Managing Water Assets in Urban Planning : Use of Satellite Images and Drones

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Motivation

- Modern urban planning in India is confronted with major challenges such as accelerated growth and land-use change, unplanned expansion and water supply management issues.
- Effective urban management decisions should be properly supported by transparent evidence that can be transmitted to public stakeholders.
- State-of-the-art remote sensing and GIS skills including the use of UAVs will allow to rise to the challenge of managing the rapidly changing urban environment of Indian cities

Rapid Urbanization in India

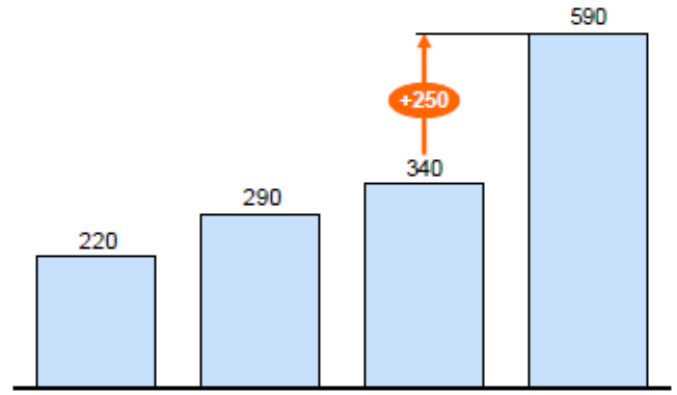
Cities accommodate nearly 31% of India's current population and contribute 63% of GDP (Census 2011). ***Urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030.***

Comprehensive development of physical, institutional, social and economic infrastructure.

- As India's **population continues to grow**, more citizens will move to cities.
- About **25-30 persons from rural areas** will **migrate every minute** to major Indian cities in search of a better livelihood and lifestyle.
- It is estimated that by **2050**, the number of people living in Indian cities will touch **843 million**.
- **Smarter ways** to manage complexities, reduce expenses, increase efficiency and improve the quality of life are required to accommodate this rapid urbanization, and make cities smart.

In MGI's base-case scenario, cities are likely to house 40 percent of India's population by 2030

Urban population
Million



	1991	2001	2008	2030
Total population, Million	856	1,040	1,155	1,470
Urbanization rate[1], %	26	28	30	40

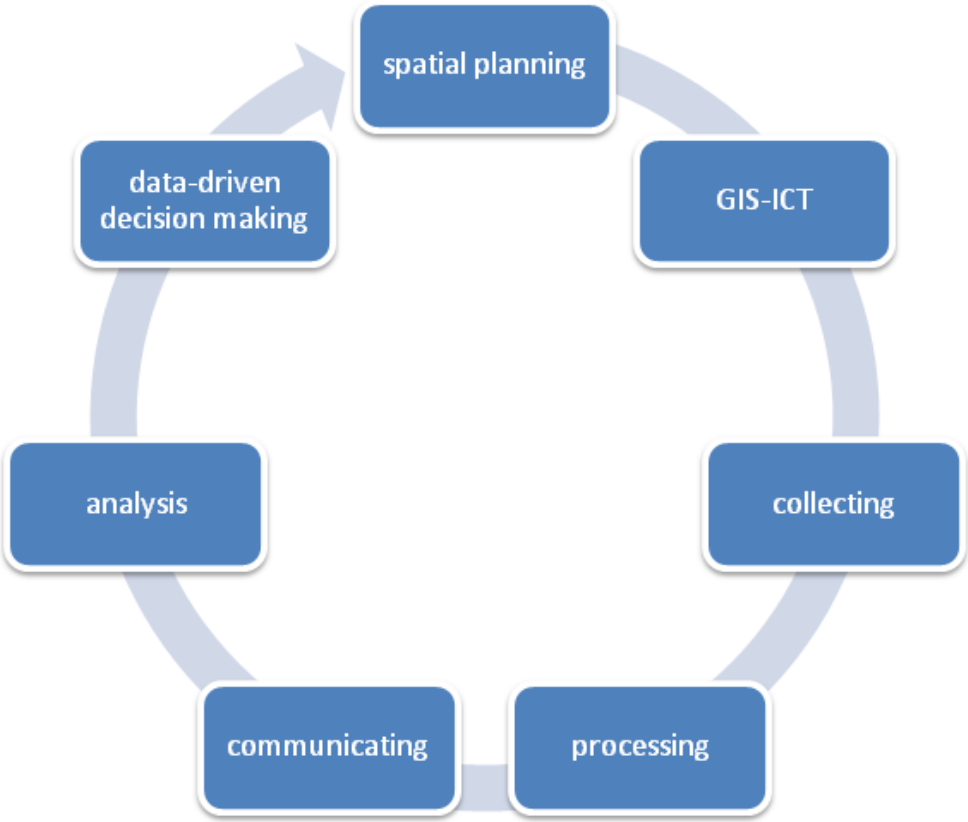
1 Defined as the ratio of urban to total population based on the census definition of urban areas; population >5,000; density >400 persons per square kilometer; 75 percent of male workers in nonagricultural sectors; and other statutory urban areas.

SOURCE: India Urbanization Econometric Model; McKinsey Global Institute analysis

Remote Sensing and GIS for a Smart City

Multidisciplinary field that includes surveying, photogrammetry, remote sensing, mapping, geographic information systems (GIS), geodesy and global navigation satellite system (GNSS)

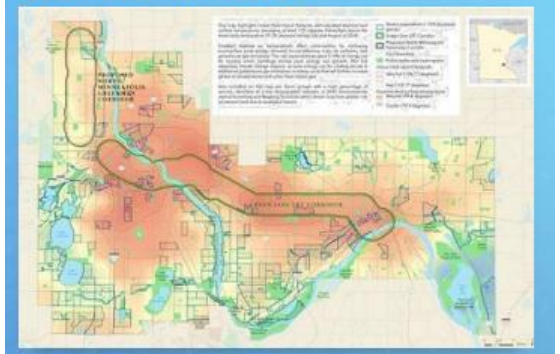
A centralized information system based on GIS provides an IT framework for maintaining and deploying data and applications throughout every aspect of the city development life cycle.



https://www.gislounge.com/how-gis-supports-the-planning-and-development-of-smart-cities/

Smart City: GIS Applications

Urban Heat Islands



Minneapolis, USA

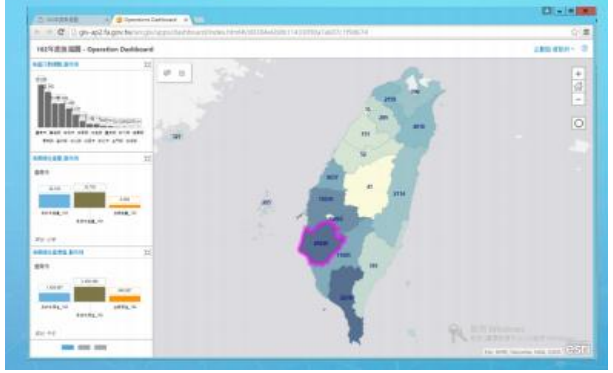
Historic District Property Values

Georgia, USA

Green Infrastructure

New Jersey, USA

Fisheries GIS



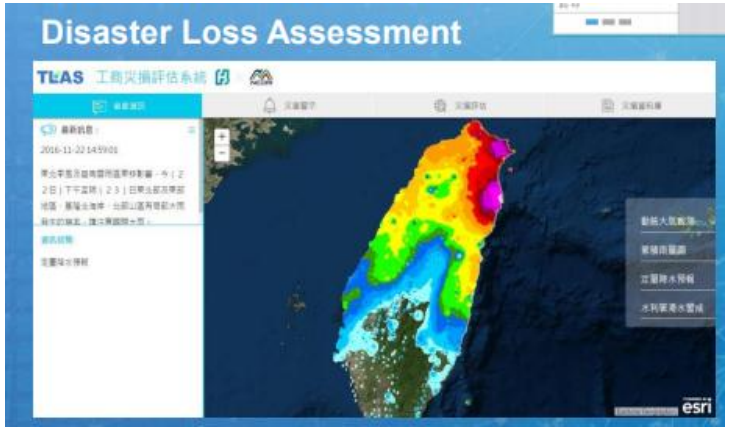
Disease Control and Prevention

China

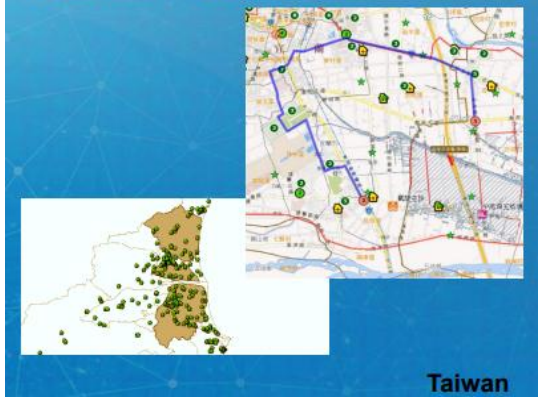
Housing Lifecycle Management

Beijing

Disaster Loss Assessment

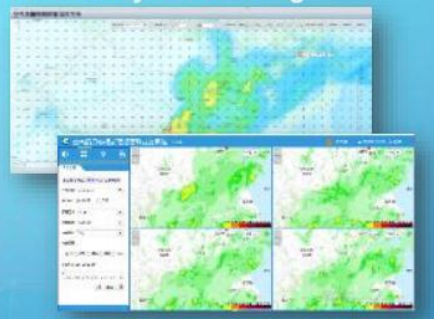


Real-time Flooding Info



Taiwan

Air Quality Forecasting



China

Environmental Monitoring

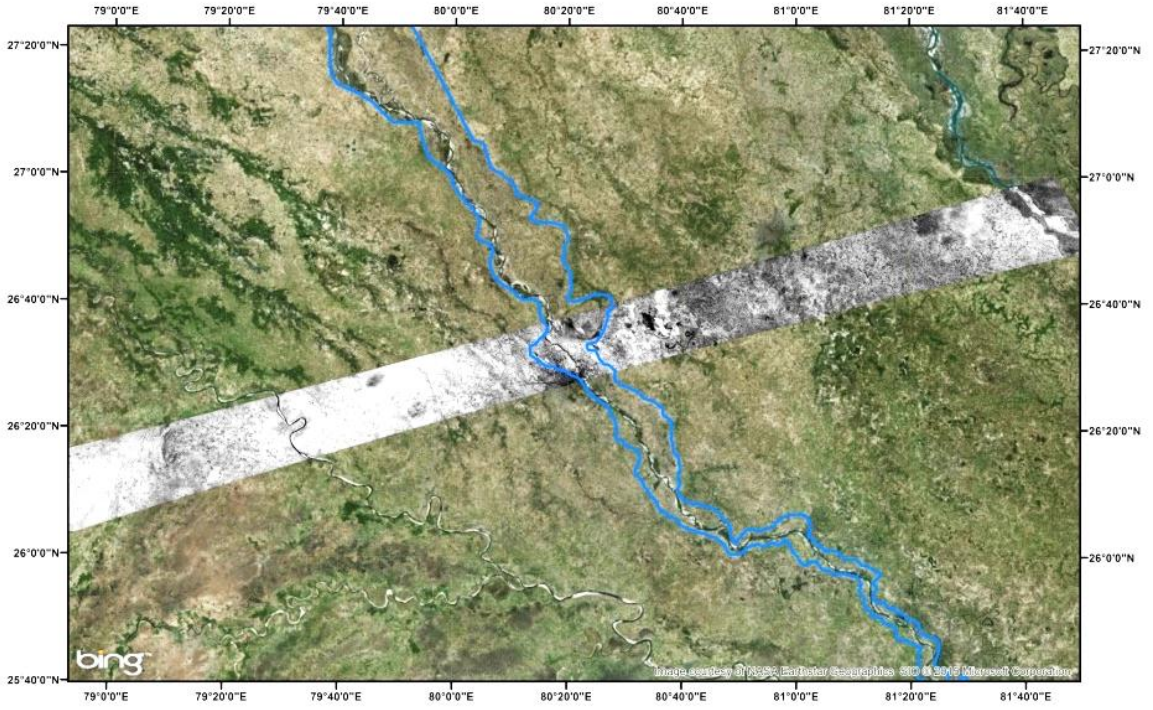
Macau

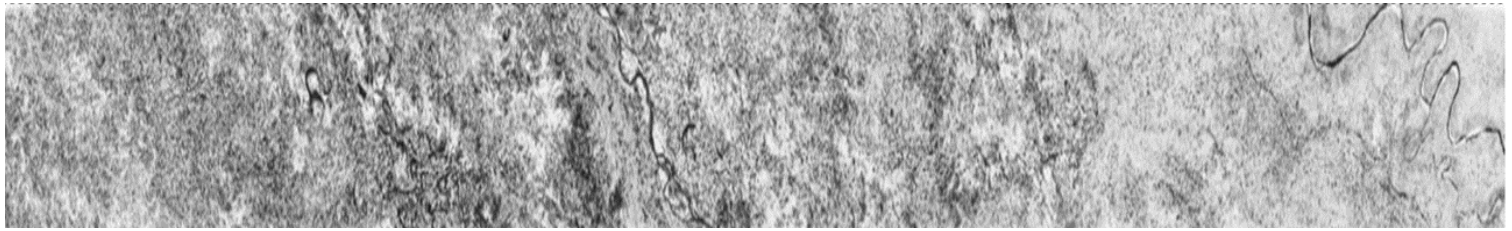
Port Management

Shanghai

Historical Remote Sensing Data: CORONA

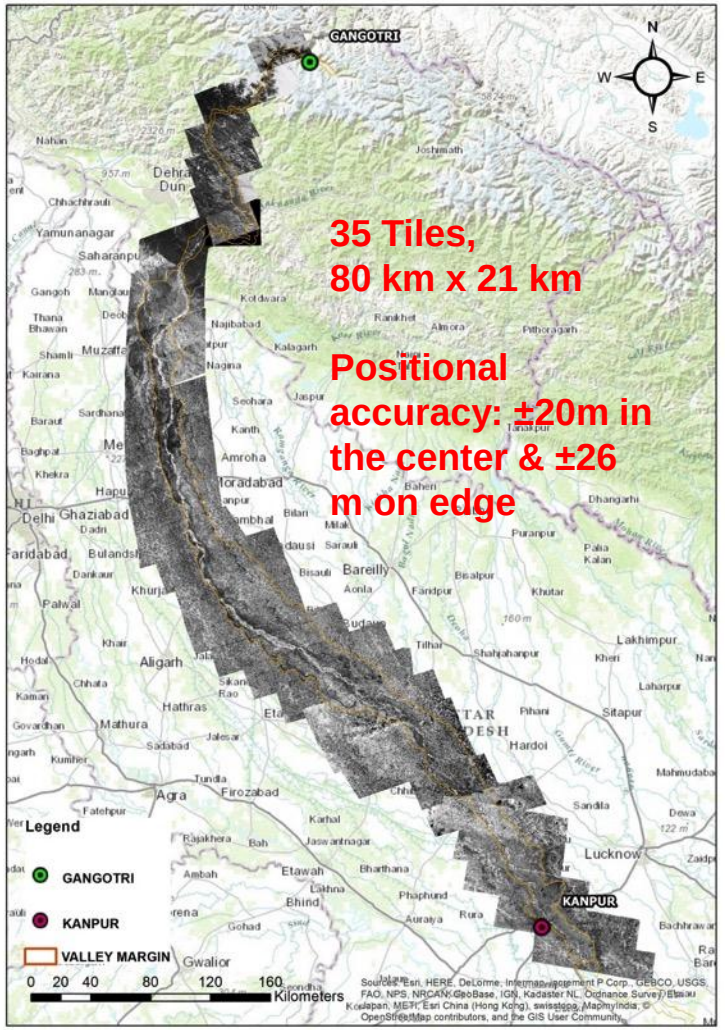
- **Corona spy-satellite images** from the 60s, now declassified, offer us a unique view of the Earth at the very early stages of intense development and thus before the urban explosion in India.
- Can help in gaining information on the urban density and major interventions on natural systems such as rivers and lakes of any region **and can thus help in reconstructing the baseline conditions for water asset management**





Historical Remote Sensing Data: CORONA

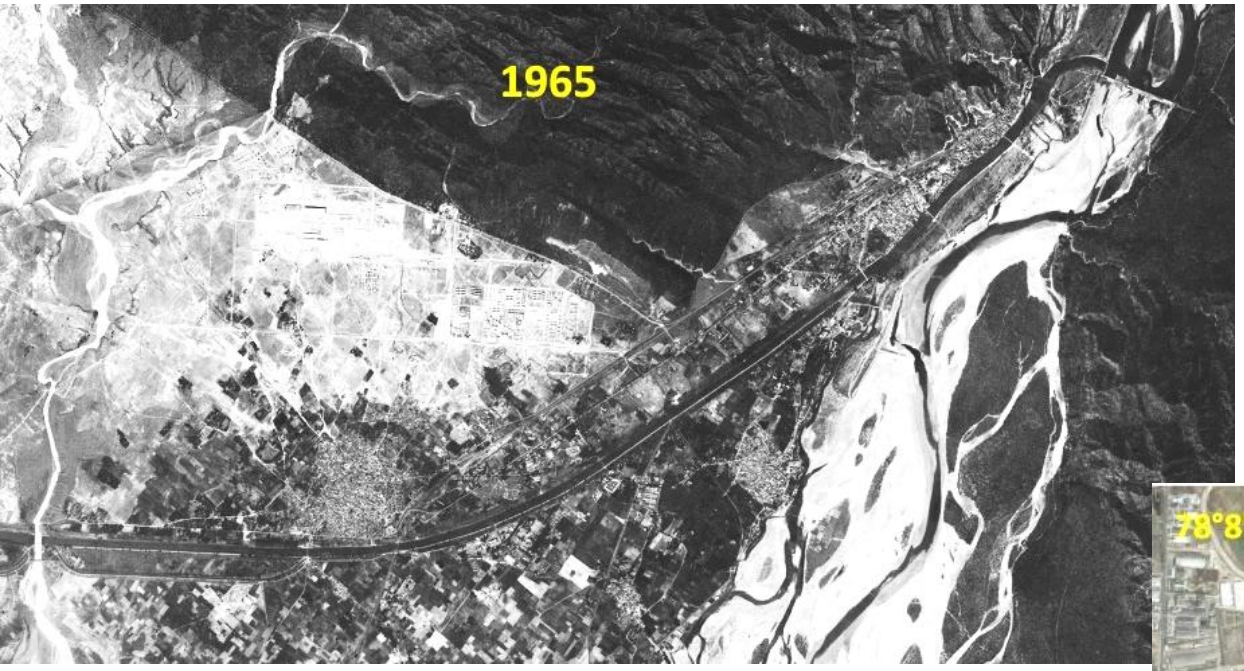
- Technical challenges:
  - Very high resolution (<10m) comes at the cost of extreme distortions
  - No information on the exact position and orientation of the satellite at the time of image acquisition - so an accurate projection of the image into conventional map coordinates is not straightforward
  - Single band data of high resolution, so image classification is very challenging to extract LULC information
- Previous work on geometric correction of Corona images supported by MOES and a current project on the Ganga basin supported by NMCG.
  - Developed a protocol for processing the Corona images for rectification and classification using textural characteristics
  - Documenting the changes in the Ganga River since 1960s - 'Reconstructing' the Ganga of the Past



The Corona Program: Summary of all Missions

Time period	Number	Nickname	Resolution	Remarks
Jun 1959 – Sep 1960	KH-1	"Corona", C	7.5 m	First series of American imaging spy satellites. Each satellite carried a single panoramic camera and a single return vehicle.
Oct 1960 – Oct 1961	KH-2	C-prime	7.5 m	Single panoramic camera and a single return vehicle.
Aug 1961 – Jan 1962	KH-3	C-triple-prime	7.5 m	Single panoramic camera and a single return vehicle.
Feb 1962 – Dec 1963	KH-4	Corona-M, Mural	7.5 m	Film return. Two panoramic cameras.
Aug 1963 – Oct 1969	KH-4A	Corona J-1	2.75 m	Film return with two re-entry vehicles and two panoramic cameras. Large volume of imagery.
Sep 1967 – May 1972	KH-4B	Corona J-3	1.8 m	Film return with two re-entry vehicles and two panoramic rotator cameras.
Feb 1961 – Aug 1964	KH-5	Argon	140 m	Low-resolution mapping missions; single frame camera.
Mar 1963 – July 1963	KH-6	Lanyard	1.8 m	Experimental camera in a short-lived program.
July 1963 – June 1967	KH-7	Gambit	0.40-1.20 m	Reconnaissance mission (‘spotting’ satellite), Second declassification in 2002
March 1973 – Oct 1980	KH-9	Hexagon	6-9 m	Mapping mission, About 130x260 km coverage; Second declassification in 2002

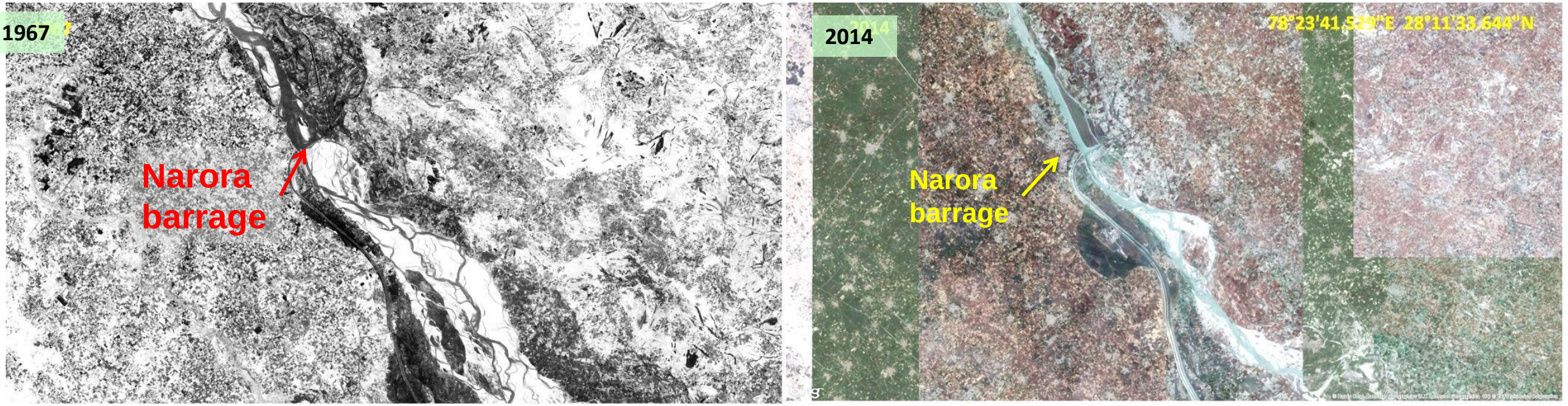
‘Reconstructing’ the Urban density of the Past from Corona archival imagery



- Corona – Spy satellite images of 1960s
- What was the original state and extent of the cities before major urban expansion?
- How to asses the level of anthropogenic disturbance on water assets?
- How to plan the Rejuvenation efforts?

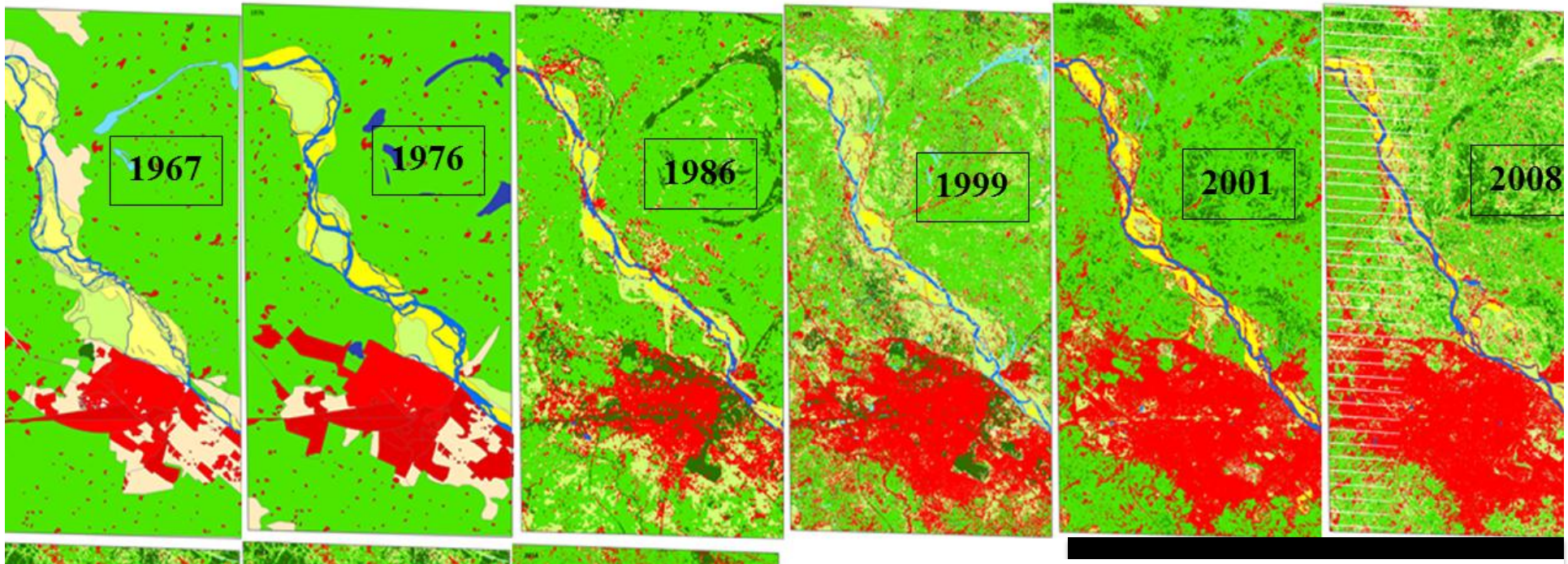
Massive urbanization around Haridwar

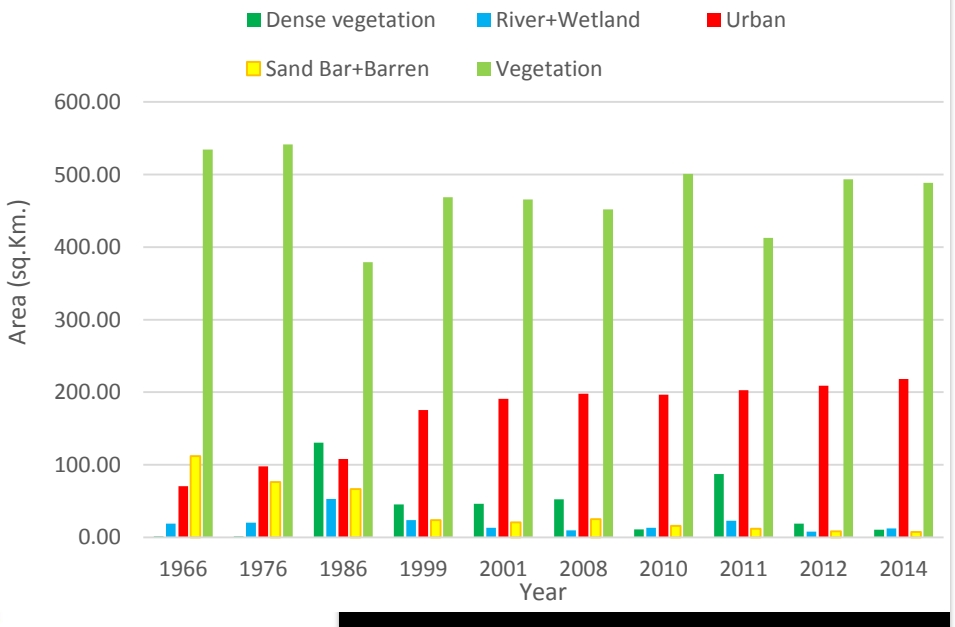
‘Reconstructing’ the Urban density of the Past from Corona archival imagery



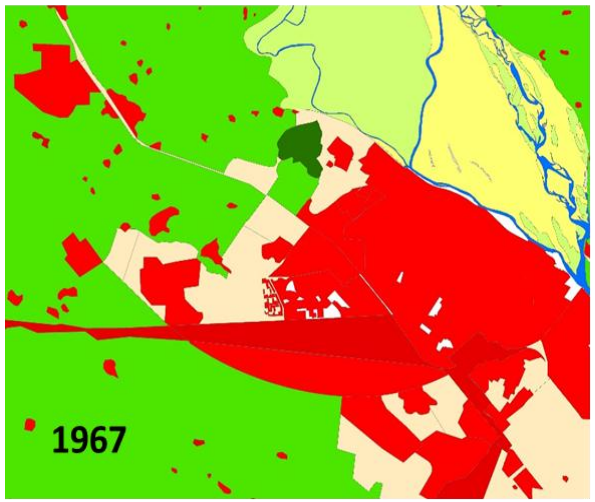
Channel modification due to Narora Barrage

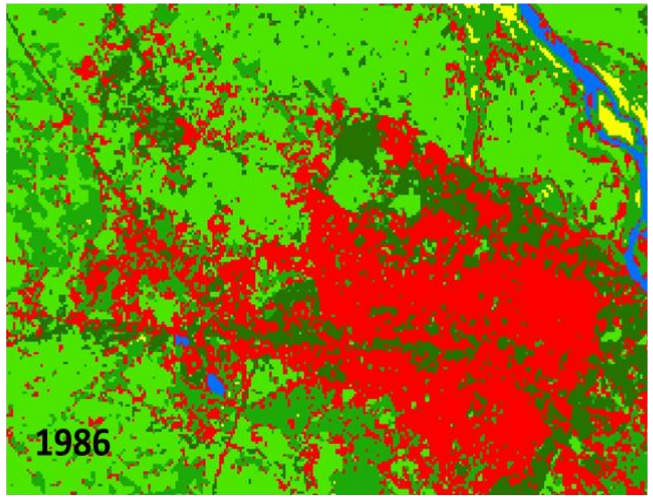
LULC changes and Urban expansion around Kanpur

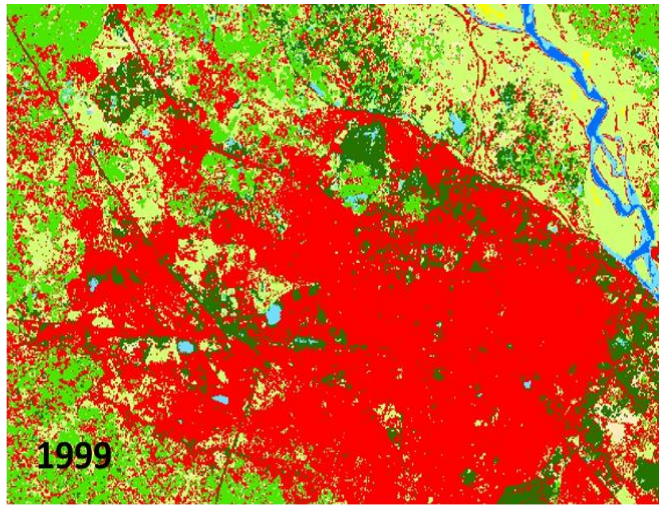


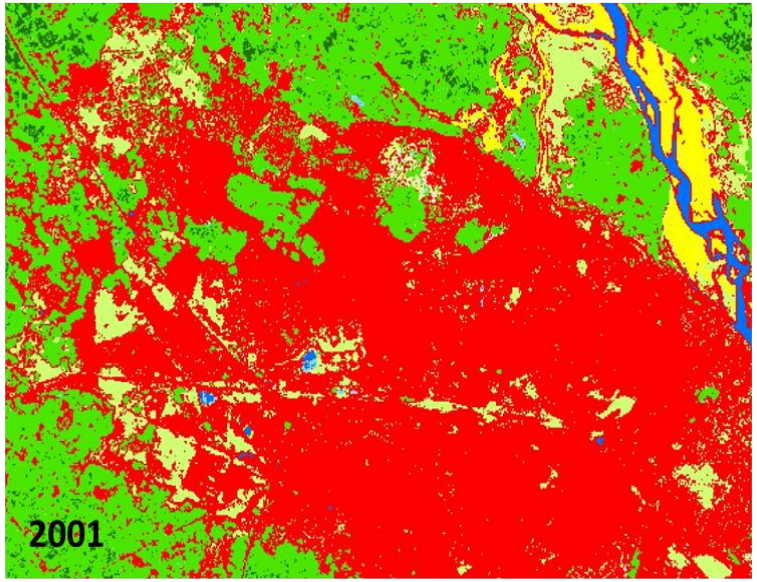


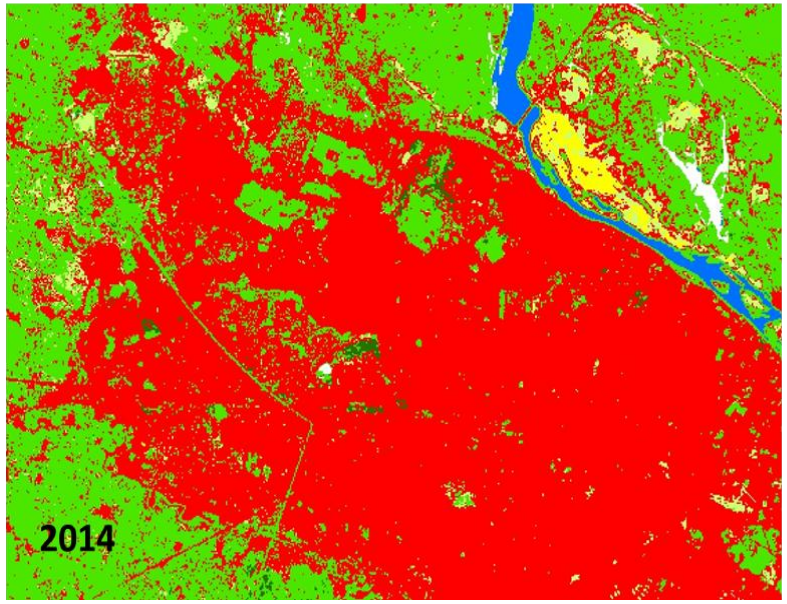
Urban Expansion (or explosion?) around Kanpur City







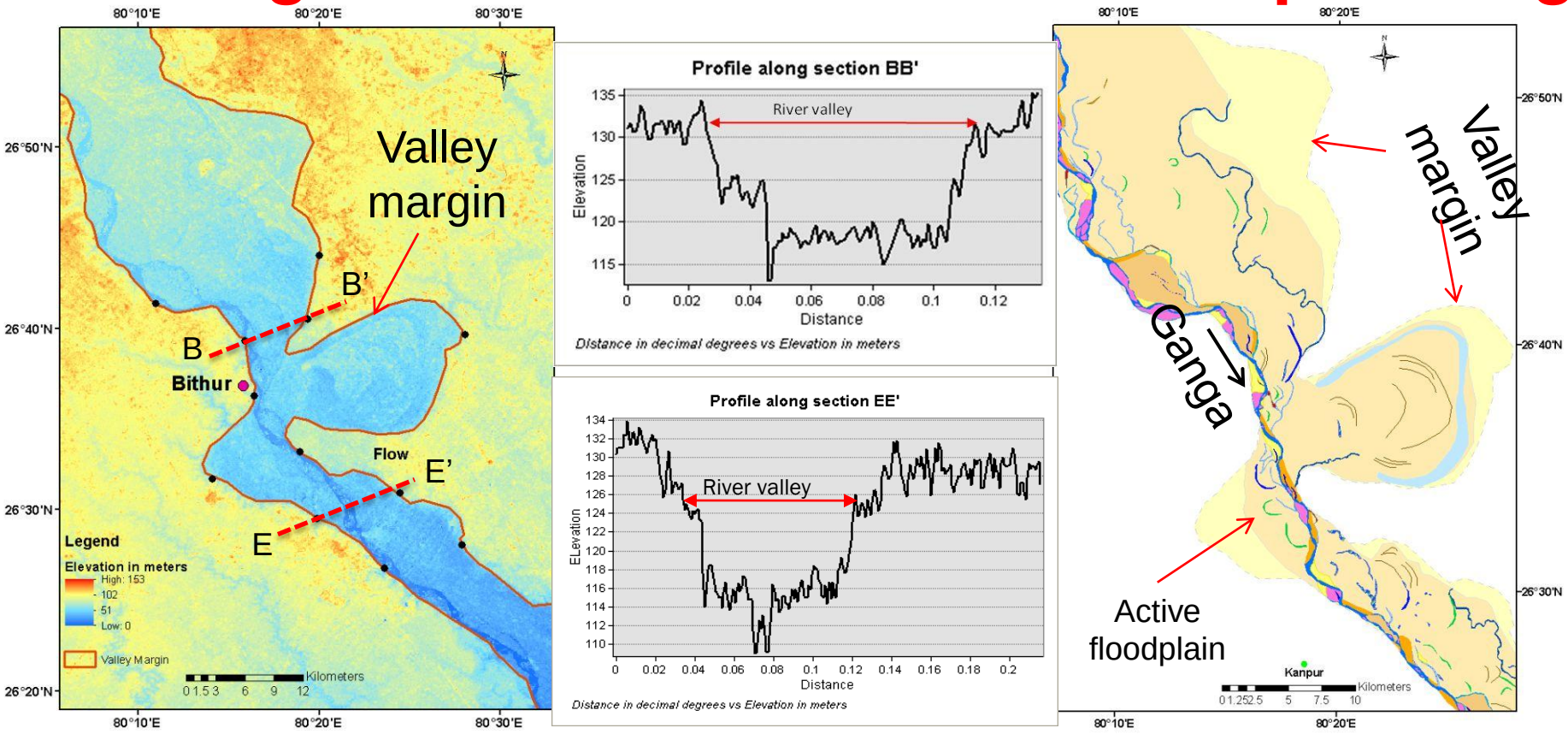




‘RIVER SPACE’ IN URBAN PLANNING

- Active floodplain and valley margin - define the ‘space’ for the river to perform its myriad functions
- A river with a complete floodplain is not just considered as the one in equilibrium but also in good health
- **The contradiction**
  - Supports a rich ecosystem - direct influence on soil fertility
  - Frequently occupied by local population at the cost of other ecosystem
  - Severely impacted by urban expansion
- Target
  - Map the active floodplain accurately (needs ability to read landscape)
  - Define permissible usage(needs policy and regulatory mechanism)
  - Restore the naturalness of the river

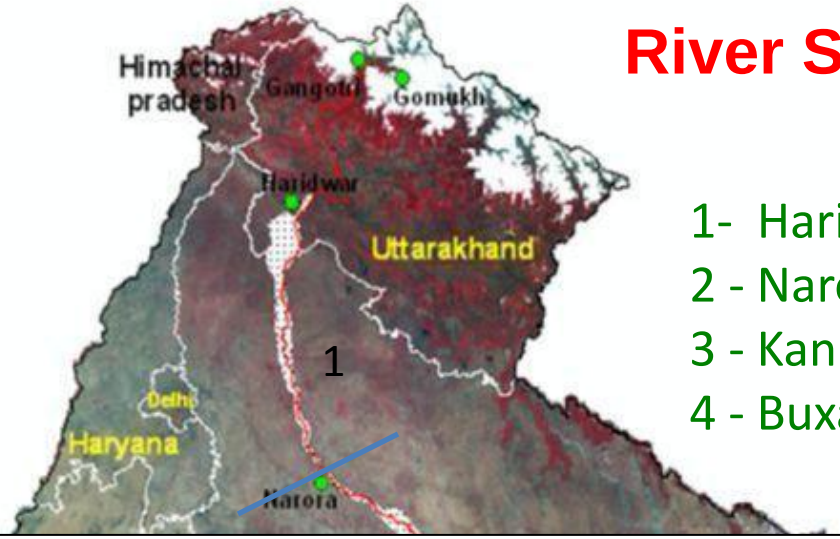
Defining ‘River Space’:
Moving towards sustainable urban planning



Valley Margin: the ‘water divide’ which is the line dividing neighbouring drainage basins (catchment) on a land surface; analogous to the ‘hydrological boundary’ between two watersheds.

Active floodplain: Areas adjacent to the river that are regularly flooded, can be mapped geomorphologically and also hydrologically (2.33 year flood)

River Space along the Ganga River



1- Haridwar to Narora
2 - Narora to Kanpur
3 - Kanpur to Buxar
4 - Buxar to Farakka

Next steps and implications:

- Define the permissible and non-permissible landuse within river space and formalize this through policy or legislation.
- River space delineation can also be linked to the flood risk in the region (floodplain zoning).
- Strong implications for groundwater recharge process and SW-GW interaction

Use of UAVs and Drones for Urban planning

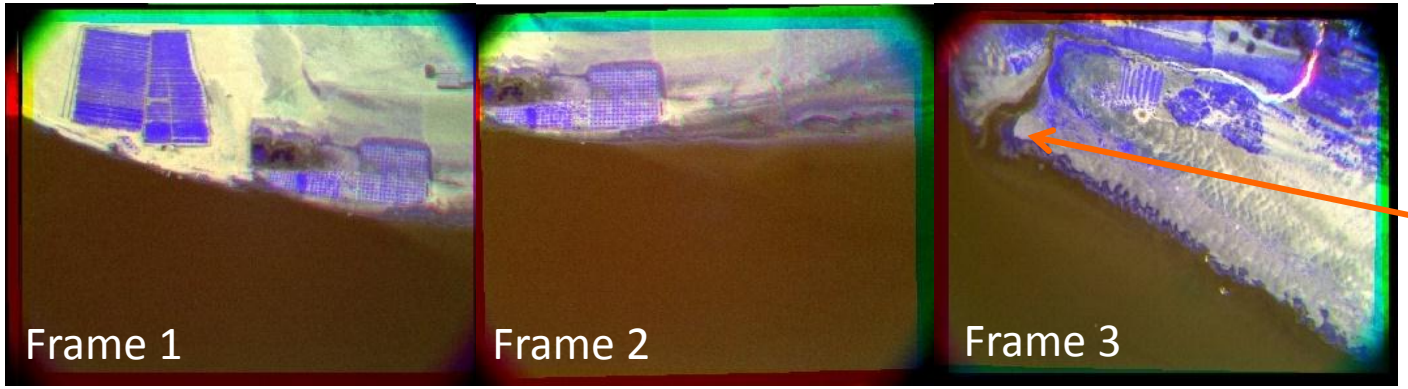
- Retrieve data from difficult-to-access areas and highly populated cities
- Faster, cheaper and more safely than ever before
- Traditional building inspections can be invasive and time-consuming, cameras with thermal imagery technology can help quickly diagnose air leakages to improve a buildings' energy efficiency.
- Can model the airflow between buildings, influence placement of vegetation and even direct the way pedestrians access and walk through the city.
- Can map major pollution sources in the city and their pathways in the rivers and other water bodies
- Can provide a big boost to Smart City Mission

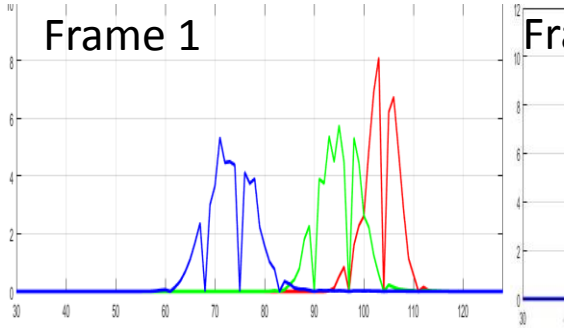
Multispectral Camera

Hyperspectral Camera

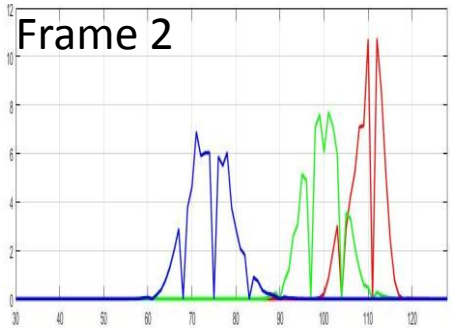
Thermal Camera

Along the channel variation in water quality due to pollutants (394,520,650 nm)

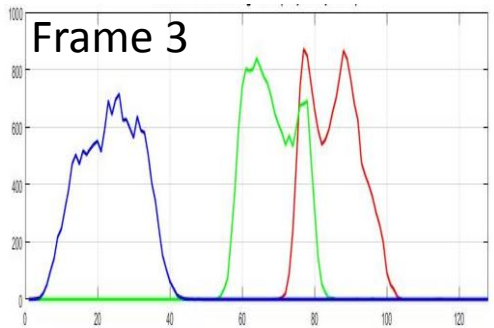




Three bands have distinct signals, respond to different parameters
(Blue – metals, green-chlorophyll, infrared-turbidity)



Similar to Frame 1, a little darker due to difference in illumination

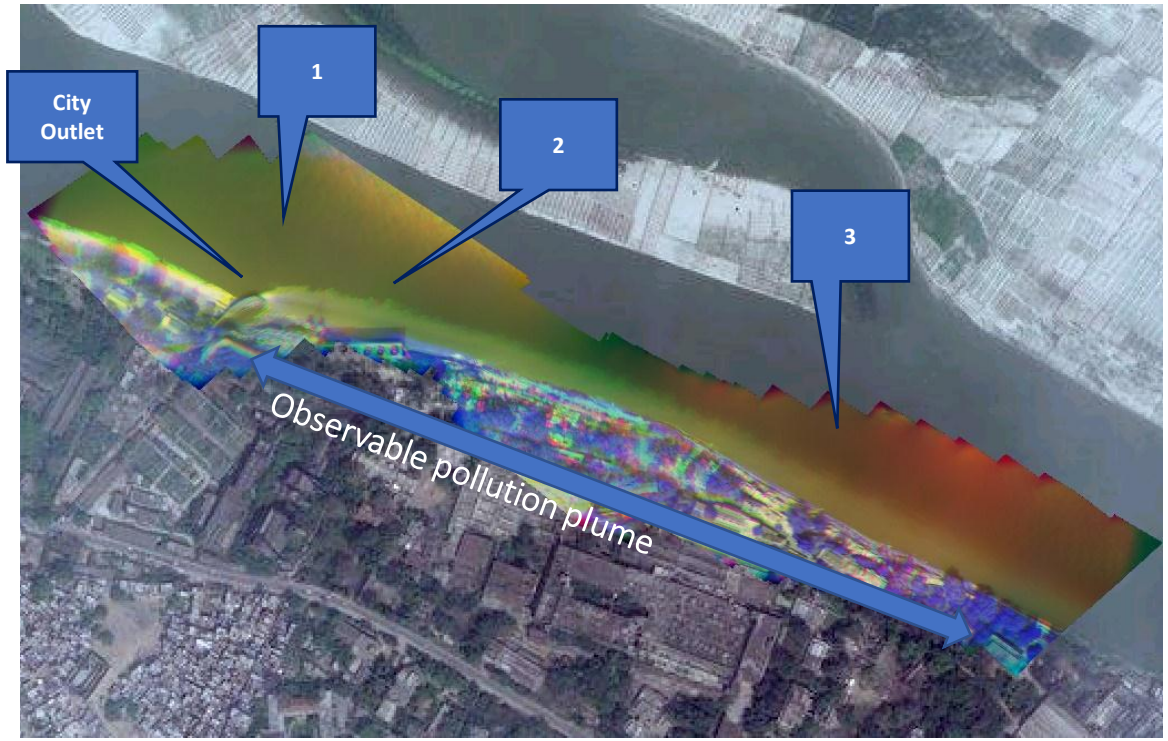


Blue band shift, sensitive to metallic ions
Infrared signal- two peaks due to turbidity

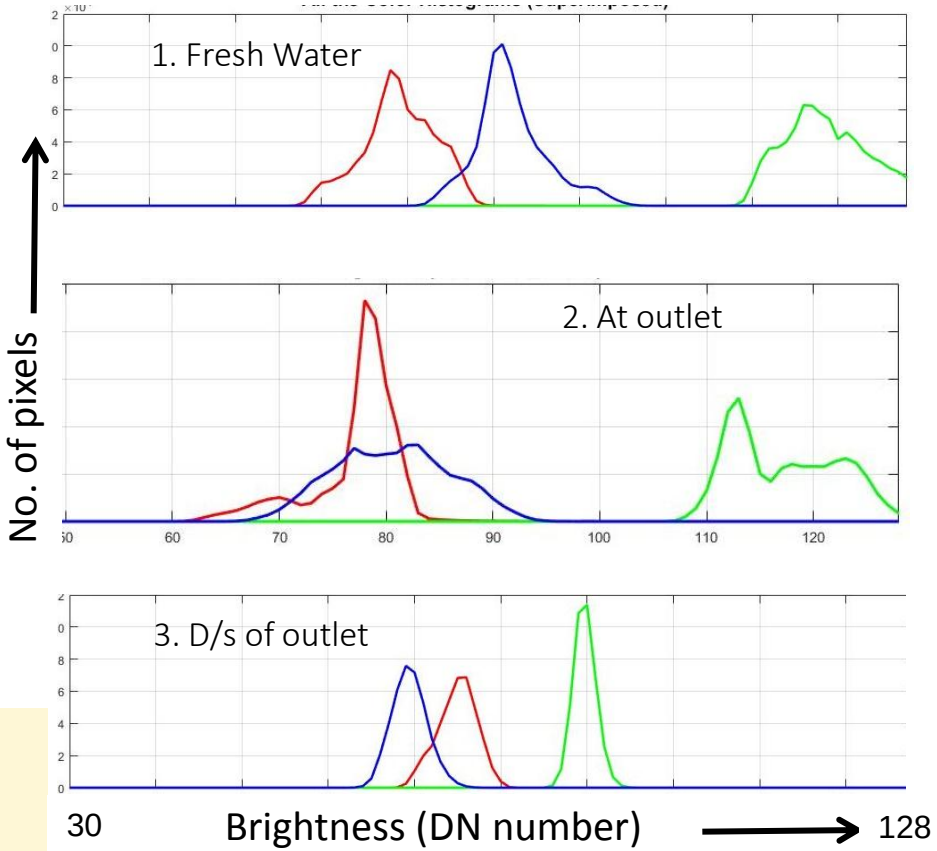
Red	520 nm
Green	650 nm
Blue	800 nm

Effect of the pollutants added by the drain

Identifying source of pollution using a multispectral camera



Histogram comparison of RGB and multispectral image (520, 650 & 800 nm band)



- Blue band shifting to left, darker, not much metallic ions
- Green band most affected, chlorophyll concentration may be higher due higher flux of N and P
- Red band very sharp at the outlet – higher particulate matter, and therefore very high turbidity

Legend:
Red ~ 800nm Band
Green ~ 650nm Band
Blue ~ 520nm Band

* All bands are have ±5nm tolerance

Drone flights: Potential for mapping pollution sources

Why drones?
High resolution, real time images

Integration with multispectral and hyperspectral sensors

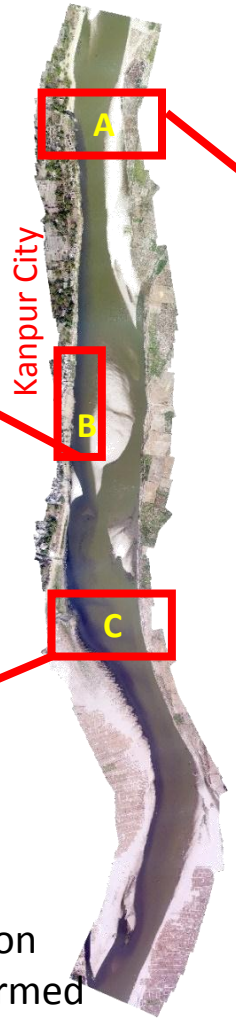
Mapping of pollution plumes – identification of source as well as downstream dispersal

Ganga water before and after Kanpur city

Total stretch: 4 km
Flight height: 273 m
Image capturing: 20 m
Camera: RGB

Drone flights: Imaging and Histogram analysis over an outlet in Ganga

B. Multiple small drain outlet



A. The Main drain outlet

C. Pollution Plume formed by incoming drain

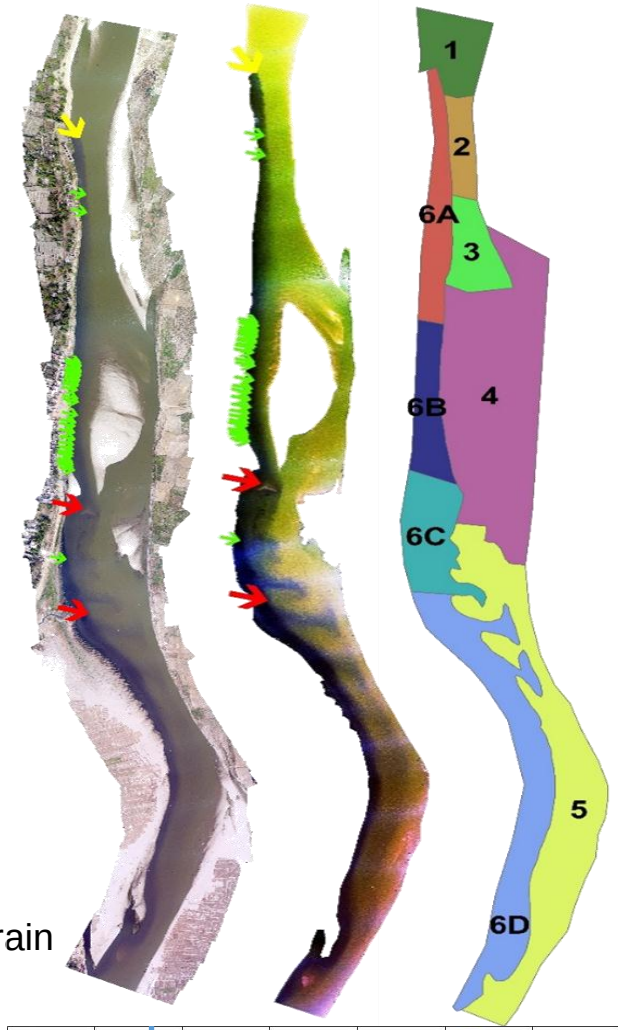
Drone flights: Imaging and Histogram analysis over an outlet in Ganga

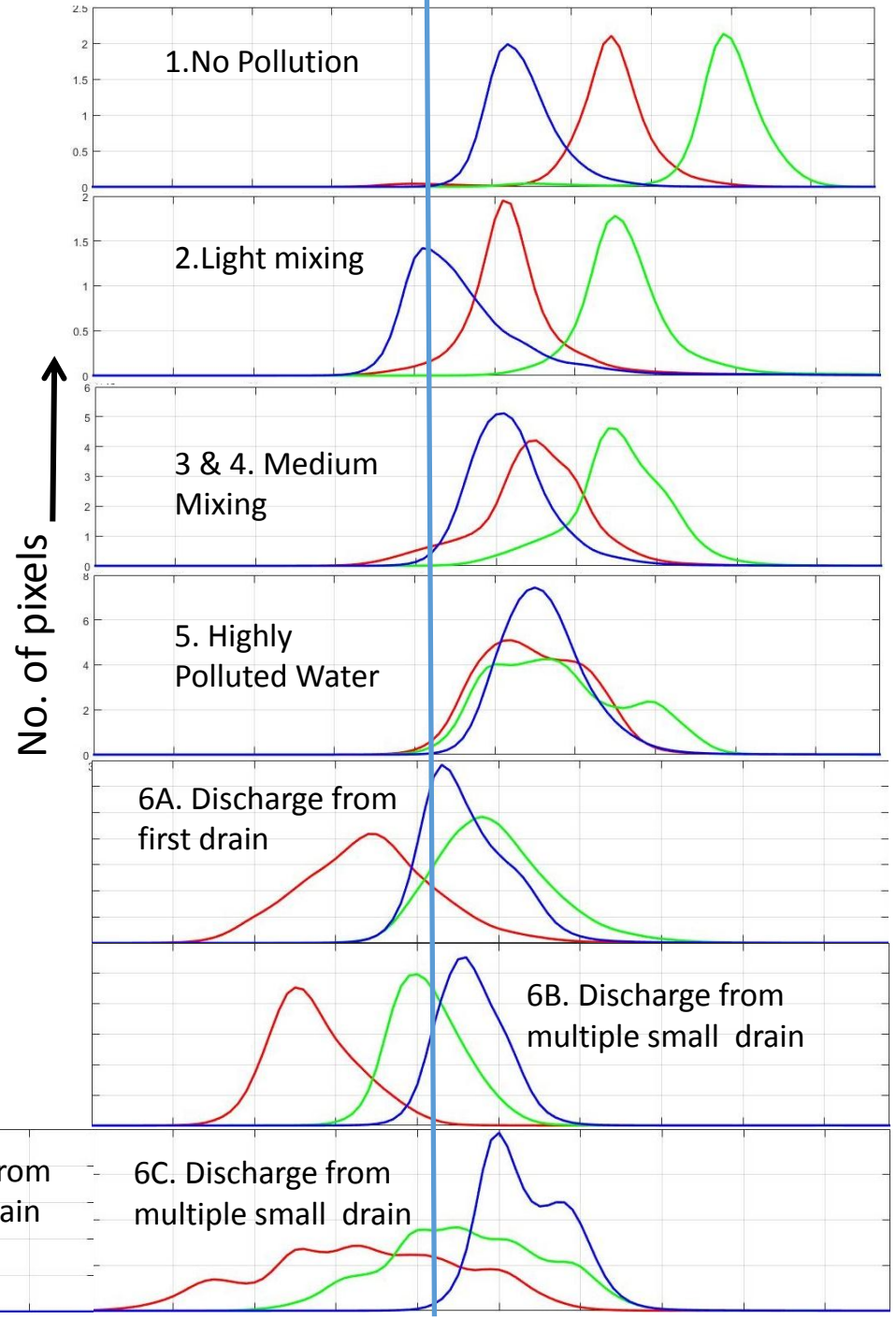
Images from left to right:
Original image with inputs from drains; After removing sandbar and then applying histogram equalization on PC1 image; Zonation of the area.

Total stretch: 4 km
Flight height: 273 m
Image capturing: 20 m
Camera: RGB

PCA analysis of three bands data (PC1 image shown)

Legend: Arrows
1.Yellow – Primary drain;
2.Green – Small drains;
3.Red – Medium sized drain





Mapping Pollution plume from Drones
Manikarnika Ghat, Varanasi

Next Steps

- Understanding of physical and digital space for urban planning for a smart city with adequate geospatial datasets and analytical capabilities.
- Help provide a clean and sustainable environment and application of ‘Smart’ Solutions by encouraging the use of remote sensing and GIS techniques e.g. consideration of ‘river space’.
- Use of drones in Urban planning is very promising but we need to create the enabling environment – DGCA rules for scientific and professional uses of drones must be simplified.
- Need to build trained manpower for the Smart Cities Mission launched by the Government of India with an objective to promote sustainable and inclusive cities.