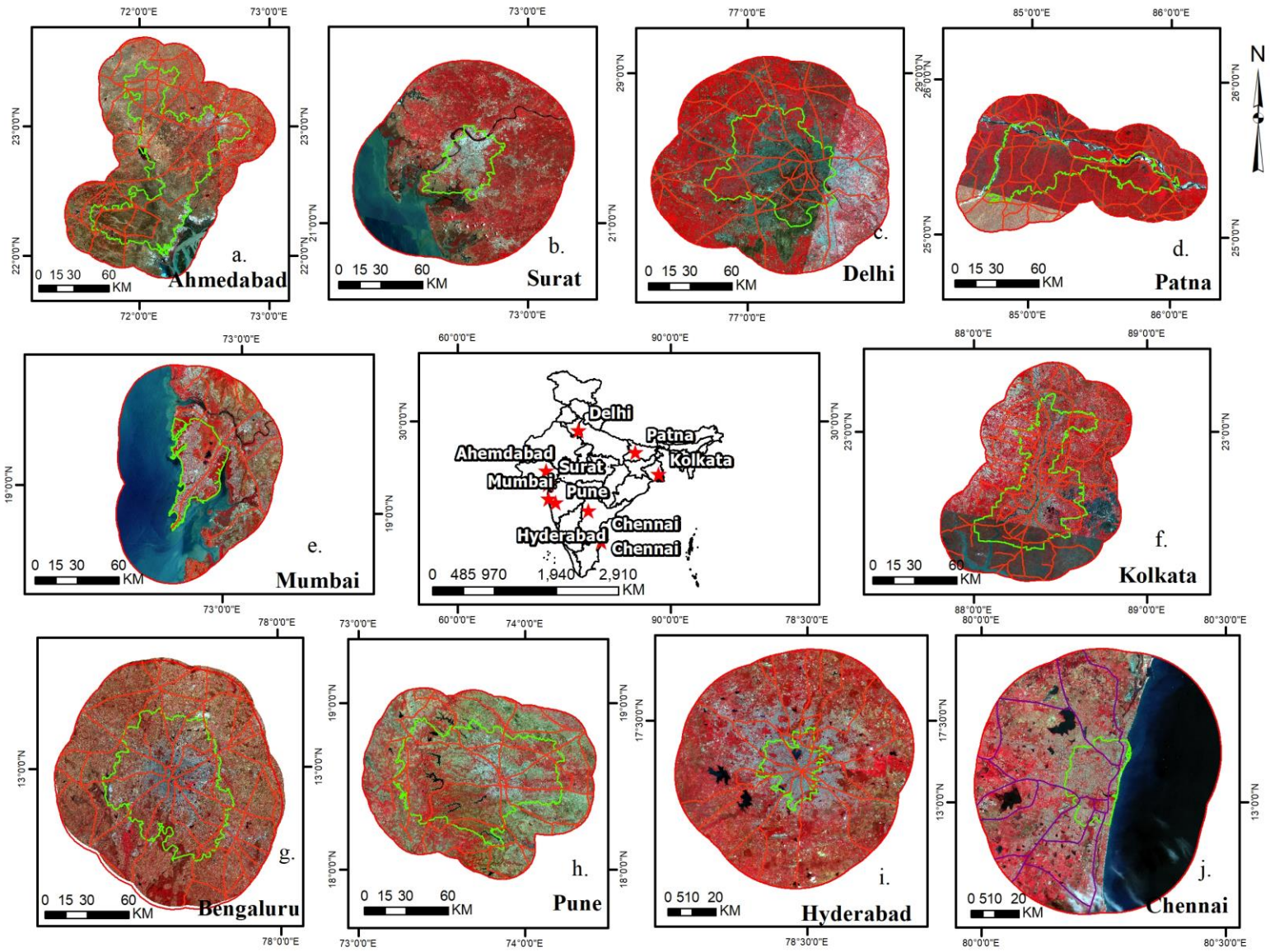
Literature Review

- The Northern parts of India are subjected to poor air quality and atmospheric pollution, mainly due to emissions from vehicles, industry, brick kilns, coal-based power plants, and crop residue burning (Singh et al. 2004, Prasad et al. 2006, Venkataraman et al. 2018).
- The air quality and atmospheric pollution in China has improved in recent years, whereas in India, the poor air quality has persistently increased over the last several decades associated with growing anthropogenic activities (**Chauhan and Singh 2017, Sarkar et al. 2018, 2019**).
- Wang et al. carried out an analysis of PM2.5 data in a number of Chinese cities, Beijing, Shanghai, Guangzhou, and Wuhan during COVID-19, and found a pronounced reduction in air pollution attributed to the reduction of emissions in transportation and industrial sectors. Muhammad et al. (2020) found 20–30%reduction in emission of NO2 in China, Spain, France, Italy, and the USA due to lockdown. Chauhan and Singh (2020) observed a decline in PM2.5 in major cities of the world.
- Coccia (2020) analysed the geo-environmental and demographic characteristics of 55 Italian cities and their relationships with the dynamics of COVID-19. The study identified, for each city, its distance from the sea, latitude, population density, air pollution levels (PM10 or ozone), climatic variables of these months (average temperature, relative humidity, predominant wind speed, rainy and foggy days), and spatial-temporal characteristics of COVID-19 and of infected people.

Need for study

- COVID-19 has disrupted the economies and the lives of individuals around the world. There are many areas of research needed regarding COVID-19. Lockdown have influenced the quality of the global environment because of decreased emissions of atmospheric pollutants.
- COVID-19 has spread its arms to 200 countries globally and the megacities of the world were particularly affected with a large number of infections and deaths, which is still increasing day by day.
- This study takes ten megacities (Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Surat, Pune, Ahmedabad and Patna) of India for a comprehensive assessment of the dynamicity of environmental quality resulting from the COVID-19 induced lockdown situation.
- In order to analyze the impact of COVID-19 on people’s lives, activities, and the natural environment, this study will investigate the spatial and temporal characteristics of Nighttime Light (NTL) radiance.

STUDY AREA



City	Area (Km²)	Elevation (m)
Delhi	1484	216
Mumbai	603	14
Kolkata	206	9
Chennai	426	7
Hyderabad	625	542
Bengaluru	741	920
Patna	109	53
Pune	331	560
Ahmedabad	464	53
Surat	474	13

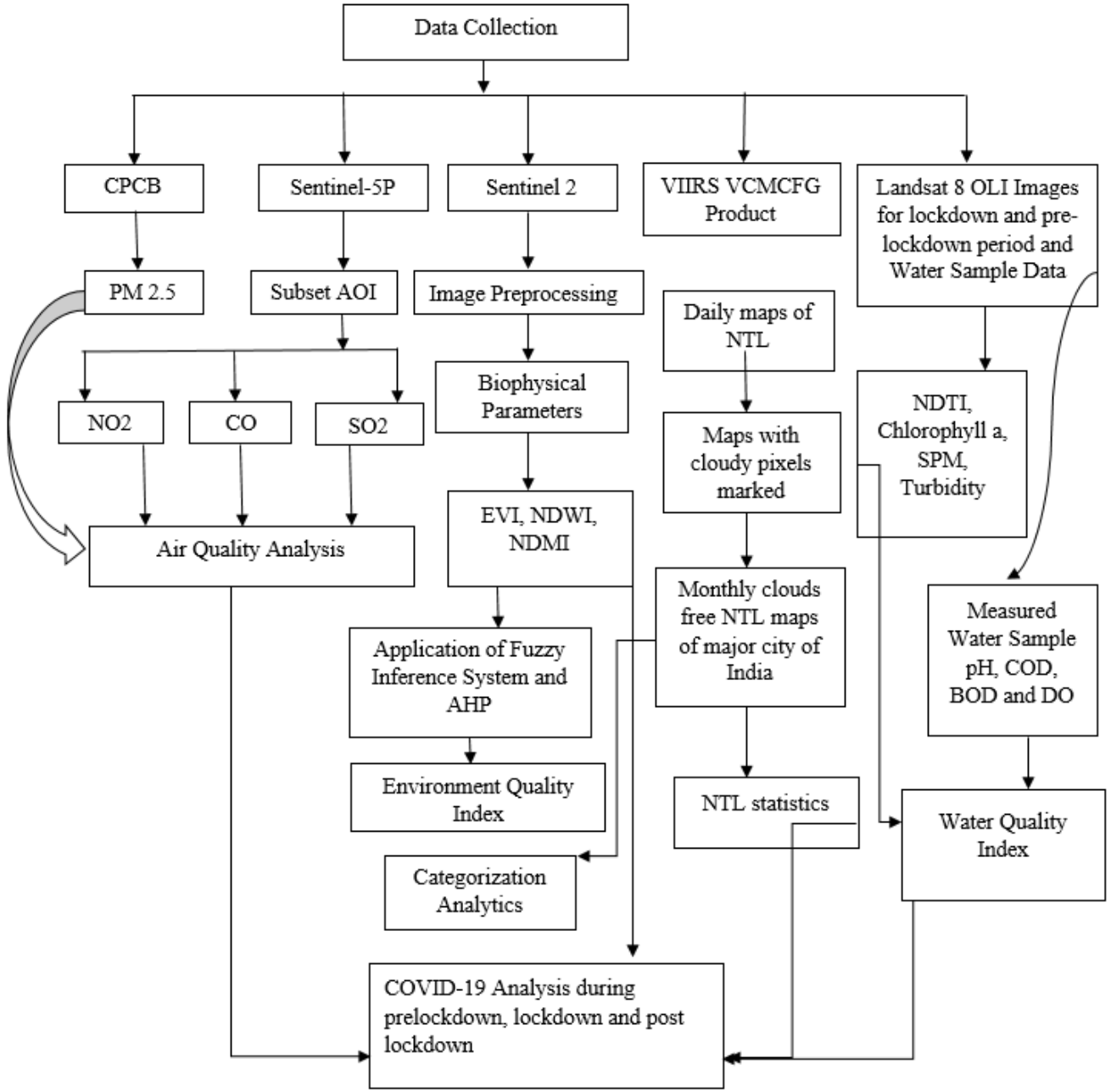
Data Used

Datasets	Spatial resolution	Temporal resolution	Source	Dataset Provider
Nitrogen Dioxide	0.01°	Daily	Sentinel 5P	European Union/ESA/Copernicus
Carbon Monoxide	0.01°	Daily	Sentinel 5P	European Union/ESA/Copernicus
Sulfur Dioxide	0.01°	Daily	Sentinel 5P	European Union/ESA/Copernicus
PM 2.5	–	Daily		CPCB
Sentinel 2	10 m	15-30 days (cloud free products)	Sentinel 2A/2B	European Union/ESA/Copernicus
COVID-19 Report	–	–	WHOd/John Hopkinse	
VIIRS VCMCFG	15 arc seconds			Earth Observation Group, Payne Institute for Public Policy, Colorado School of Mines
Landsat 8	30 m	16-day repeat cycle	Landsat 8 OLI	USGS
Google Mobility Data		Daily		Google Community Mobility Reports
Water Sample Data (pH, BOD, COD and DO)				CPCB

Software Used

- Google Earth Engine, Python, and Arc GIS

Methodology



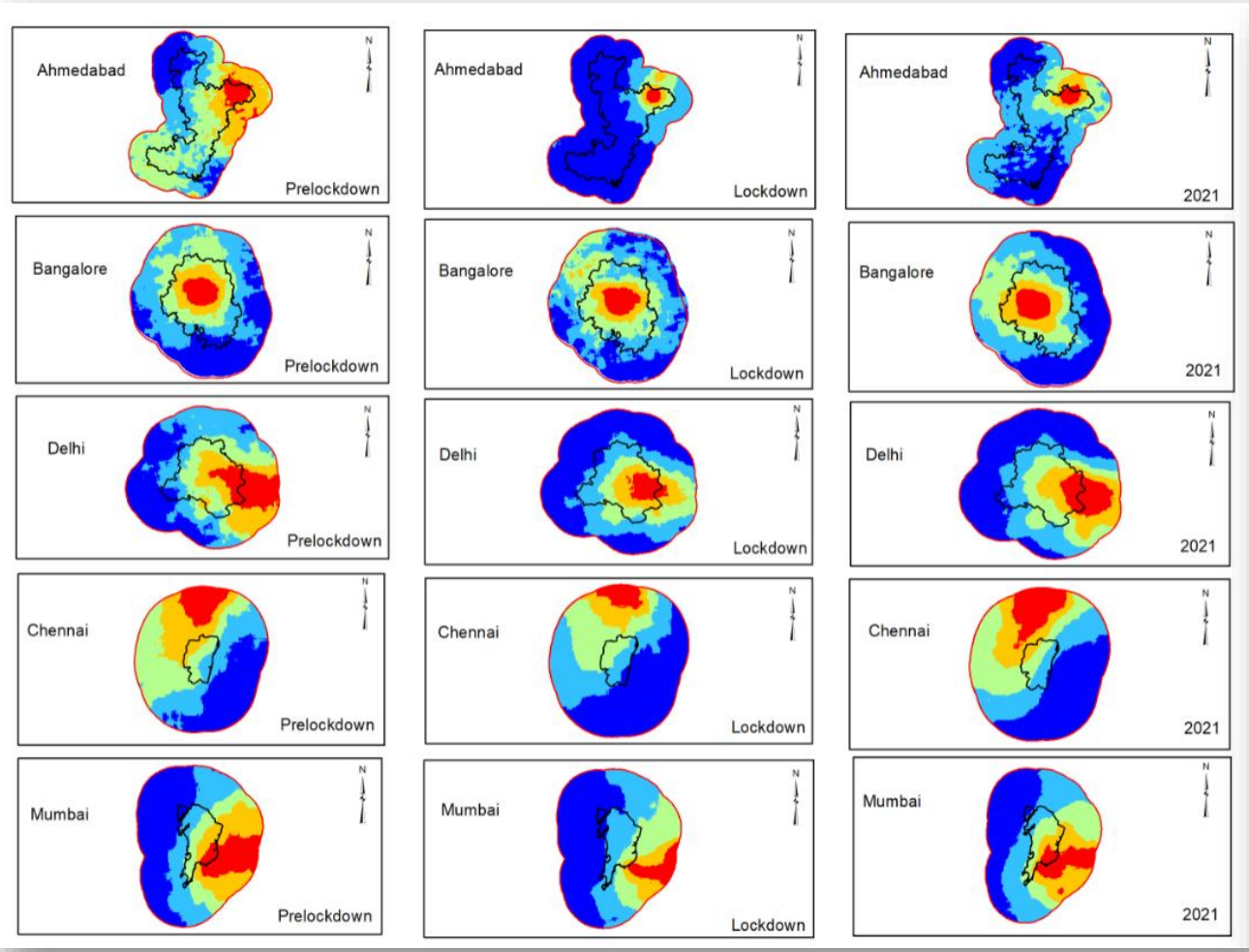
Chapter 1: Analyzing the impact of the COVID-19 pandemic induced lockdown on atmospheric pollution in the urban and peri-urban environment of major Indian cities

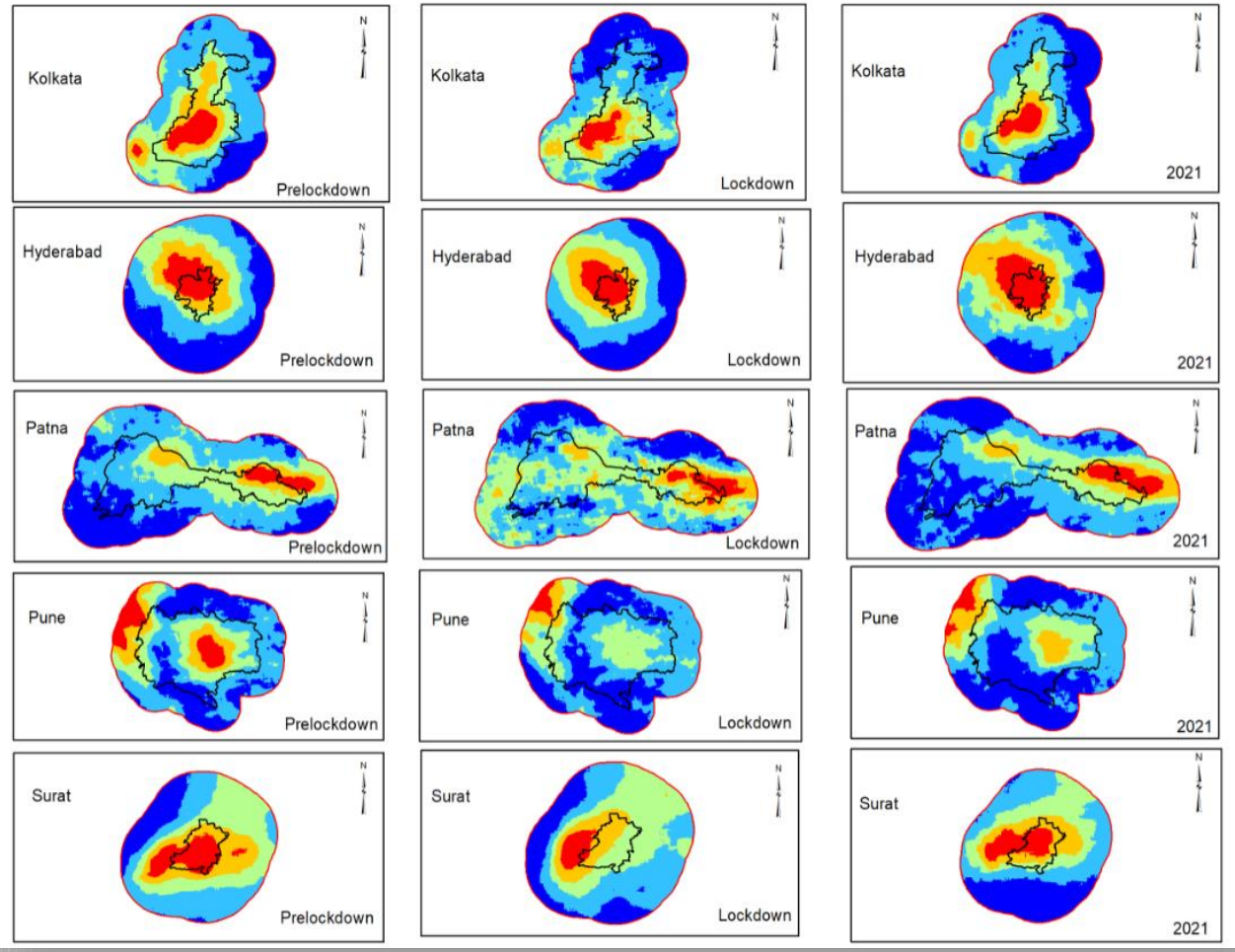
Introduction

- Indian metro cities have been among the top 20 most polluted cities in the world, exceeding the quality of the CPCB India's defined air quality index (AQI) and thus the World Health Organization (WHO).
- According to the Central Pollution Control Board of India (CPCB), the major five constituents of air pollution are particulate matters (PM), Nitrogen oxide (NO2), Sulphur dioxide (SO2), carbon monoxide (CO), and ozone (O3) and, among them, the most prevalent threats for human health are PM10 and PM2.5.
- In India, approximately a million people died in 2015 as a result of high levels of ambient PM.
- Environmental quality data collected across time and space in India's megacities may be required to design new strategies to support continued development.
- In the past 4 to 5 years, Delhi has often featured in the list of cities that do not comply with the national ambient air quality standards. Moreover, it has also been included among the world’s most polluted cities on multiple occasions.
- The average annual concentration of PM during 2013 to 2018 was consistently above 250 ug m-3 (AQI poor); However, also includes the period of monsoon, during which the PM levels remain low, and the air quality is usually worst during winter when conditions for pollutant dispersion are unfavorable.

Results and Discussion

Nitrogen Dioxide Concentration during pre-lockdown (March 25- 31 May 2019), Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)

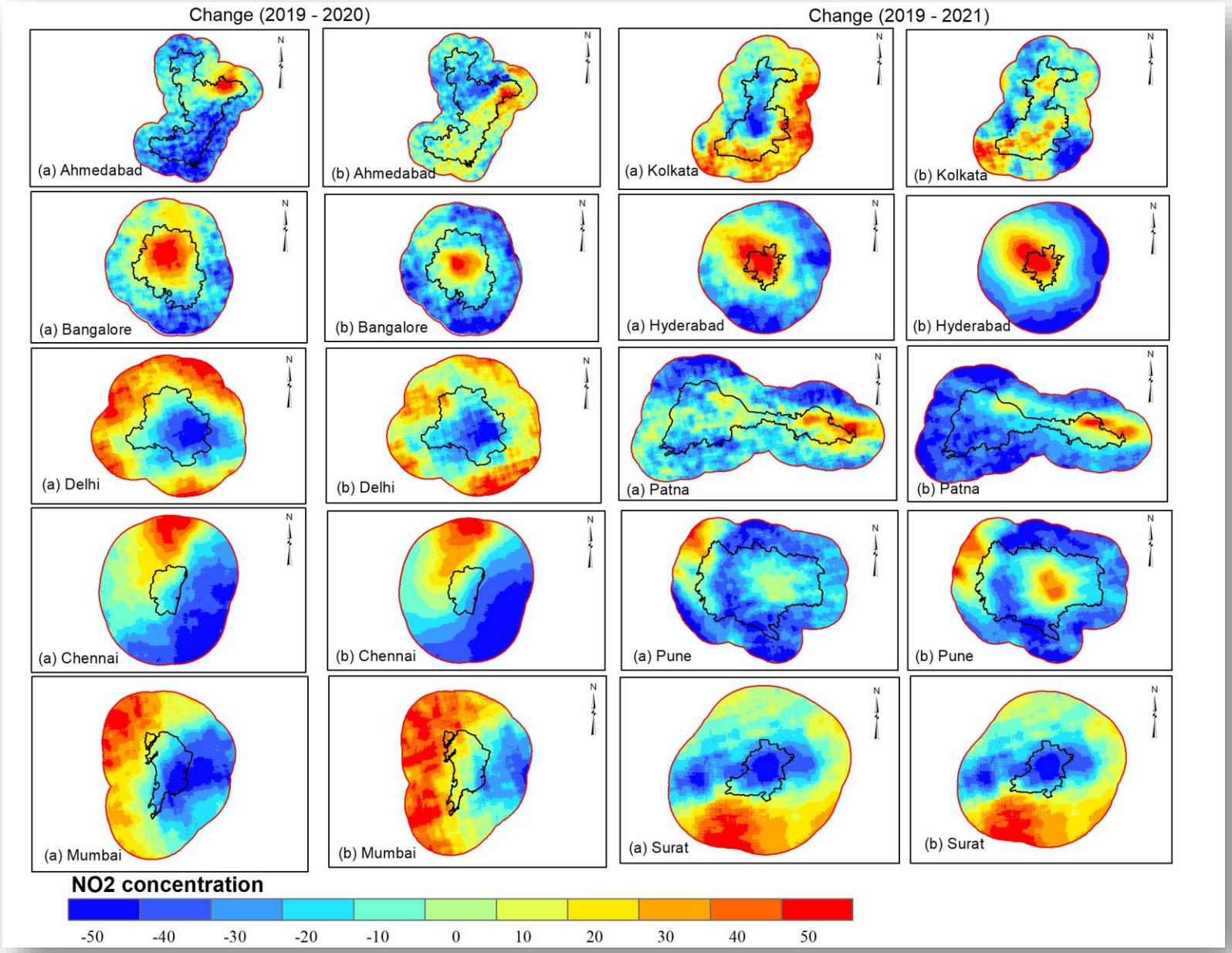




NO2 Concentration (mol/m^2)

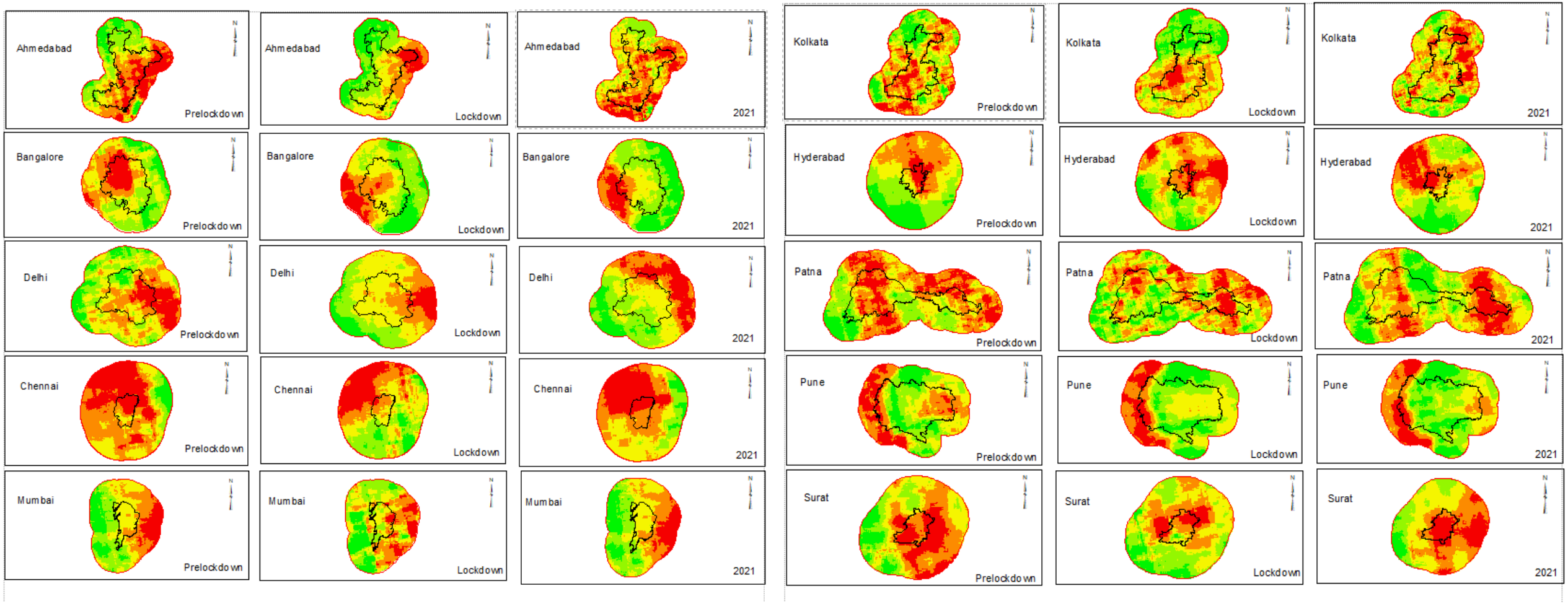
< 0.00003 | 0.00003 - 0.00004 | 0.00004 - 0.00005 | 0.00004 - 0.00007 | > 0.00007

0 15 30 60 90 120 KM

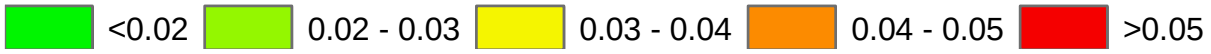


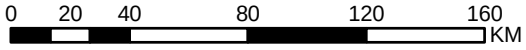
- The variations of the mean NO2 conc. over the Delhi in 2019 is 0.00026 mol/m2 but in 2020 it dropped to 0.000011 mol/m2 decreased by 49% and again it started to rise in 2021 0.00002 mol/m2 with a increased by 30% .
- The variations of the mean NO2 conc. over the Mumbai in 2019 is 0.00023 mol/m2 but in 2020 it dropped to 0.00011 mol/m2 decreased by 12% and again it dropped in 2021 0.00016 mol/m2 with a decreased by 35% .
- The variations of the mean NO2 conc. over the Bangalore in 2019 is 0.00012 mol/m2 but in 2020 it dropped to 0.000081 mol/m2 decreased by 36% and again it rise in 2021 0.000012 mol/m2 with a increased by 45% .
- The variations of the mean NO2 conc. over the Kolkata in 2019 is 0.00016 mol/m2 but in 2020 it dropped to 0.00011 mol/m2 decreased by 6% and again it started to rise in 2021 0.000013 mol/m2 with a increased by 42%

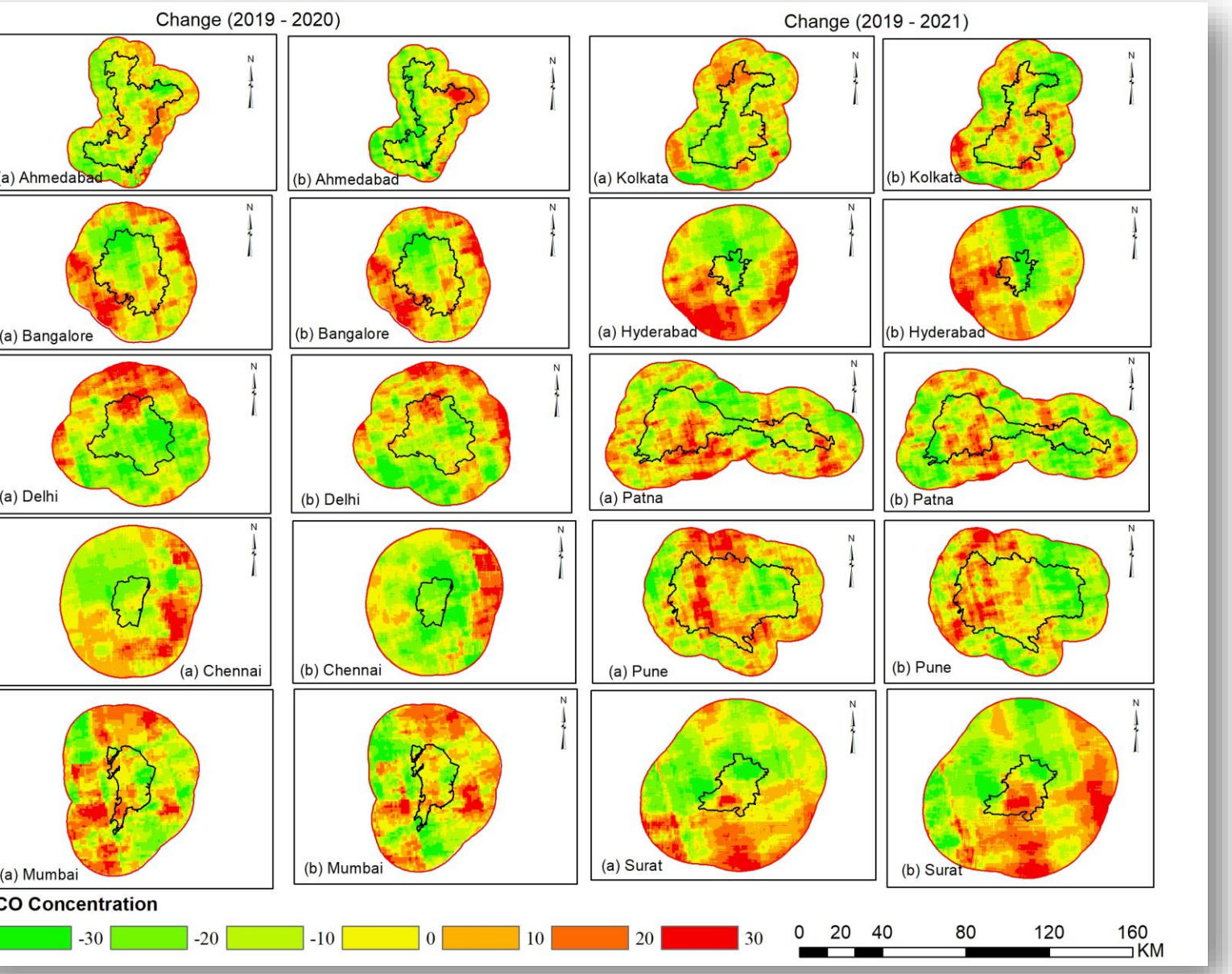
Carbon Monoxide Concentration during pre-lockdown (March 25- 31 May 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)



CO (mol/m^2)

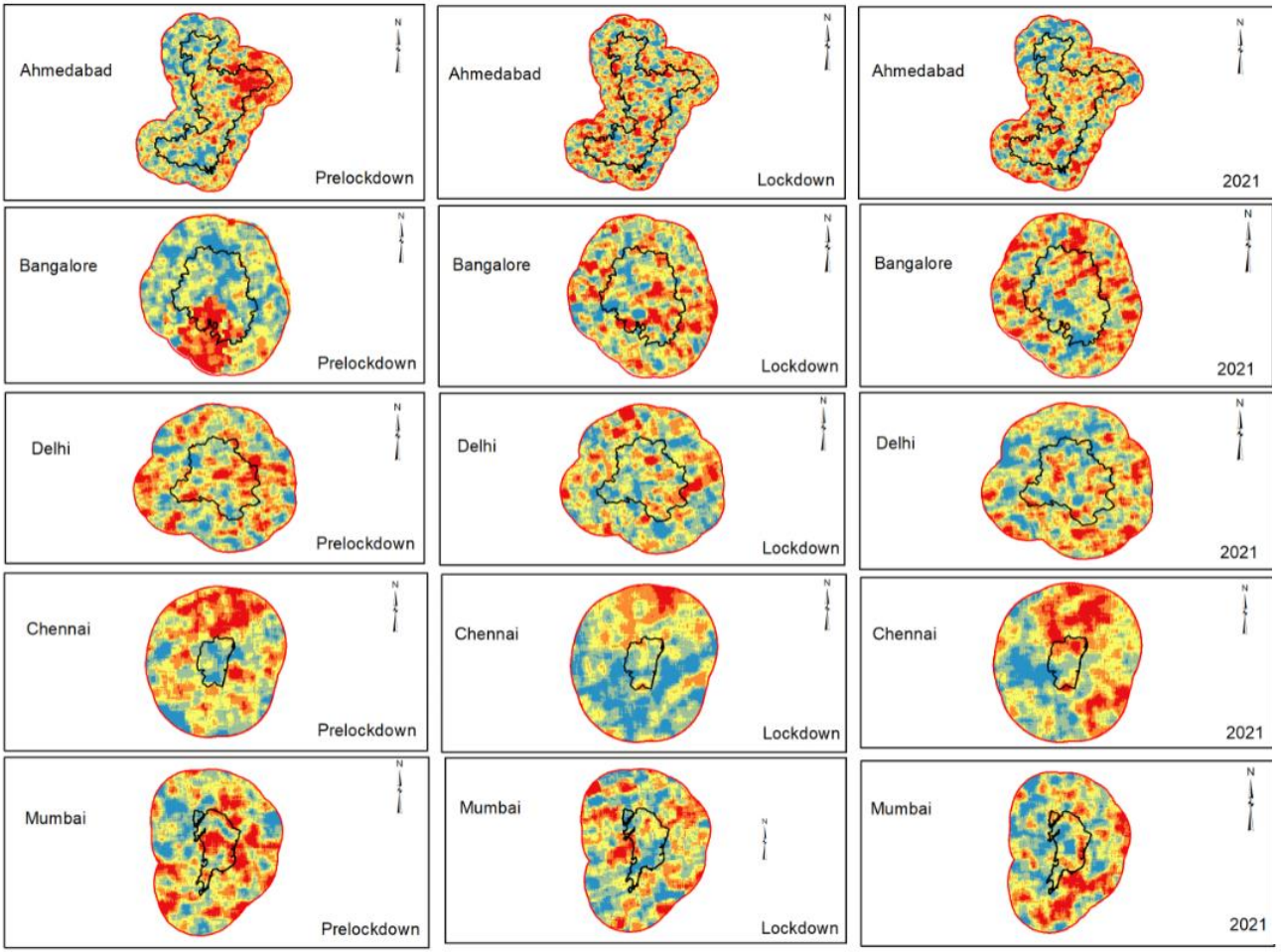


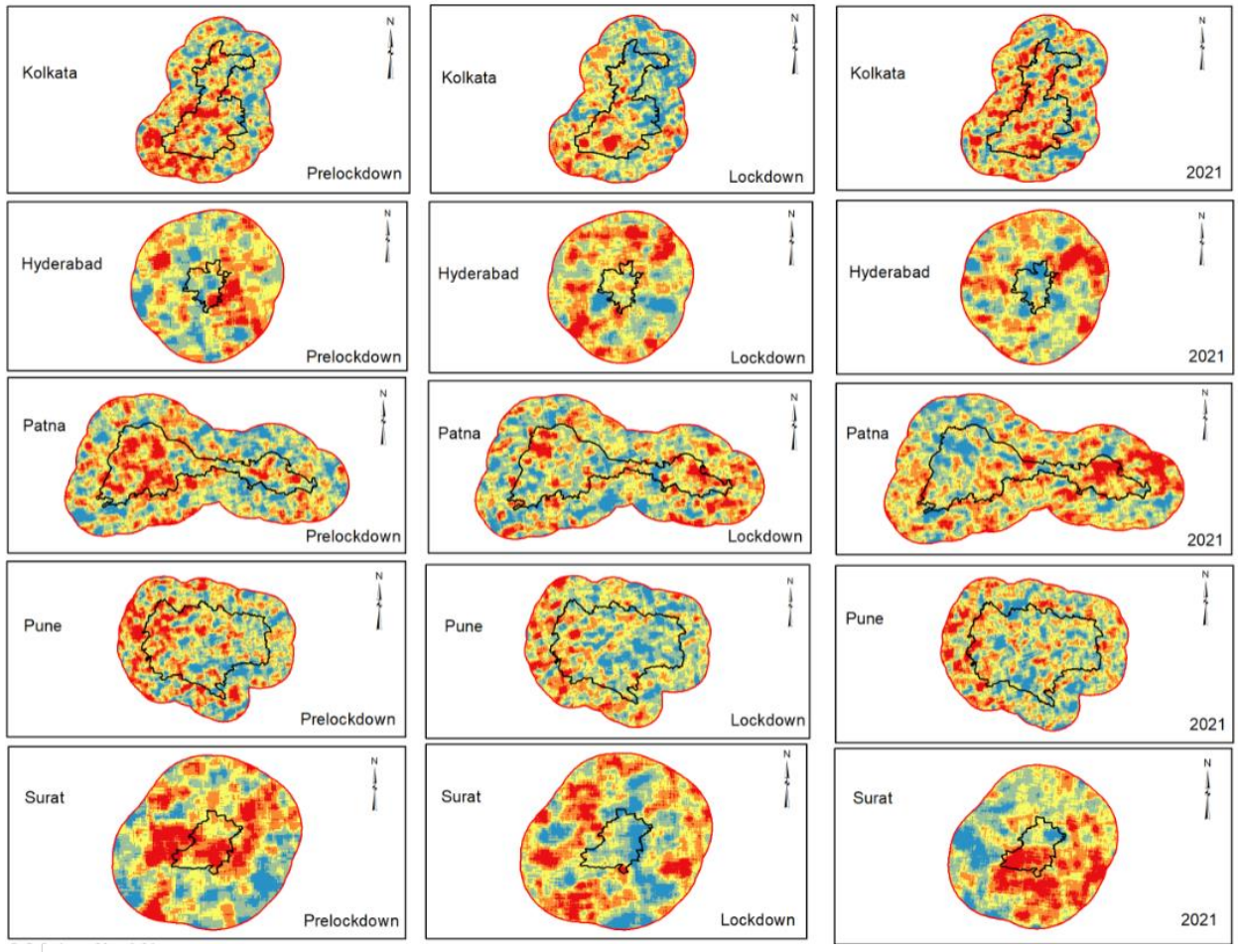




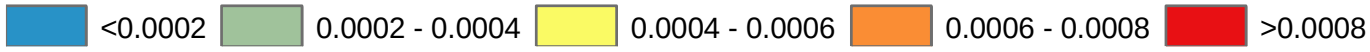
- CO was identified to be the most prominent air pollutant as its average concentration across cities in 2019, and 2020 varied between 0.0175 to 0.0565 and 0.0194 – 0.0471 mol/m2, respectively.
- CO levels decreased significantly (p=0.000) during the lockdown period, however the magnitude of the drop was smaller than that of NO2.
- The total reduction in average CO levels in 2020 across cities was1-8% and the same during the period of lockdown 2 was 1-6%. Only basic services were permitted in April, which was the most substantial cut.
- Mean CO concentration over Delhi in prelockdown 2019 was 0.0427 mol/m2, in lockdown 1 mol/m2 was 0.0426 and during lockdown 2 was 0.0453 mol/m2.
- Variations CO concentration anomaly was decreased by 12 % during lockdown 1 from prelockdown, 2019 period again it went up by 15% during lockdown 2 from the base year 2019 (Prelockdown).

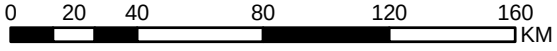
Sulfur dioxide Concentration during pre-lockdown (March 25- 31 May 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)



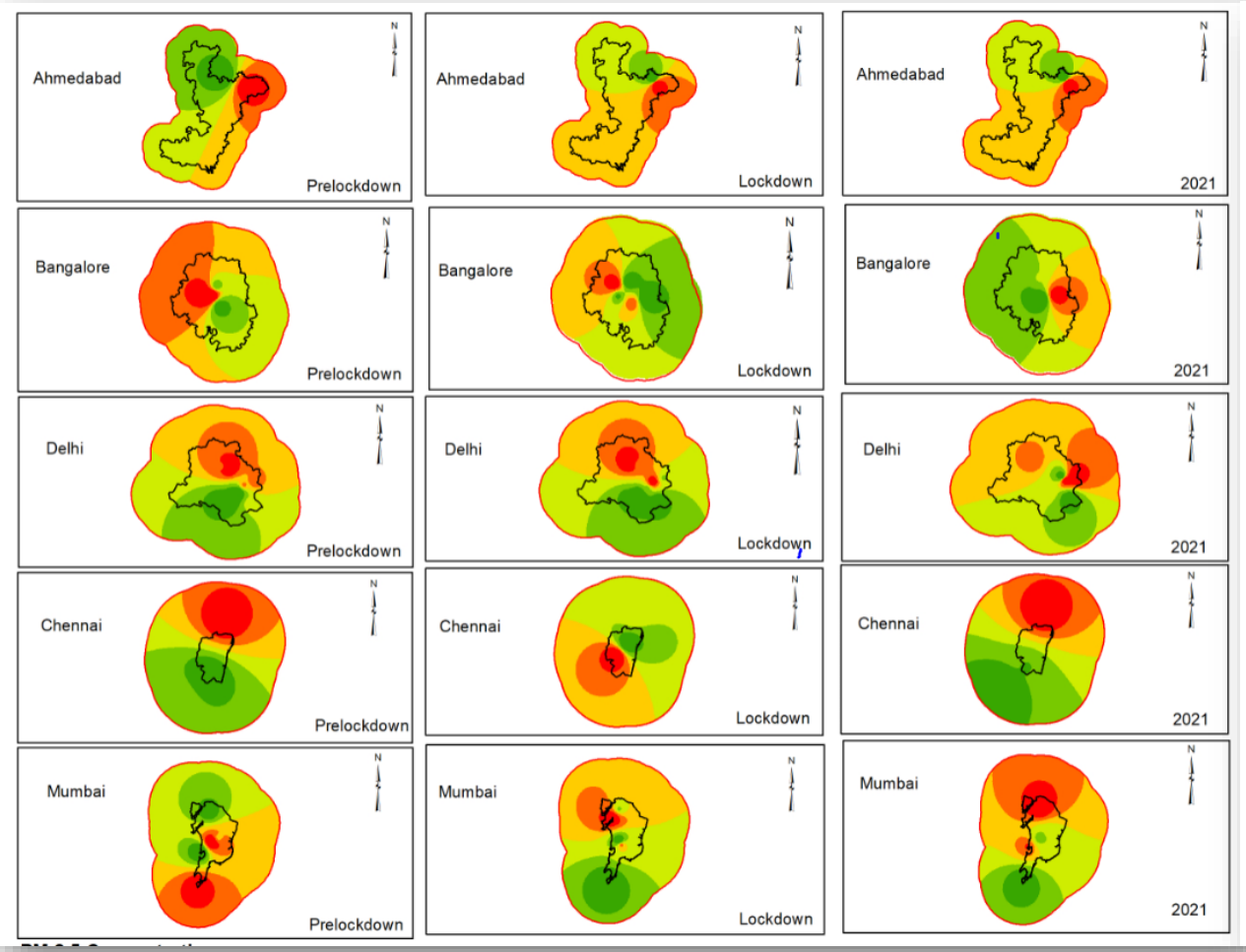


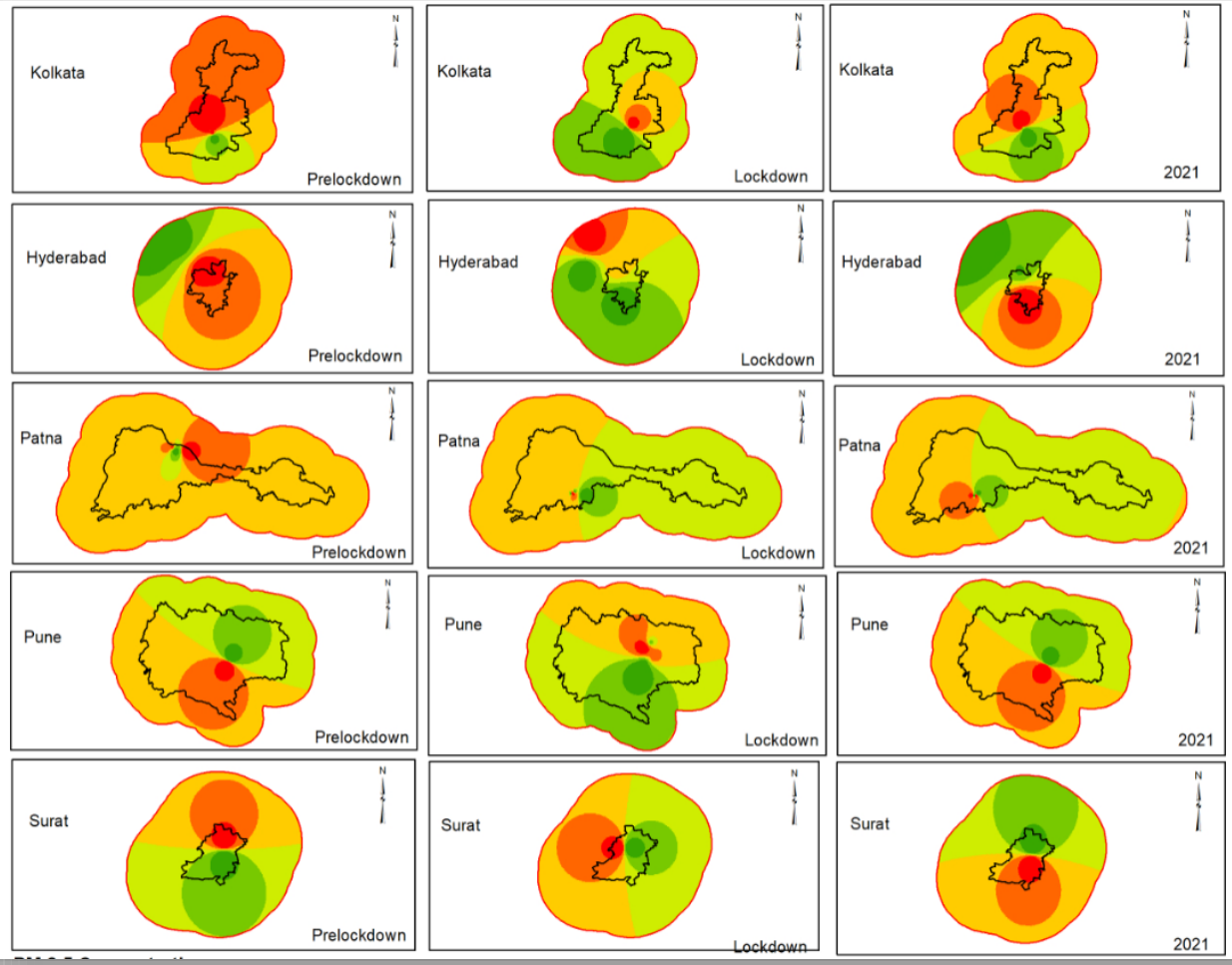
SO2 (mol/m^2)





PM 2.5 Concentration during pre-lockdown (March 25- May 31 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)





PM 2.5 Concentration

0 -50 | 51 - 100 | 101 - 200 | 201 - 300 | 301 - 400 | 401 - 500

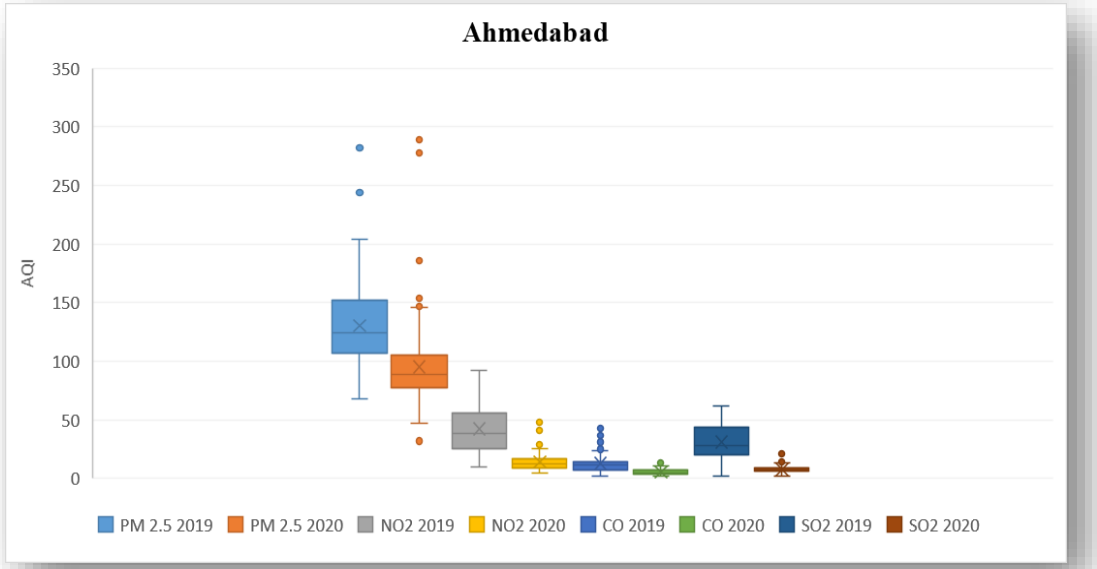
0 15 30 60 90 120 KM

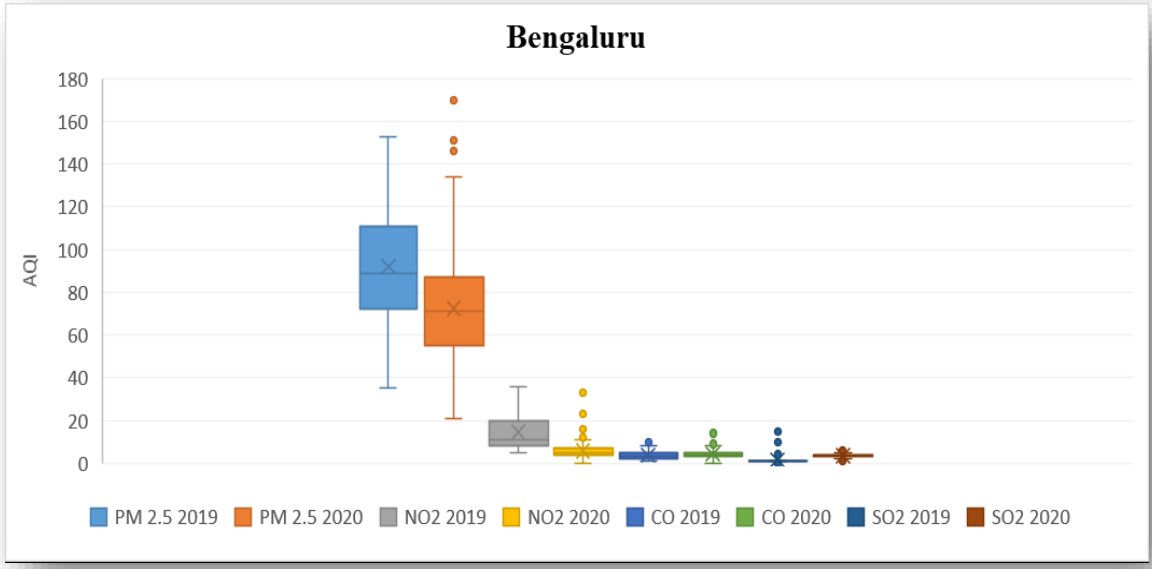
Daily mean concentration of PM2.5 in ten megacities in India during pre-lockdown, lockdown 1 (2020) and lockdown 2 (2021)

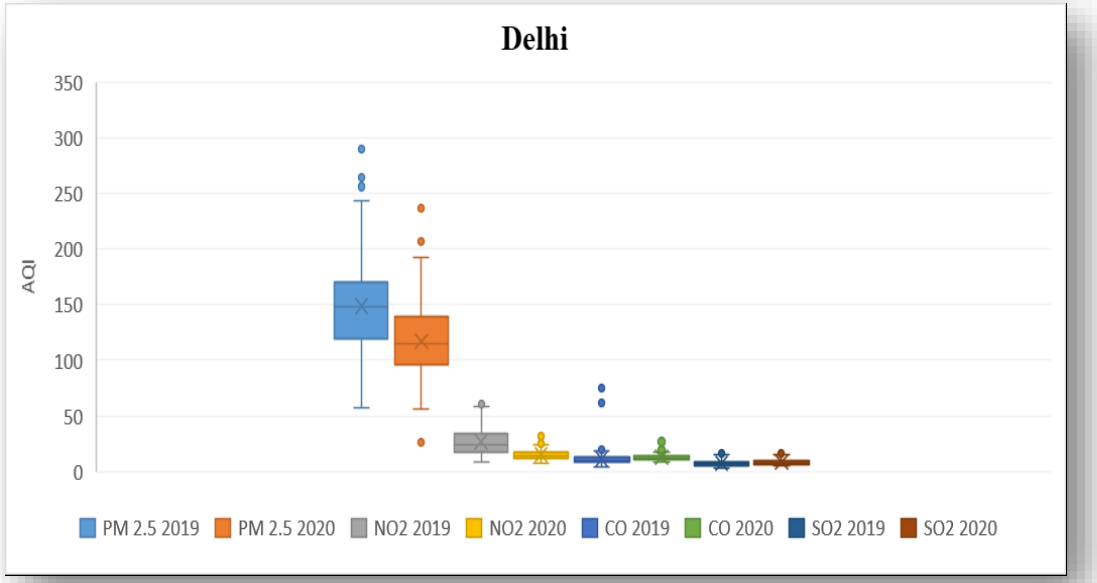
	Prelockdown 2019 (25 March - 31 May)	Lockdown 2020 (25 March – 31 May)	Lockdown 2021 (1 March - 10 May)	% Change during pre-lockdown and lockdown 2020	% Change during lockdown 2020 and lockdown 2021
Ahmedabad	140	88	98	-37.14	11.36
Bengaluru	98	68	74	-30.61	8.82
Delhi	240	116	115	-51.67	0.86
Chennai	118	68	93	-42.37	36.76
Mumbai	134	77	59	-42.53	-23.37
Kolkata	162	80	83	-50.61	3.75
Hyderabad	121	86	71	-28.92	-17.44
Patna	219	95	112	-56.62	17.89
Pune	157	66	44	-57.96	-33.33
Surat	119	77	59	-35.29	-23.37

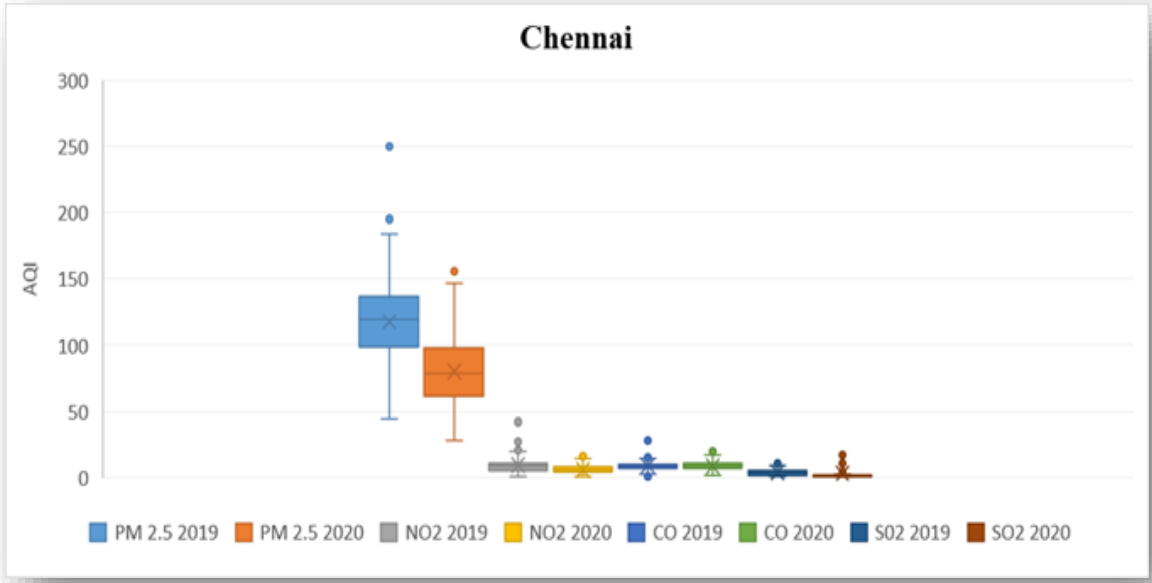
- PM2.5 concentrations is one of the determinants of air quality as well as environmental quality.
- PM 2.5 comes from a variety of sources, including fireplaces, automobile engines, and coal or natural gas-fired power plants. PM 2.5 concentration in the air which may destroy human comforts and creates lots of respiratory diseases.
- A significant decrease in PM2.5 was observed in Mumbai (-42.53% change in daily mean), followed by Kolkata (-50.61%), Delhi (-51.67%), Chennai (-42.37%), Bengaluru (-30.61%), Ahmedabad (-37.14), Patna (-56.62%), Pune (-57.96), Surat (-35.29%) and the least reduction in Hyderabad (-28.92%) during lockdown 2020 than pre-lockdown 2019-20.

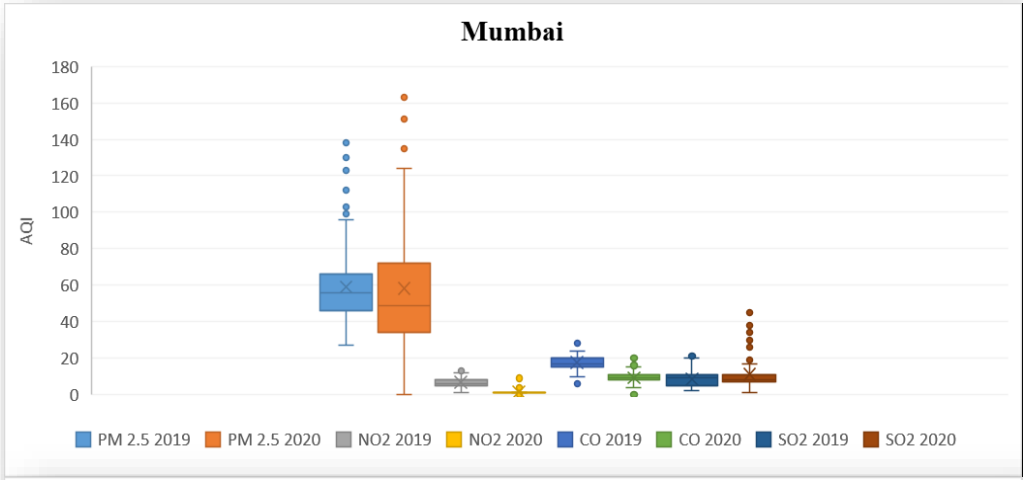
The interquartile distribution of AQI

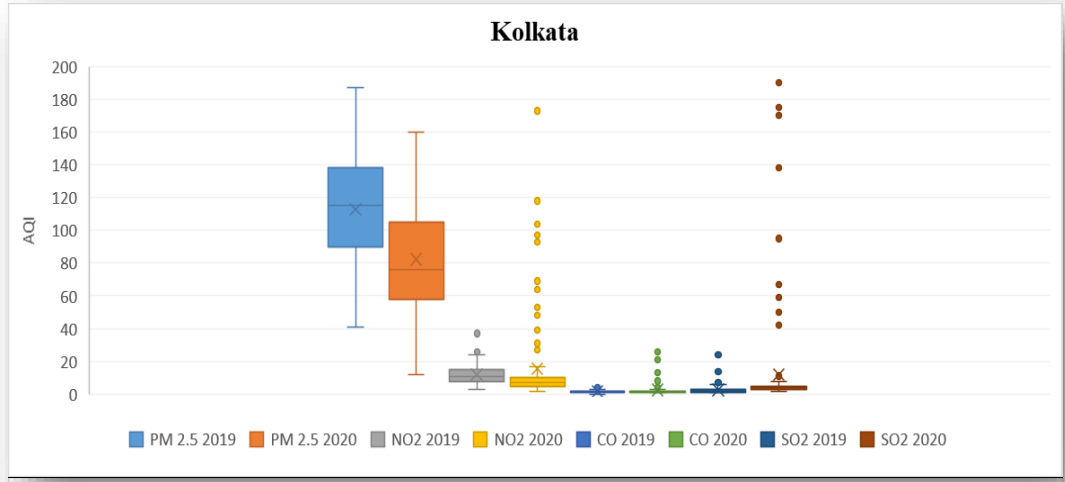


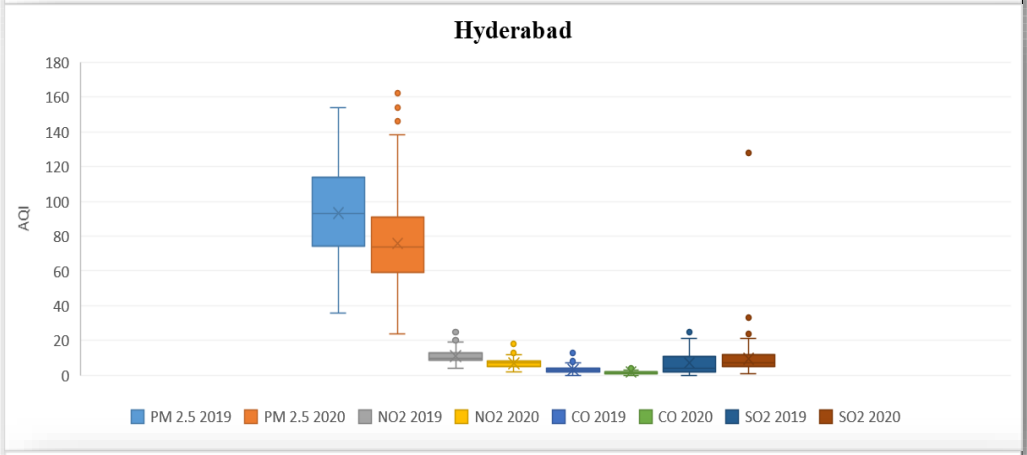


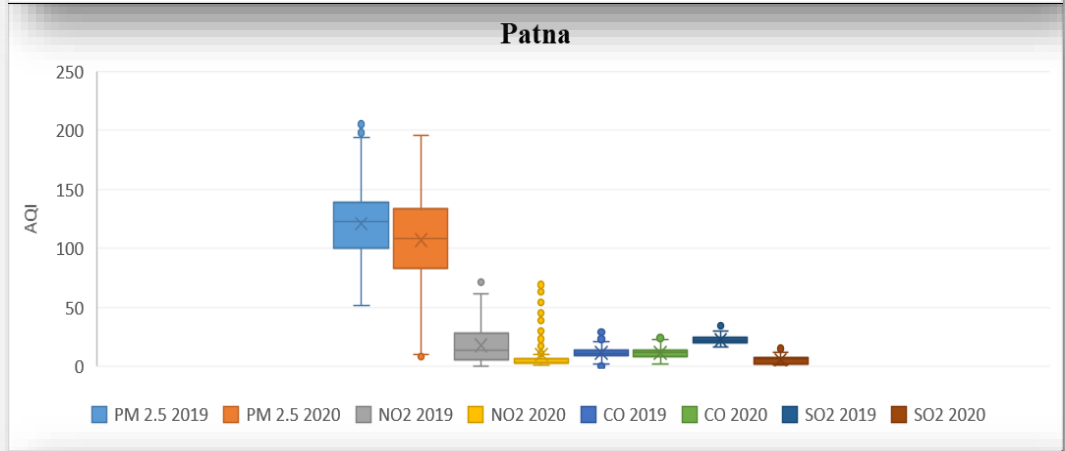


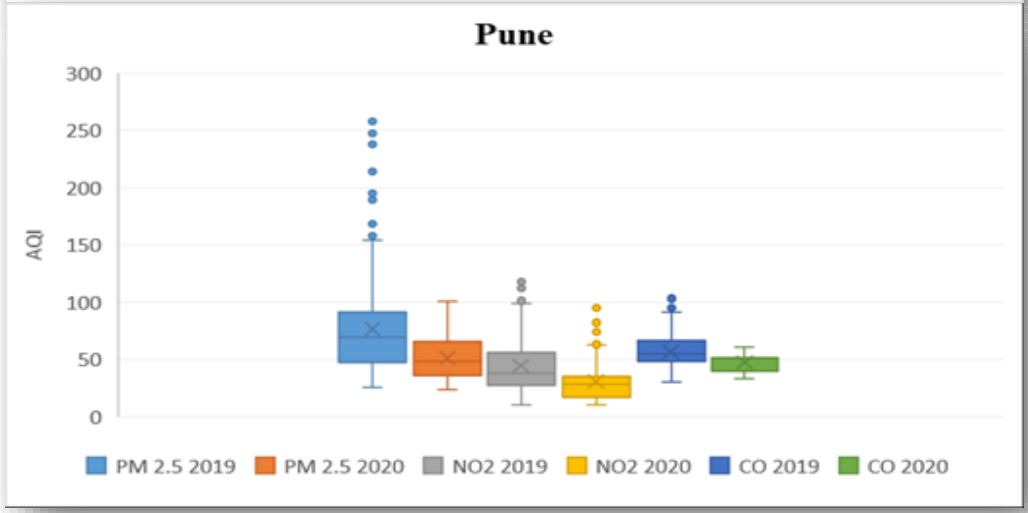


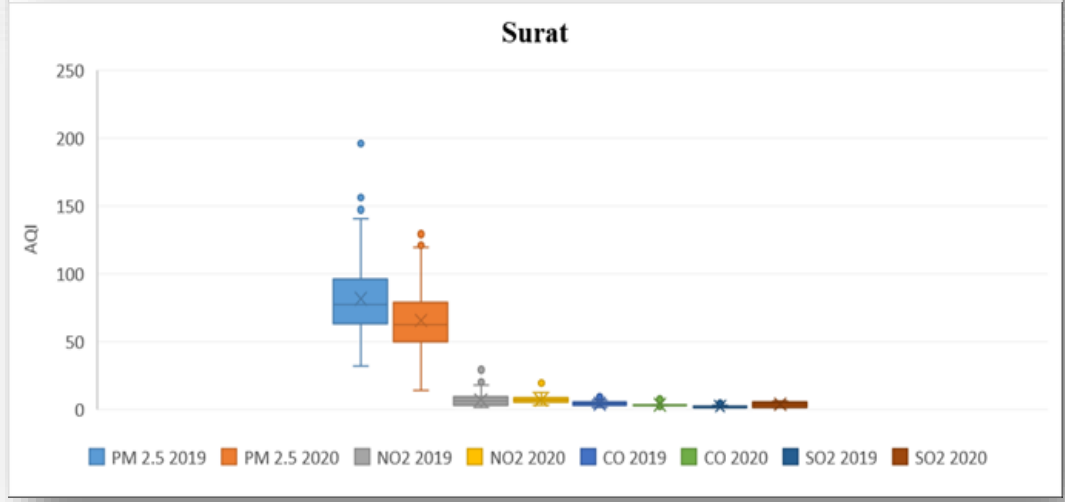

Mumbai
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020
SO2 2019
SO2 2020


Kolkata
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020
SO2 2019
SO2 2020

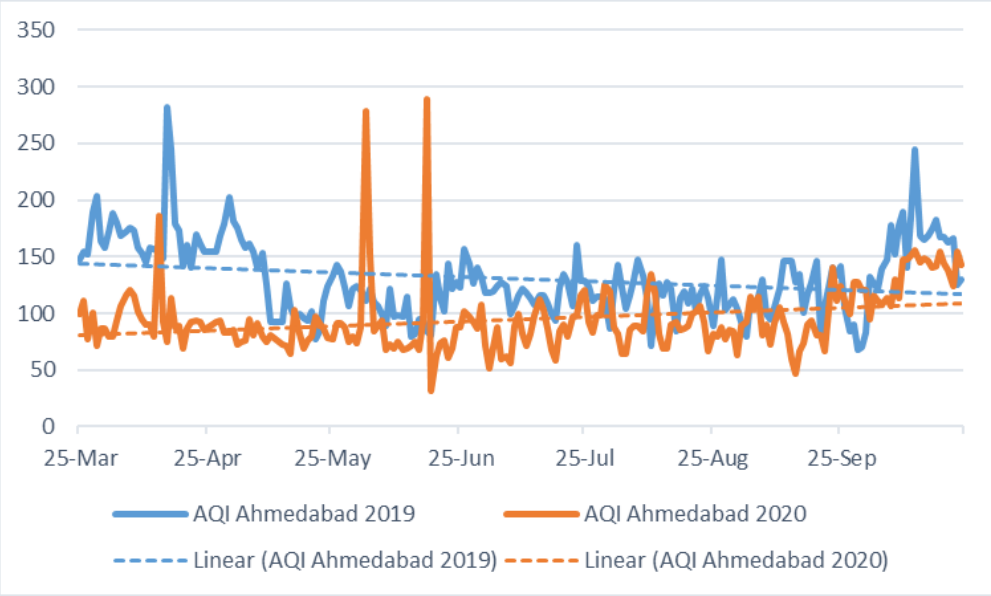

Hyderabad
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020
SO2 2019
SO2 2020

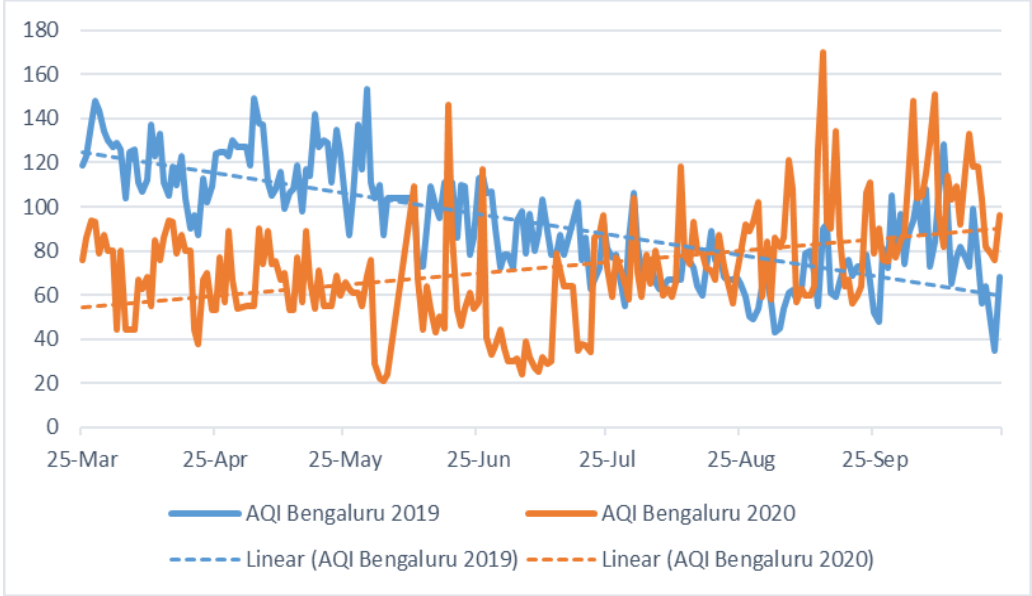

Patna
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020
SO2 2019
SO2 2020

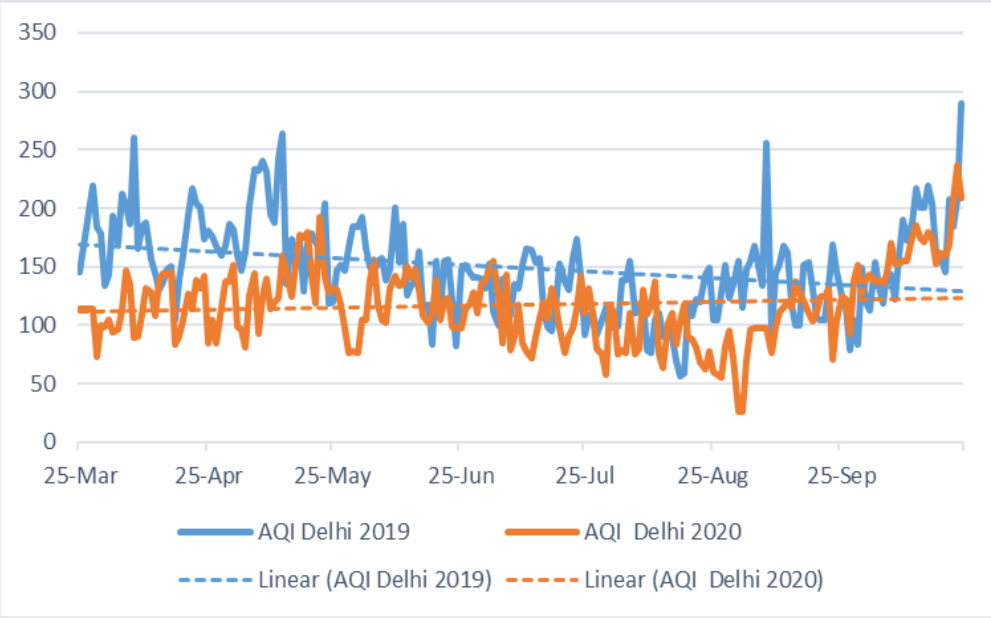

Pune
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020

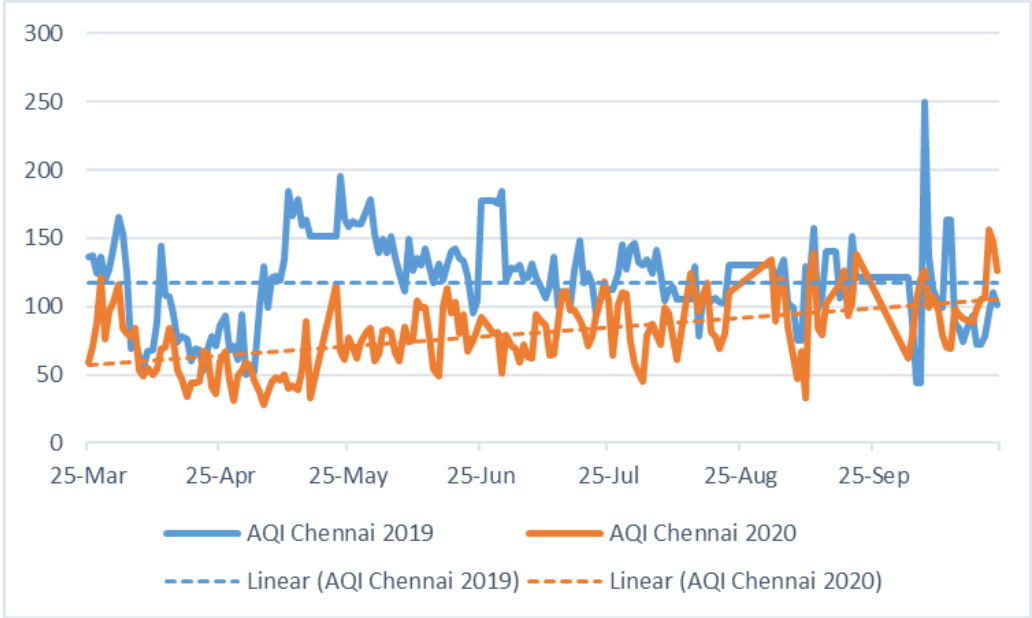

Surat
AQI
PM 2.5 2019
PM 2.5 2020
NO2 2019
NO2 2020
CO 2019
CO 2020
SO2 2019
SO2 2020

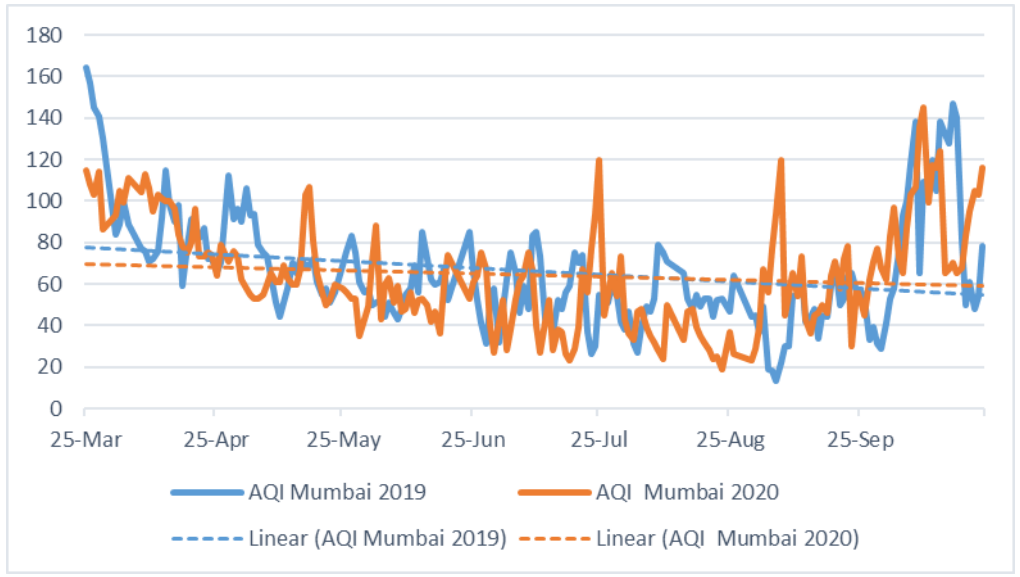
Temporal variation in AQI in all the ten megacities of India

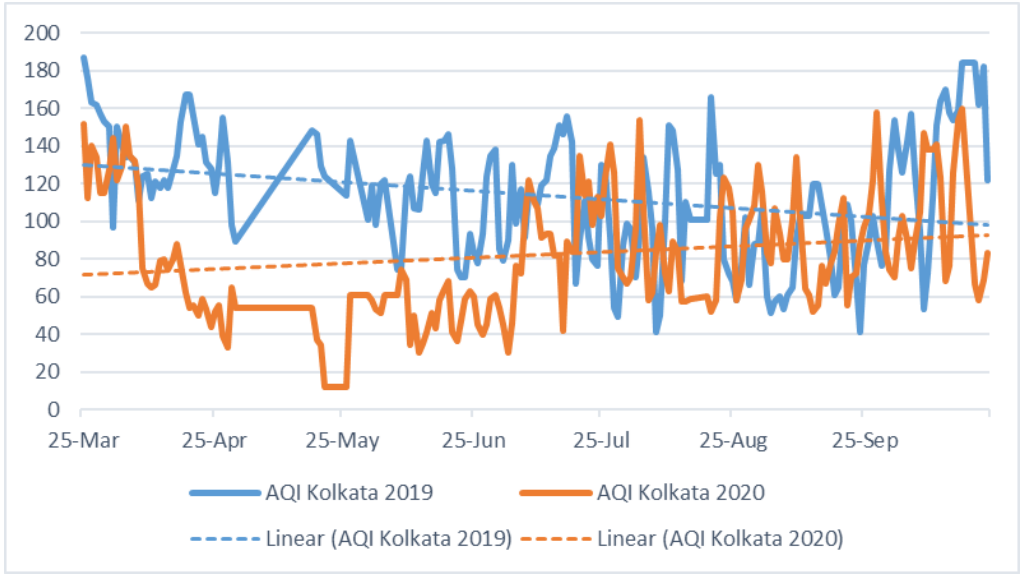


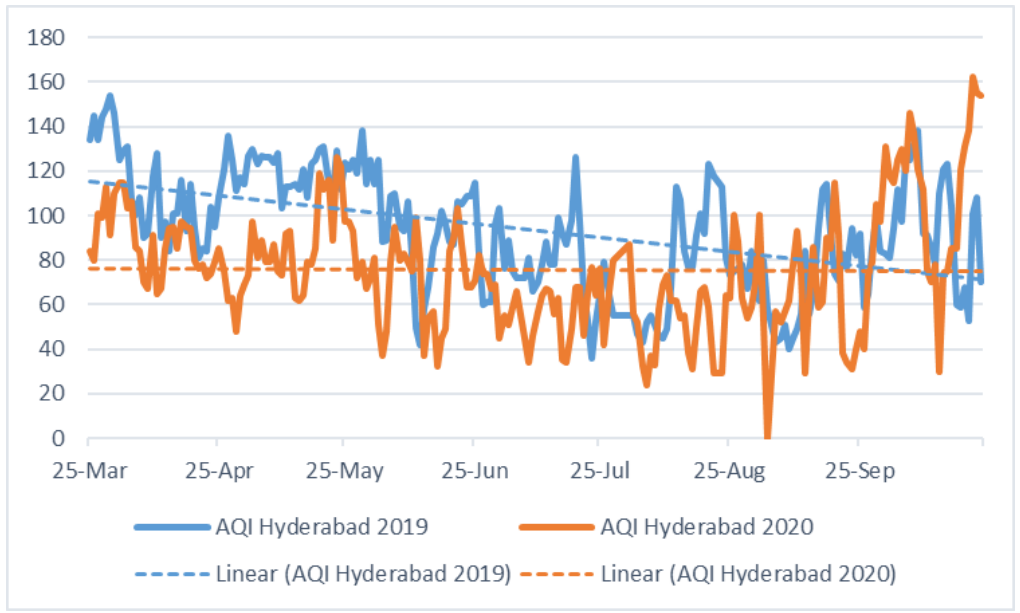


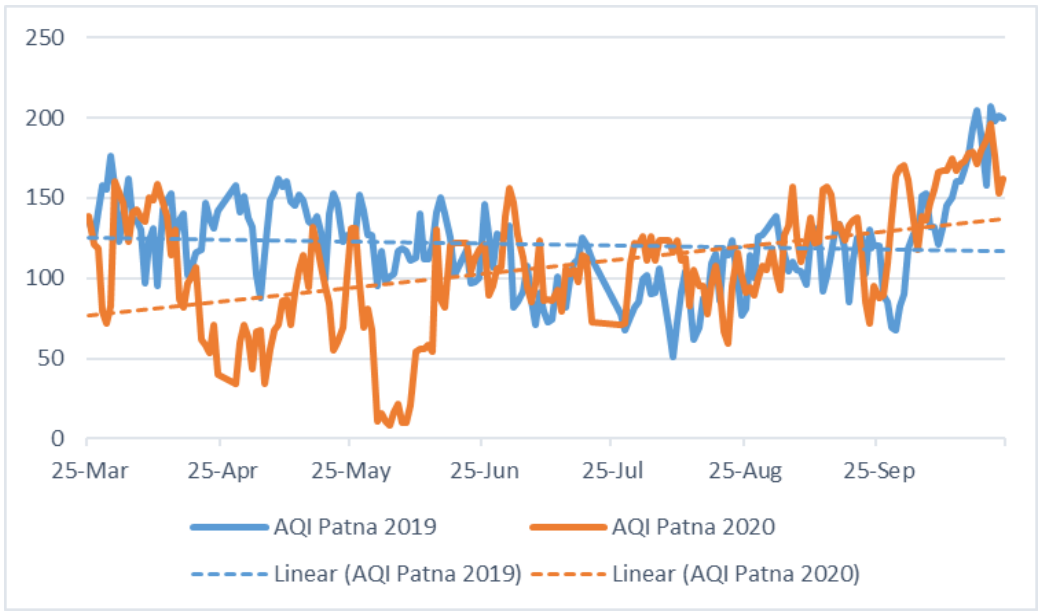


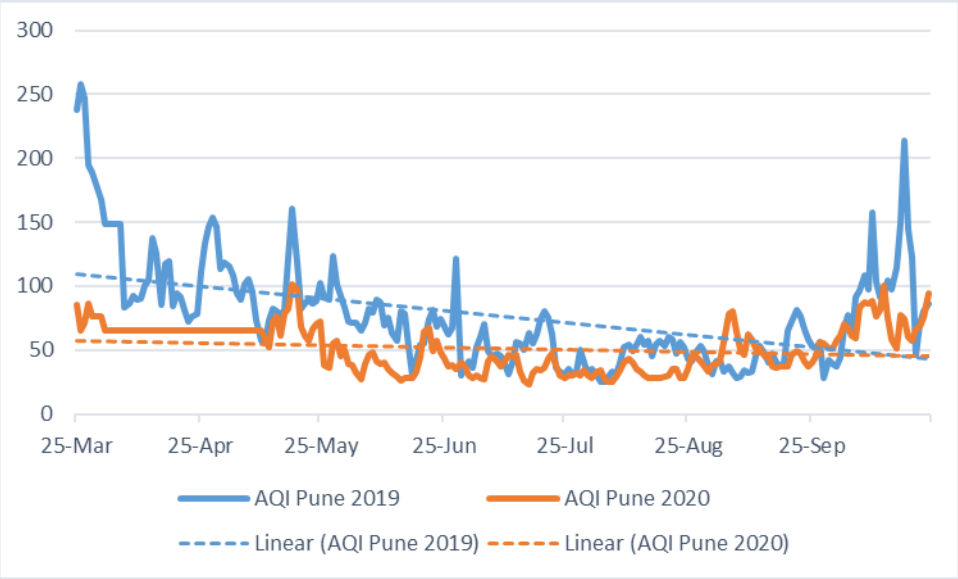


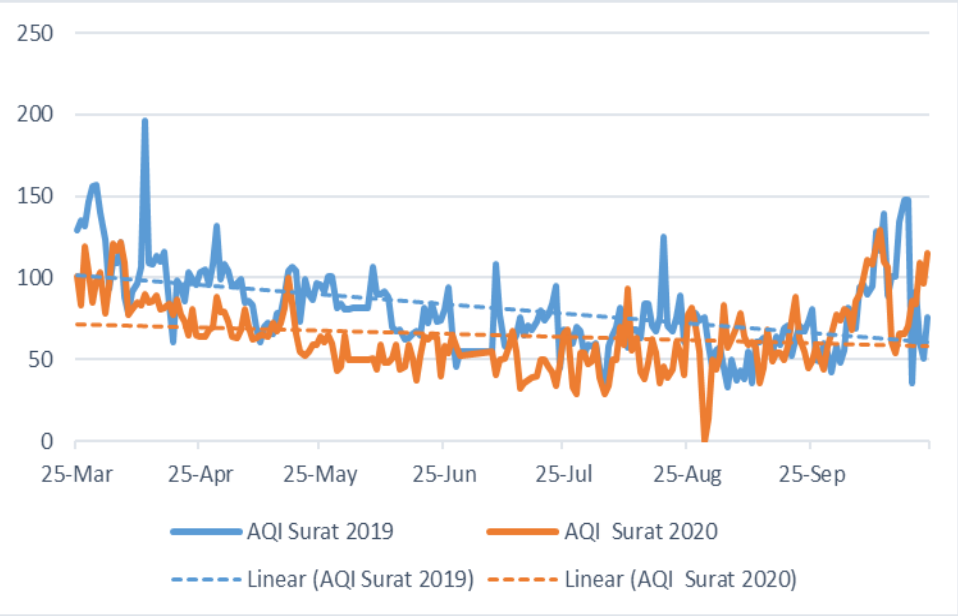

180
160
140
120
100
80
60
40
20
0
25-Mar
25-Apr
25-May
25-Jun
25-Jul
25-Aug
25-Sep
AQI Mumbai 2019
AQI Mumbai 2020
Linear (AQI Mumbai 2019)
Linear (AQI Mumbai 2020)


200
180
160
140
120
100
80
60
40
20
0
25-Mar
25-Apr
25-May
25-Jun
25-Jul
25-Aug
25-Sep
AQI Kolkata 2019
AQI Kolkata 2020
Linear (AQI Kolkata 2019)
Linear (AQI Kolkata 2020)


180
160
140
120
100
80
60
40
20
0
25-Mar
25-Apr
25-May
25-Jun
25-Jul
25-Aug
25-Sep
AQI Hyderabad 2019
AQI Hyderabad 2020
Linear (AQI Hyderabad 2019)
Linear (AQI Hyderabad 2020)


250
200
150
100
50
0
25-Mar
25-Apr
25-May
25-Jun
25-Jul
25-Aug
25-Sep
AQI Patna 2019
AQI Patna 2020
Linear (AQI Patna 2019)
Linear (AQI Patna 2020)





- Among all the major cities of India Delhi was identified to be the most polluted city.
- The average AQI in Delhi from March 25th to May 31st, 2019, was 242.38 ± 96.20 with maximum and minimum values of 349 and 66, respectively.
- A considerable temporal variation in AQI was observed, and the days for which AQI values were <100 correlated well with precipitation (R2 = 0.63). In the absence of precipitation, the AQI was consistently in either moderately polluted (27.90%), poor (33.33%), very poor (27.13%) or severe (4.65%) category.
- The average AQI during 2020 was significantly lower ($p < 0.000$) than its corresponding value for 2019. The average AQI in Delhi came down from 349 (very poor) in 2019 to 180.14 (moderately polluted) in 2020. The measures of dispersion (standard error: 5.25, standard deviation: 59.73) were also lower for 2020.
- It suggests that the improvement in air quality was consistent.

Conclusion

- The study's findings demonstrate the effectiveness of lockdown in reducing air pollution across industries. A small increase in emission levels was seen as limitations were lifted during the lockdown 2 period. The most significant decrease was observed for NO2 (both ground level and total column concentration) and PM 2.5.
- Likewise, a considerable influence on the ground level concentration of PM 2.5 was evident. The AQI was consistently better than the previous year 2019. The total column concentration of SO2 was higher in all cities, despite the fact that the pollution load at ground level was much lower.
- During the lockdown, air quality improved significantly due to reduced motor activity, avoiding re-suspension of roadside dust, a prohibition on construction operations, and favourable meteorology. The limits had a substantial influence on the region's air quality, but the benefits began to wane when restrictions were eased in order to reclaim pre-COVID levels of economic activity.

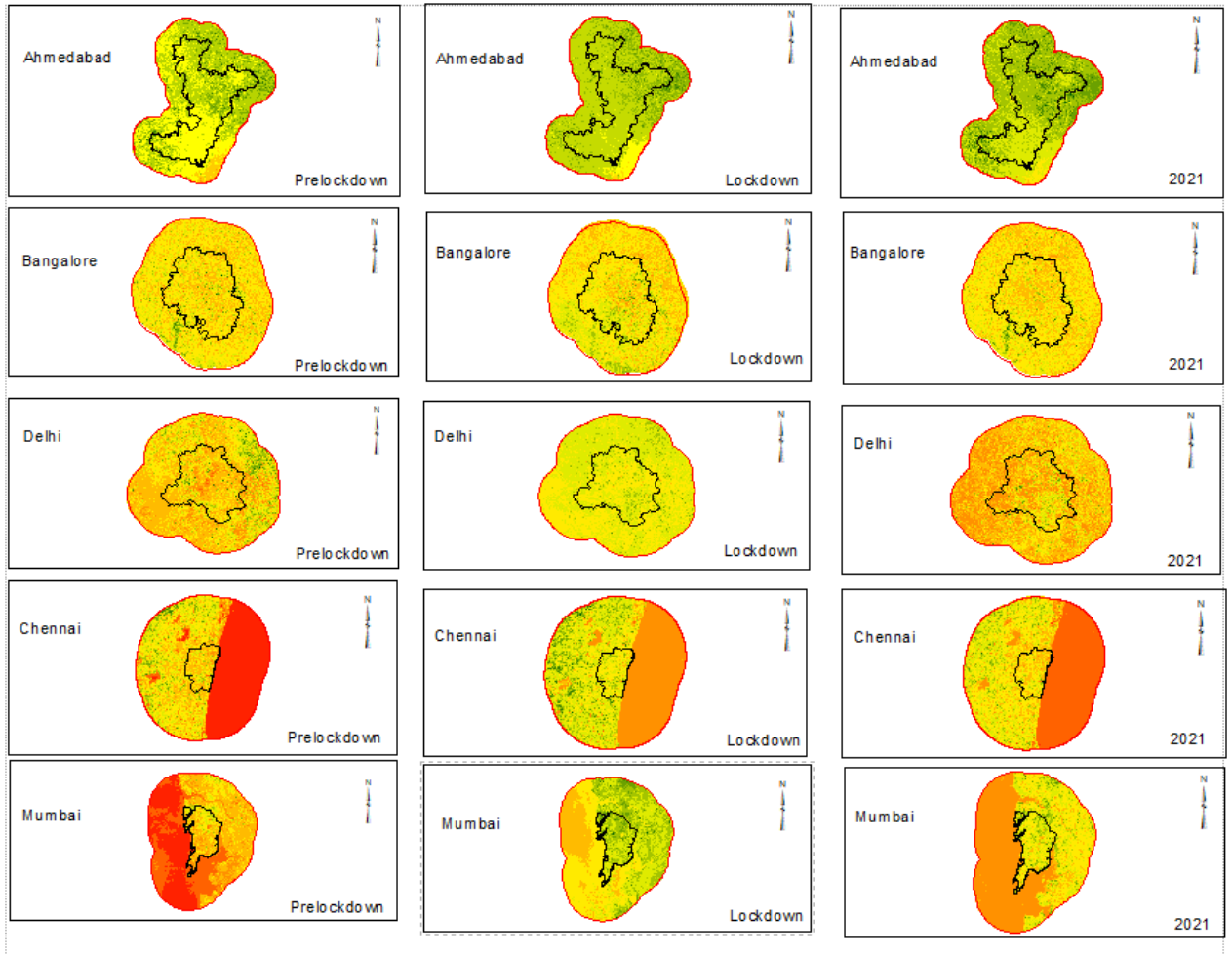
Chapter 2: Assessing the changes in vegetation cover using different biophysical parameters

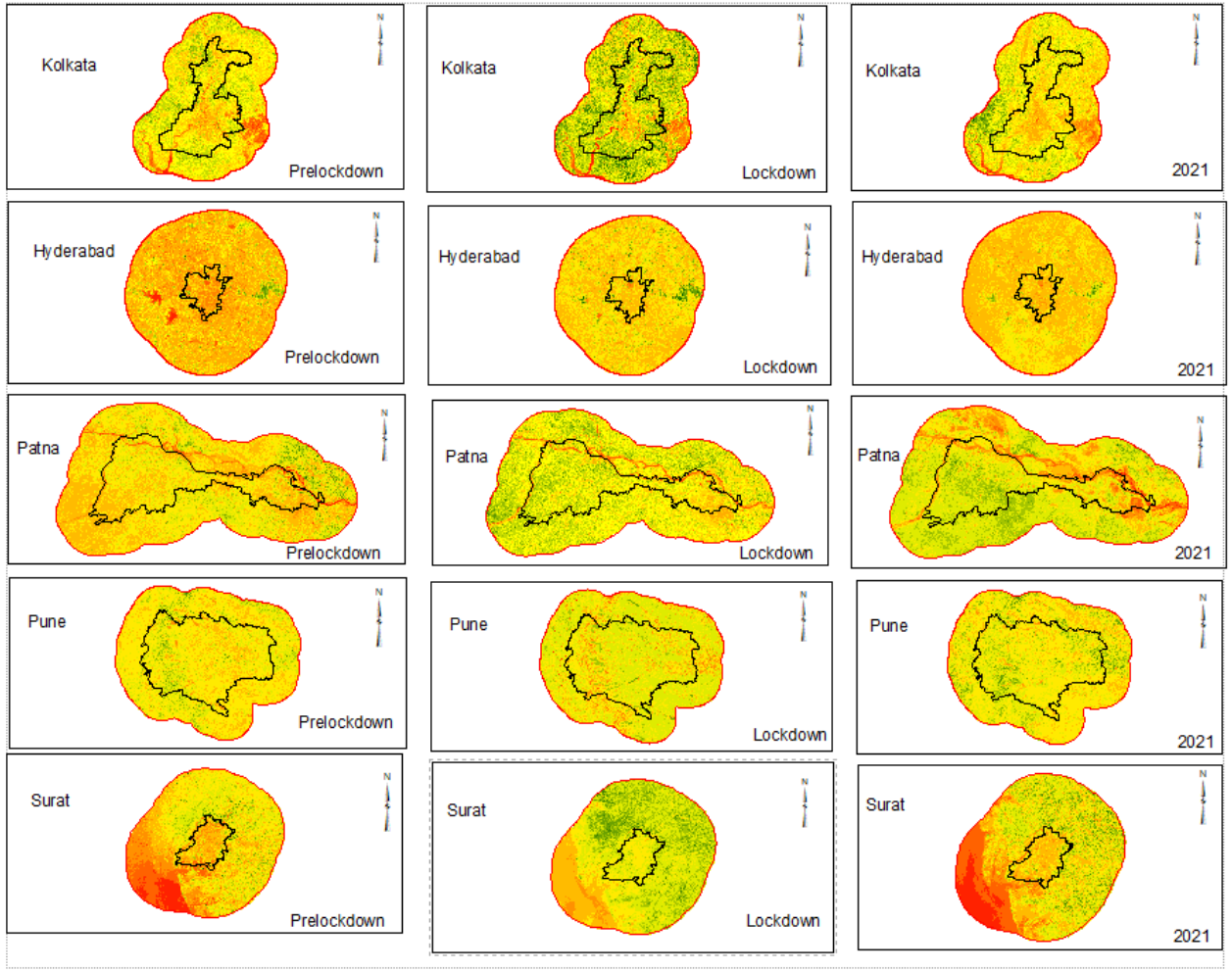
Introduction

- Temporal and spatial information regarding environmental quality in the megacities of India might be the prerequisite to formulate new strategies to endorse further development.
- Urban Environmental Quality assessment depends on multidimensional factors such as spatial, physical, social, and economic traits of the town milieu of the environment, which makes it more complex; this complex nature demands a broad understanding of the environmental degradation process and its driving forces.
- An exceeded standard amount of suspended particulate matters (PM10 and PM2.5) in the air is a high threat for public respiratory systems produced from industries, vehicles, dust, and residential energy. Keeping in mind the importance of of these parameters for assessing Urban Environmental Quality Index (UEQI), this study considered seven main elements which are mentioned earlier within the literature, namely, PM2.5 concentrations, NO2, CO, SO2, NDVI, NDWI and NDMI.
- Although NDVI, NDWI, and NDMI are more or less stable in nature, apart from the undisturbed condition of the natural environment thanks to imposition of the lockdown phenomenon, these parameters can also change slightly, and, above all, these parameters are vital for assessing environmental quality.

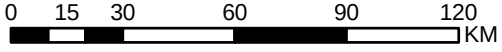
Results and Discussion

EVI during prelockdown(March 25 – 31 May 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)

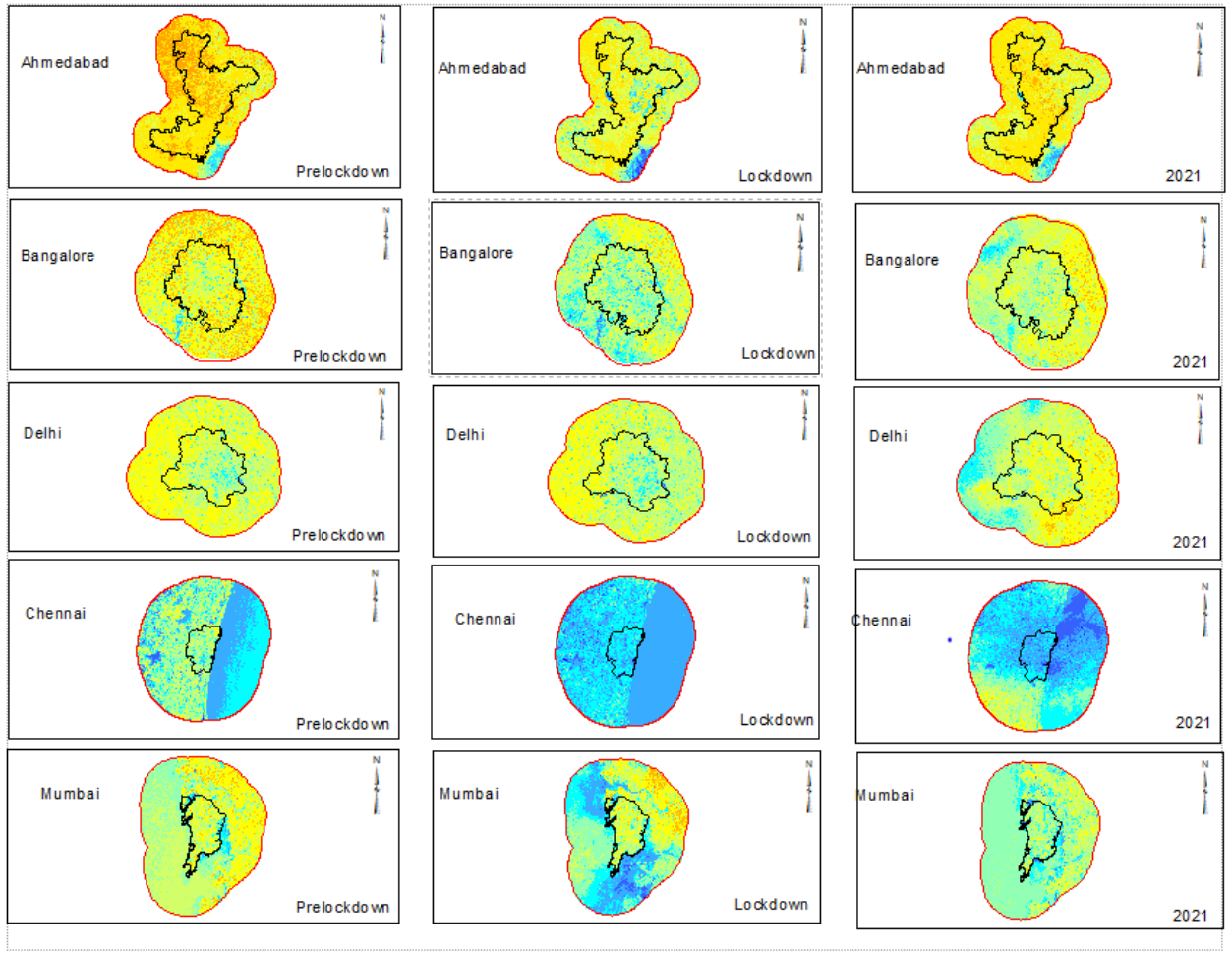


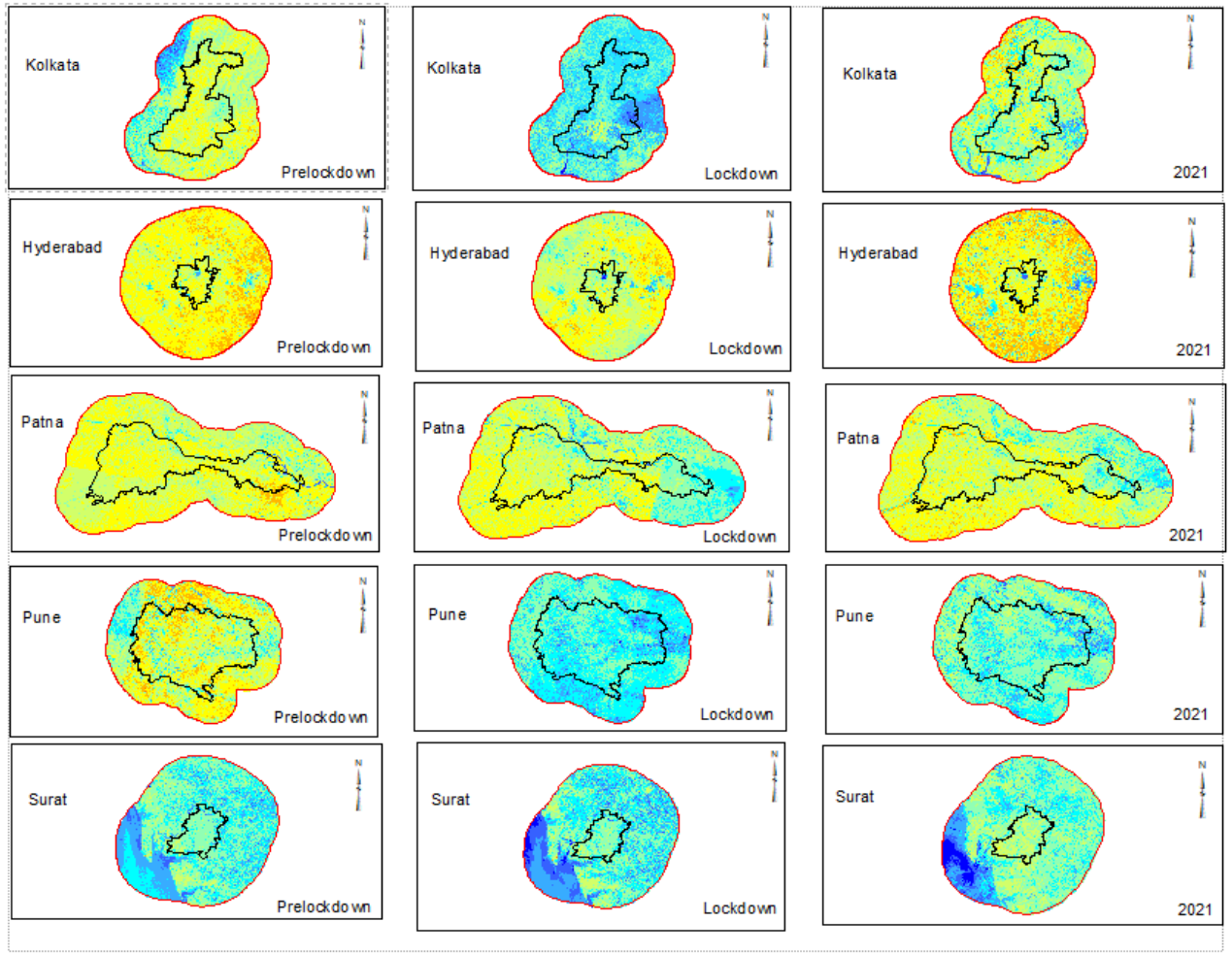


Enhanced Vegetation Index

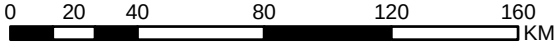


NDWI during prelockdown (March 25 – 31 May 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)

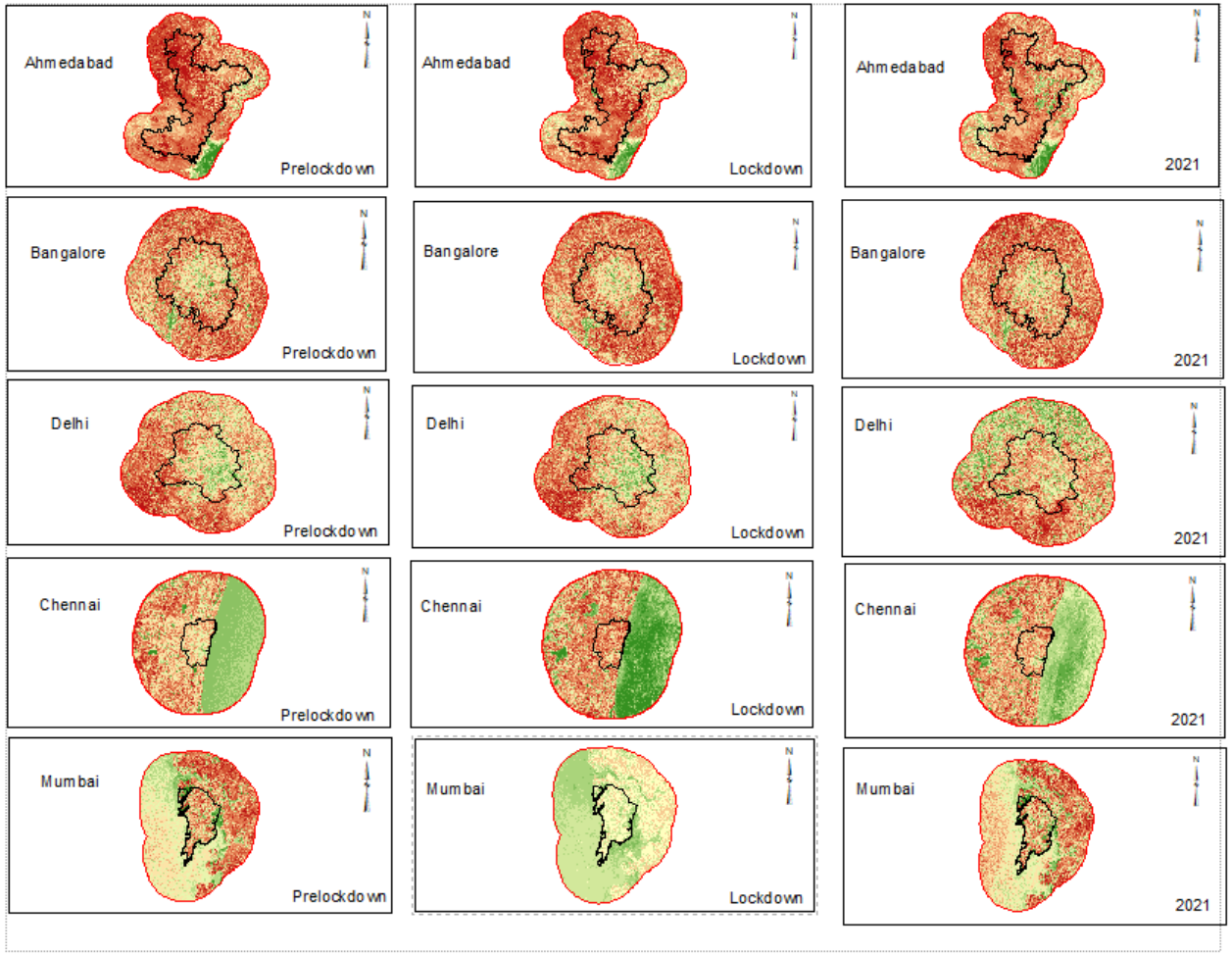


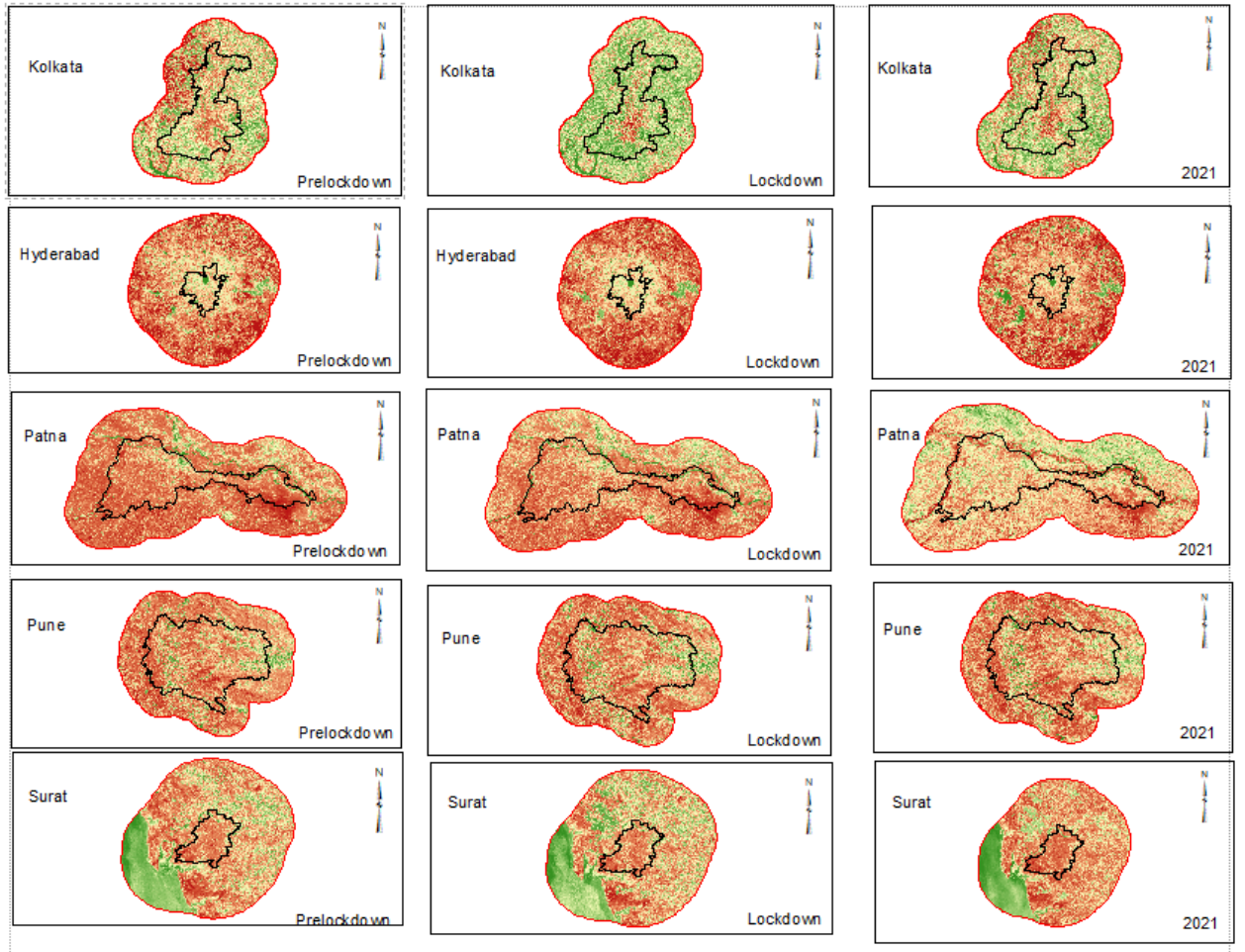


Normalized Difference Water Index



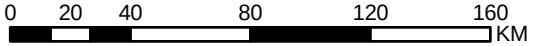
NDMI during prelockdown (March 25 – 31 May 2019) , Lockdown 1 (March 25 – 31 May 2020) and Lockdown 2 (March 1 – 10 May 2021)



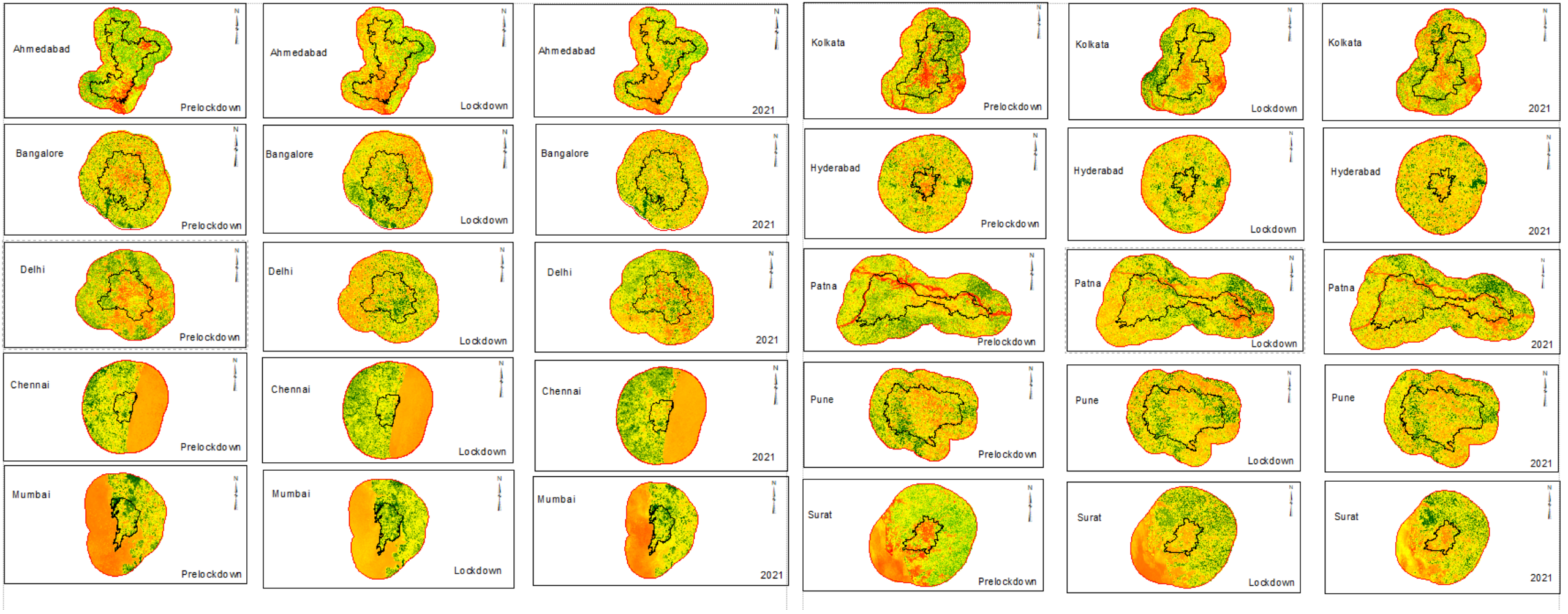


Normalized Difference Moisture Index

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1



Environment Quality Index during prelockdown (October 1- March 24) , lockdown (March 25 – 31 May) and post lockdown (June 1 – 24 October)



Environmental Quality Index

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

0 20 40 80 120 160
KM

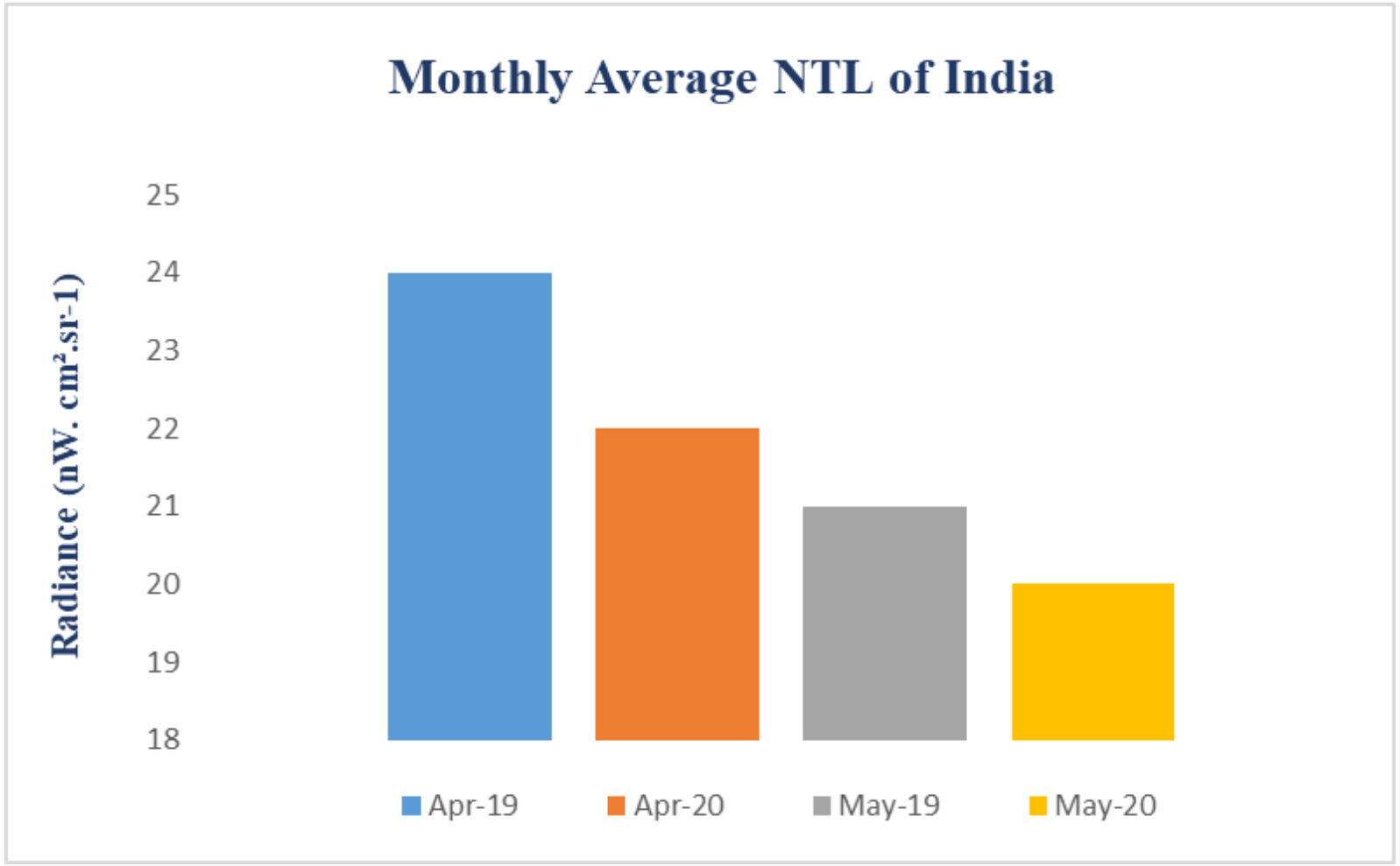
Conclusion

- The findings of this study substantiate the effectiveness of lockdown in improving environmental quality across all mega cities of India. During the lockout, environmental indicators such as PM 2.5 concentration, EVI, NDWI, and NDMI all improved.
- This study found that overall environmental quality has improved for all ten studied megacities investigated over the previous year (same months), although according to the general tendency of environmental quality degradation, 2020 must have the worst environmental condition than the environmental condition of 2019.
- The environmental quality had improved in lockdown 1 but its slightly degraded during lockdown 2 period. The environmental quality index map shows that the environment is improving, which is a sign of hope for environmentalists in this crisis.

Chapter 3: Analysing the implications of COVID-19 induced lockdown on various urban function

Introduction

- The year 2020 will be etched in our lifetimes as the most economically and emotionally stressful year in a generation because of the COVID-19 global pandemic. It was estimated that the pandemic slow down the global economic growth from 3% to 6 % in 2020.
- The pandemic has caused an economic slump beyond anything the world has experienced in nearly a century, with massive levels of unemployment and the economic and social costs associated with the many lives lost.
- Remote sensing data and technologies are widely used in the study of natural disasters and the spread of epidemics. Nighttime Light (NTL) images have the capability to not only tell people where the facilities are but also depict when and how they are used. Therefore, the citizens' reaction to the lockdown and quarantine policies can be reflected and monitored.
- Therefore, the citizens' reaction to the lockdown and quarantine policies can be reflected and monitored. Earth Observation group has released some comparisons between the NTL imagery before and during the lockdown of India and demonstrated the economic impact of the COVID 19 pandemic in India.



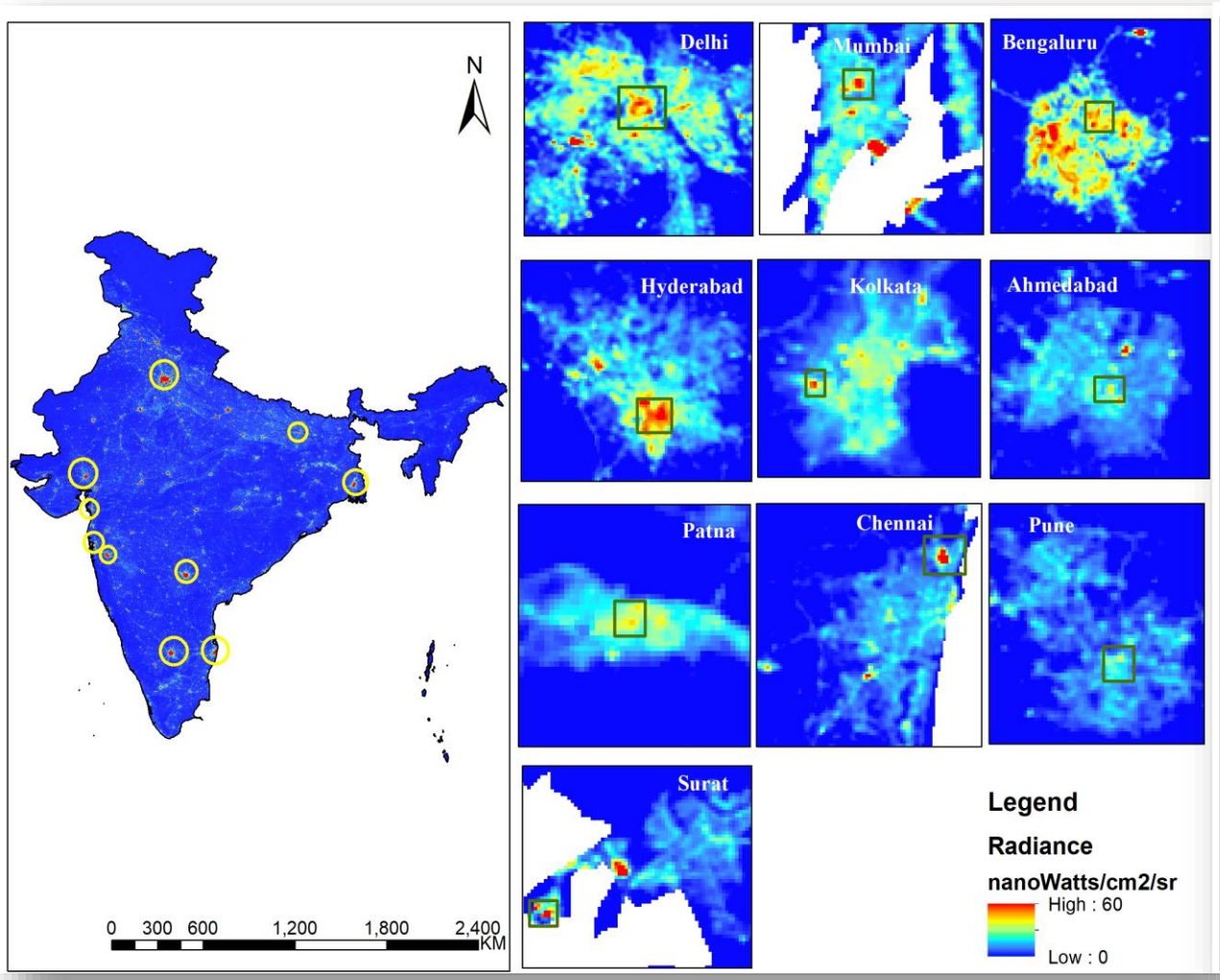
- This graph shows the monthly NTL radiance of India for the same season during lockdown and Pre-lockdown period. In the pre-lockdown period shows the higher radiance than the lockdown period.
- However, this has obviously changed due to the outbreak of COVID-19, as the graph shows. Because the lockdown policy implemented on 25 March 2020 and lasted in end of May , the mean value in April and May has clearly decreased.

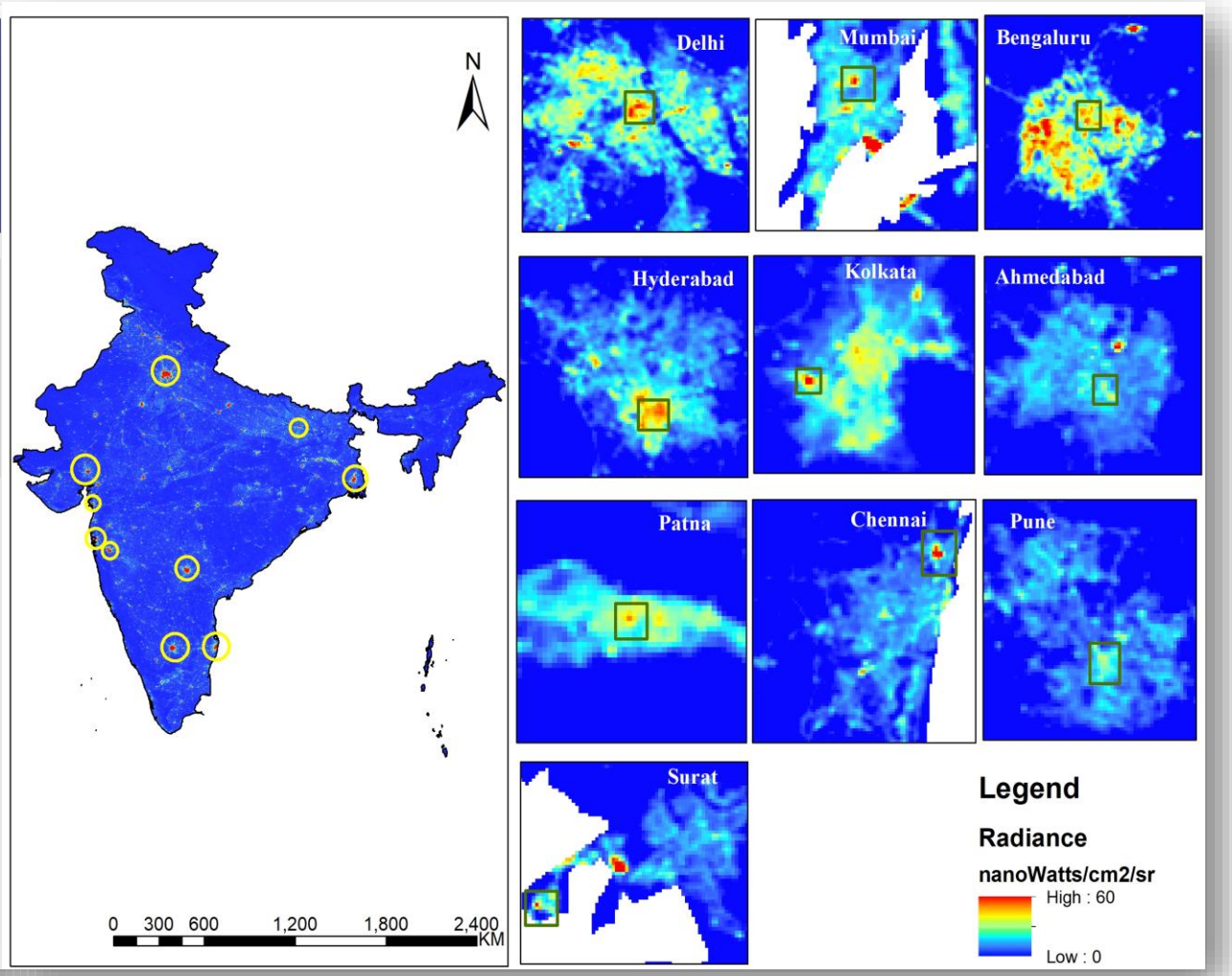
Results and Discussion

Monthly Average NTL radiance of India before lockdown (2019) compared with lockdown (2020)

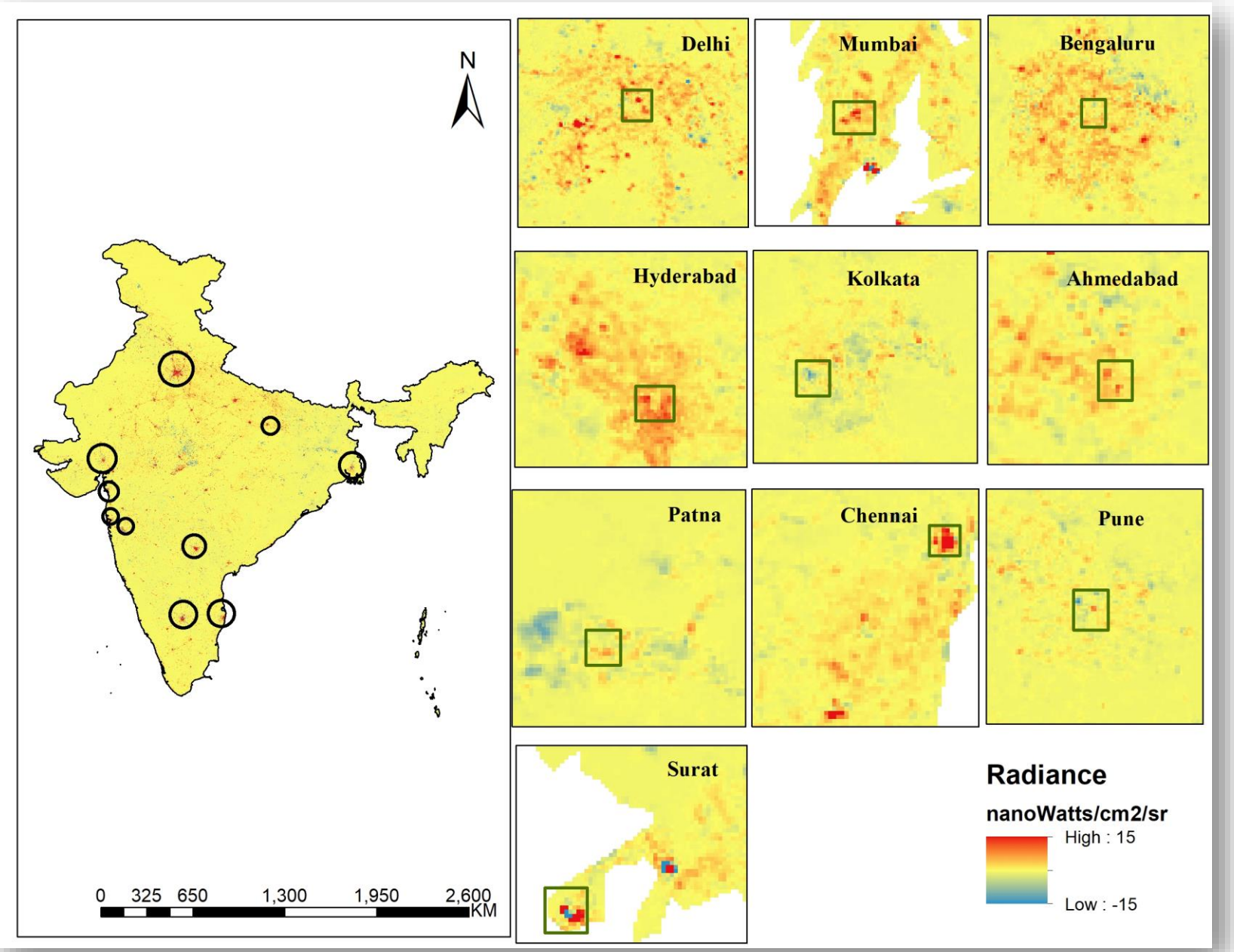
2019 (April – May), Pre-lockdown

2020 (April – May), Lockdown Period

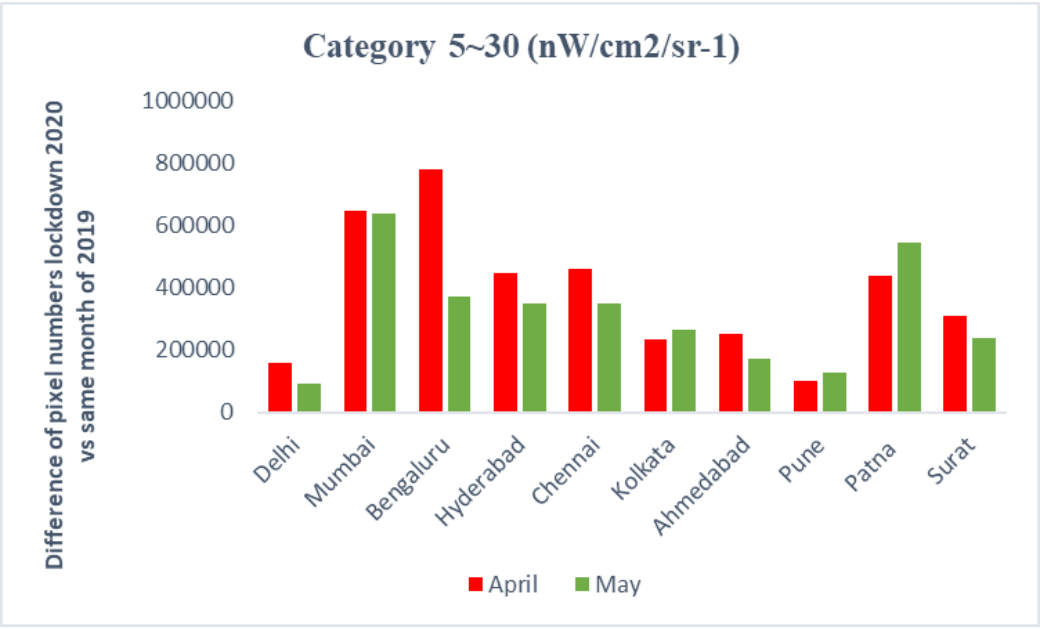


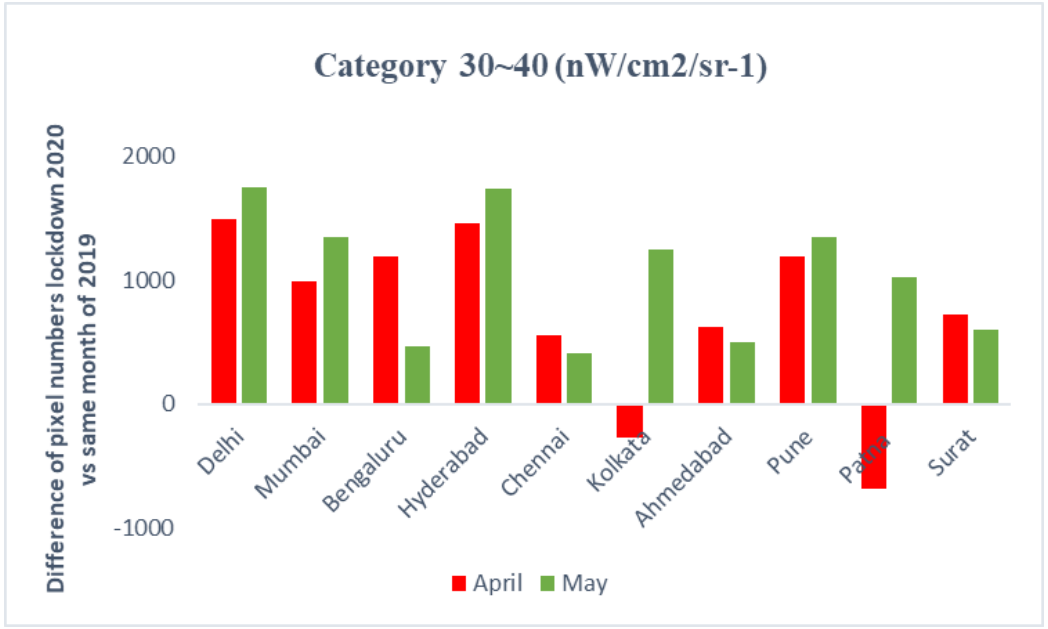


This figure showing change between Pre-lockdown and Lockdown Period

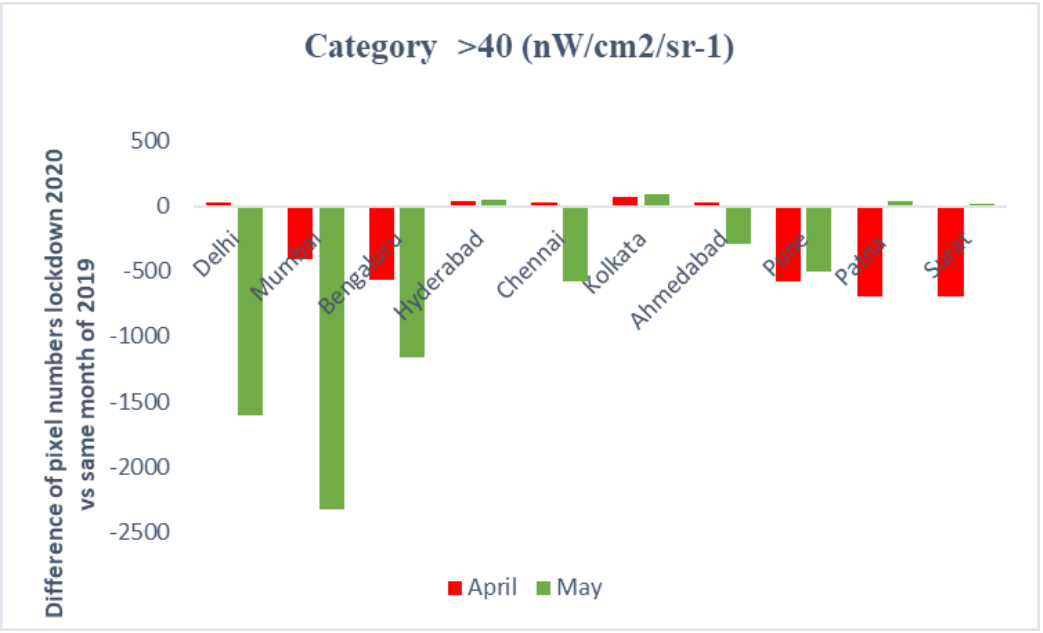


- Indian government had implemented the nationwide lockdown since the midnight of 24th March 2020, to restrict the contagion's spread.
- Due to this strict quarantine policies resulting, the majority of the people spending their time at home.
- The average NTL radiance during the lockdown period was lowered than the Pre-lockdown Period.
- For all the months during the city lockdown, there are significantly more pixels in the residential category and fewer pixels in the commercial centers than before. The number of transportation and public facilities lights decreased in lockdown period.





5~30 (Residential
30~40
(Transportation
facilities
>40 (Commercial
Centers)



- For the 5 ~ 30 nWcm2sr-1 categories, of residential areas all 10 mega cities of India have higher NOP in April and May 2020 than the same month of 2019. These spatiotemporal patterns are due to the stay-at-home policies and more people spending their nights at home.
- For the 30 ~ 40 nWcm2sr-1 group which reflects the anthropogenic NTL of transportation facilities. 8 cities showing higher pixels i.e. positive values except Patna and Kolkata.
- For greater than 40 nWcm2sr-1 represents the commercial centers. For commercial centers pixels their numbers decreased significantly during lockdown, compared to before in most cities. People tended to avoid going to shopping and entertainment centers due to the quarantine policies and fear of getting infected.

Conclusion

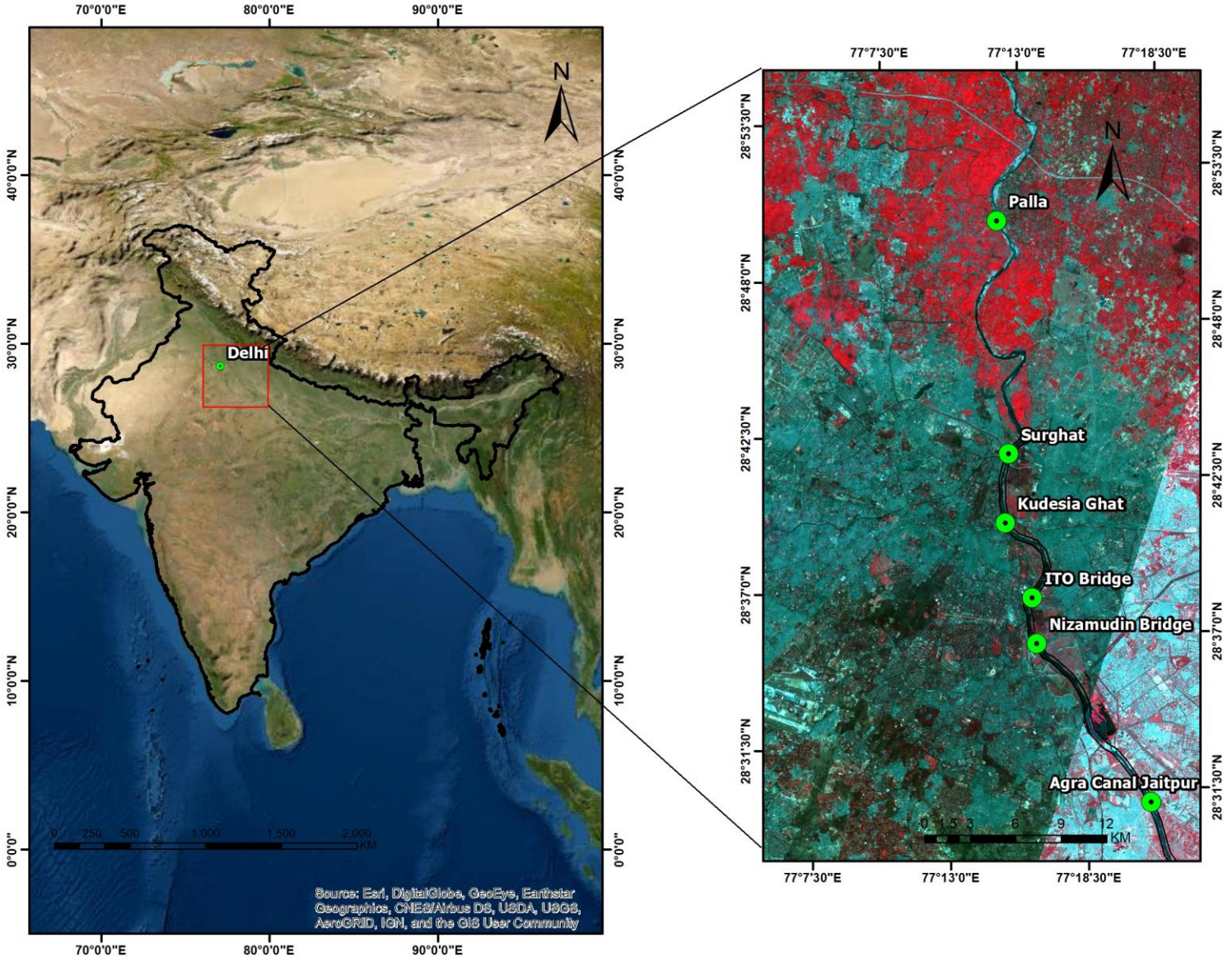
- This study provides detailed spatiotemporal analytics on the impact of COVID-19 on human lives as reflected by Nighttime light.
- The mean radiance of NTL radiance decreases during lockdown phase in India from the same month of pre-lockdown period 2019. From the statistics of NTL, we can conclude that the NTL radiance decreases in all the cities of India during lockdown period w.r.t. pre-lockdown period.
- Several restrictions were imposed by the government such as shutdown of industrial activities, commercial centers, transportation activities, ban of construction activities, etc.
- People were doing work from home during lockdown. COVID-19's spread and related policies have a huge impact on people's daily life as well as the environment.

Chapter 4: Analyzing and verifying the change in the quality of water of Yamuna river due to lockdown

Introduction

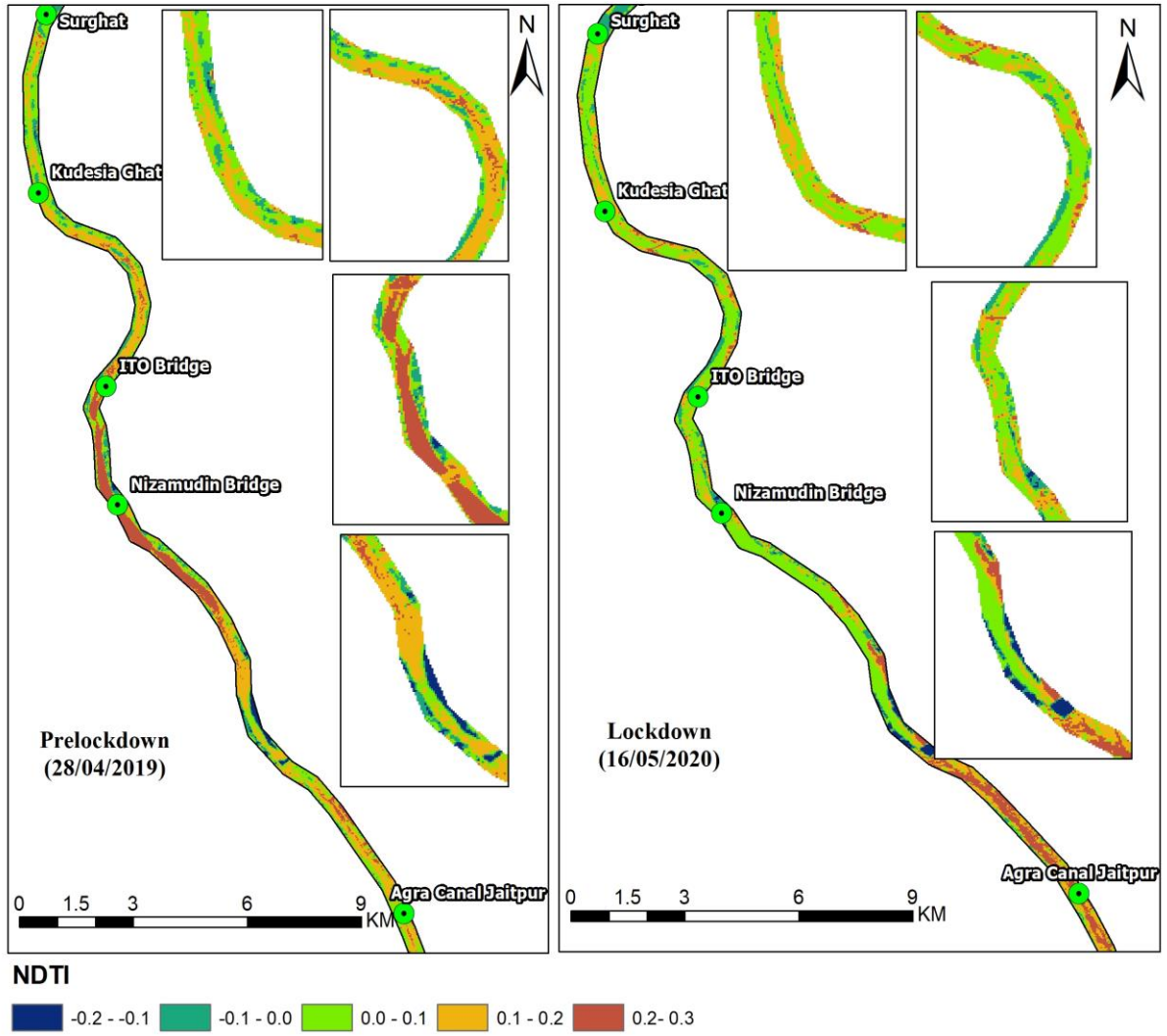
- Rapid industrial development in the last few decades has added huge loads of pollutants to our rivers. Water pollution is a major problem in India.
- The main causes of water pollution include discharge of industrial effluents, municipal sewage, oil spills, introduction of fertilizers and chemicals and mining.
- Discharge activities contribute the highest to water pollution. Only about 10% of the waste water generated is treated; the rest is discharged as it is into our water bodies. Due to this, pollutants enter into groundwater, rivers and other water bodies (Hindustan Times, March 2013).
- Water quality index (WQI) expresses overall water quality at a certain location and time, based on several water quality parameters reducing great amount of parameters to a number that expresses the acceptability of water to the user.
- In the present study an attempt has been made to determine the water quality index of industrial outlet and along river Yamuna in Delhi, India. For calculating the WQI, the following eleven parameters were considered: pH, total dissolved solids, Chemical oxygen demand, dissolved oxygen and biological oxygen demand.

Location map of the study area

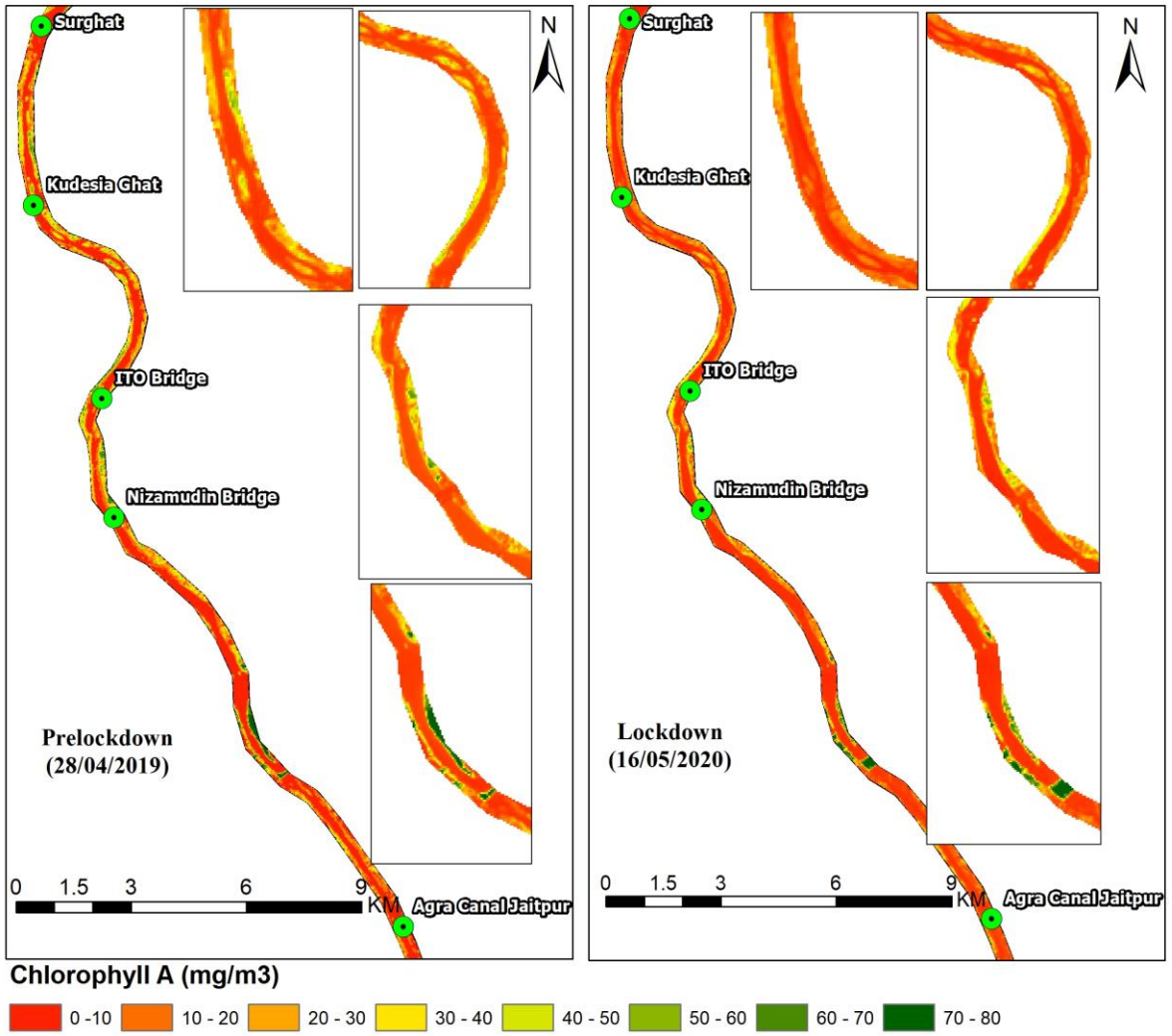


- River Yamuna is the largest tributary of Ganga. The total length of Yamuna River from its origin at Saptrishi Kund to its confluence with Ganga at Allahabad is 1376 km.
- Yamuna is traversing through Uttarakhand, UP, Haryana, Himachal Pradesh, Rajasthan, MP and Delhi.
- The main stream of river originates from the Yamunotri glacier near Bander punch peaks in the Mussoorie range of the lower Himalayas in Uttarkashi district of Uttarakhand.
- There are unlimited numbers of industrial units, draining immense amount of untreated water in Yamuna existing in Delhi, Faridabad, Mathura and Agra.
- CPCB had estimated that there were approximately 359 industrial units, which directly or indirectly discharge their effluents in Yamuna (Misra, 2010).
- This study is intended to monitor the water quality status in vicinity of industries and along river Yamuna in Delhi during COVID-19 Lockdown period.

Normalized Difference Turbidity Index during Lockdown and Pre-lockdown period

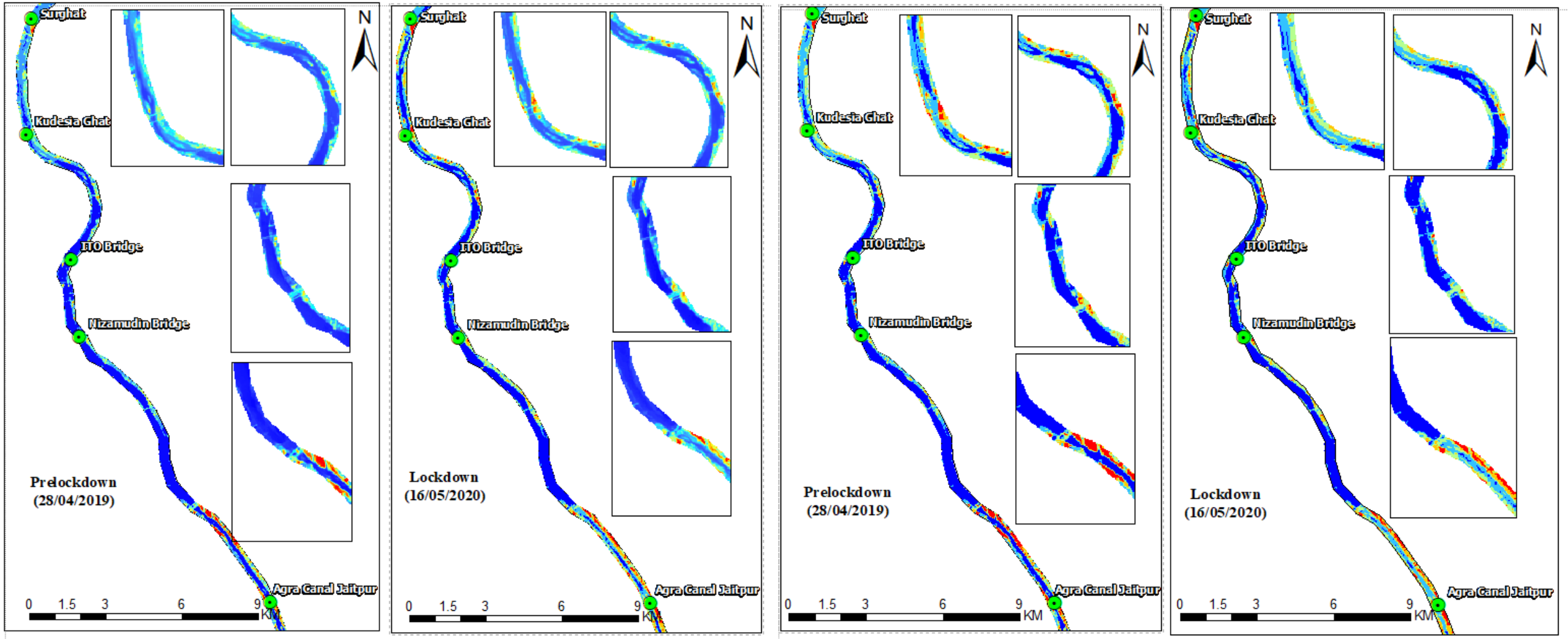


Chlorophyll a during Lockdown and Pre-lockdown period



Suspended Particulate Matter during Lockdown and Pre-lockdown period

Turbidity during Lockdown and Pre-lockdown period



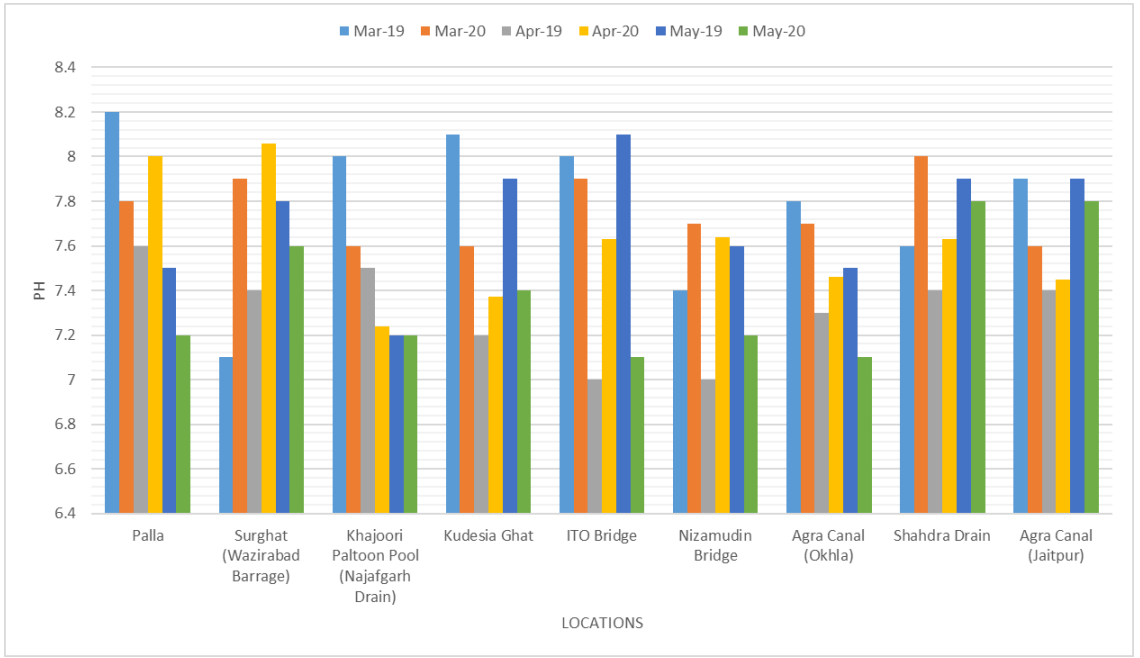
Suspended Particulate Matter (mg/l)

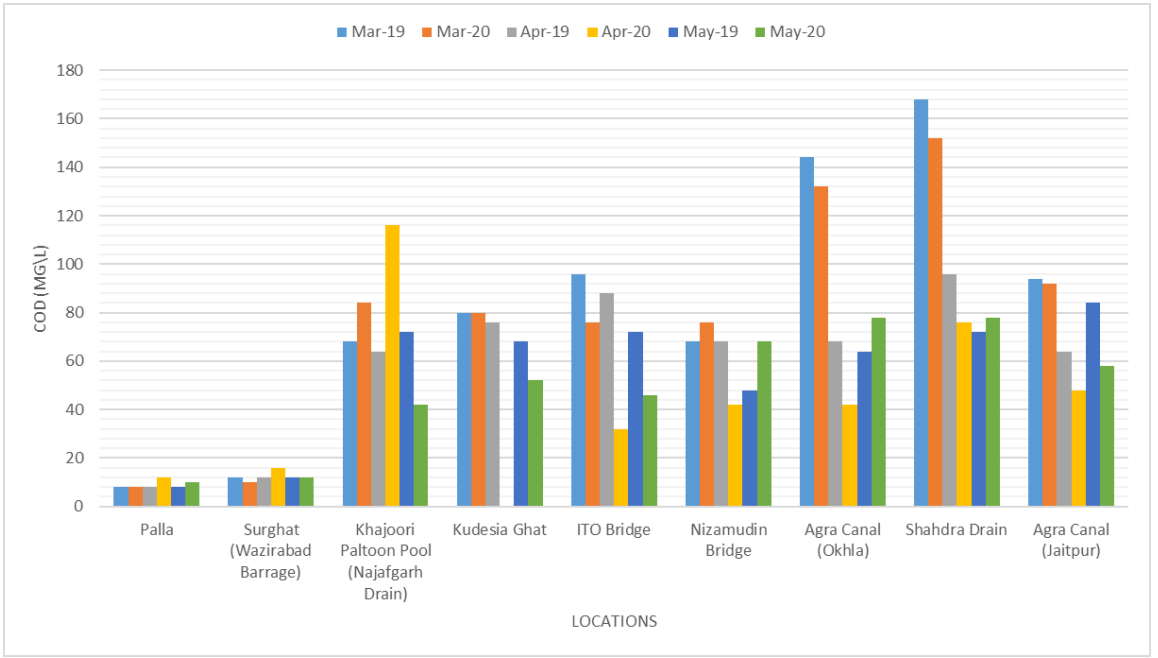
0 -10 | 10 - 20 | 20 - 30 | 30 - 40 | 40 - 50 | 50 - 60

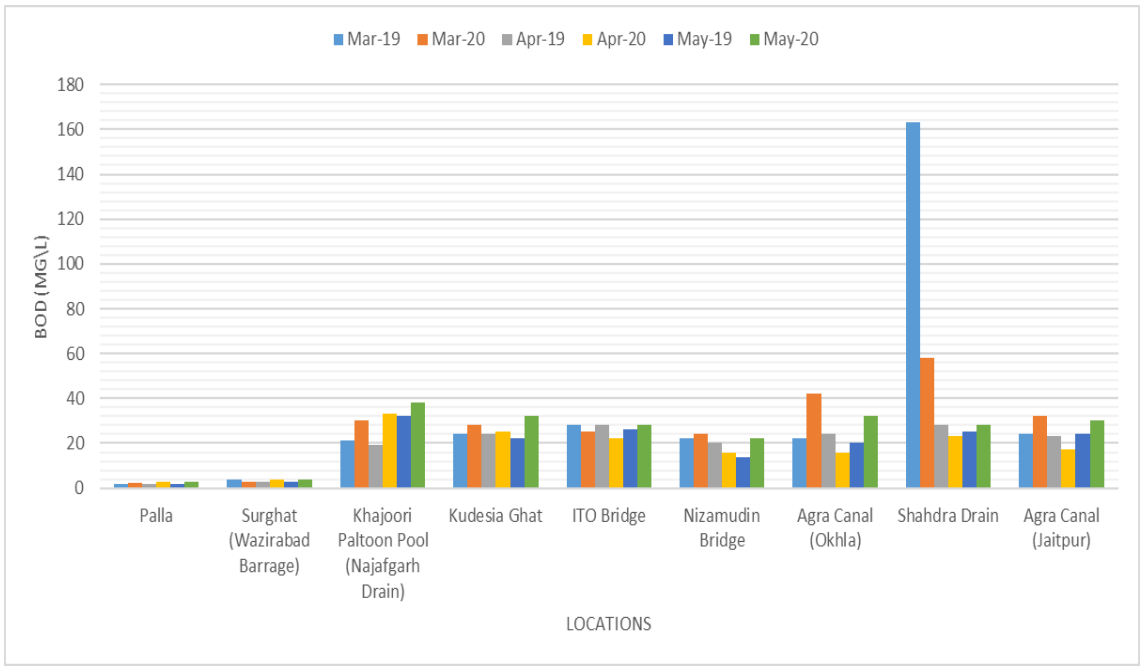
Turbidity (FNU)

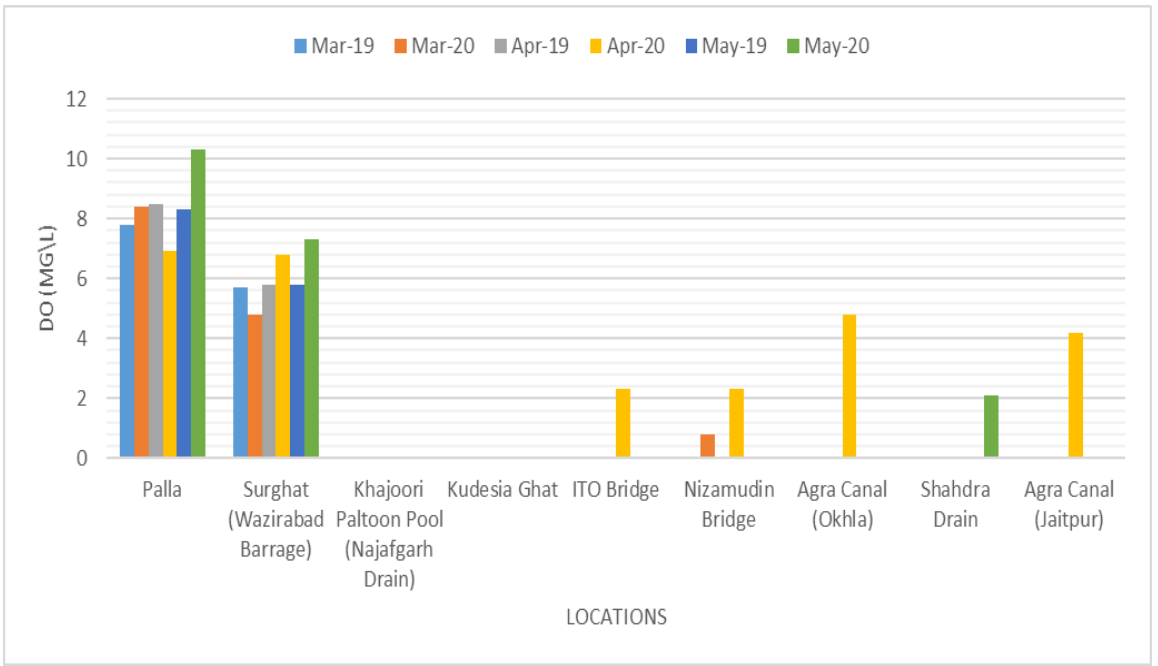
<50 | 50 - 100 | 100 - 200 | 200 - 300 | >300

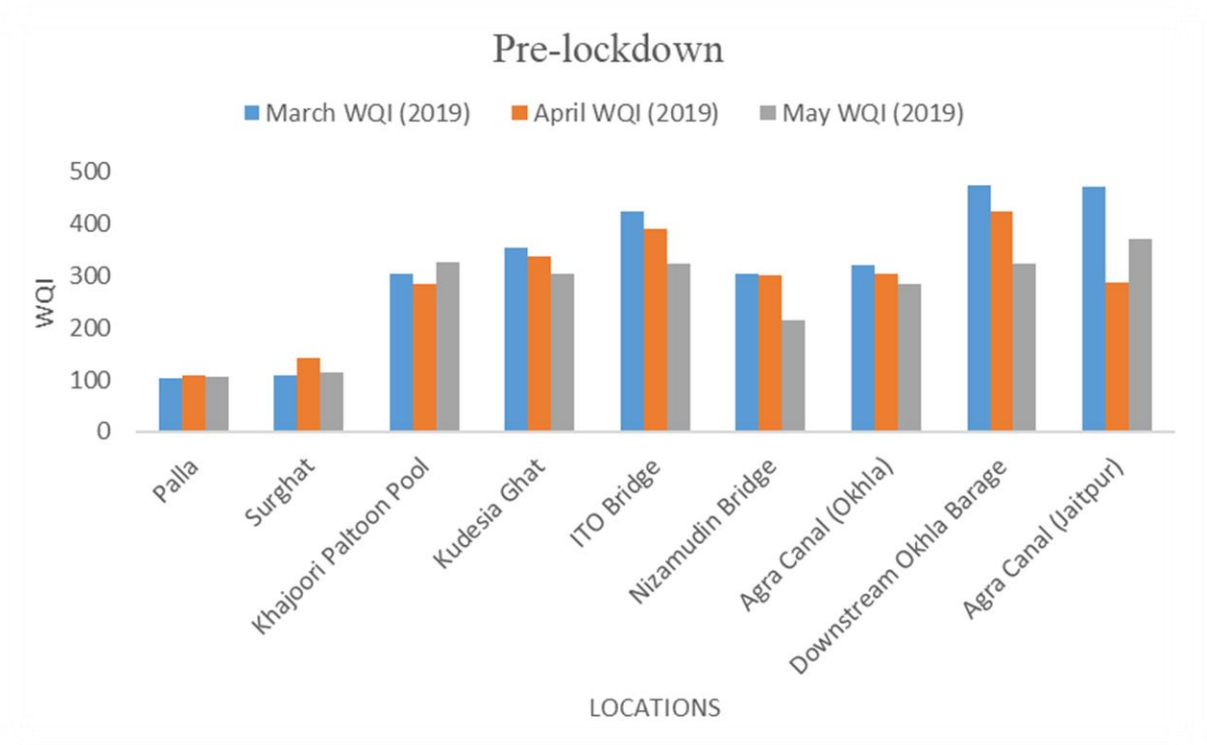
Water Quality Status during Lockdown and Pre-Lockdown Period

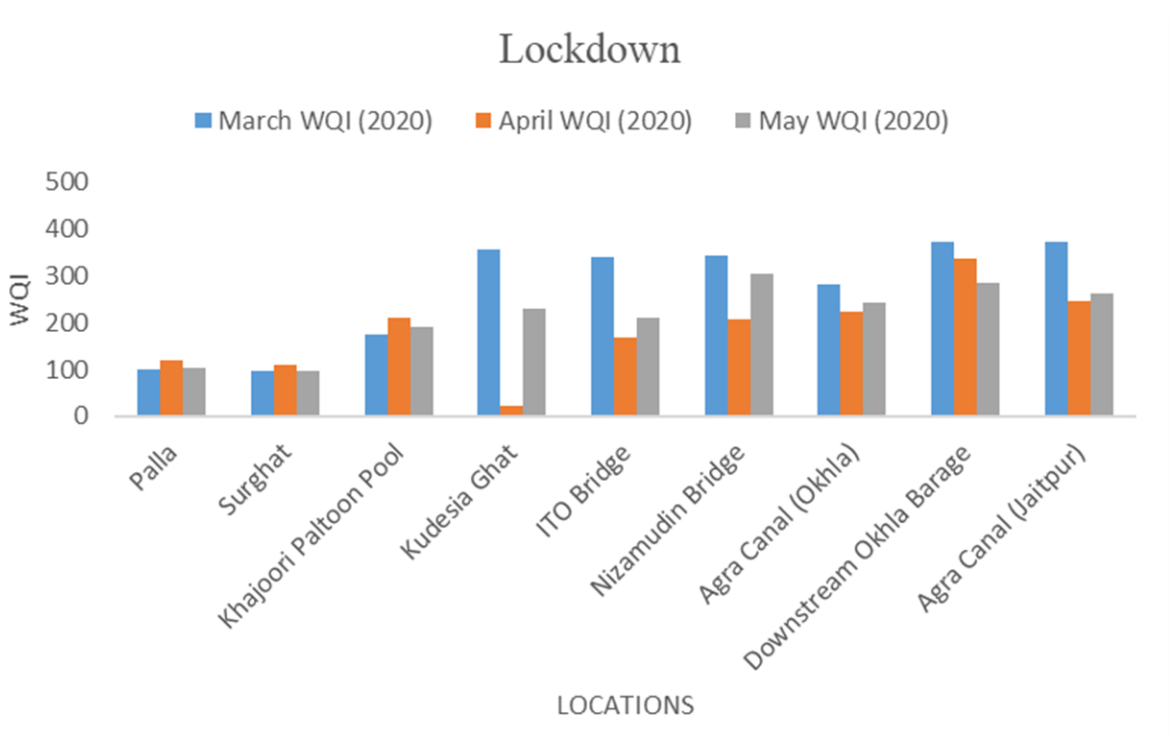












Water Quality Index (WQI) Value	Water Quality Status	Grading
0 - 25	Excellent Water Quality	A
26 – 50	Good Water Quality	B
51 – 75	Poor Water Quality	C
76 - 100	Very Poor Water Quality	D
Above 100	Unfit for drinking	E

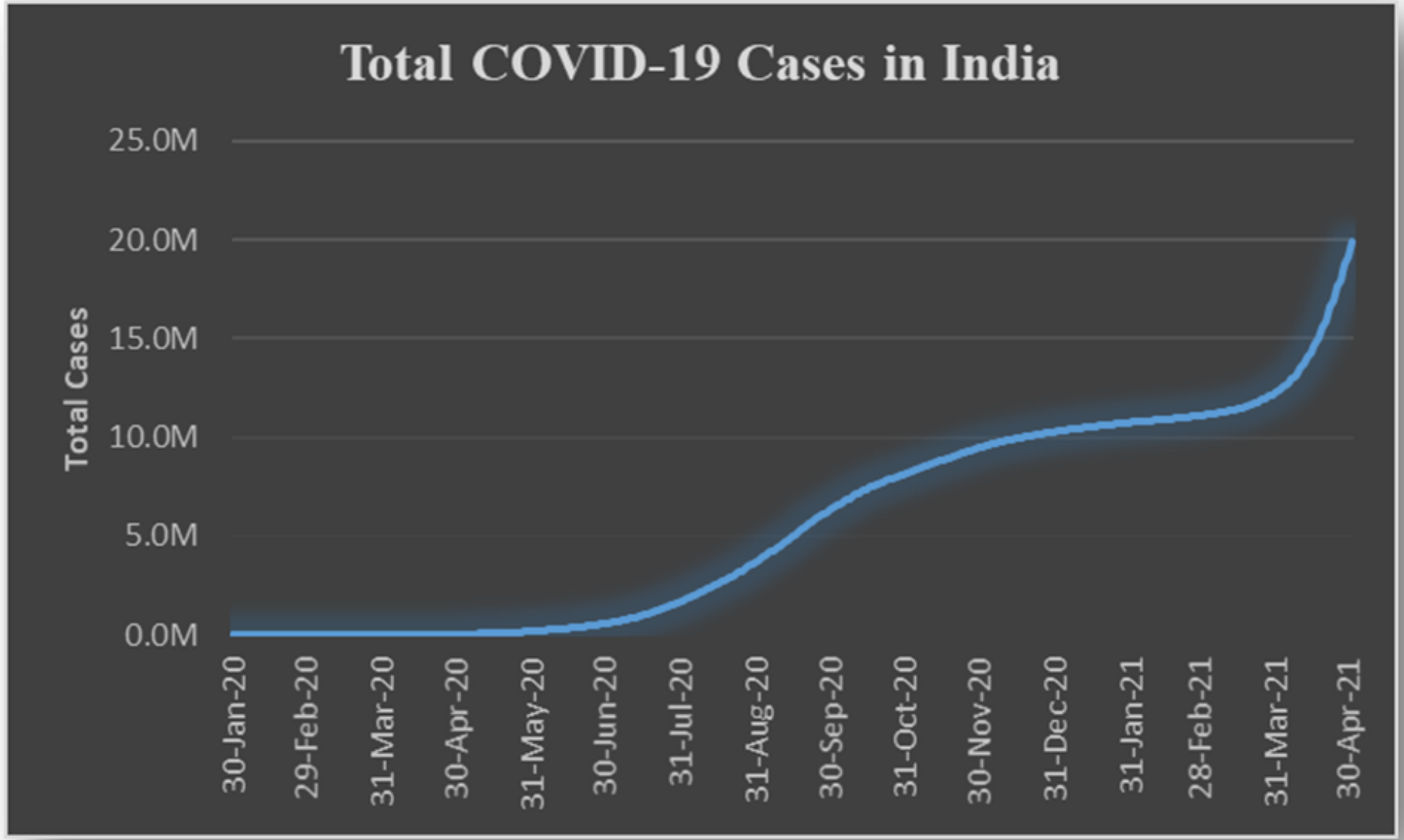
Conclusion

- Lockdown has had significant impacts on the water quality of the Yamuna river within its Delhi stretch. This has enhanced the water quality index of Yamuna river. This study also revealed that the condition of Yamuna river is critical and the extent of pollution is very high but during the lockdown period water quality has been improved.
- All the discharge activities before lockdown contribute the highest to its pollution. DO was observed to be zero in Yamuna at Nizamuddin drain which is a great concern for aquatic life. With fast urbanization & industrialization the generation of wastewater has taken a phenomenal growth. There was also a significant reduction in turbidity and SPM in the river.
- The assessments were limited by data limitations, but the fact that the Yamuna's water quality has improved could be convincingly proven. Despite these changes, the WQI status could not meet the CPCB's requirements.
- The COVID-19 worldwide pandemic is a once-in-a-lifetime event that is currently causing havoc on the world. However, one of its byproducts offers a once-in-a-generation opportunity to rethink and restructure existing structures, as well as put in place effective procedures to clean up one of India's most contaminated rivers and the country's other similarly afflicted waterways.

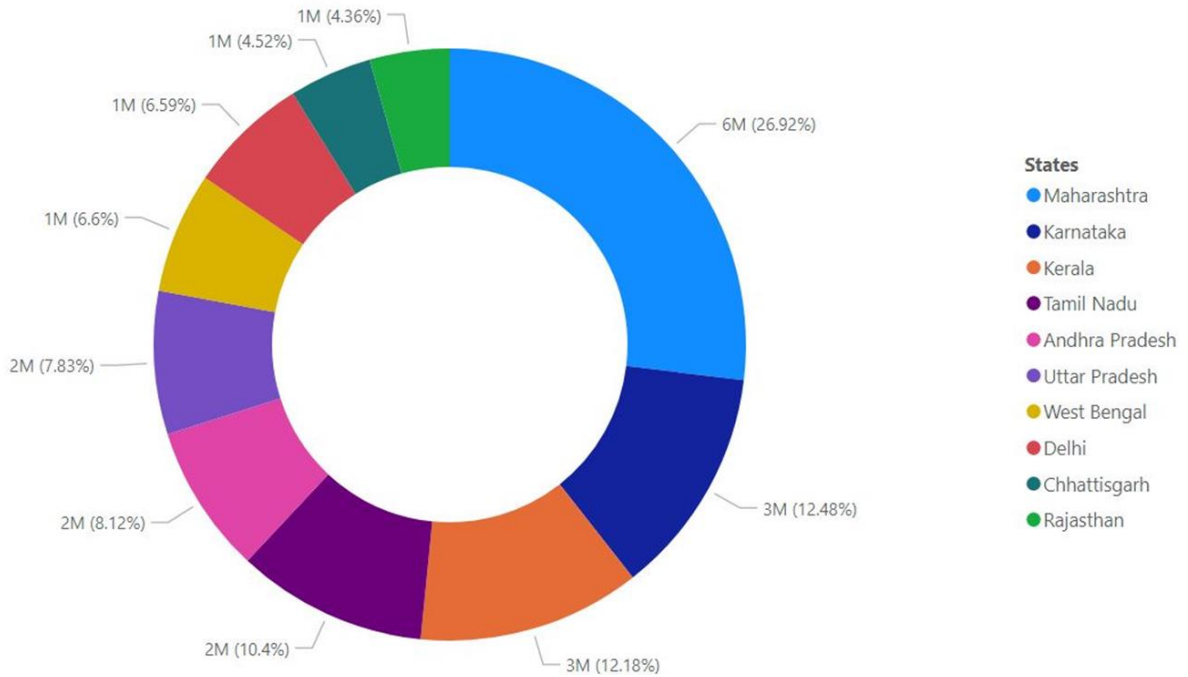
Chapter 5: Analyzing the impact of COVID-19 in regions of major inequality during the major disaster events

Introduction

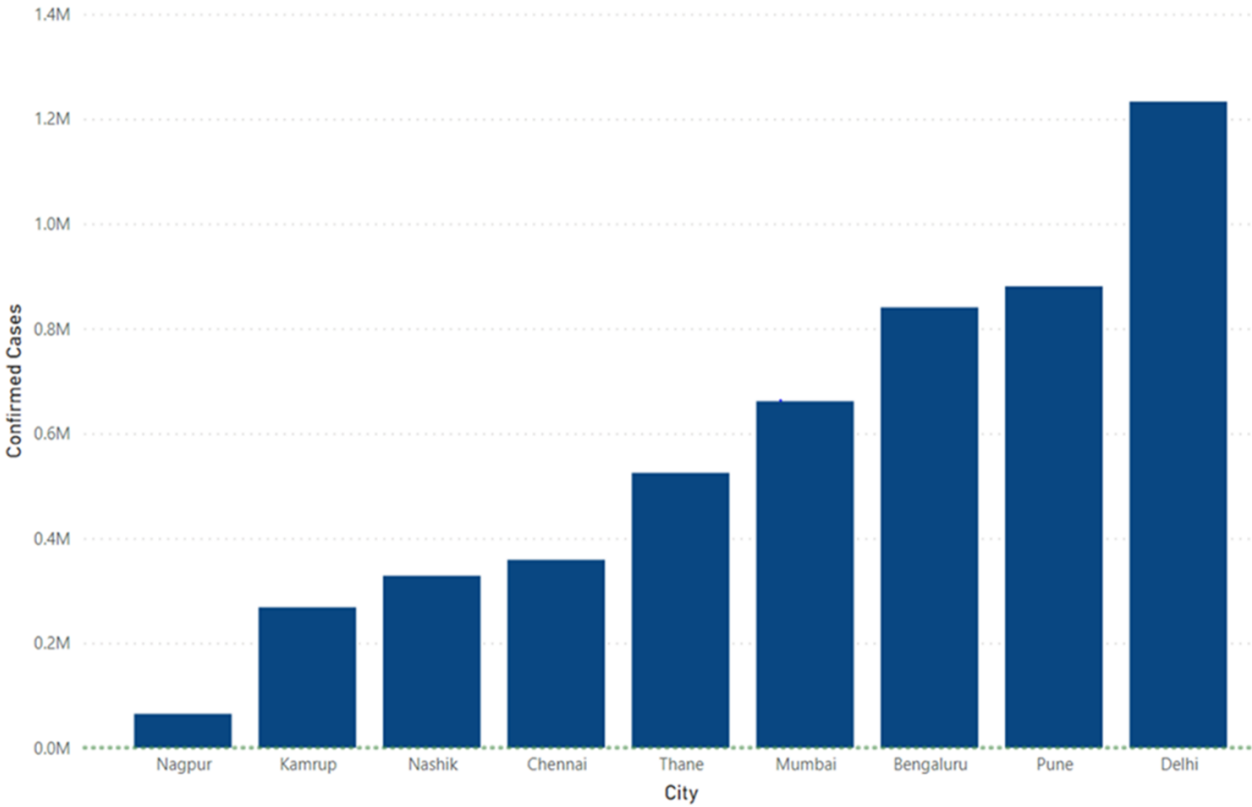
- As the number of COVID-19 cases rises every day in its second wave, governments are enacting tight restrictions on people's movements in order to prevent the disease from spreading further. We looked at mega cities of India that have been the worst affected and how restrictions imposed have led to change in their mobility
- The global response to the COVID-19 pandemic has brought a significant changes in human mobility patterns.
- Aim of this study is to analyze the impact of COVID-19 in regions of major inequality during the major disaster events. Mobile tracking data from thousands of recreationists were used to assess high resolution spatio-temporal changes in activity.
- During lockdown, traveler habits altered significantly, traversing from 'No travel - 100% work-from-home' to 'Limited travel'. Though the COVID-19 situation appears to be stabilizing in a few states, it is uncertain when normalcy will be restored and what the new normal will include.
- The goal of this study is to see whether types of venues, such as grocery stores, retail stores, parks, workplaces, residential areas, and transit stations, are more related with COVID-19 in India.


Total COVID-19 Cases in India
Total Cases
25.0M
20.0M
15.0M
10.0M
5.0M
0.0M
30-Jan-20
29-Feb-20
31-Mar-20
30-Apr-20
31-May-20
30-Jun-20
31-Jul-20
31-Aug-20
30-Sep-20
31-Oct-20
30-Nov-20
31-Dec-20
31-Jan-21
28-Feb-21
31-Mar-21
30-Apr-21

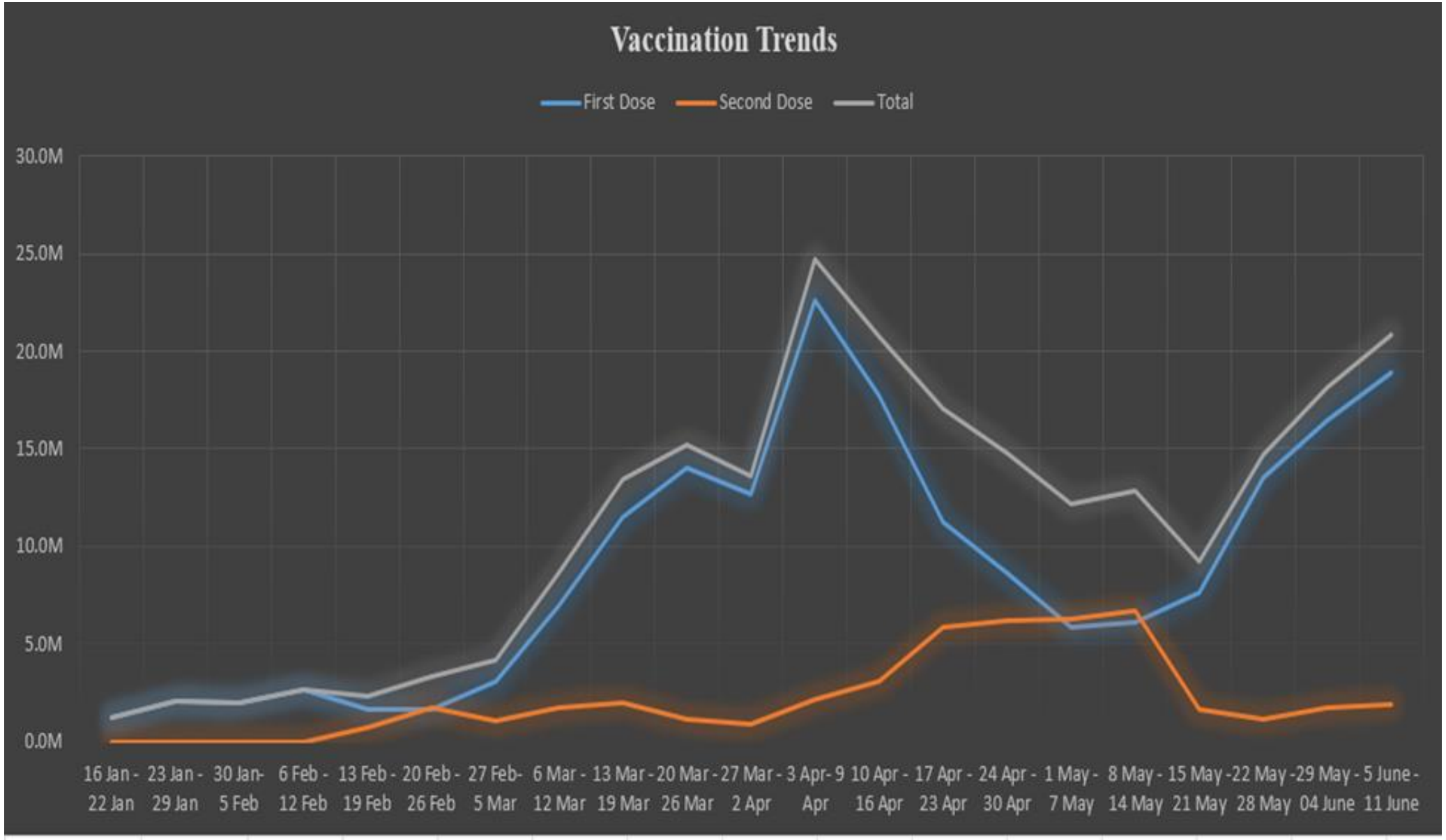
Most affected states of India due to the pandemic (As of June 8, 2021)



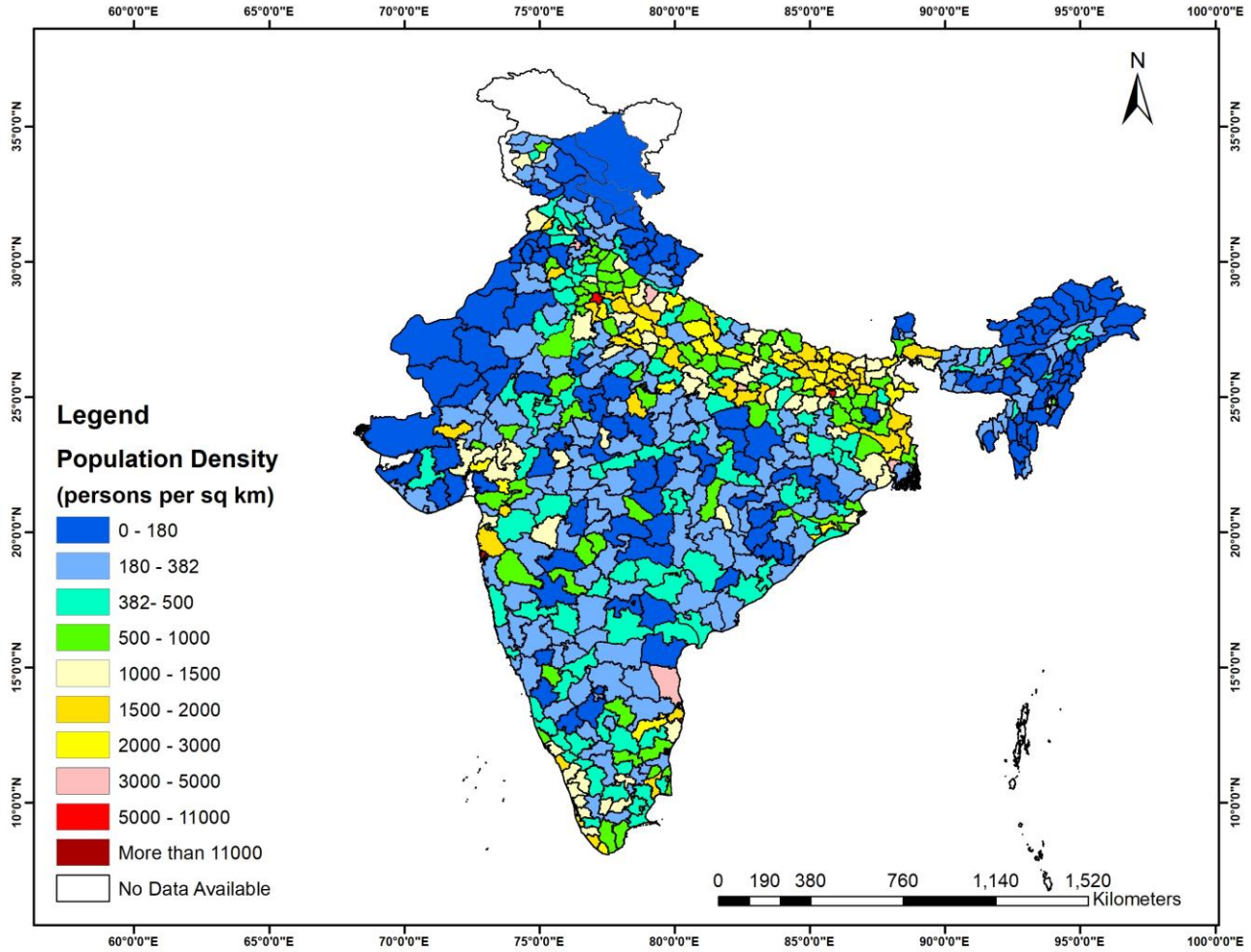
Most affected cities in India with the highest number of cases (As of May 5, 2021)



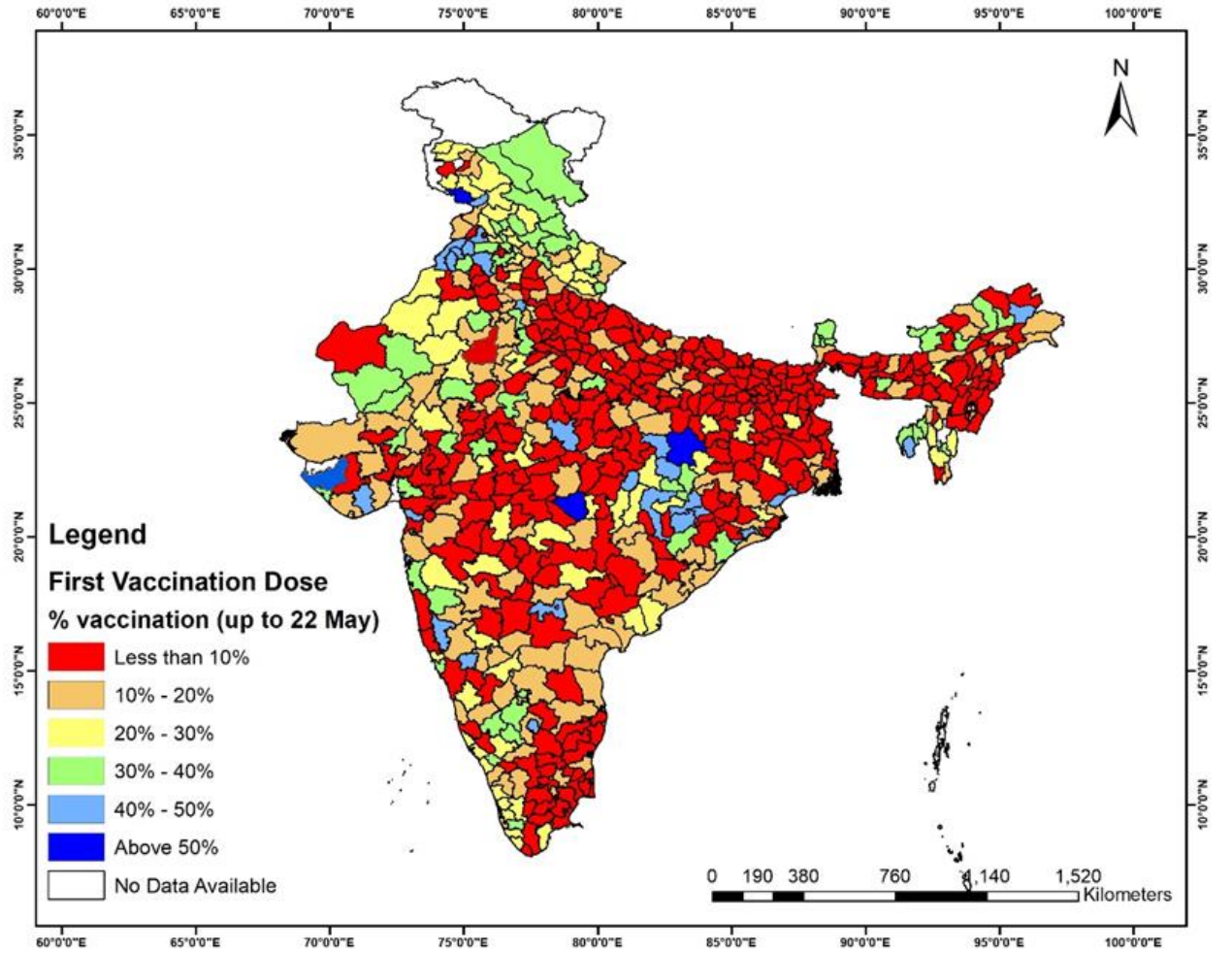
COVID Vaccination Progress (up to 11 June, 2021)



District wise population density of India

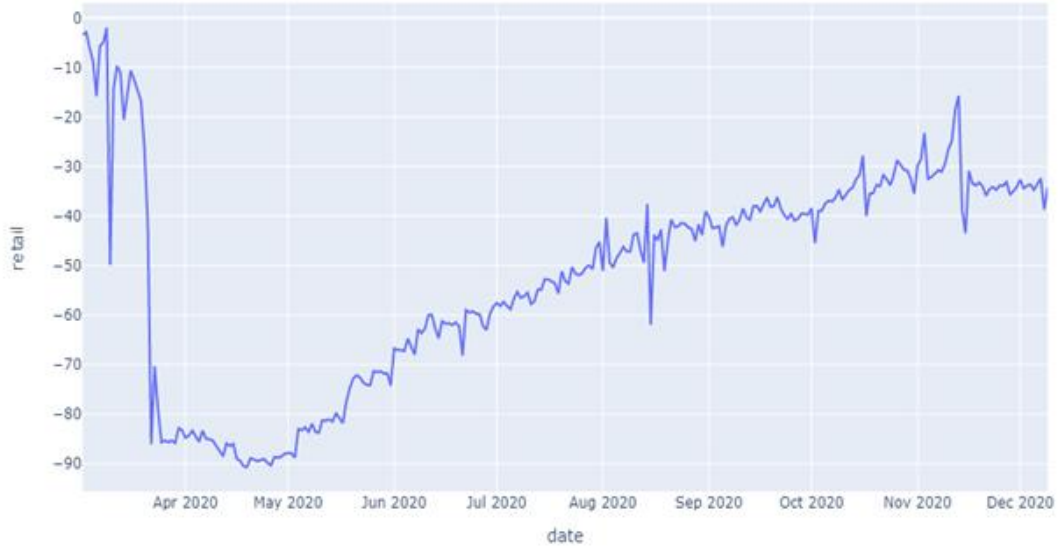


India's district wise COVID – 19 vaccination coverage (up to 22 May, 2021)

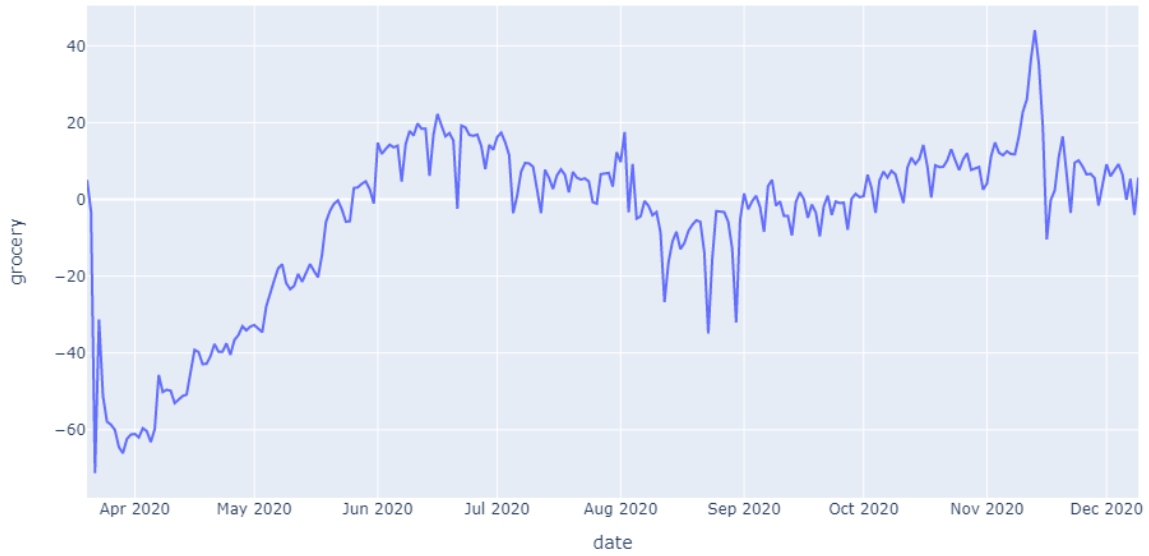


COVID – 19 Mobility (India)

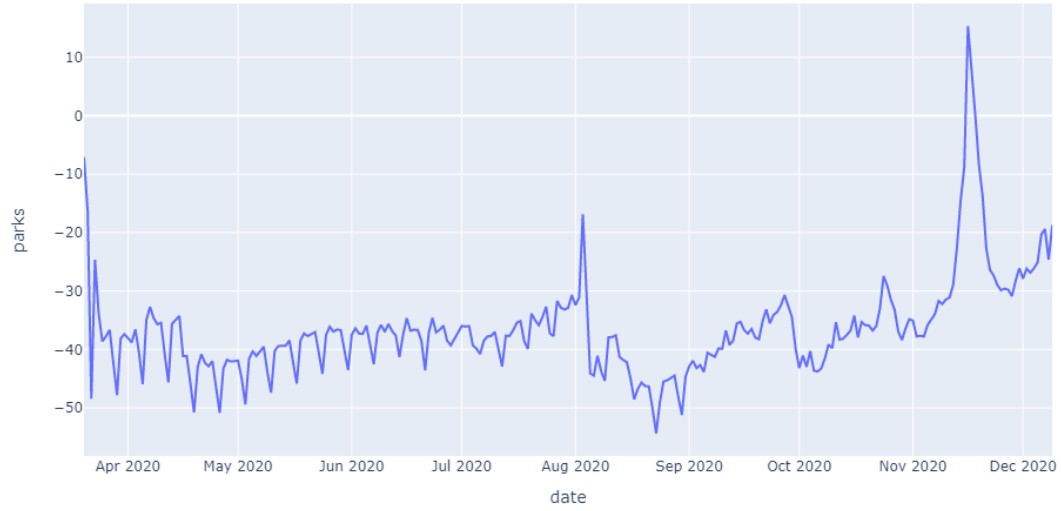
Retail and Recreation



Grocery

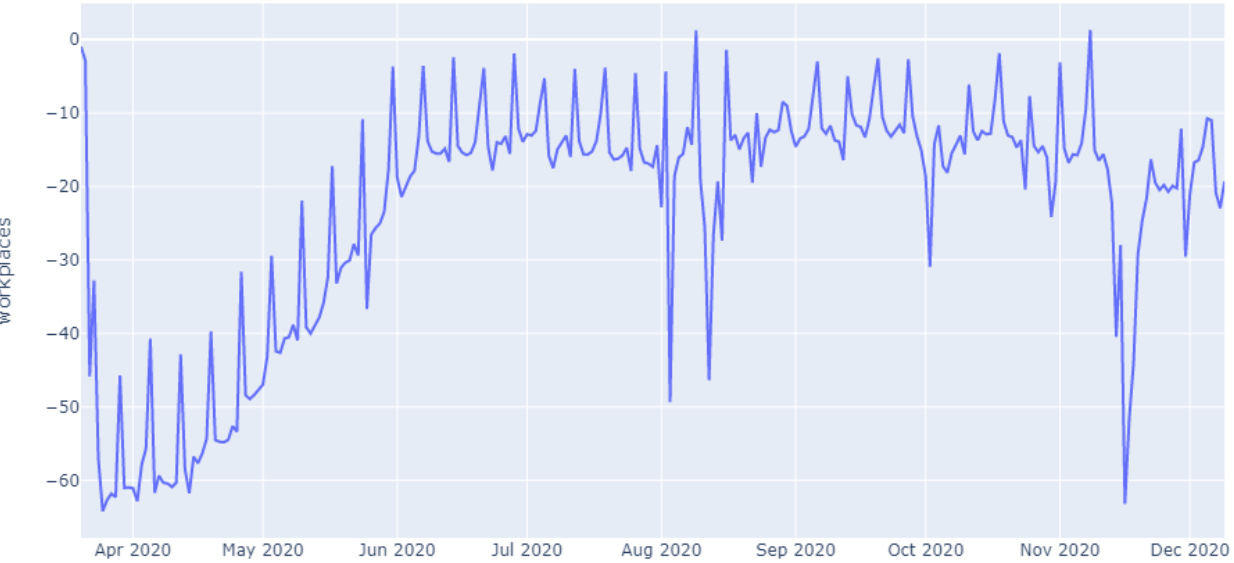


Parks

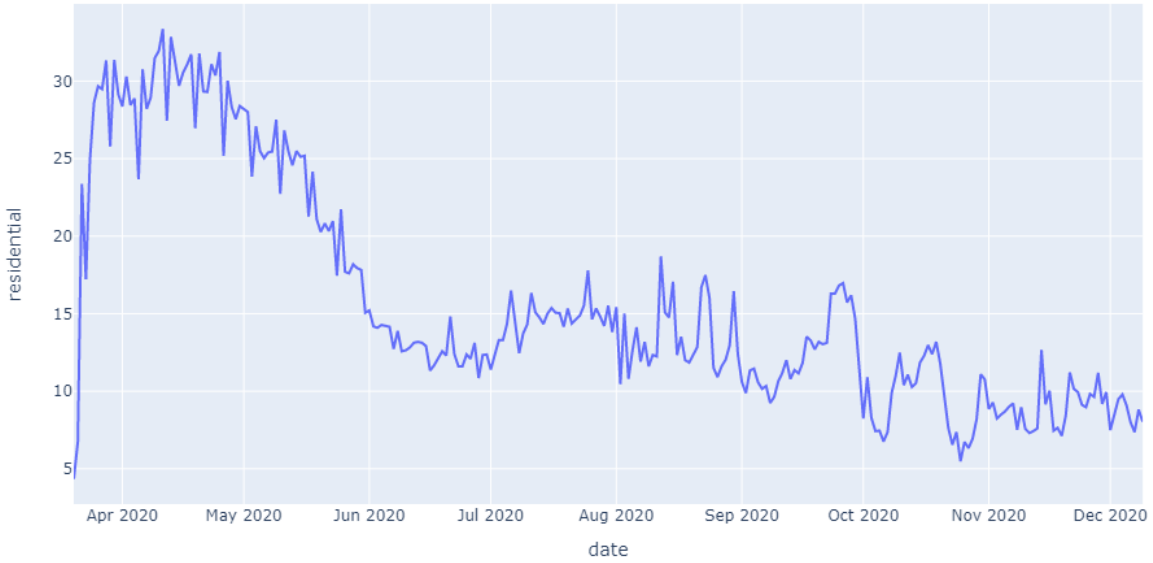


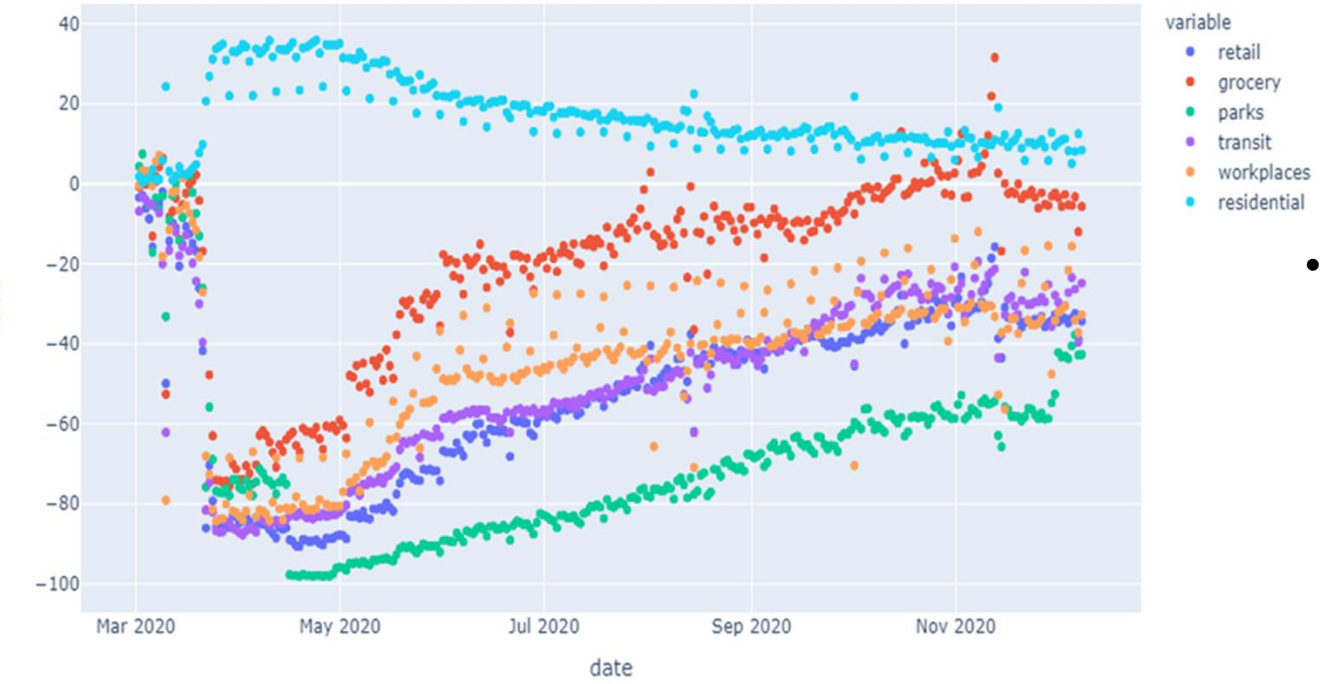
Transit

Workplaces



Residential





- Results compares the number of visits and length of stay at various locations to a baseline. We used the same type of aggregated and anonymised data that Google Maps uses to report popular times for locations to determine these changes.
- Movement towards places of work decreased by 72 percent from the baseline on March 25, 2020, the lowest level ever recorded. Similarly, in the early days of the lockdown, people's movement towards transit terminals such as bus and metro stations dropped by nearly 70% as things came to a halt due to restrictions on public transportation.

Conclusion

- The goal of this study was to emphasize the central importance of vaccine development and immunization tactics used during a pandemic in a densely populated country (India). This study can be used as a starting point for future pandemic preparedness, as well as to personalize and develop tactics that will benefit the general public.
- The present COVID-19 pandemic has triggered rapid development, emergency use authorization, and unprecedented collaboration among numerous parties. Vaccination may be a cost-effective strategy for people's survival and a better quality of life, as well as for the resuscitation of India's economy, however there are still doubts. Vaccination, for example, may not be effective for certain people. As a result, the vaccine platforms must be re-evaluated on a regular basis.
- This study was more focused on the mobility trends in India. Movement towards places of work decreased by 72 percent from the baseline on March 25, 2020, the lowest level ever recorded. Similarly, in the early days of the lockdown, people's movement towards transit terminals such as bus and metro stations dropped by nearly 70% as things came to a halt due to restrictions on public transportation.
- According to this study, retail and recreation sector is more adversely affected during lockdown. It reached its lowest point as a result of a complete shutdown ordered by governments around the world in order to address the current health issue. Similarly, going to parks, beaches and gardens have reduced by 37 percent.

References

- Mahato, S.; Pal, S.; Ghosh, K.G. Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. Sci. Total Environ. 2020, 730, 139086.
- Sharma, S.; Mathur, S. Analysing the Patterns of Delhi's Air Pollution. In Advances in Data Sciences, Security and Applications; Springer: Singapore, 2020; pp. 33–44.
- Mukherjee, A.; Agrawal, M. Air pollutant levels are 12 times higher than guidelines in Varanasi, India. Sources and transfer. Environ. Chem. Lett. 2018, 16, 1009–1016. Garaga, R.; Sahu, S.K.; Kota, S.H. A review of air quality modeling studies in India: Local and regional scale. Curr. Pollut. Rep. 2018, 4, 59–73. Guo, H.; Kota, S.H.; Sahu, S.K.; Hu, J.; Ying, Q.; Gao, A.; Zhang, H. Source apportionment of PM2. 5 in North India using source-oriented air quality models. Environ. Pollut. 2017, 231, 426–436.
- World Health Organization. Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. 2016. Available online: http://who.int/phe/publications/airpollution-globalassessment/en/ (accessed on 20 May 2020).
- Lal Preet, Kumar Amit, Kumar Shubham, Kumari Sheetal, Saikia Purabi; The dark cloud with a silver lining: Assessing the impact of the SARS COVID-19 pandemic on the global environment, Department of Geoinformatics, Central University of Jharkhand, Brambe-835205, Ranchi, Jharkhand, India.
- Liu Qian, Sha Dexuan, Liu Wei, Houser Poul, Zhang Luyao, Hou Ruizhi, Lan Hai; Spatiotemporal Patterns of COVID-19 Impact on Human Activities and Environment in Mainland China Using Nighttime Light and Air Quality Data, Department of Geography and Geoformation Science, George Mason Univ., Fairfax, VA 22030, USA; phouser@gmu.edu (P.H.); cflynn8@gmu.edu (C.F.)


Thank you!