Inventorization of Water Bodies (Rivers,Ponds, Lakes and Tanks) using Remote Sensing Techniques

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Importance of Water Bodies

- Provide water resources and food for millions of humans
- Habitat and ecosystem services
- Biodiversity and sustenance of thousands of species
- Components of carbon and nutrient cycles
- Recreational value
- Mitigation of climate variability
- Irrigation
- Hydroelectric power
- Transportation corridors
- Flood control

Source : http://www.cawater-info.net/

EO for Water Resources

- Water Resources Assessment
- Inventory - Glacial Lakes/Water bodies
- Water Budgeting & Water Balance Modelling
- Hydrological & Snowmelt Runoff Modeling

- Irrigation Performance Evaluation
- Surface Water Logging & Soil Salinity/Alkalinity Mapping

- Reservoir Sedimentation
- Flood Mapping & Damage Assessment
- Flood Forecasting & Inundation Simulation

- interlinking of rivers
- Canal alignment & Land irrigability (Pre-feasibility)
- Ranking of hydropower sites
- Dams Submergence Area Analysis
- Catchment area analysis
- Flood Hazard Zone Mapping

- Rehabilitation & Relocation Studies
- Irrigation Infrastructure Mapping &
- Assessment Potential Created

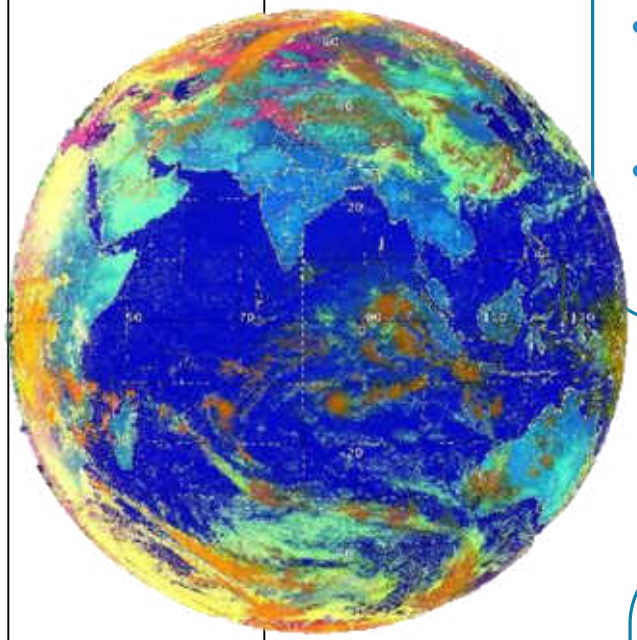
Dynamics of waterbodies: Drivers of change

Surface water bodies are essential water storage units :

- **Agriculture**
  - **water drawn from surface water bodies**
  - **Huge infrastructure / establishments created for irrigation facilities.**
- **Hydro-Power :Continuous increase in number of large dams**
- **Large number of smaller irrigation tanks / water bodies under construction apart from the major reservoirs**
- **Industrial sector**

Mayurakshi dam

REMOTE SENSING – WHY?



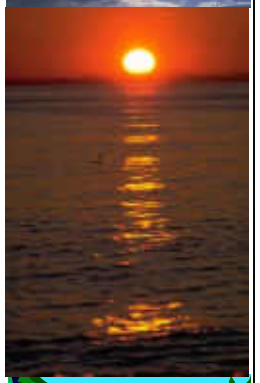
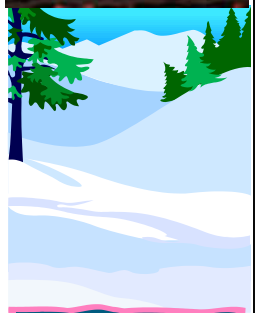
- Synoptic view
- Higher repetitively
- Multispectral imaging capability
- Data in digital format
- Inaccessible area coverage
- Cost effective

Advantages:

- **Long time series and data continuity: tracks progress**
- **Establishes baselines and trends**
- **Consistency and comparability among multiple countries**
- **Diversity of measurements**
- **Complements traditional statistical methods**
- **Cross-check with *in situ* data**
- **Mostly free and open access**

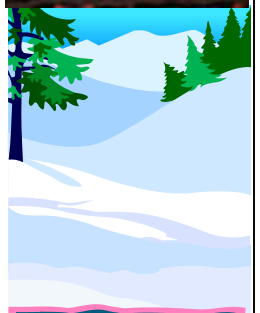
Remote Sensing in Hydrology and Water Resources

- Qualitative observation – Through interpretation thumb rules, tone, texture, shadow, pattern, location etc
- Quantitative observation – Geometric form, patterns, lineament, area, shape, length, landuse / landcover, fractures, fault
- Correlation and modeling – Estimation of soil moisture, snow depth or water equivalent, sediment load, precipitation etc.

Issues addressed by remote sensing of Surface water

- Inventory, Mapping and Monitoring
- Extent and area of water
- Assessment of inter and intra seasonal as well as annual surface water spread dynamics
- Progress of cropping area and irrigated agriculture and water utilisation pattern
- Qualitative and quantitative measurement of turbidity
- Catchment analysis



Spectral response of water

Sun – light interaction

- Absorption and scattering by pure water.
- Scattering, diffraction and reflection by suspended particles in impure water.

Affecting variables

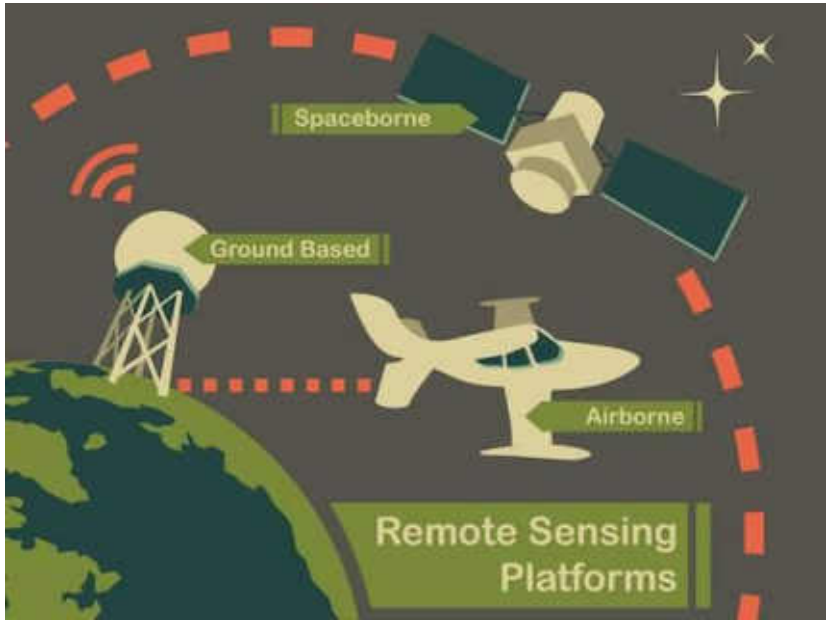
- Time of the year
- Sun elevation angle
- Aerosol and molecular content of the atmosphere
- Water vapor content in the atmosphere
- Roughness of water
- Water color

- Water turbidity
- Characteristics of suspended particles
- Depth of water
- Characteristics of bottom material
- Submerged or emergent vegetation

What is remote sensing?

Remote sensing is obtaining information about an object from a distance.
A photograph is a very common form of remote sensing.
There are different ways to collect data, and different sensors are used depending on the application.

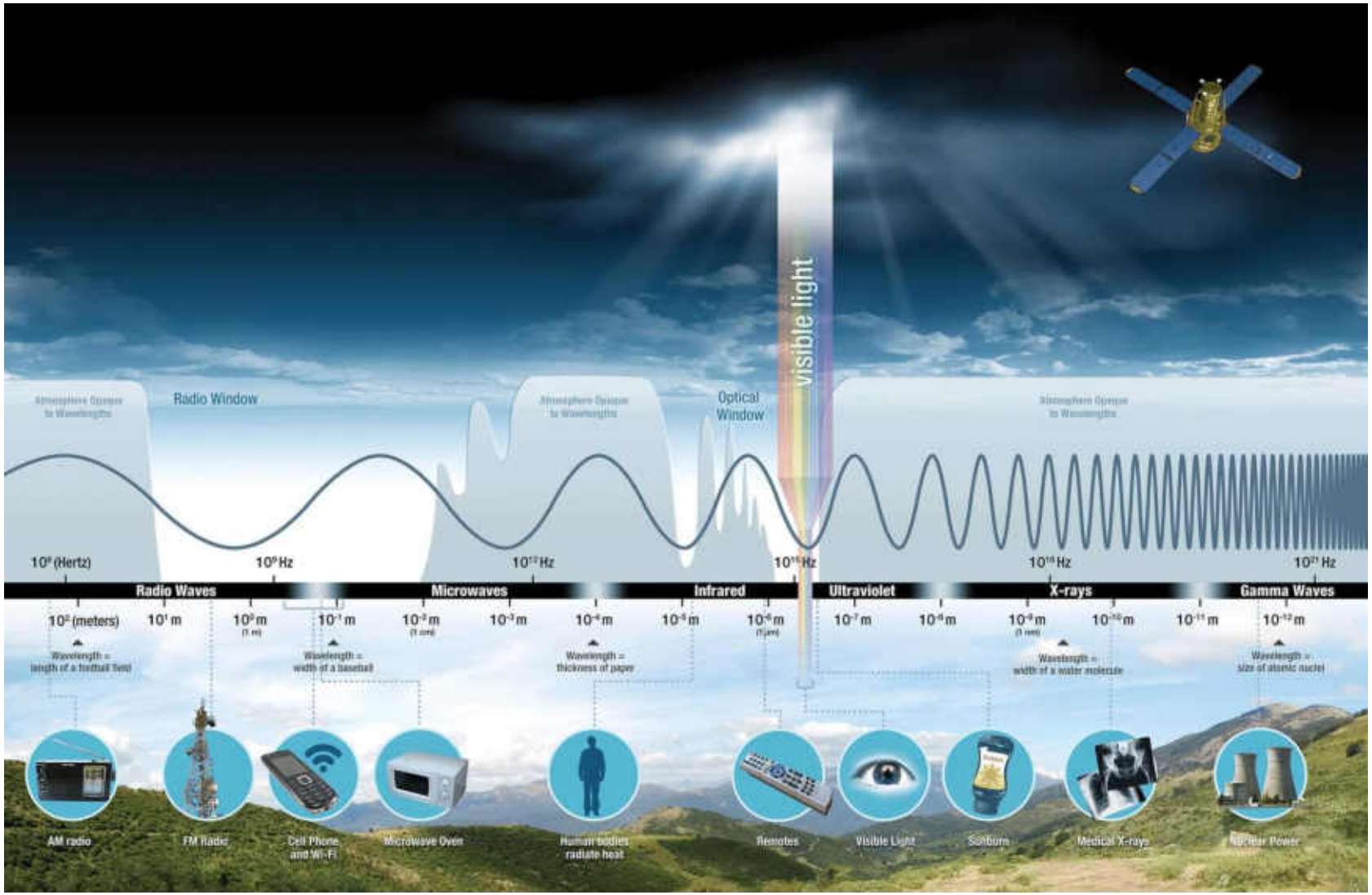
What information do you need?
How much detail?
How frequently do you need the data?



Source : NASA-ARSET

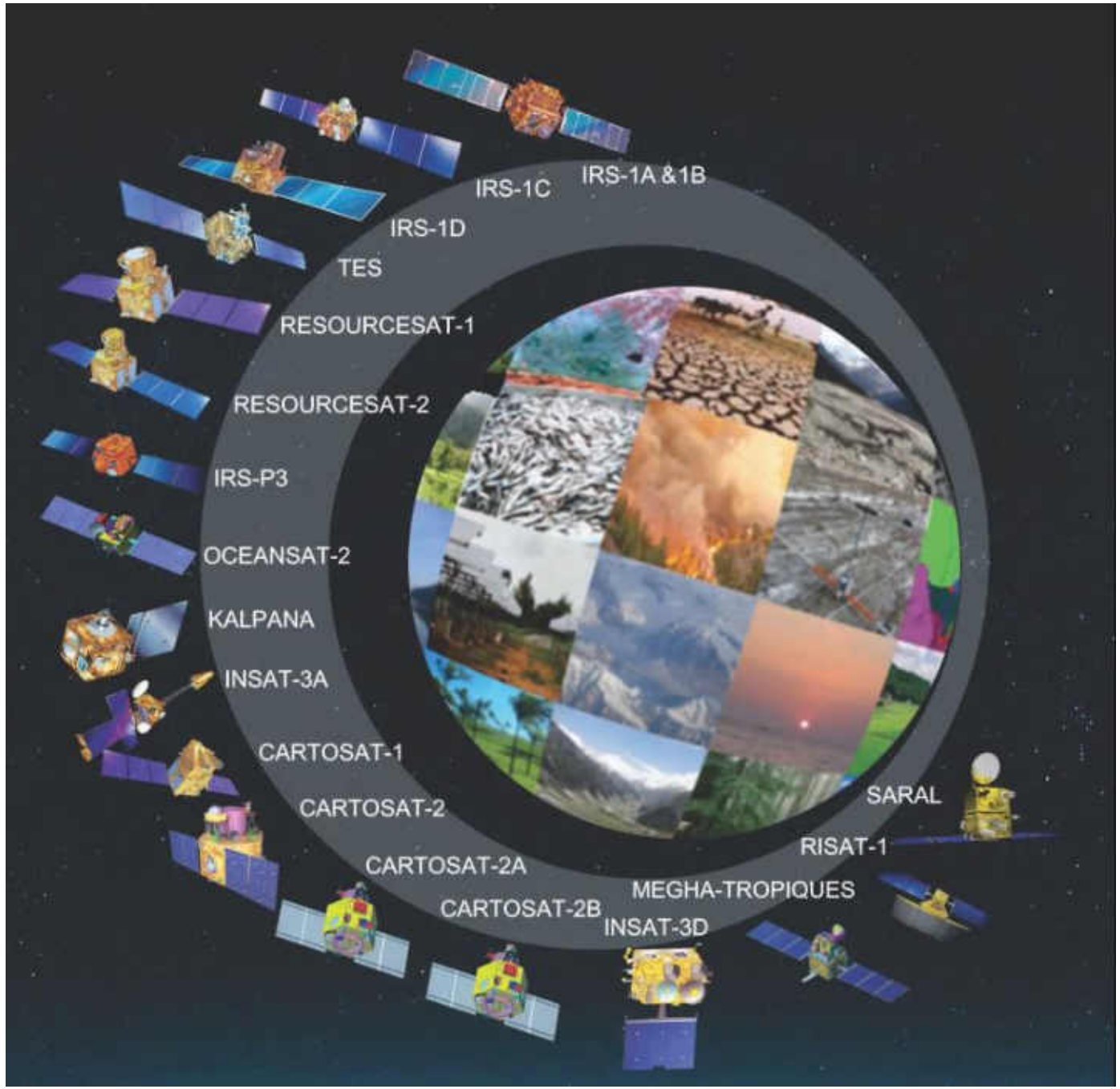
Measuring Properties of the Earth

Satellite sensors - calibrated to detect various wavelengths along the electromagnetic spectrum, often including visible light.



Source : NASA-ARSET

Indian Remote Sensing Satellites



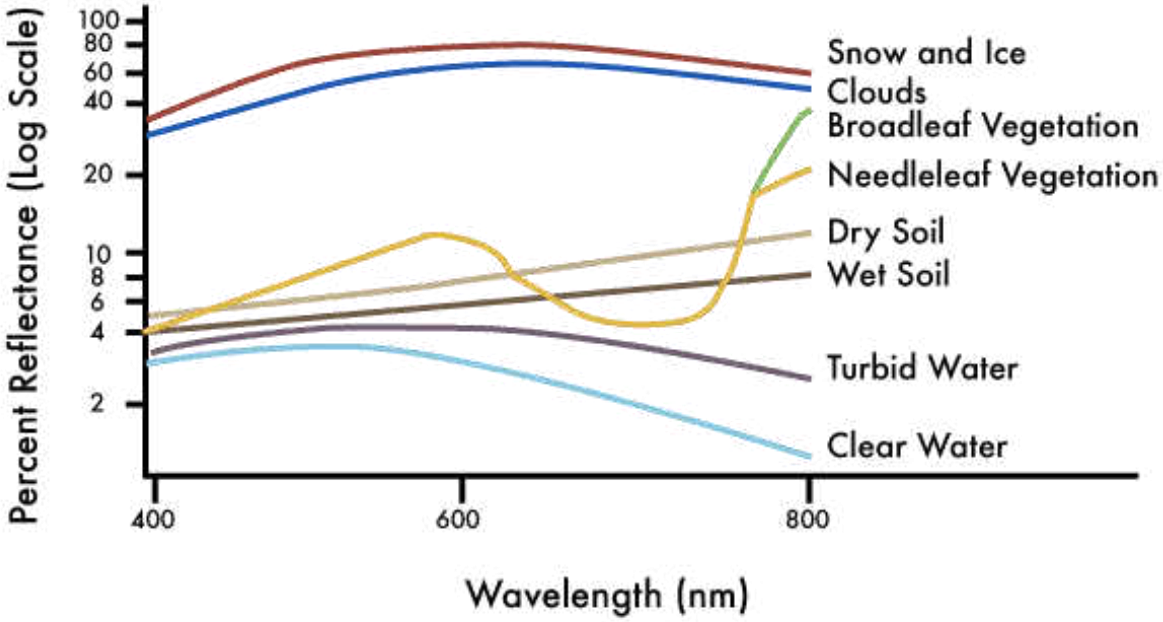
Satellite Missions Available for Water Resource Monitoring

Satellites	Data Availability	Sensors	Resolution
RISAT-1	July 2012 - July 2017	SAR	223 km swath; 1 m, 3 m, 9 m, 21m, 55m; 4 day revisit
Resourcesat- 1/ 2	May 2003 - present	LISS-4 Mx/Mono	70 km swath; 5.8 m ; 5 day revisit
		LISS -3	141 km swath; 23.5 m; 24 day revisit
		AWiFS	740 km swath; 56 m; 56 day revisit
Landsat 7	4/15/1999 –present	Enhanced Thematic Mapper (ETM+)	185 km swath; 15 m, 30 m, 60 m; 16 day revisit
Landsat 8	2/1/2013 –present	Operational Land Imager (OLI)	185 km swath; 15 m, 30 m, 60 m; 16 day revisit
Terra & Aqua	Terra - 12/18/1999 –present Aqua - 5/4/2002 –present	MODerateResolution Imaging Spectroradiometer (MODIS)	2330 km swath; 250 m, 500 m, 1 km; 1-2 day revisit
Suomi NPP	11/21/2011 –present	Visible Infrared Imaging Radiometer Suite (VIIRS)	3040 km swath; 375 m –750 m; 1-2 day revisit
Sentinel 2A and 2B	Sentinel-2A (6/23/2015 -present) Sentinel-2B (3/7/2017 –present)	Multi Spectral Imager (MSI)	290 km swath; 10 m, 20 m, 60 m; 5 day revisit
Sentinel 3A	2/16/2016 –present	Ocean and Land Colour Instrument (OLCI)	1270 km swath; 300 m; 27 day revisit

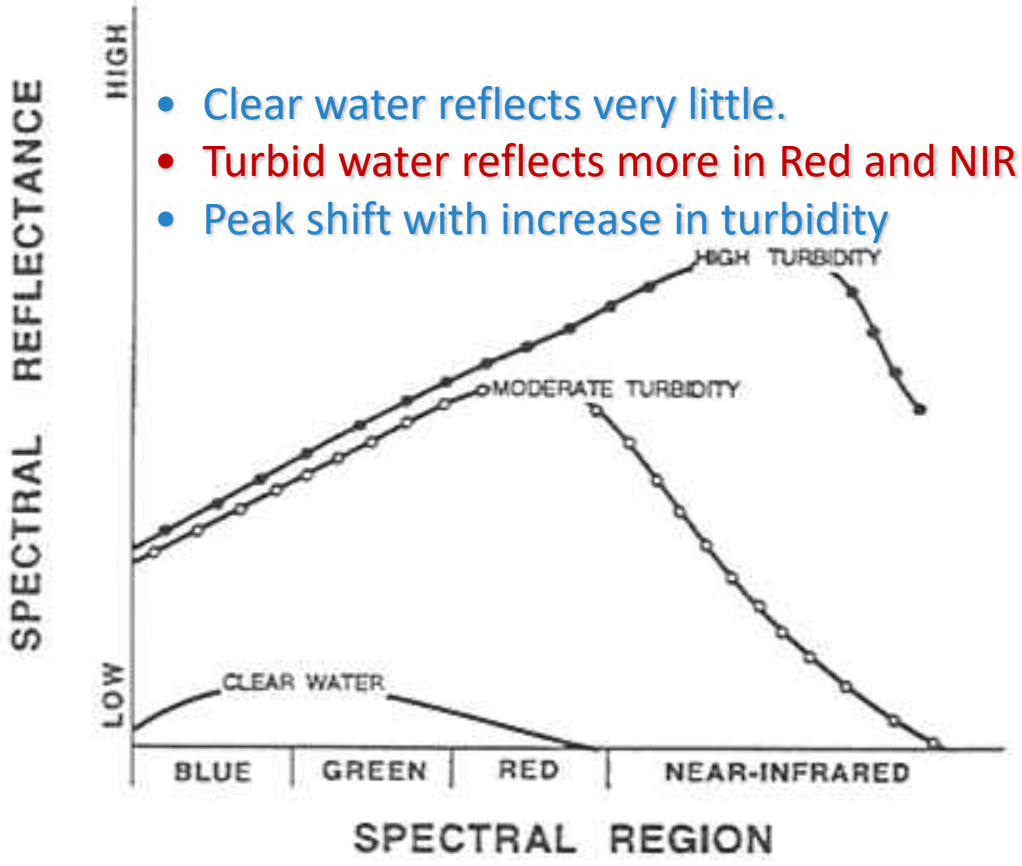
Optical Satellite Imagery

Spectral Signatures

- Different materials reflect and absorb different wavelengths of electromagnetic radiation.
- Reflected wavelengths detected by a sensor
- Determine the type of material it reflected off



Compare the relationship between percent reflectance and the reflective wavelengths of different components of the Earth's surface.



- Clear water reflects very little.
- Turbid water reflects more in Red and NIR
- Peak shift with increase in turbidity

Optical Satellite Images

Most of the contemporary image processing softwares have modules for image processing Technique

- Extraction of inherent spectral pattern in satellite data
- Categorization of pixels into various classes
- Interpretation and selection of these classes representing water surface are manually carried
- Grouped to derive water spread

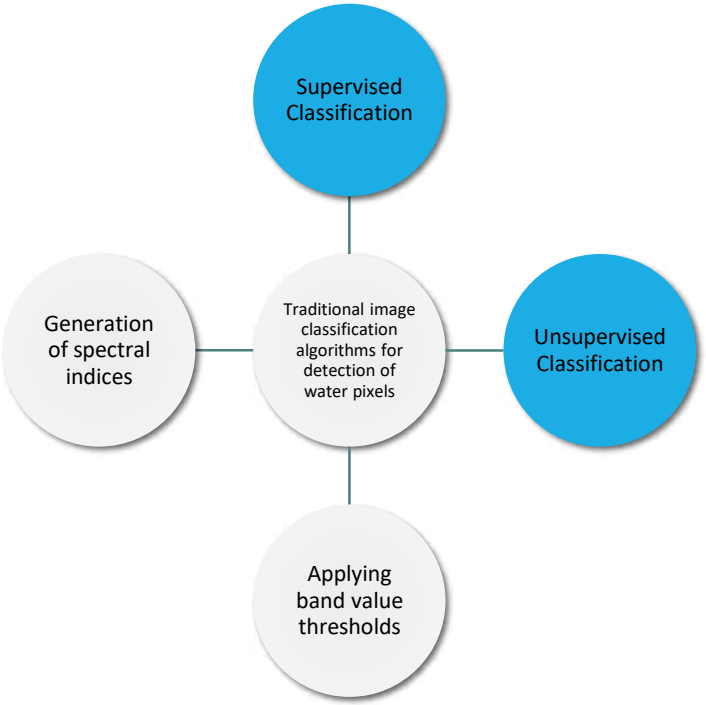
Satellite Image Processing

Supervised classification

- spectral signature sets are generated from water bodies
- Used as basis for the classification
- Limitation - May not accommodate all types of water bodies that might exist in other images across the region

Unsupervised classification

- Number of classes are defined and classified
- The corresponding classes pertaining to water pixels have to be determined by visual interpretation techniques by the analyst to arrive at water layer



Wetland Classification System

The classification system is **based on Ramsar Convention definition of wetlands**, which provides a broad framework for delineating wetlands and is amenable to remote sensing data.

It considers all parts of a water mass including its ecotonal area as wetland.

In addition, Ramsar Convention, considers fish and shrimp ponds, saltpans, reservoirs etc. as wetlands.

The Wetland Classification System besides including all wetlands incorporates deep-water habitats and impoundments.

Main criteria followed in this system are:

- Wetland hydrology, i.e. manifestation of water on the satellite imagery.
- Wetland vegetation - mainly hydrophytes and other aquatic vegetation in a part or whole of the wetland as observed on satellite data.

Sr. No.	Level I	Level II	Level III
1	Inland Wetlands	Natural	Lake/Pond
2			Ox-Bow Lake/ Cut-Off Meander
3			High Altitude Wetland
4			Riverine Wetland
5			Waterlogged
6			River/Stream
7		Man-made	Reservoir/Barrage
8			Tank/Pond
9			Waterlogged
10			Salt Pan
11			Aquaculture Pond
12	Coastal Wetlands	Natural	Lagoon
13			Creek
14			Sand/Beach
15			Intertidal Mud Flat
16			Salt Marsh
17			Mangrove
18			Coral Reef
19		Man-made	Salt Pan
20			Aquaculture Pond

Source: Manual on Wetland classification System, SAC, Ahmedabad

Lakes

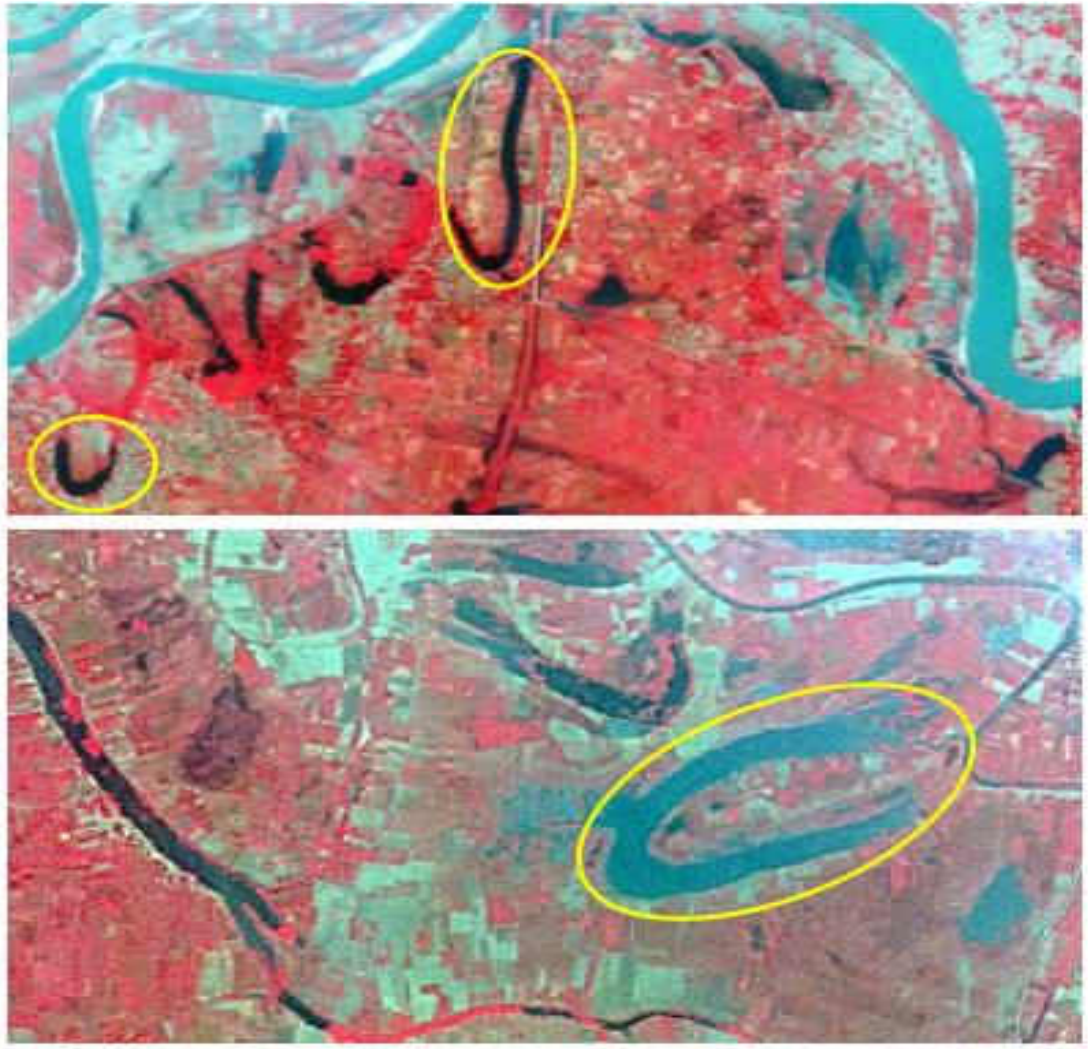
Lakes (1101): Larger bodies of standing water occupying distinct basins (Reid *et al*, 1976). These wetlands occur in natural depressions and normally fed by streams/rivers. On satellite images lakes appear in different hues of blue interspersed with pink (aquatic vegetation), islands (white if unvegetated, red in case of terrestrial vegetation). Vegetation if scattered make texture rough.

Bishnupur district, Manipur

Baramulla district, Jammu & Kashmir

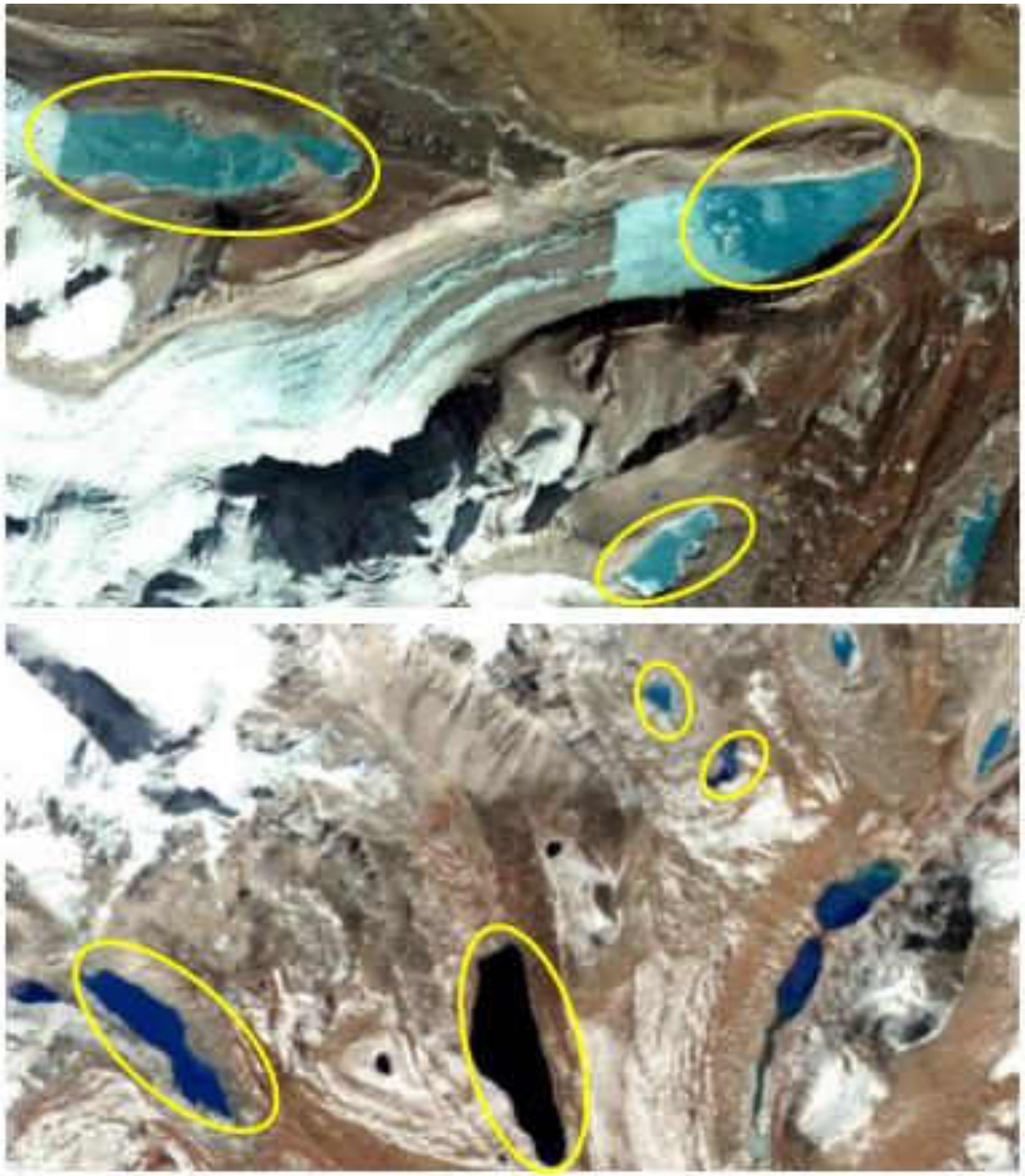
Ox-bow lakes

Ox-bow lakes/ Cut-off meanders (1102) : A meandering stream may erode the outside shores of its broad bends, and in time the loops may become cut-off, leaving basins. The resulting shallow crescent-shaped lakes are called oxbow lakes (Reid *et al*, 1976). On the satellite image Ox-bow lakes occur near the rivers in plain areas. Some part of the lake normally has aquatic vegetation (red/pink in colour) during pre-monsoon season.



Khagaria, Bihar

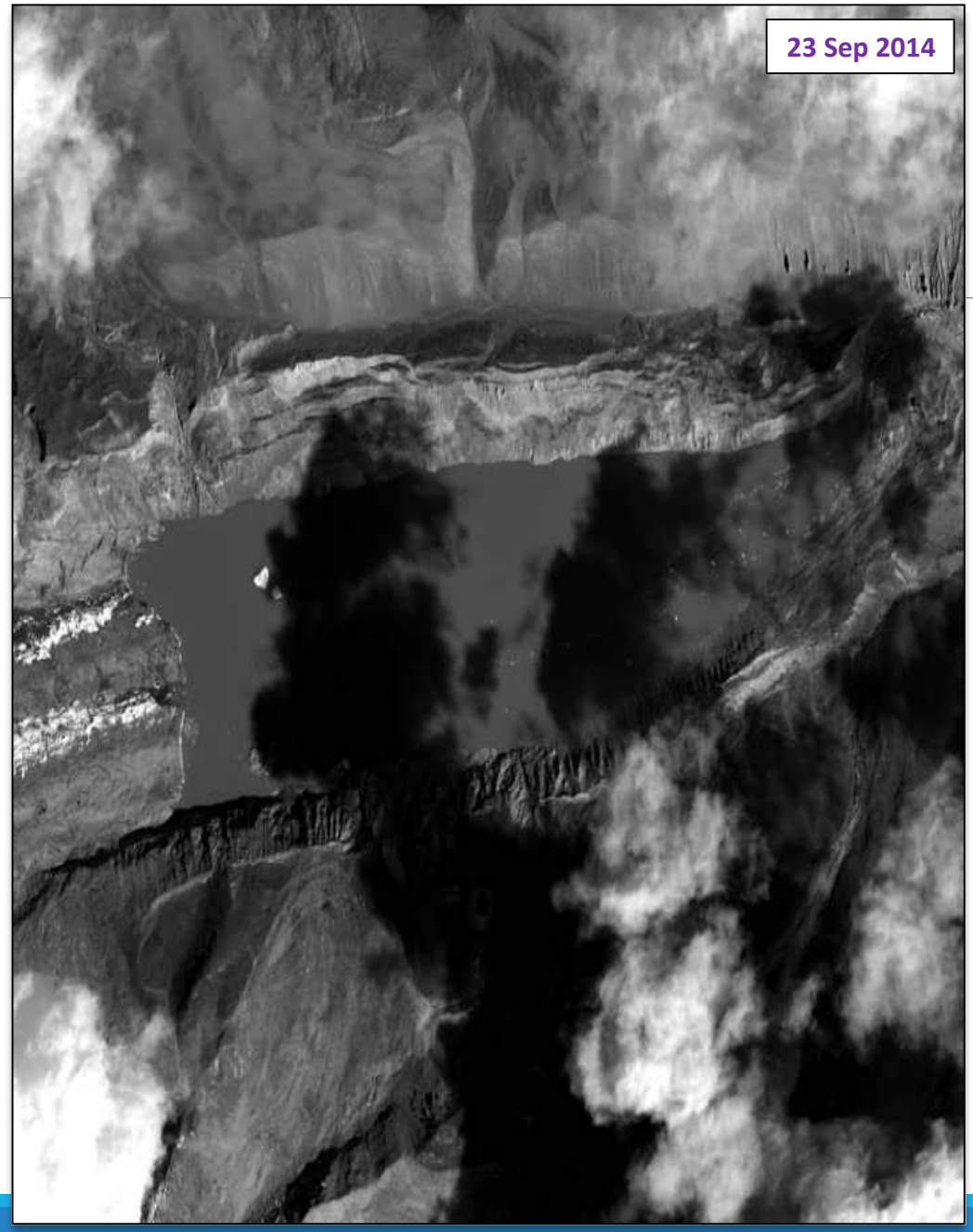
High altitude lakes



North District, Sikkim

Glacial lakes monitoring

- Inventory and Monitoring of Glacial Lakes & Water Bodies in the Himalayan Region of Indian River Basins
- Spatial extent greater than 50 ha



End use

- GLOF studies
- Ministry of Water Resources

Details

- Himalayan region of Indian River basins
- Resourcesat AWiFS

Marsh: A frequently or continually inundated wetland characterised by emergent herbaceous vegetation adapted to saturated soil conditions. In European terminology a marsh has a mineral soil substrate and does not accumulate peat (Mitsch and Gosselink, 1986). Tone is grey blue and texture is smooth.

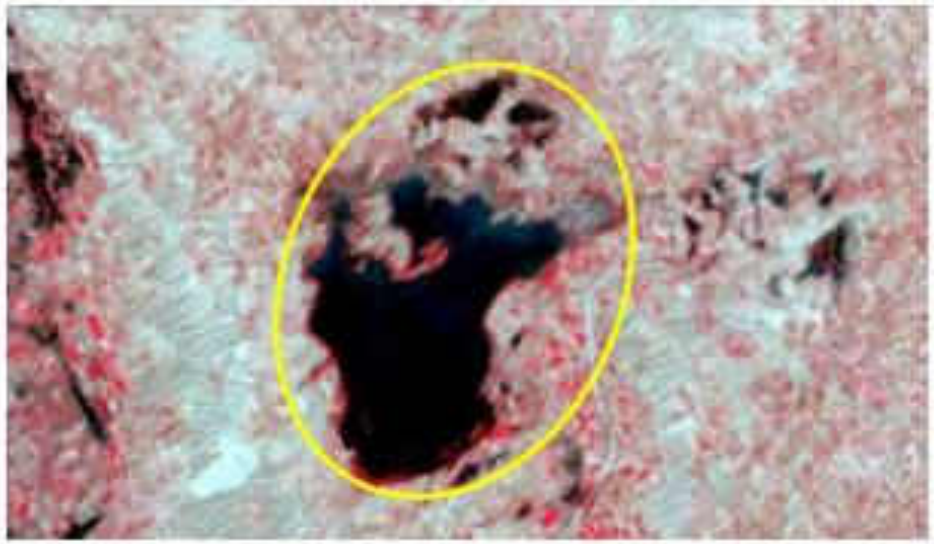
Comment: Using satellite data it is difficult to differentiate between swamp and marsh. Hence, both have been clubbed together as 'Riverine wetlands'.

Baramulla District, Jammu & Kashmir

Bhagalpur District, Bihar

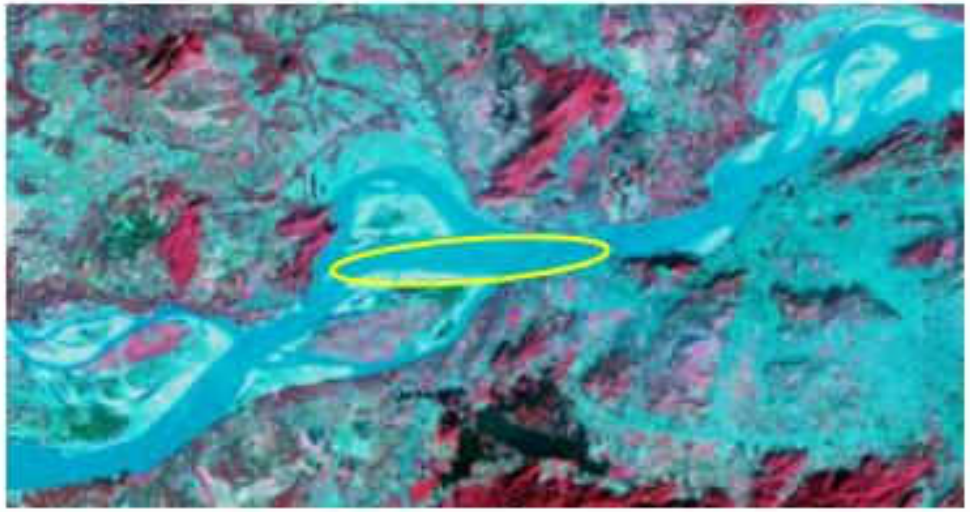
Waterlogged –Natural (1105): Said of an area in which water stands near, at, or above the land surface, so that the roots of all plants except hydrophytes are drowned and the plants die (Margarate *et al*, 1974). Floods or unlined canal seepage and other irrigation network may cause waterlogging. Spectrally, during the period when surface water exists, waterlogged areas appear more or less similar to lakes/ponds. However, during dry season large or all parts of such areas dry up and give the appearance of mud/salt flats (grey bluish).

Surndranagar district, Gujarat

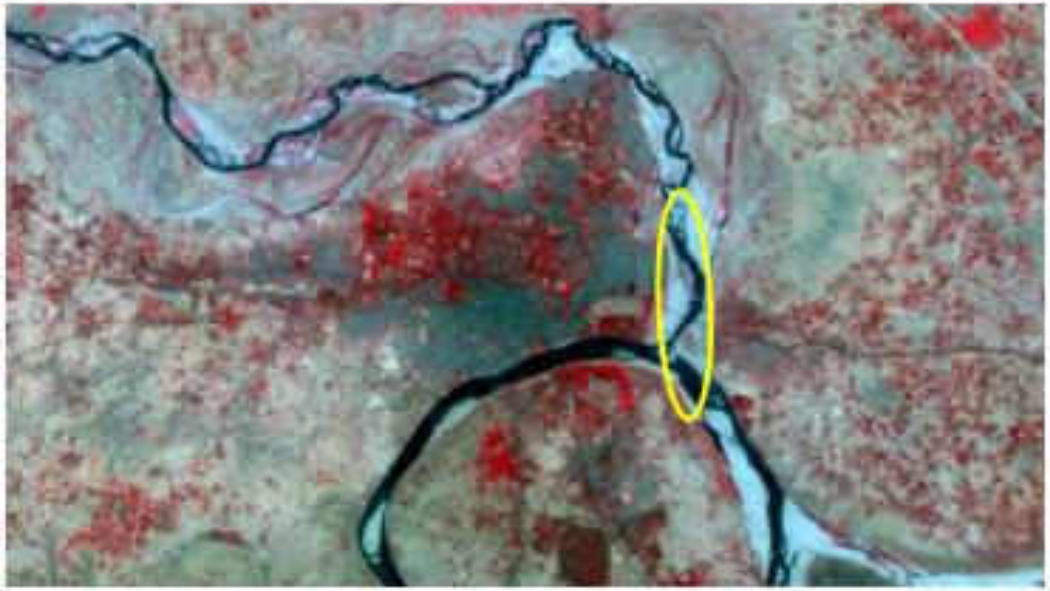


Barmer district, Rajasthan

River/stream (1106): Rivers are linear water features of the landscape. Rivers that are wider than the mapping unit will be mapped as polygons. Its importance arises from the fact that many stretches of the rivers in Indo-Gangetic Plains and peninsular India are declared important national and international wetlands (Ex. The river Ganga between Brajghat and Garh Mukteshwar, is a Ramsar site, Ranganthattu on the Cavery river is a bird sanctuary etc.). Wherever, rivers are wide and features like sand bars etc. are visible, they will be mapped.



Kamarup district, Assam

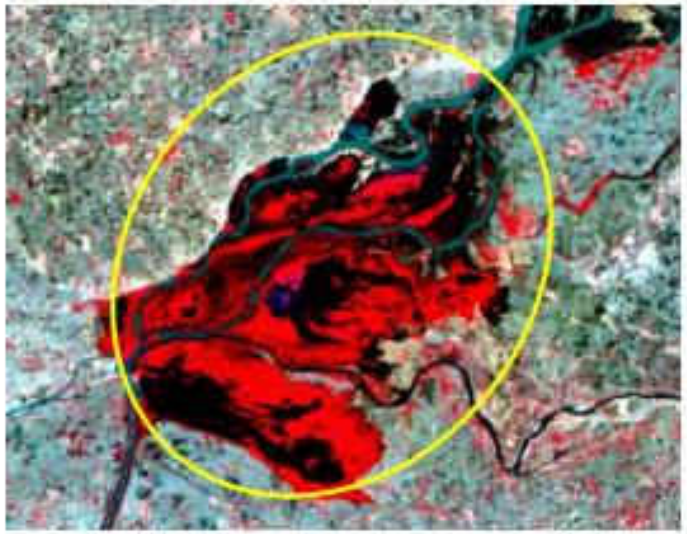


Prayagraj, Uttar Pradesh

Reservoir/Barrage (1201)

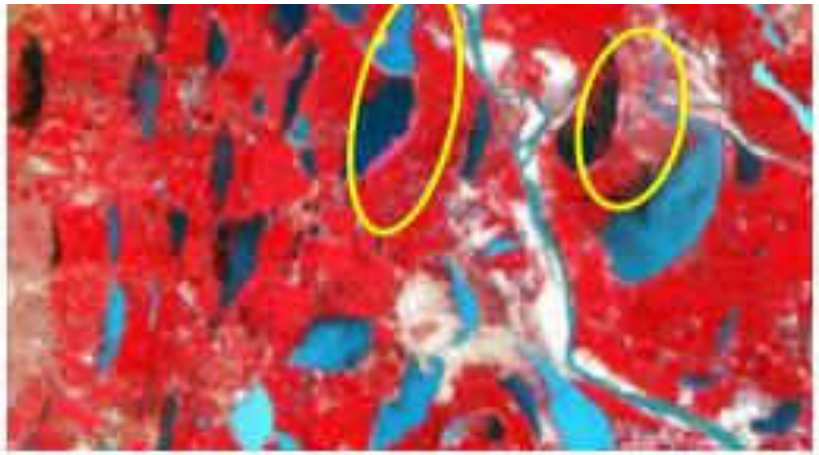
Pong Reservoir, Himachal Pradesh

Reservoir: A pond or lake built for the storage of water, usually by the construction of a dam across a river (Margarate et al, 1974). On RS images, reservoirs have irregular boundary behind a prominent dyke. Wetland boundary in case of reservoir incorporates water, aquatic vegetation and footprint of water as well. In the accompanying images aquatic vegetation in the reservoir is seen in bright pink tone.



Harike Barrage, Punjab

Barrage: Dykes are constructed in the plain areas over rivers for creating Irrigation/water facilities. Such water storage areas develop into wetlands (Harike Barrage on Satluj – a Ramsar site, Okhla barrage on the Yamuna etc. – a bird sanctuary). Water appears in dark blue tone with a smooth texture. Aquatic vegetation appears in pink colour, which is scattered, or contiguous depending on the density. Reservoirs formed by barrages will be annotated as Reservoir/Barrage.



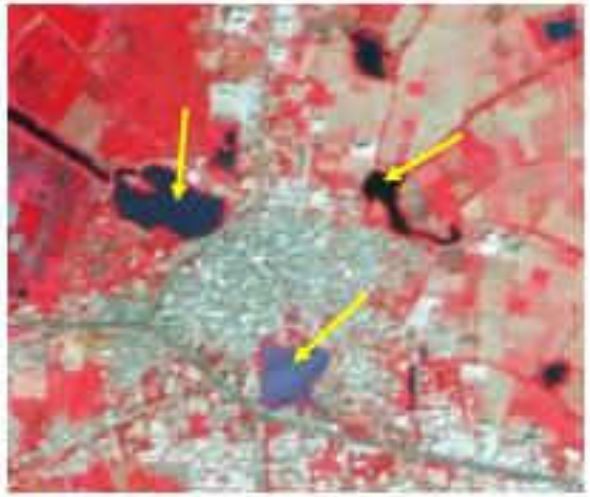
Tank/Pond in Pudukkotai district, Tamilnadu

Abandoned quarries in North Goa district, Goa

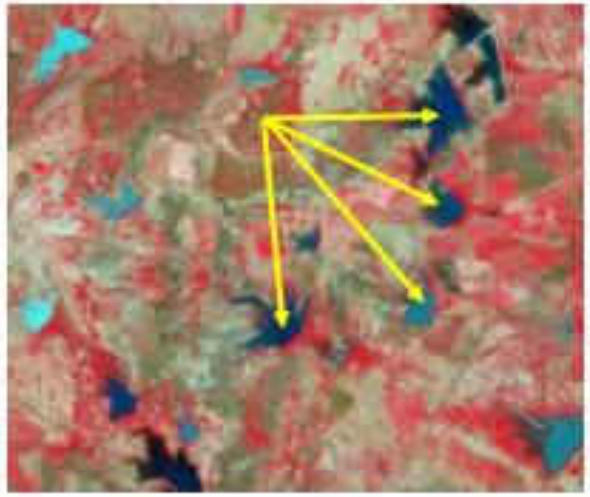
Ponds Generally, suggest a small, quiet body of standing water, usually shallow enough to permit the growth of rooted plants from one shore to another (Reid *et al*, 1976). Tanks appear in light blue colour showing bottom reflectance.

In this category Industrial ponds/ mining pools comprising Abandoned Quarries are also included. Quarry is defined as "An open or surface working or excavation for the extraction of stone, ore, coal, gravel or minerals"

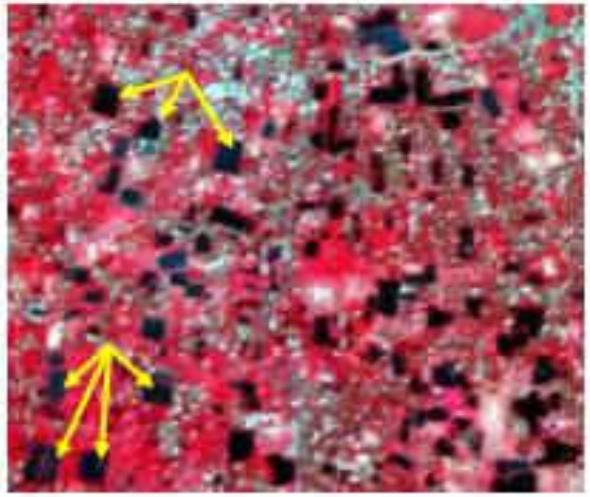
Ash Pond, Korba, Chattisgarh



Urban Tank/Pond, Ahmedabad, Gujarat



Small size check dams, Patan district, Gujarat



Tank/Pond, South 24 Paraganas district, West Bangal

Surendranagar district, Gujarat

Bikaner district, Rajasthan

Waterlogging due to Canal Seepage

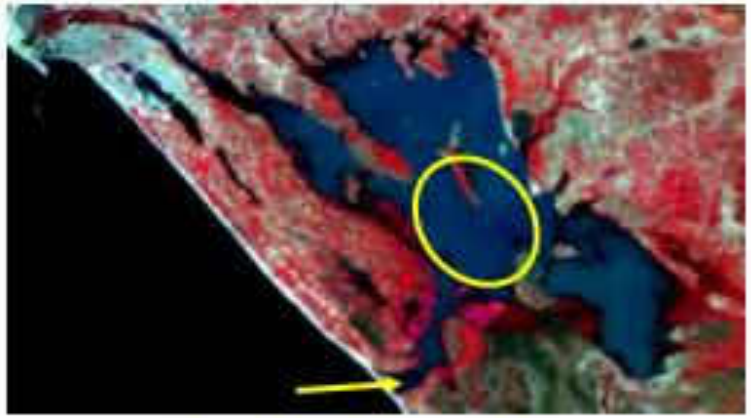
Salt pans (1204): Inland salt pans in India occur in Rajasthan (Sambhar lake). These are shallow rectangular man-made depressions in which saline water is accumulated for drying in the sun for making salt.

Salt pans in the vicinity of Samhar Lake, Naguar district, Rajasthan

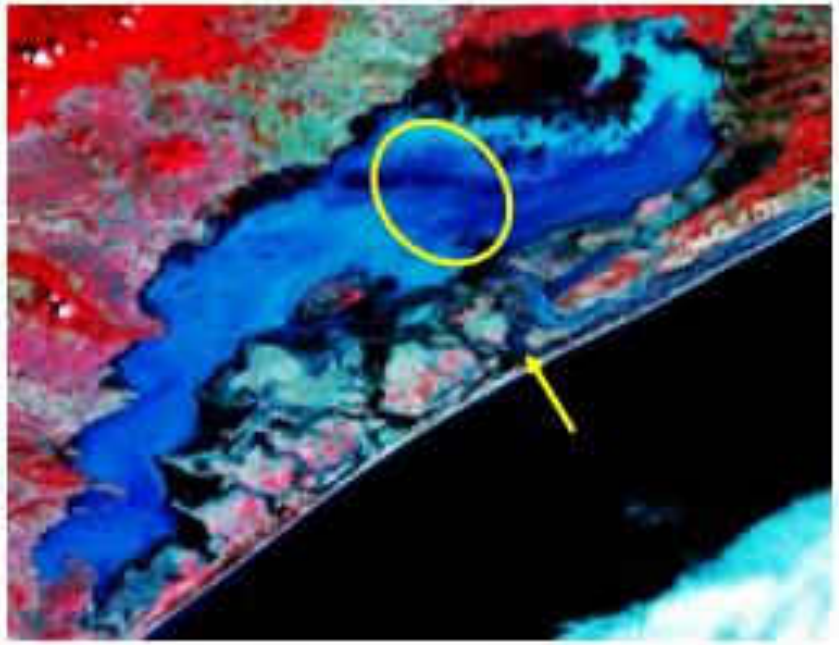
Aquaculture Ponds (1205): Aquaculture is defined as "The breeding and rearing of fresh-water or marine fish in captivity. Fish farming or ranching". The water bodies used for the above are called aquaculture ponds (Encyclopaedic Directory of Environment, 1988). Aquaculture ponds are geometrical in shape usually square or rectangular. Tone is blue.

Aquaculture Ponds, Imphal West district, Manipur

Backwater: A creek, arm of the sea or series of connected lagoons, usually parallel to the coast, separated from the sea by a narrow strip of land but communicating with it through barred outlets (Margarate *et al*, 1974).

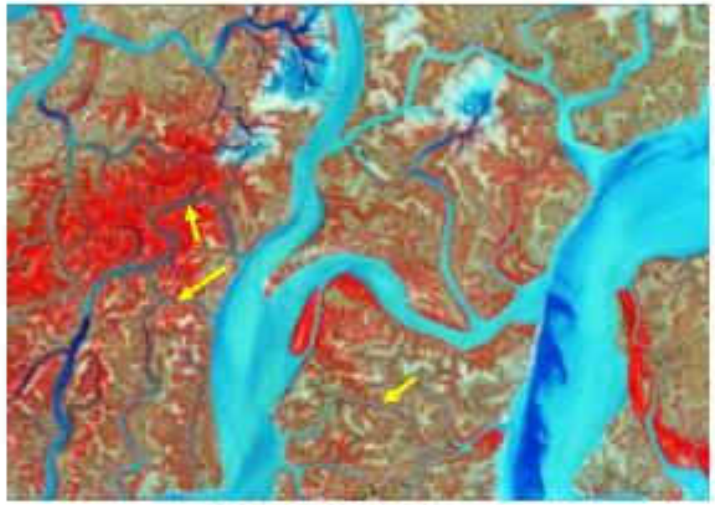


Porbandar district, Gujarat



Chilika Lagoon, Odisha

Creek (2102): A notable physiographic feature of salt marshes, especially low marshes. These creeks develop as do rivers "with minor irregularities sooner or later causing the water to be deflected into definite channels" (Mitsch and Gosselink, 1986). Creeks will be delineated, however, their area will not be estimated.

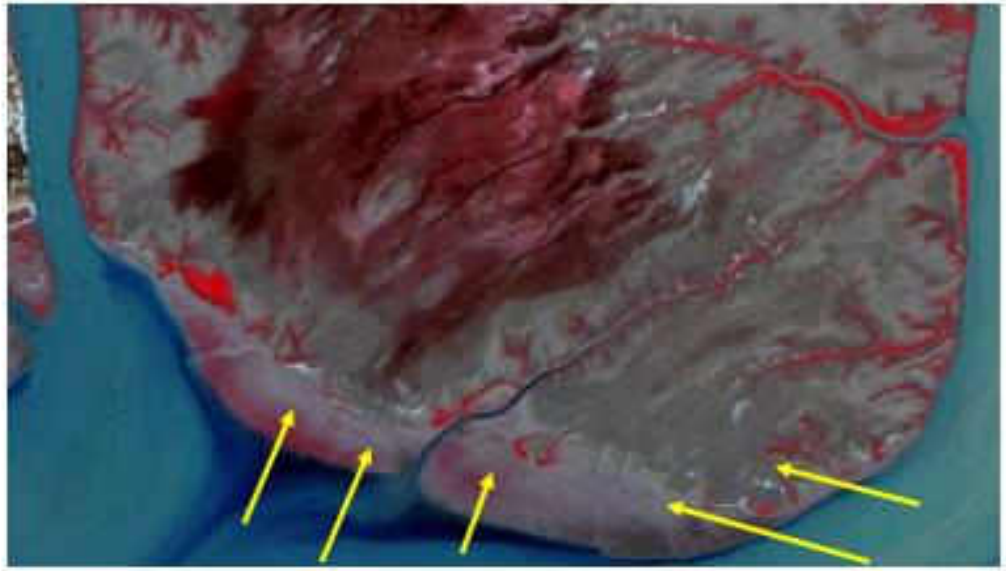


Kachchh District, Gujarat

Sand/Beach (2103): Beach is an unvegetated part of the shoreline formed of loose material, usually sand that extends from the upper berm (a ridge or ridges on the backshore of the beach, formed by the deposit of material by wave action, that marks the upper limit of ordinary high tides and wave wash) to low water mark (Clark, 1977). Beach comprising rocky material is called rocky beach.

South Goa district, Goa

Intertidal mudflats (2104) : Most vegetated/unvegetated areas that are alternately exposed and inundated by the falling and rising of the tide. They may be mudflats or sand flats depending on the coarseness of the material of which they are made (Clark, 1977).



Kachchh district, Gujarat

Salt Marsh (2105): Natural or semi-natural halophytic grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water level fluctuates either tidally or non- tidally (Mitsch and Gosselink, 1986). Salt marshes look in grey red shade when wet with salt encrusted bare soils.

Salt marsh in the vicinity of creeks, Kachchh district, Gujarat

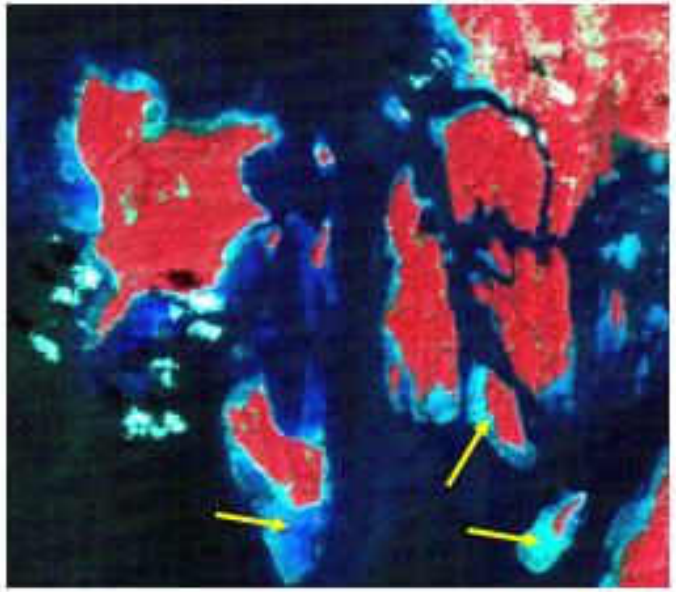
Mangroves (2106) : The mangrove swamp is an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical coastlines (Mitsch and Gosselink, 1986). On the satellite images mangroves occur in red colour if in contiguous patch.

Mangroves in Bhitarkanika, Odisha

Mangroves in Bhitarkanika, Odisha

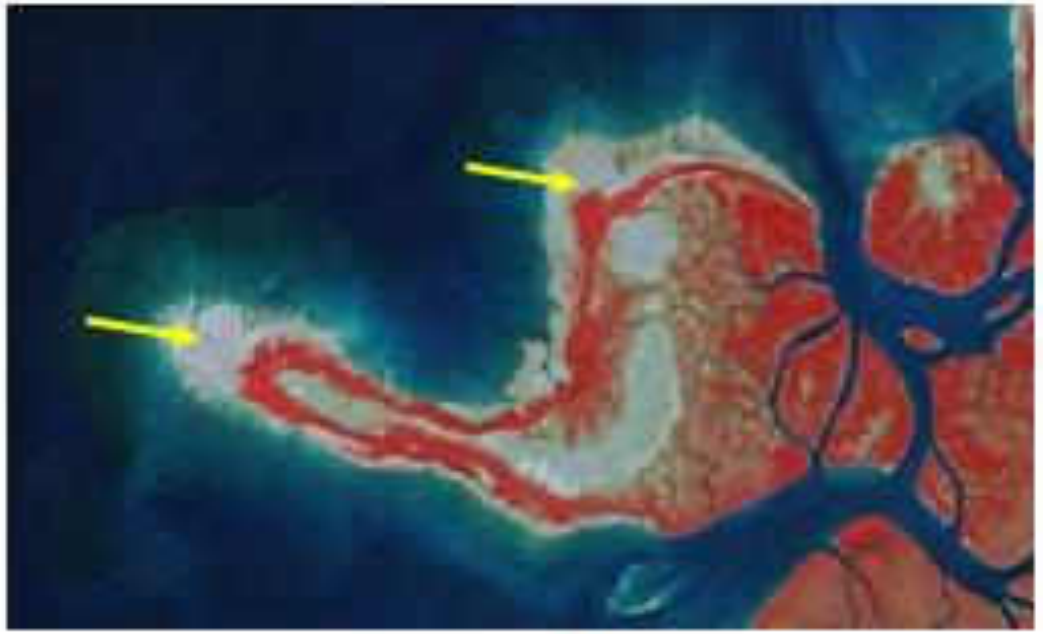
Mangroves in Chorao Island, Goa

2106 Coral reefs: Consolidated living colonies of microscopic organisms found in warm tropical waters. The term coral reef, or organic reef is applied to the rock- like reefs built-up of living things, principally corals. They consist of accumulations of calcareous deposits of corals and corraline algae with the intervening space connected with sand, which consists largely of shells of foraminefera. Present reefs are living associations growing on this accumulation of past (Clark, 1977). Reefs appear in light blue shade.



Coral Reef, Andaman & Nicobar Islands

Coral Reef, Andaman & Nicobar Islands



Coral Reef, Gujarat

Salt pans (2201): An undrained usually small and shallow rectangular, man-made depression or hollow in which saline water accumulates and evaporates leaving a salt deposit (Margarate *et al*, 1974). Salt pans are square or rectangular in shape. When water is there appearance is blue while salt is formed tone is white.

Nagapattinam district, Tamilnadu

Aquaculture ponds (2202): Aquaculture is defined as "The breeding and rearing of fresh-water or marine fish in captivity. Fish farming or ranching". The water bodies used for the above are called aquaculture ponds (Encyclopaedic Directory of Environment, 1988). Aquaculture ponds are geometrical in shape usually square or rectangular. Tone is blue.

West Godavari district, Andhra Pradesh

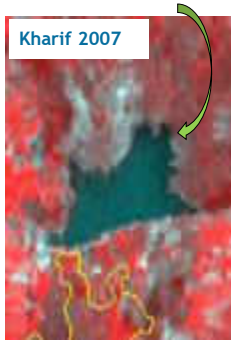
Revival of Minor Irrigation Tanks – Satellite Data Inputs

National Project on Repair, Renovation & Restoration (NPRRR) of Water Bodies linked to Agriculture

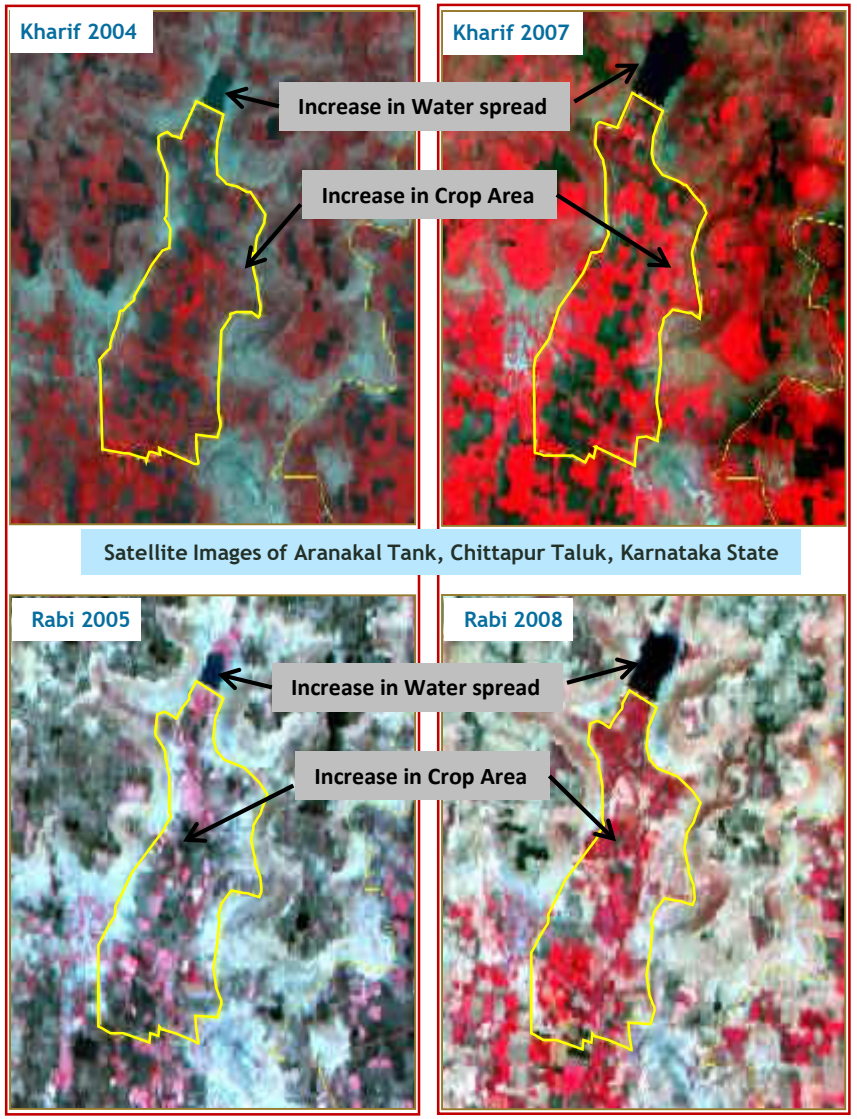
- **742 tanks in 9 districts in 6 states were evaluated for impact of RRR scheme**
- **Satellite data of pre (2004-05) and post (2007-08) implementation was used to assess the impact**
- **Tank-wise changes in water spread, irrigation utilization were quantified**

Satellite Images of Peddacheru, Mahabubnagar Telangana State

Increase in Water spread due to Desilting



Pre-NPRRR	Post-NPRRR
Kharif 2004	Kharif 2007
Rabi 2005	Rabi 2008

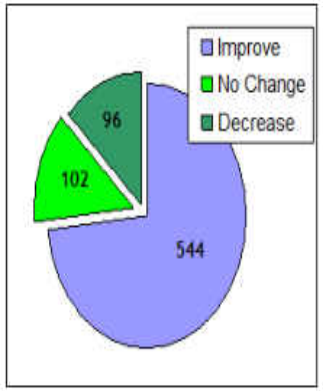


Satellite Images of Aranakal Tank, Chittapur Taluk, Karnataka State

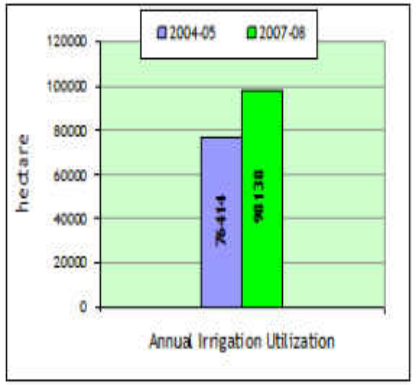
Satellite Images are in False Colour Composite

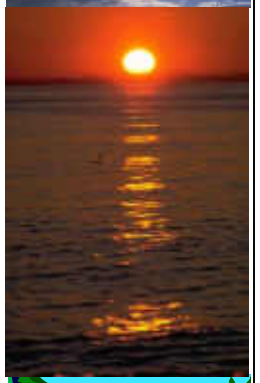
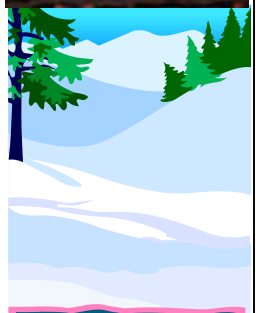
Tank Command boundary is shown in yellow colour

Overall Performance



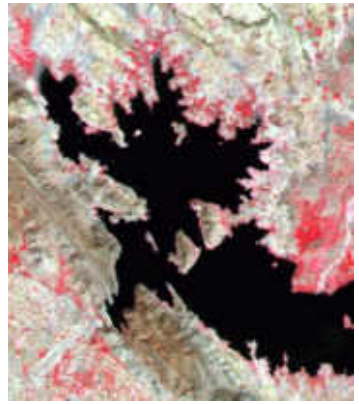
Increase in Irrigation Utilization



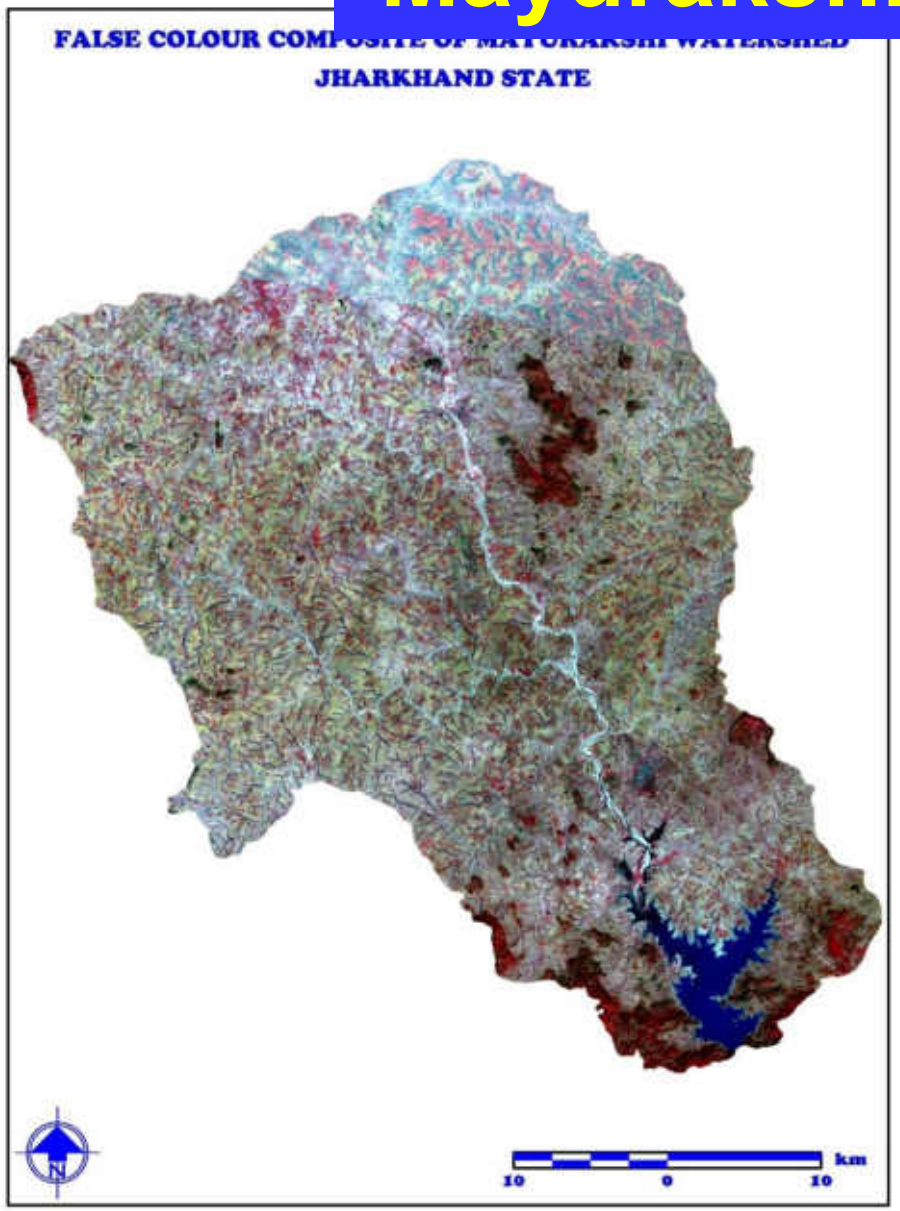



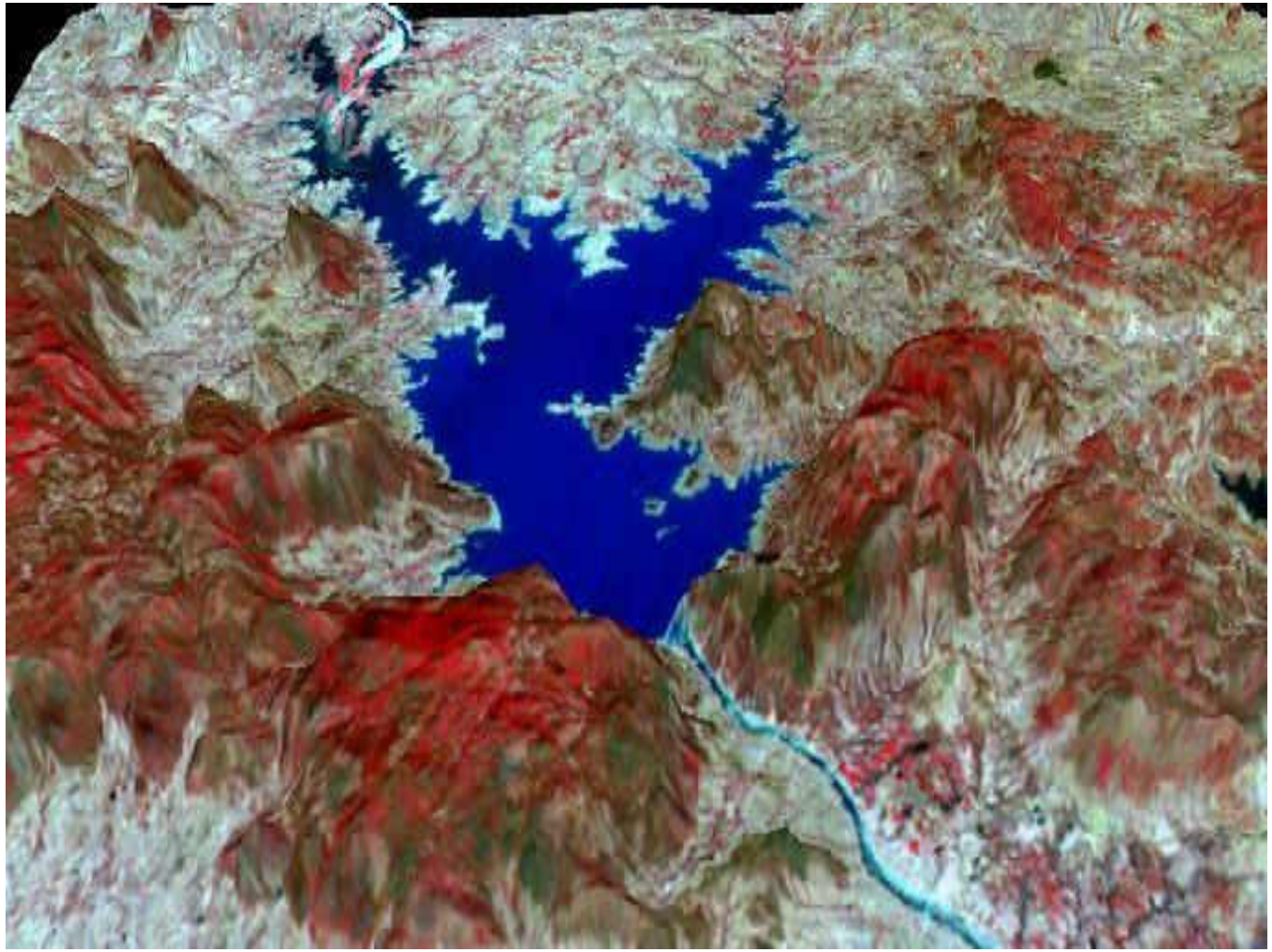
Relative estimate of turbidity

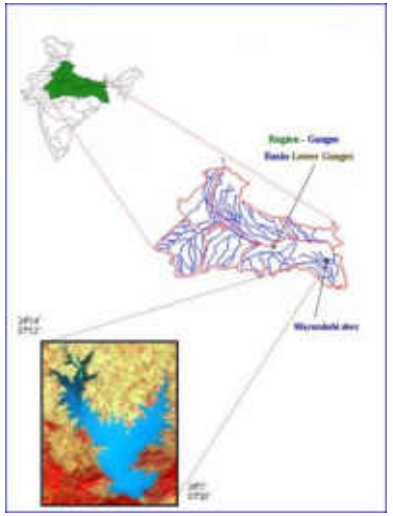
Colour on image	Relative turbidity
Black	None
Dark blue	Slight
Medium blue	Moderate
Light blue	Heavy
White	Very heavy



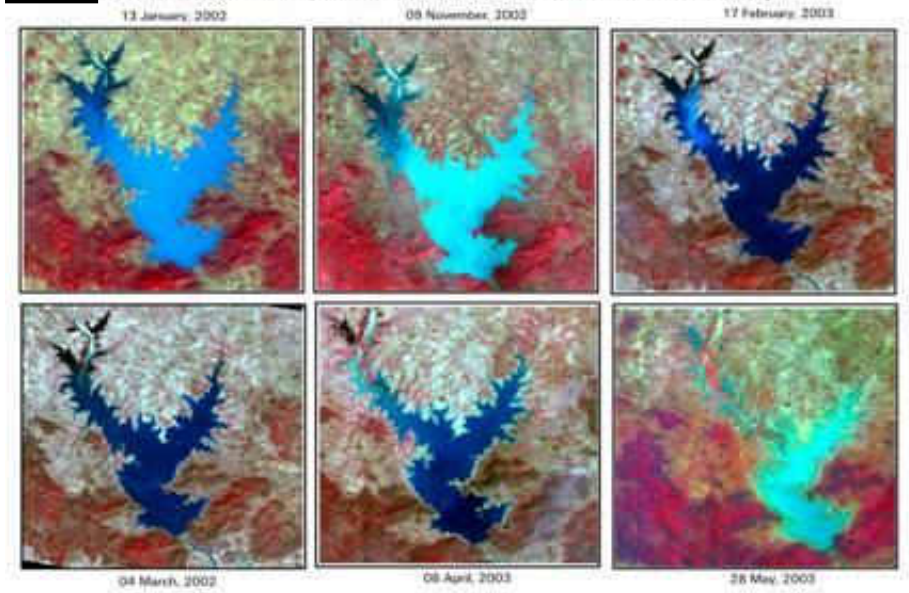
Mayurakshi catchment



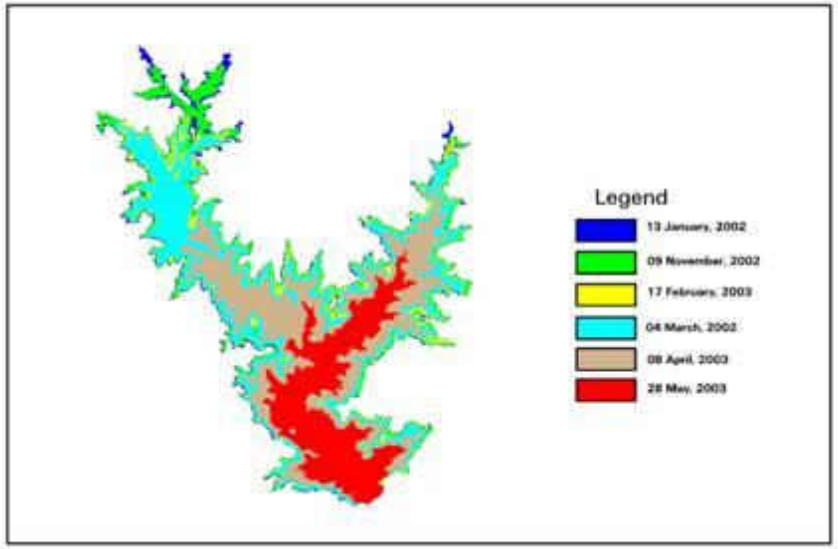




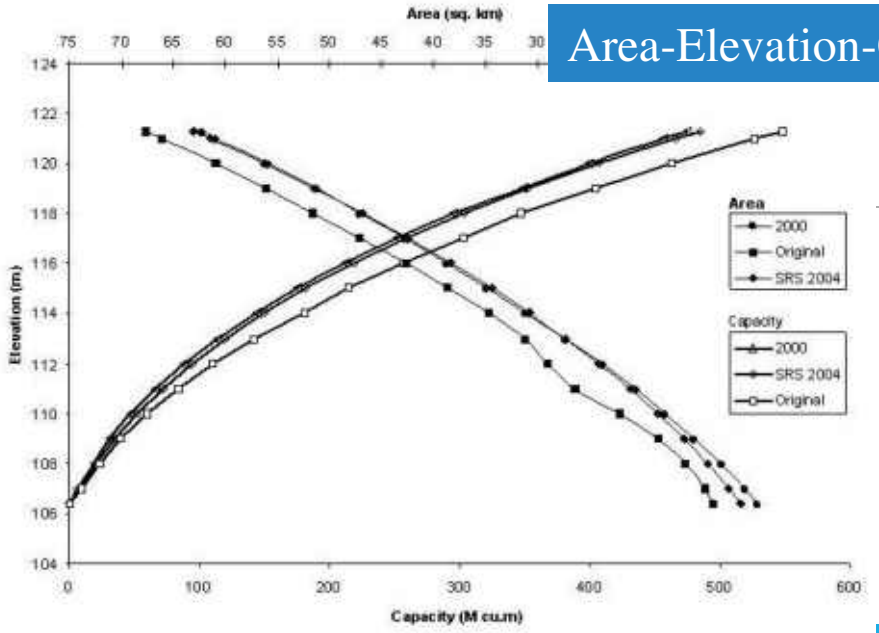
False Colour Composites of the scenes used for the study



Water Spread Areas of Mayurakshi Reservoir



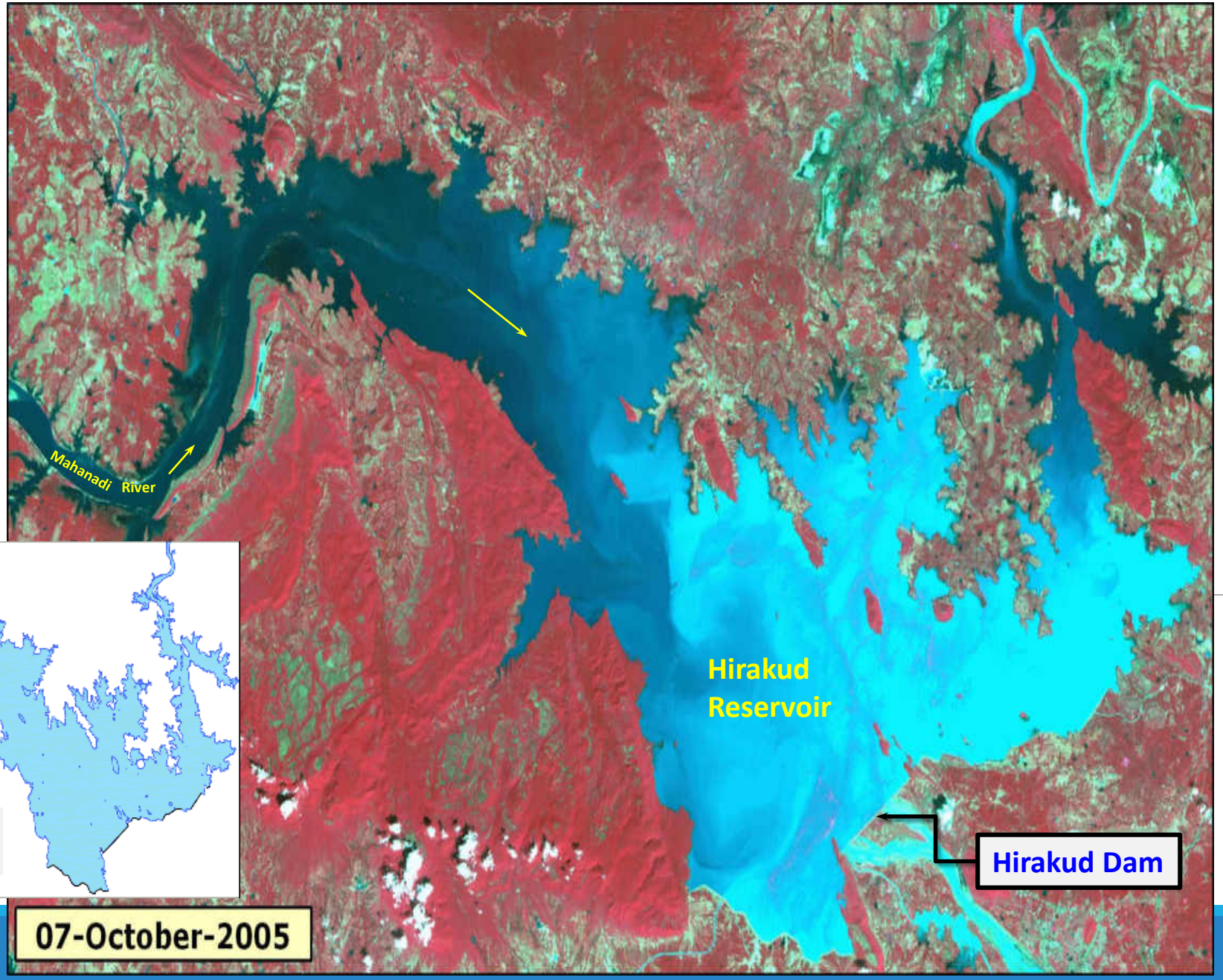
Area-Elevation-Capacity curve

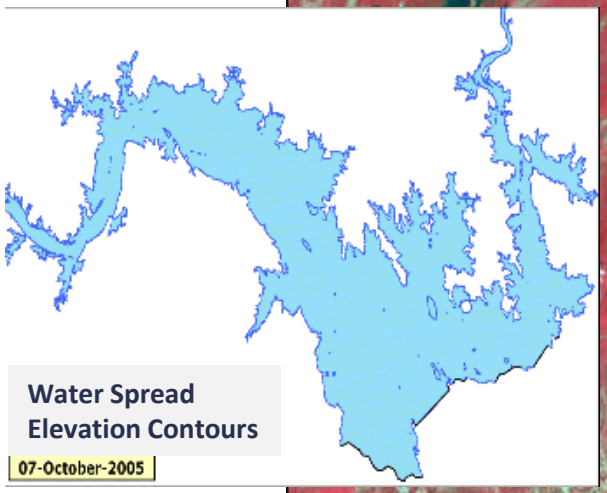


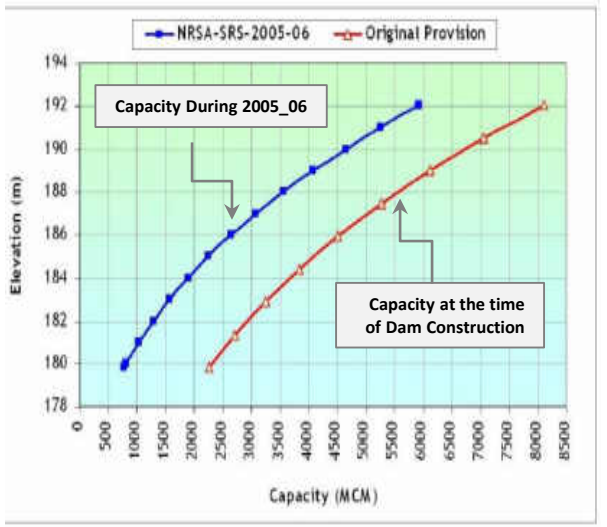
j. Degraded lands in the catchment area
k. Formation of gullies in the catchment area

l. & m. Gullied lands in the catchment area

Reservoir Capacity Loss due to Sedimentation



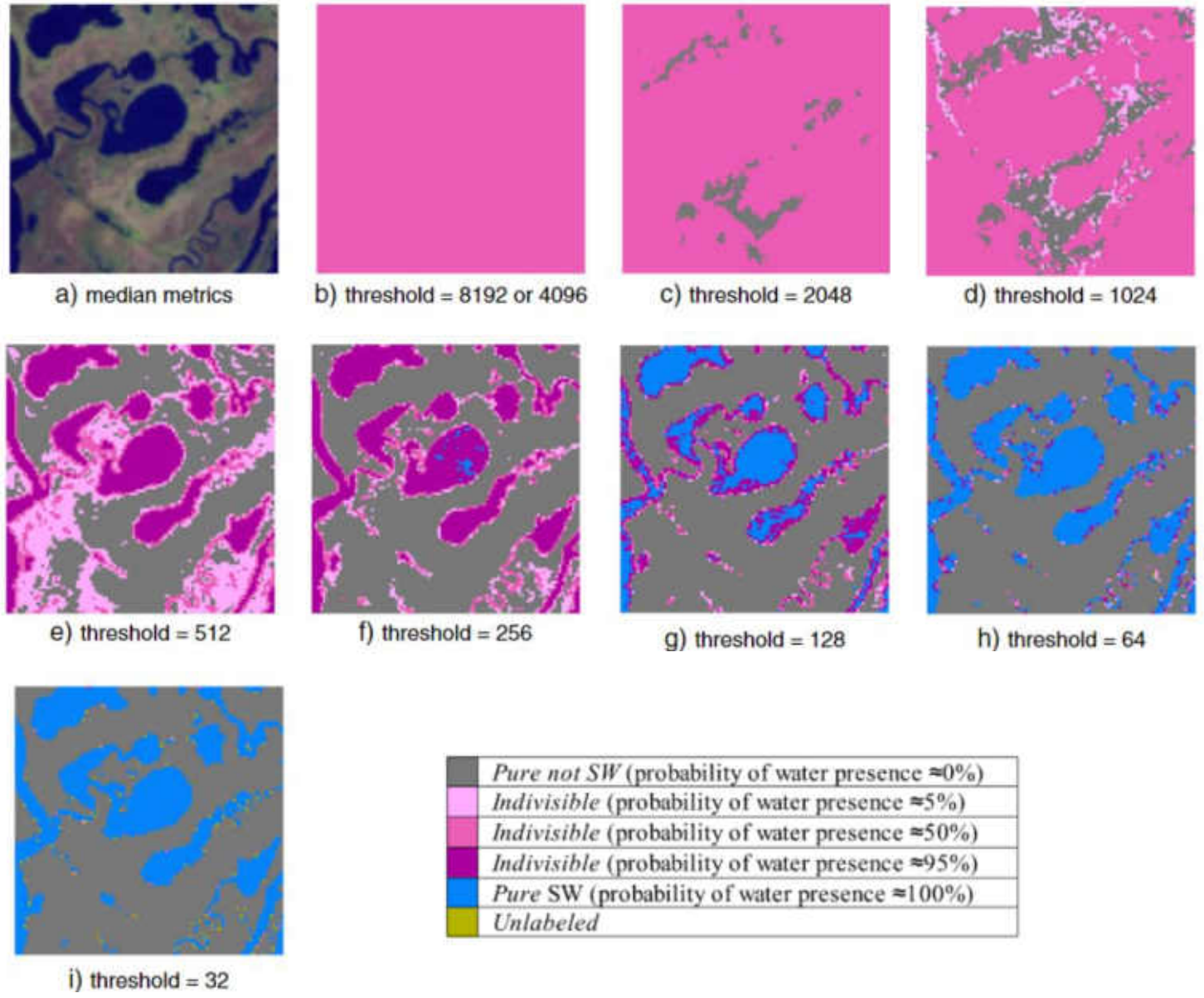




- *Time-series satellite data provides water elevation contours of the Reservoir*
- *Comparing with historic records, reduction in storage capacity due to sedimentation can be computed*

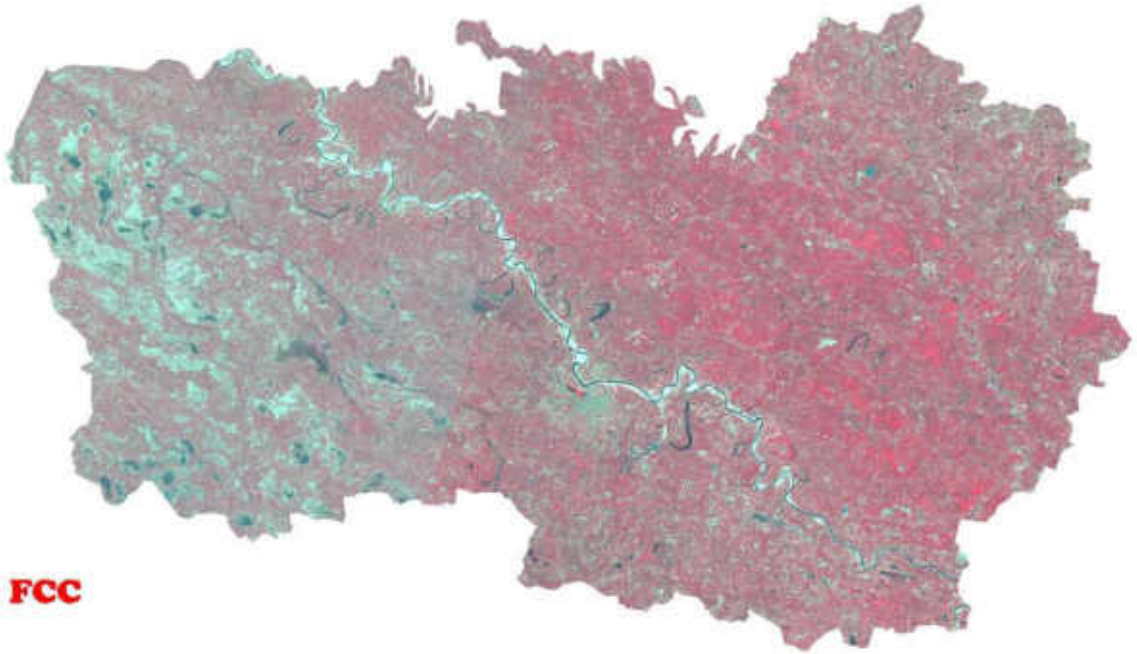
Band Thresholding

- Digital number (DN) ranges for a water pixel in different bands are defined
- Used for extraction of water bodies.

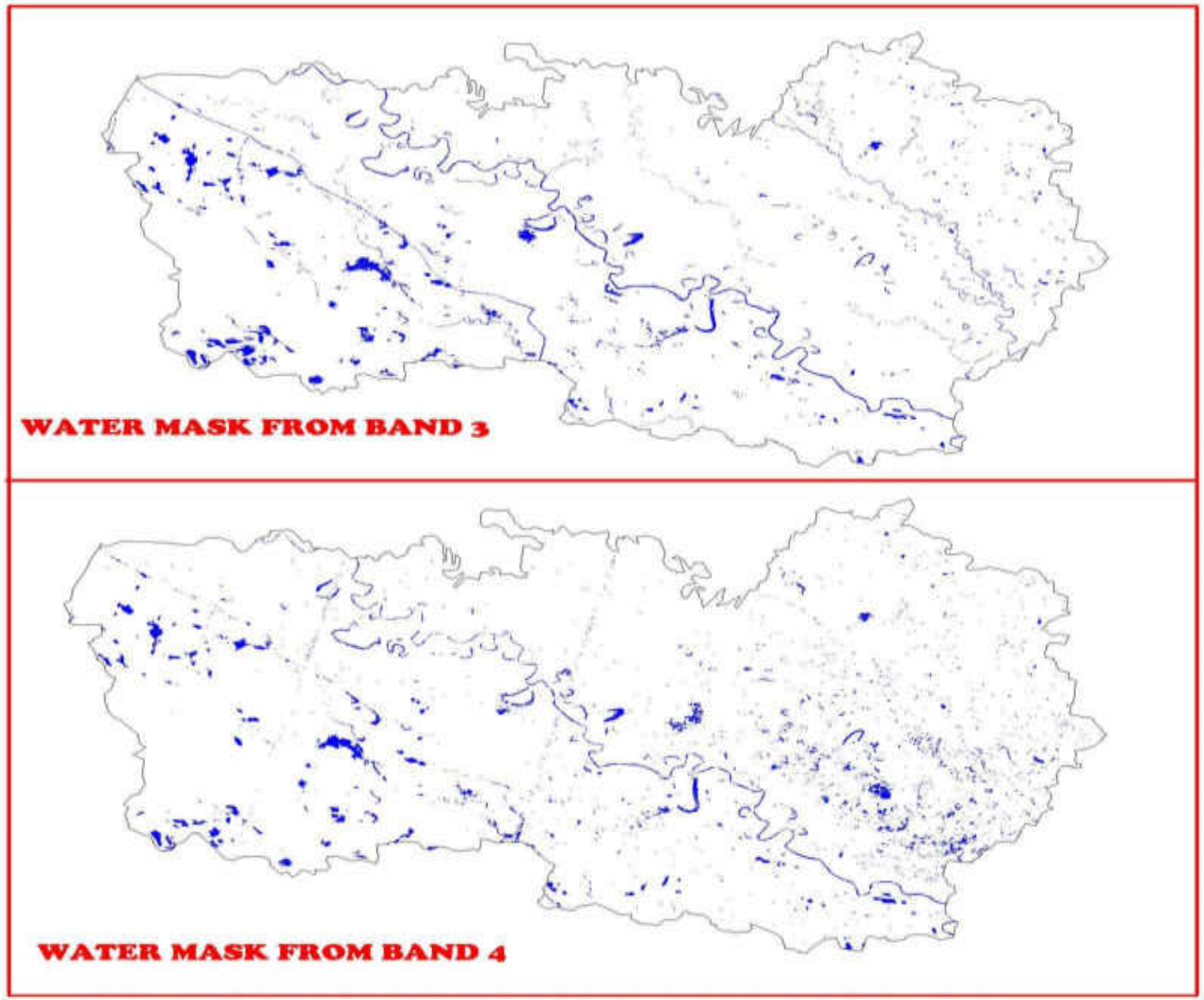


Source : https://doi.org/10.1016/j.rse.2015.04.022

Limitations - Band threshold method



STD. FCC



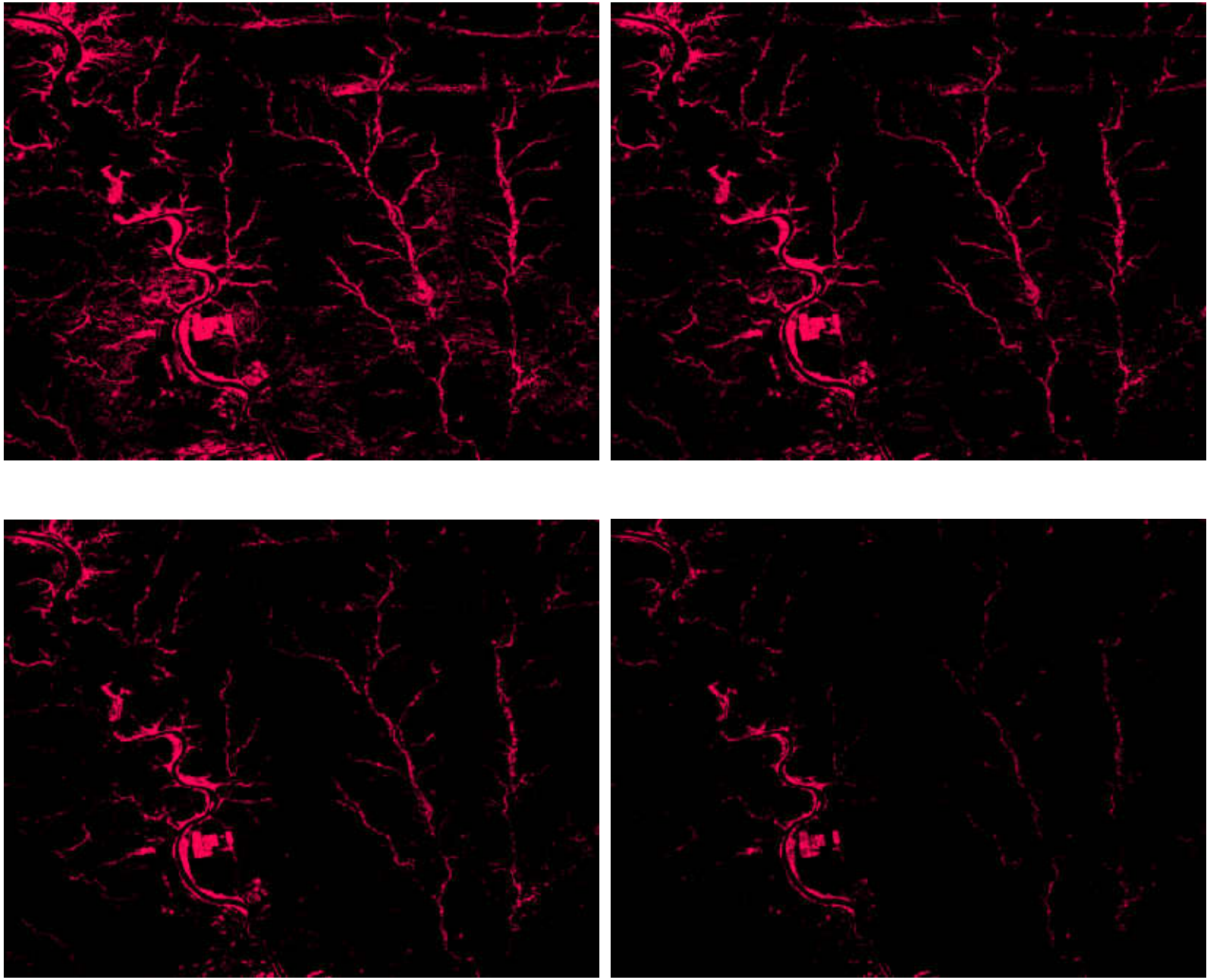
MUZAFFARPUR DISTRICT, BIHAR

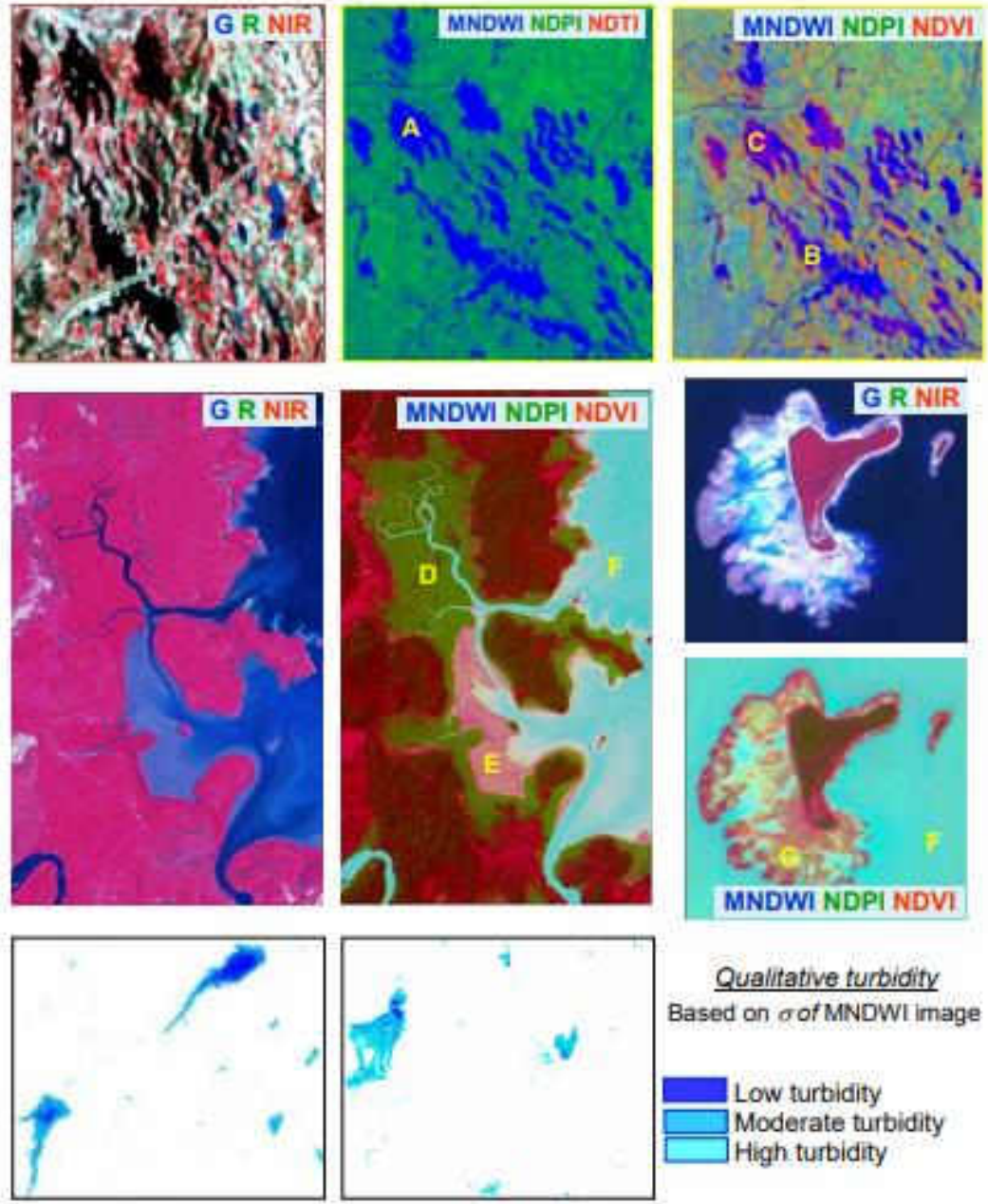
Band Ratios - Popular indices

- **NDVI (Normalised Difference Vegetation Index)**
- **NDWI (Normalized Difference Water Index)**
- **MNDWI (Modified Normalized Difference Water Index)**
- Use spectral information available in any of two spectral bands such as Green, SWIR or Green, NIR

- NDWI = $(Green - NIR)/(Green + NIR)$
- MNDWI= $(Green - SWIR)/(Green + SWIR)$
- NDPI = $(SWIR - Green)/(SWIR + Green)$
- NDTI = $(Red - Green)/(Red + Green)$
- NDVI = $(NIR - Red)/(NIR + Red)$

NDVI Thresholding





A: Inland wetland, B: Open-water, C: Wetland vegetation, D: Mangrove vegetation, E: Intertidal mudflat, F: Water (marine) and G: Vegetation over coral-reef

Literature review – optical imagery

- Normalized Difference Water Index (**NDWI**) and Modified Normalized Difference Water Index (**MNDWI**) were used by McFeeters et al., 1996 and Hanqiu, et al., 2006.
- ISRO has mapped **wet lands at national level** in India and atlas was released under Natural Resources Census (NRC) programme.
- **National Global lakes and wetlands database** at levels viz. large lakes, reservoirs, smaller water bodies, and wetlands. - Lenher, et .al, 2004
- **Maps of Canada's wetlands** using optical, radar and DEM data - Li et al., 2005.
- **A dataset of China' lakes**, which were constructed- Ma et al., 2011
- **Live storage capacity** useful for reservoir planning, operations, and sedimentation assessment (Frazer et al., 2000, Suresh Babu et.al., 2003, Manavalan et.al., 1993, Hui, et al., 2008).
- **Automated extraction algorithm** for the delineation of surface water bodies using IRS Resourcesat AWiFS, LISS III and implemented on national datasets - Subramaniam et al., 2011

Other Limitations – Optical Satellite Images

Techniques are scene specific - and may not be applicable to other areas

Requirement of manual intervention

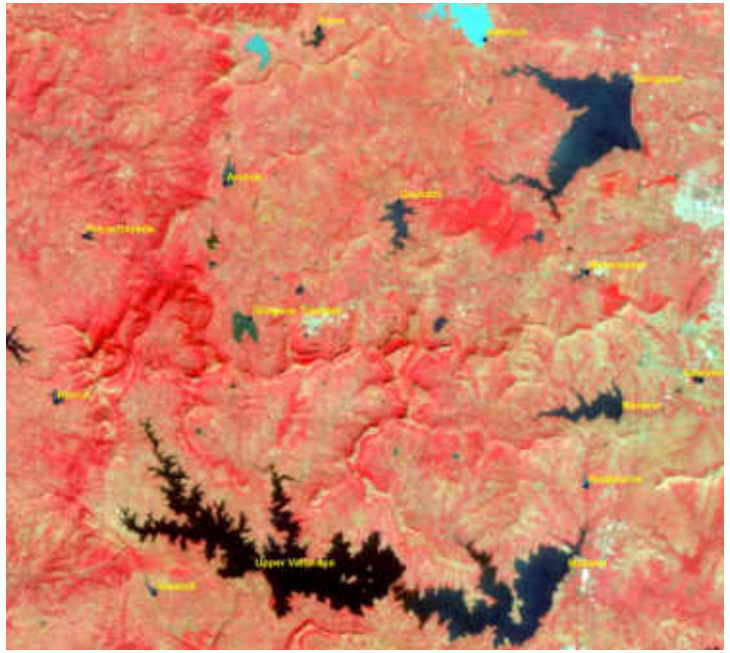
- Processing time increases
- Commitment of errors in surface water area delineation

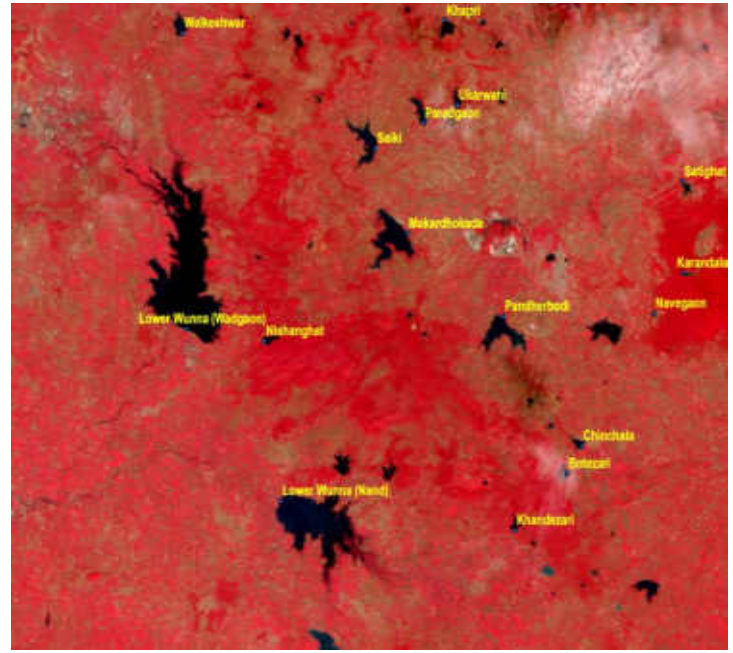
Popular indices NDWI, MNDWI

- Range for water pixel varies from one water body to other
- Range varies from one image to another image
- Spectral information available in other bands of a sensor are not fully utilized.

Limitations

- Techniques are scene specific - and may not be applicable to other areas
- Assigning of these parameters or threshold limits are highly subjective in nature
  - **Vary from image to image**
    - Across the seasons / years
    - Different geographical settings





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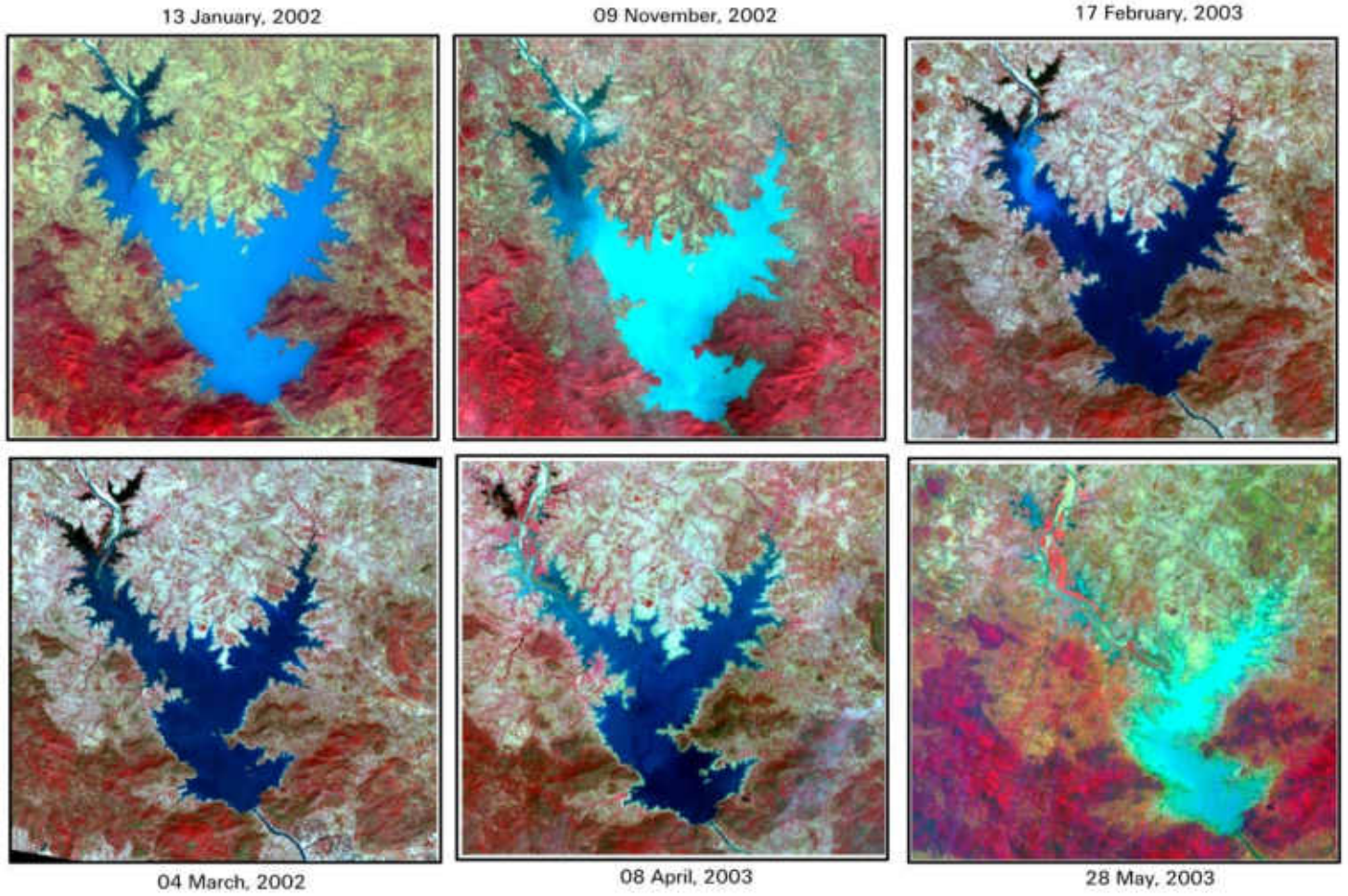

Limitations

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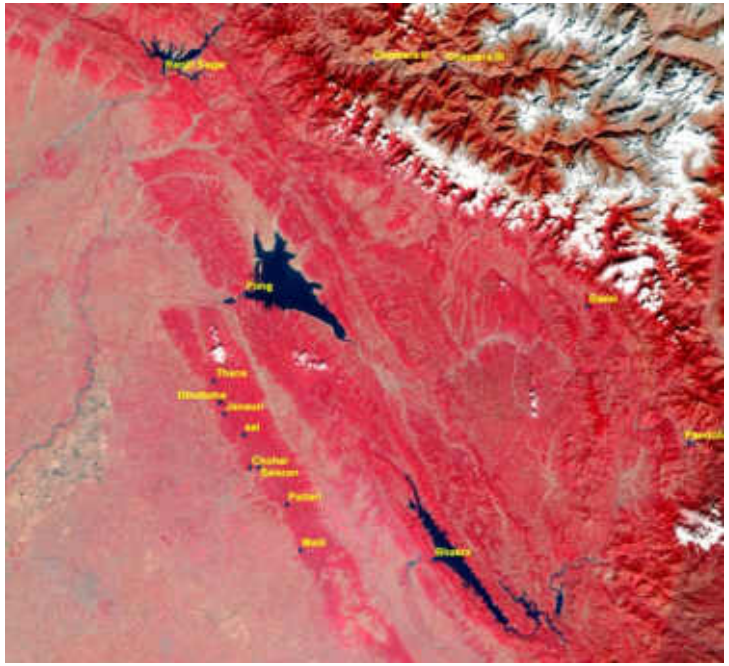
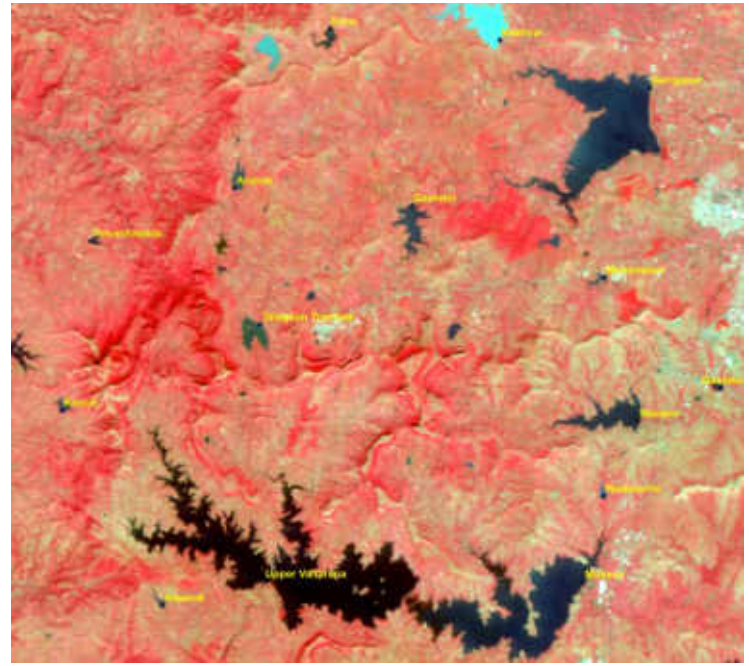
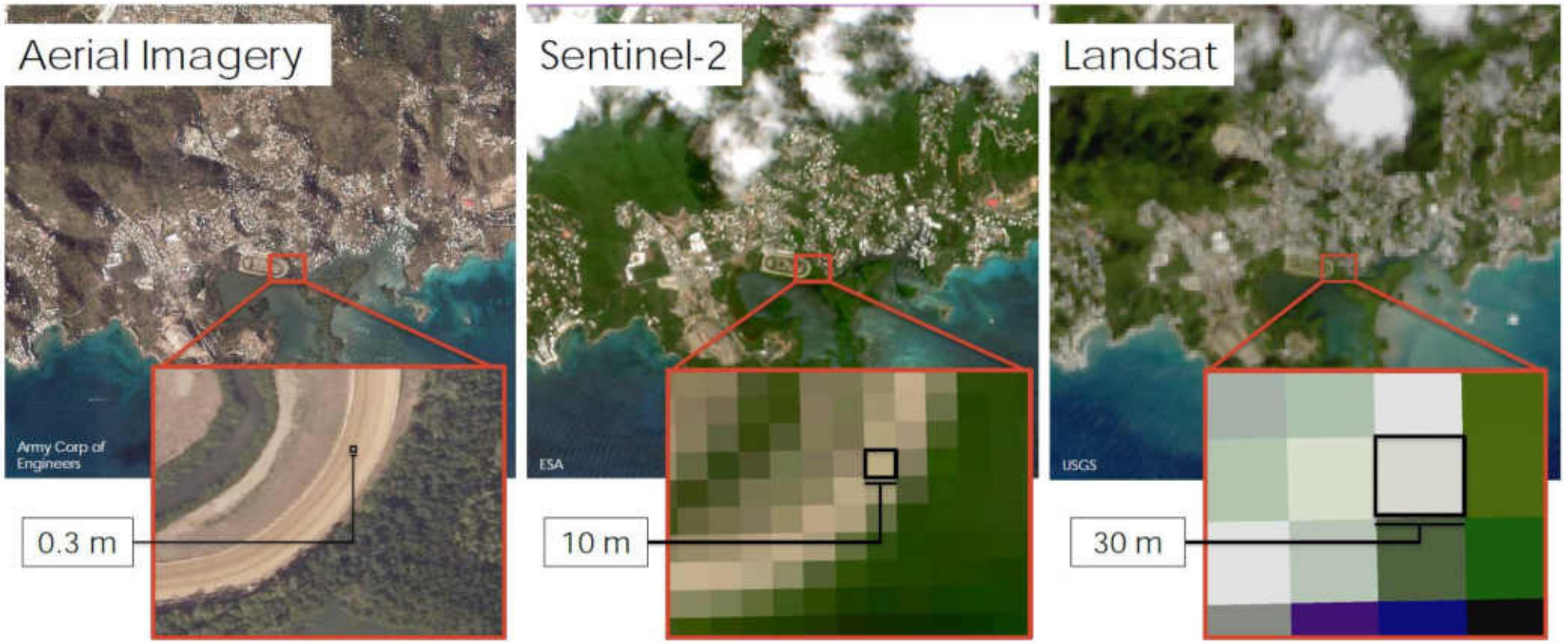




Spatial Resolution - Limitations



Constraints of using Satellite Imagery

- Even Landsat (30 m) resolution might be too coarse for narrow rivers or creek systems
- May need even higher spatial resolution
  - from either airborne (or drone) platforms (cm-m scale)
  - commercial satellites that have a spatial resolution of <5 m
- Information on pixels close to river borders might be “contaminated” with information from land
- Cloud cover

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3. *Encyclopaedic Directory of Environment (*1988). (Ed. By G.R. Chatwal, D.K. Pandey, and K.K. Nanda). Vol. I-IV, Anmol Publications, New Delhi.

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5. Garg, J.K., Singh, T.S. and Murthy, T.V.R. (1998). *Wetlands of India*. Project Report: RSAM/sac/resa/pr/01/98, June 1998, 240 p. Space Applications Centre, Ahmedabad,

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Sensor Data Collection

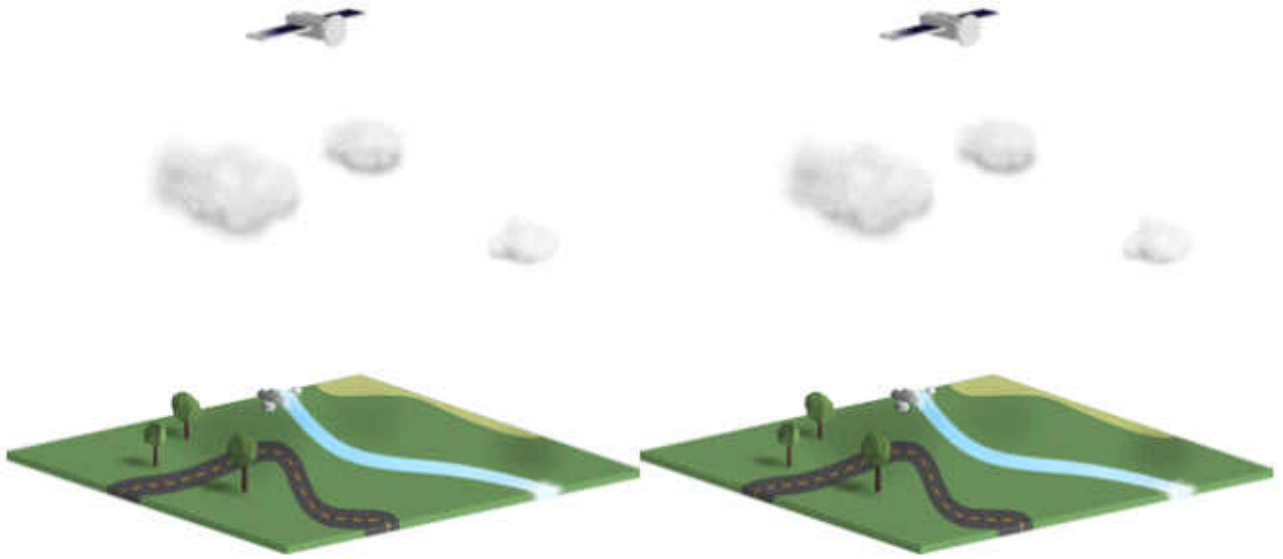
Passive remote sensing:

- Depends on reflected and emitted radiation from the Earth
- **Examples**: AWiFS, LISS-3, LISS-4, Landsat, MODIS (Terra/Aqua)

Active remote sensing:

- The instrument sends beams of radiation and measures its return.
- **Examples**: RISAT - Radar, LIDAR

Passive vs. Active Sensors



Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

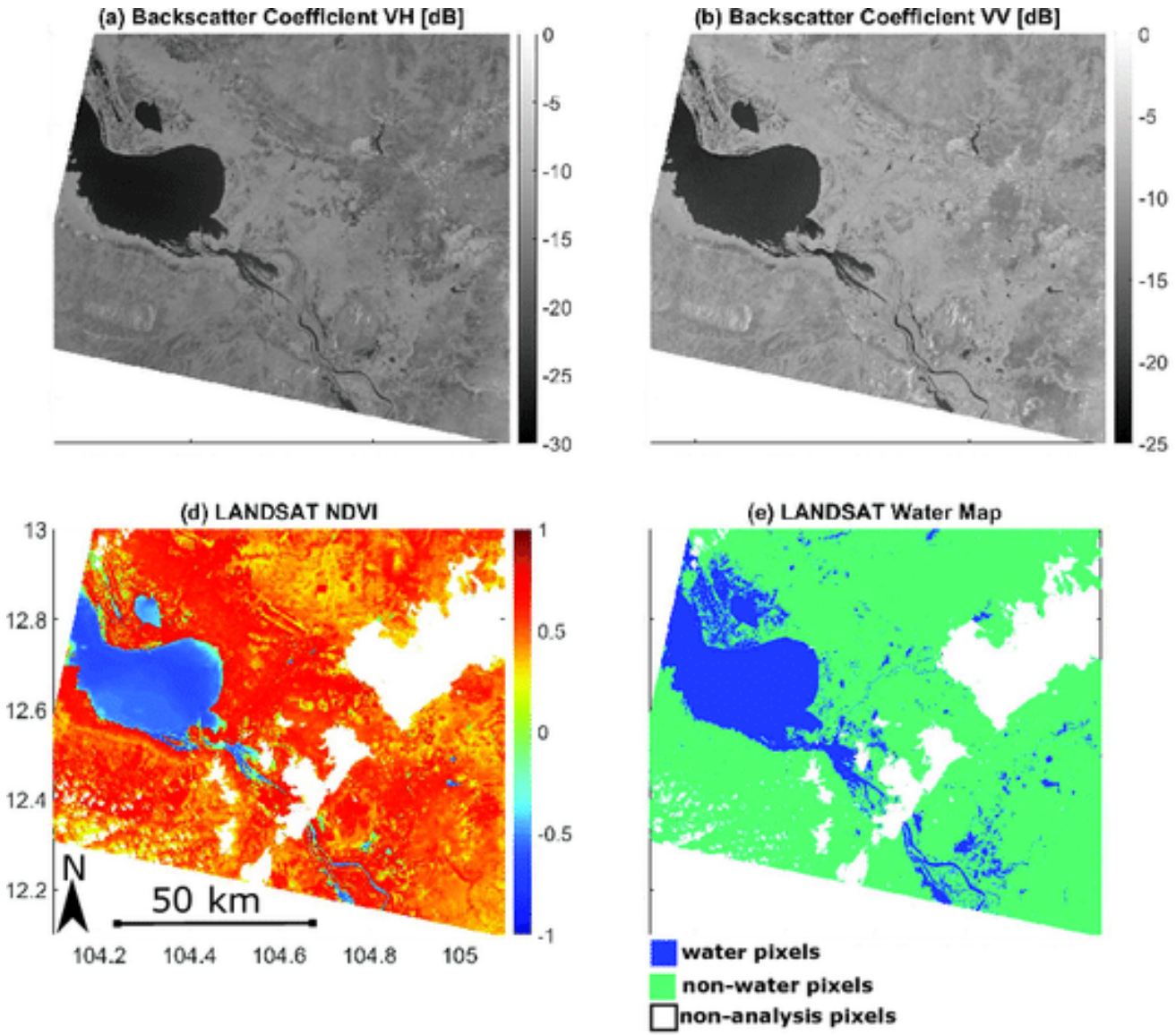
Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

Microwave Satellite Imagery

Microwave Satellite Imagery

- The application potentials of microwave datasets with hydrological perspective
  - Van der Sanden 2004, Sokol et al., 2004 and Brisco et al., 2008.
- The influence of incidence angle on backscatter varies according to ground layer characteristics, including surface roughness, presence/absence of standing water, soil moisture, and the forest structure (Megan et al., 2008).
- **Sigma naught**
  - Chiefly a function of incidence angle
  - Varying by about 5 dB for the smooth targets such as bare soil, surface water (Ross et al., 1998)
  - Varying by about 10dB for other land-use features (Horritt et al., 2002).
- Separability between different classes was performed by the visual investigation of, incident angle based HH and HV scatter plots (Brisco et al., 2011) to finalize the thresholds.

Microwave Imagery



Source : Surface Water Monitoring within Cambodia and the Vietnamese Mekong Delta over a Year, with Sentinel-1 SAR Observations

Literature Review – Microwave data

- Mapping techniques considering various parameter for delineation of surface water bodies
  - **Polarization ratios-** Brisco et al., 2011, Schroeder et al., 2010
  - **Concurrent use** of optical and radar images - Laura Brown et al., 2006
  - **ISODATA algorithm** - Maria et al., 2002
  - **Adaptive thresholding** - Liu et al., 2004
  - **Active contour model** - Horritt et al., 2002, Thomas et al.,
  - Multi-polarization radar images utilized for **flood inundation** mapping and monitoring - Van der Sanden 2004, Hu et al., 2007 and Panchagnula et al., 2012
  - **Wetland mapping applications** using optical and radar data - Junhua et al., 2005 and Jean-Robert et al., 2010

- **RISAT-2B**
  - launched on May 21, 2019
  - Providing microwave datasets on regular basis
  - Can be used for operational hydrological applications.

ISRO's Initiatives

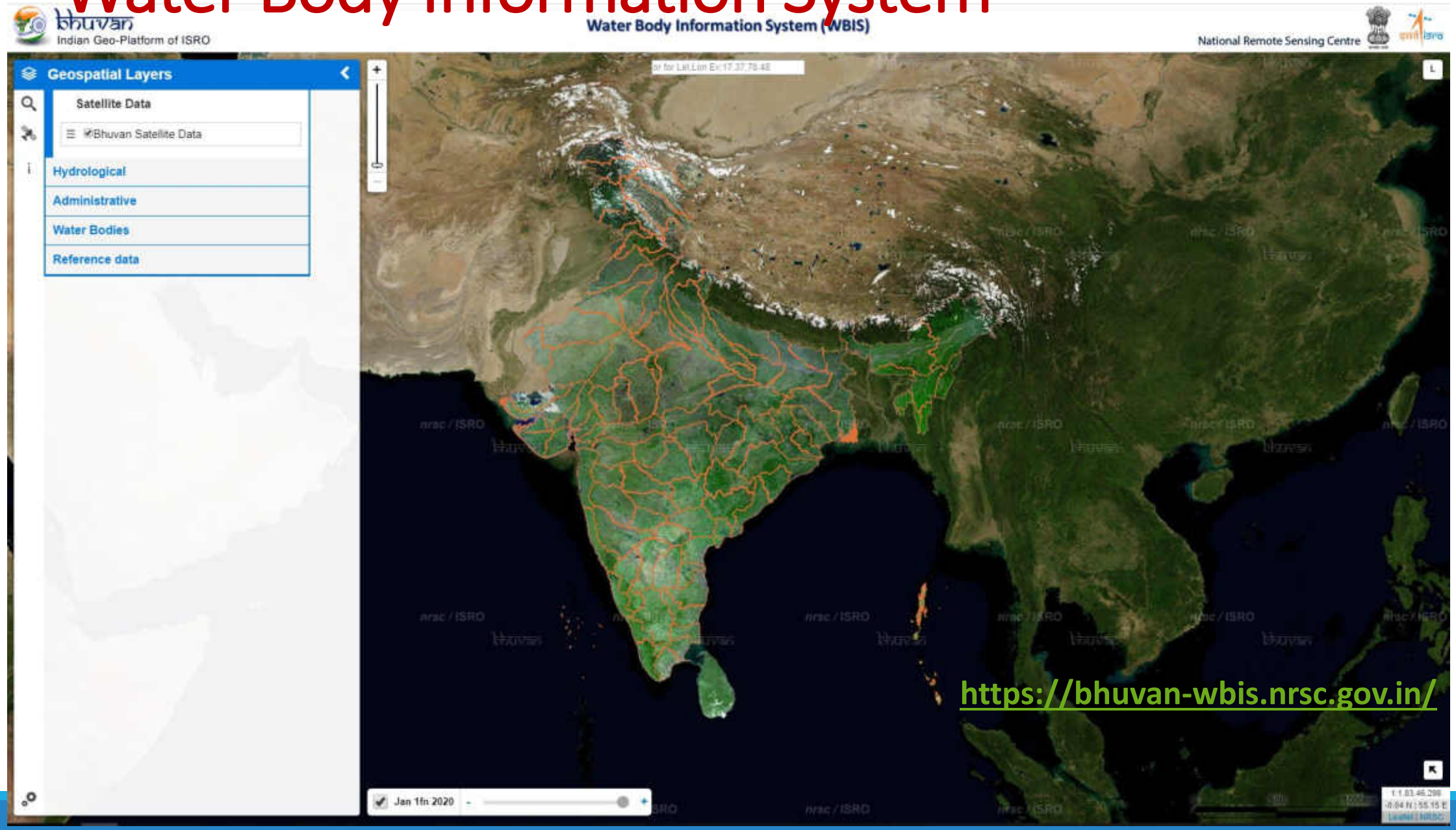
Water Body Information System
NRSC

National Wetland mapping project
SAC

Updation of the NWIA database of 2006-07 and a renewed inventory and assessment of wetlands at 1: 25,000 scale at national level

Source: Resourcesat-2/2A LISS-III data of 2017 (post-monsoon) and 2018 (pre-monsoon), and SAR data of 2017 (monsoon)

Water Body Information System



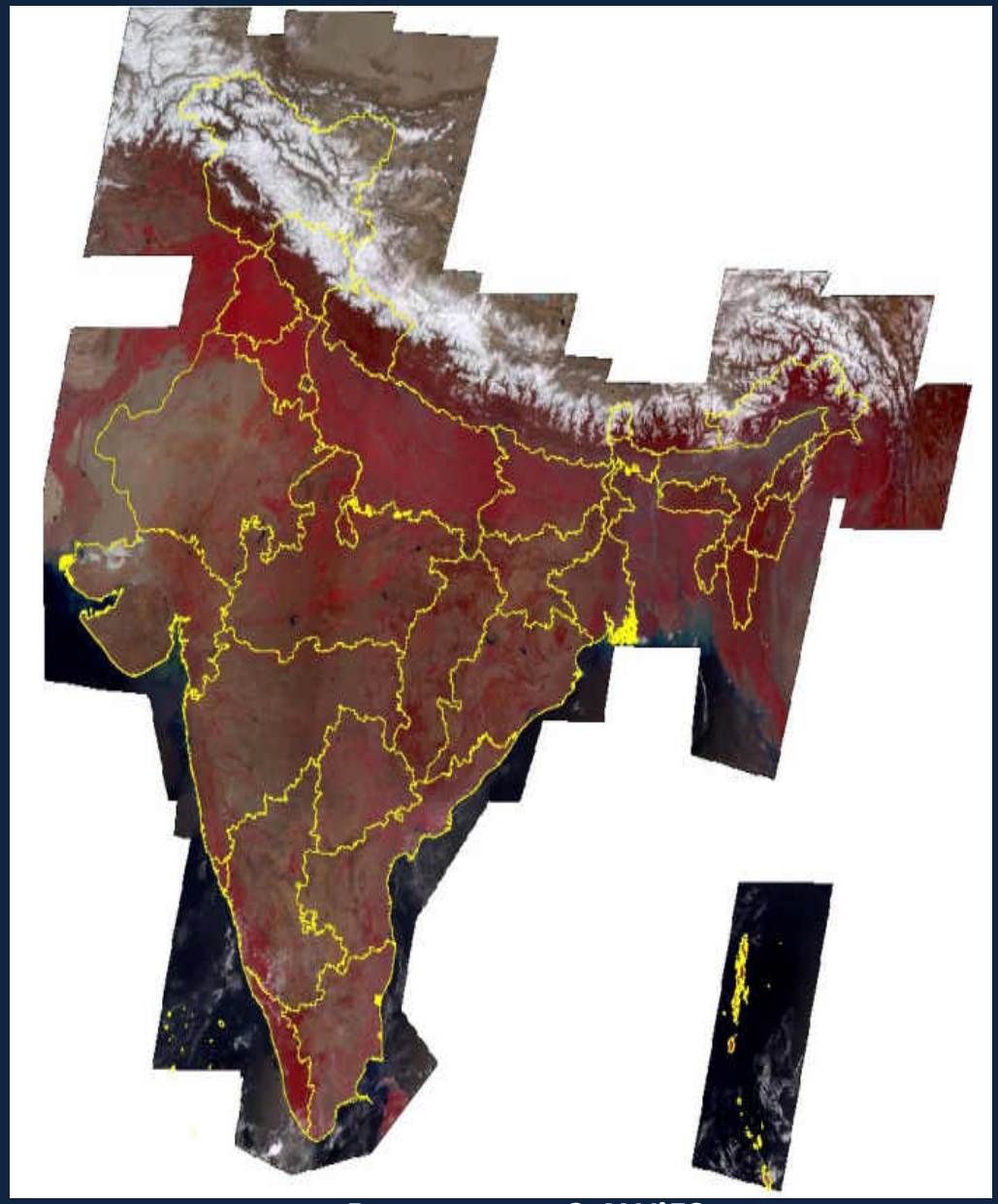
Water Resources

Water Bodies Extraction from Satellite Data – Automation

- Large number of spatio-temporal satellite data sets are being processed with Automatic Extraction Algorithms in near real time .
- Surface water bodies layer at 15 day interval is generated at National level and hosted on Bhuvan .

- Surface water dynamics
- Quantification of Surface Water Res.
- Assessment of Hydrological drought

- Information at National level
- Resourcesat-AWiFS ; RISAT-1 MRS are used



Resourcesat-2 AWiFS

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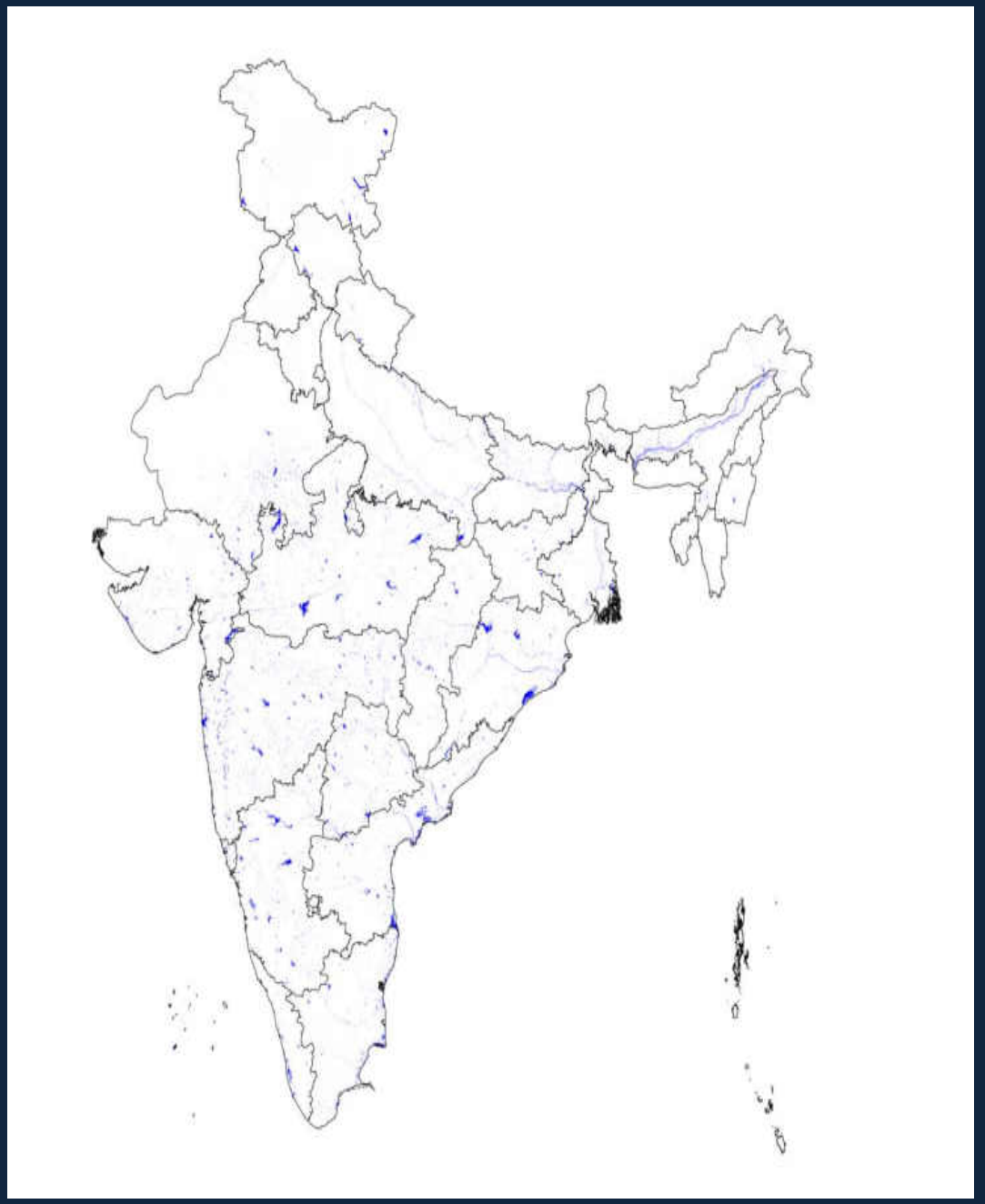

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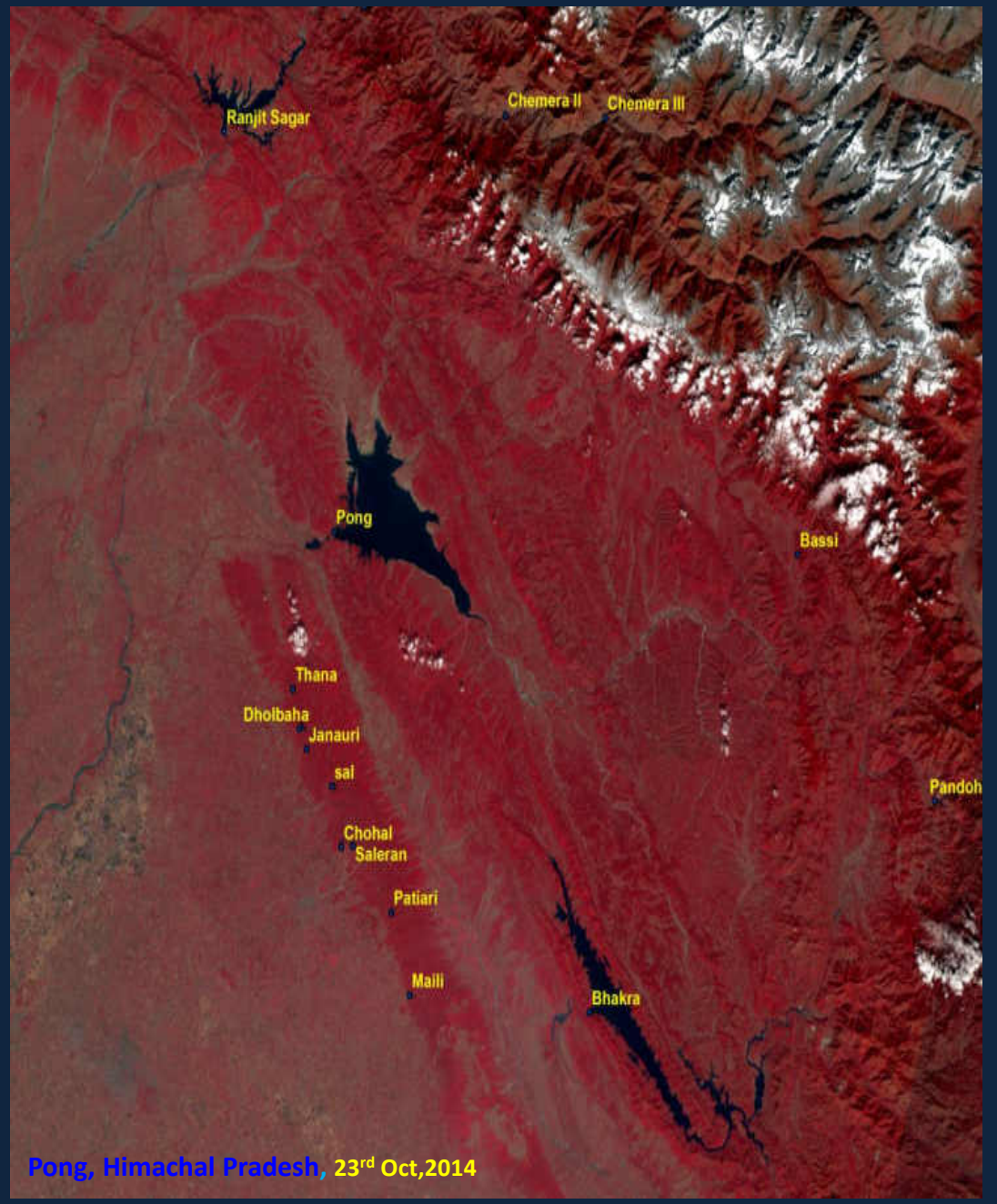

Pong, Himachal Pradesh, 23rd Oct,2014

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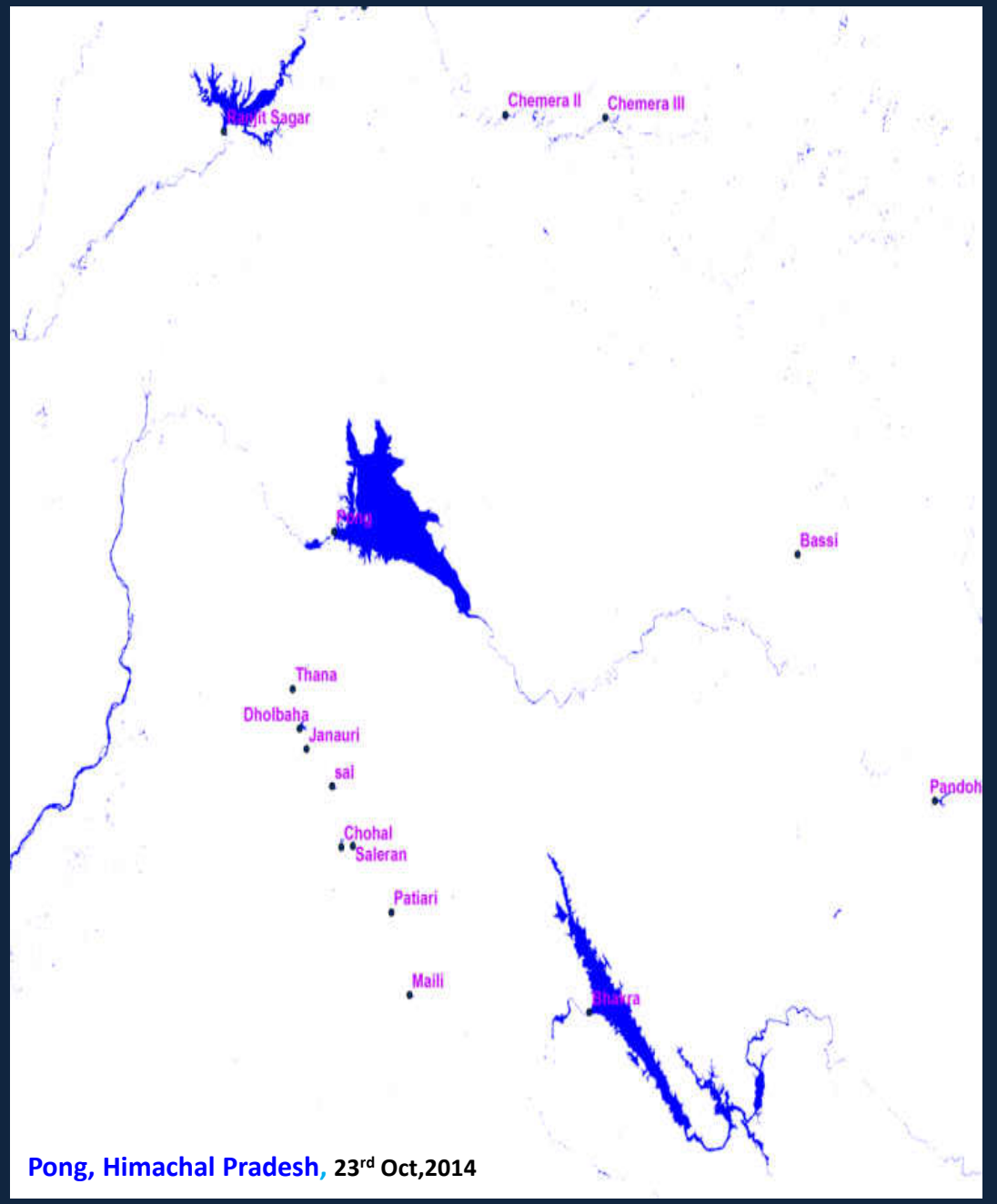

Pong, Himachal Pradesh, 23rd Oct,2014

Water Resources

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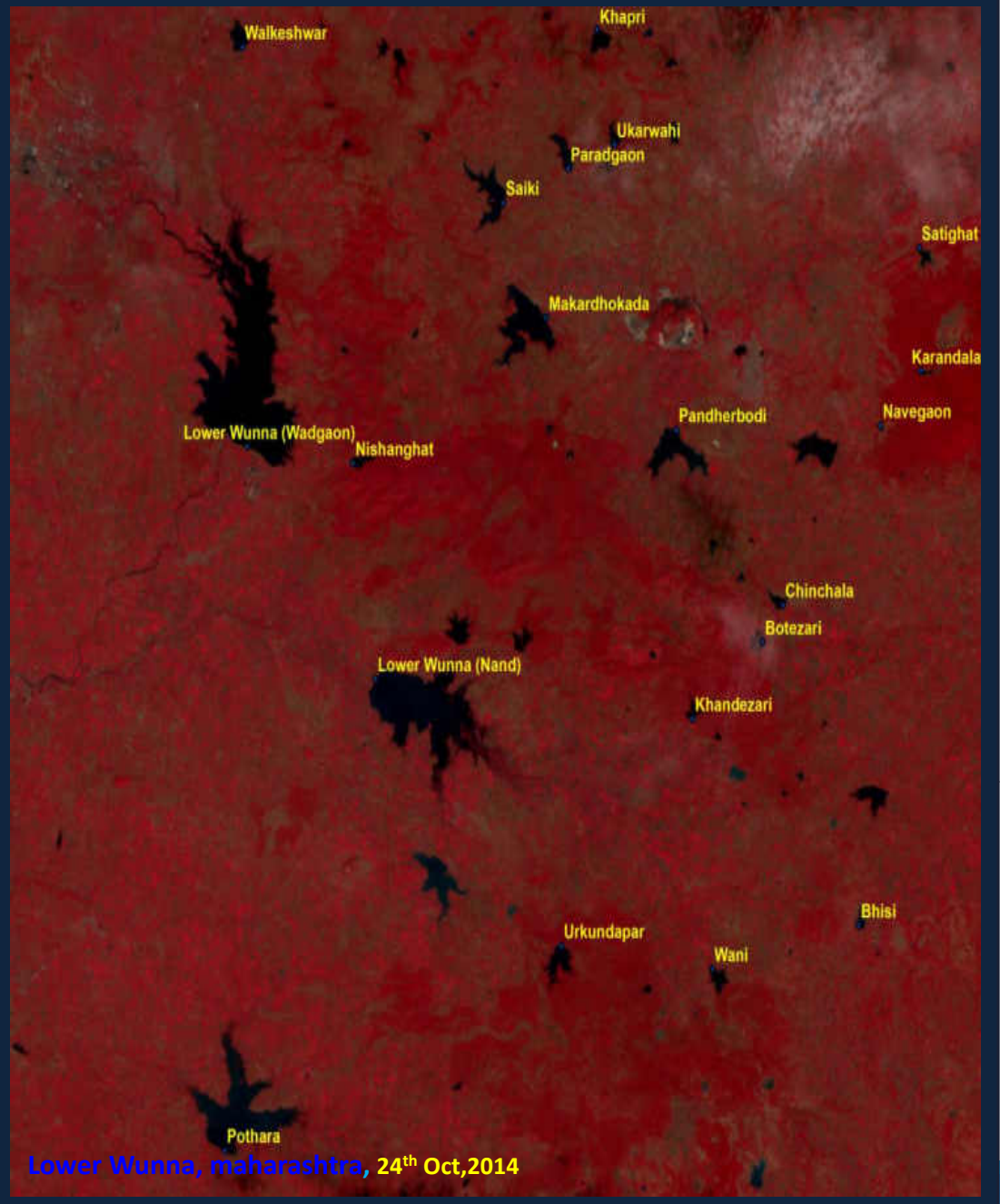

Lower Wunna, maharashtra, 24th Oct,2014

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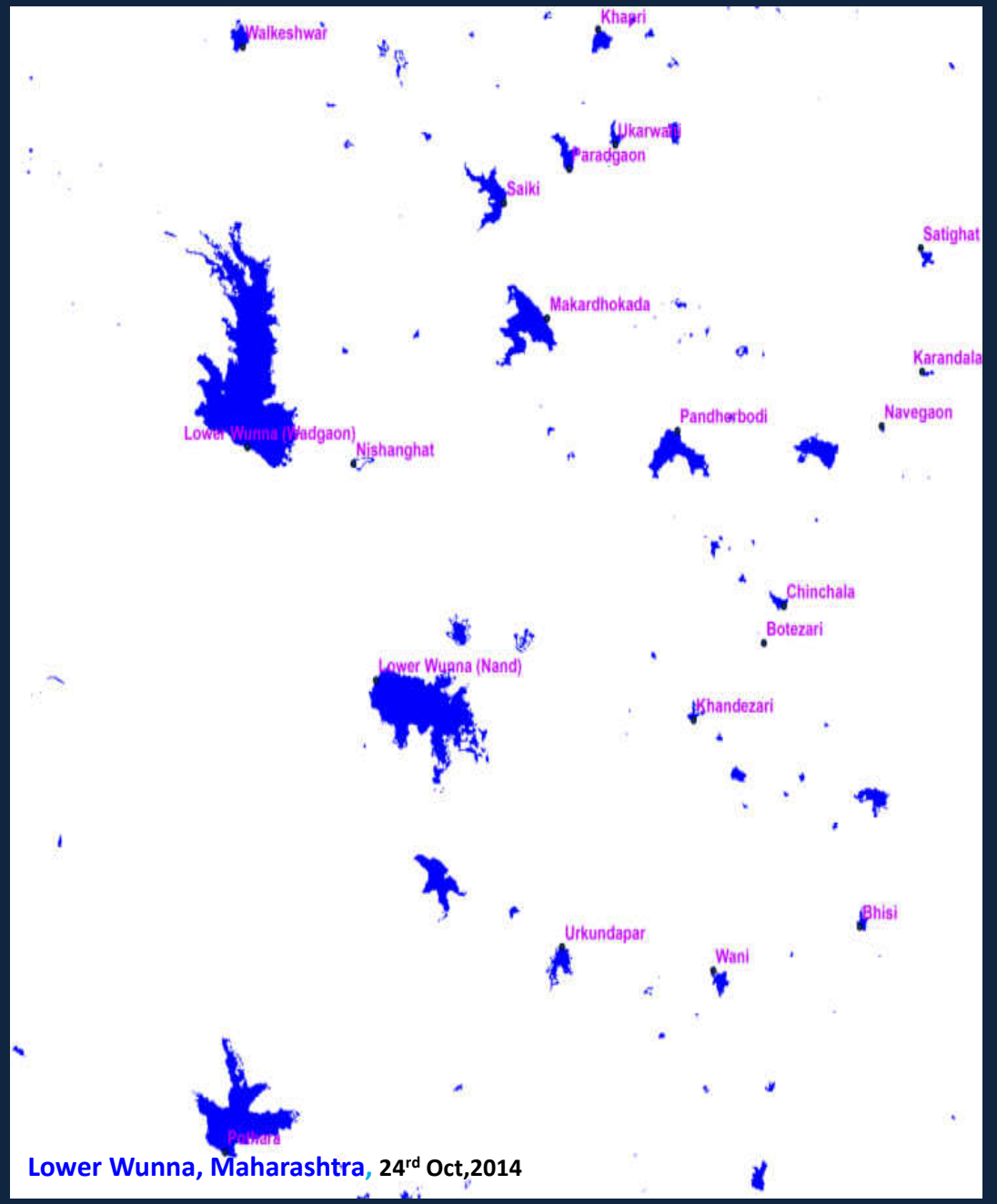

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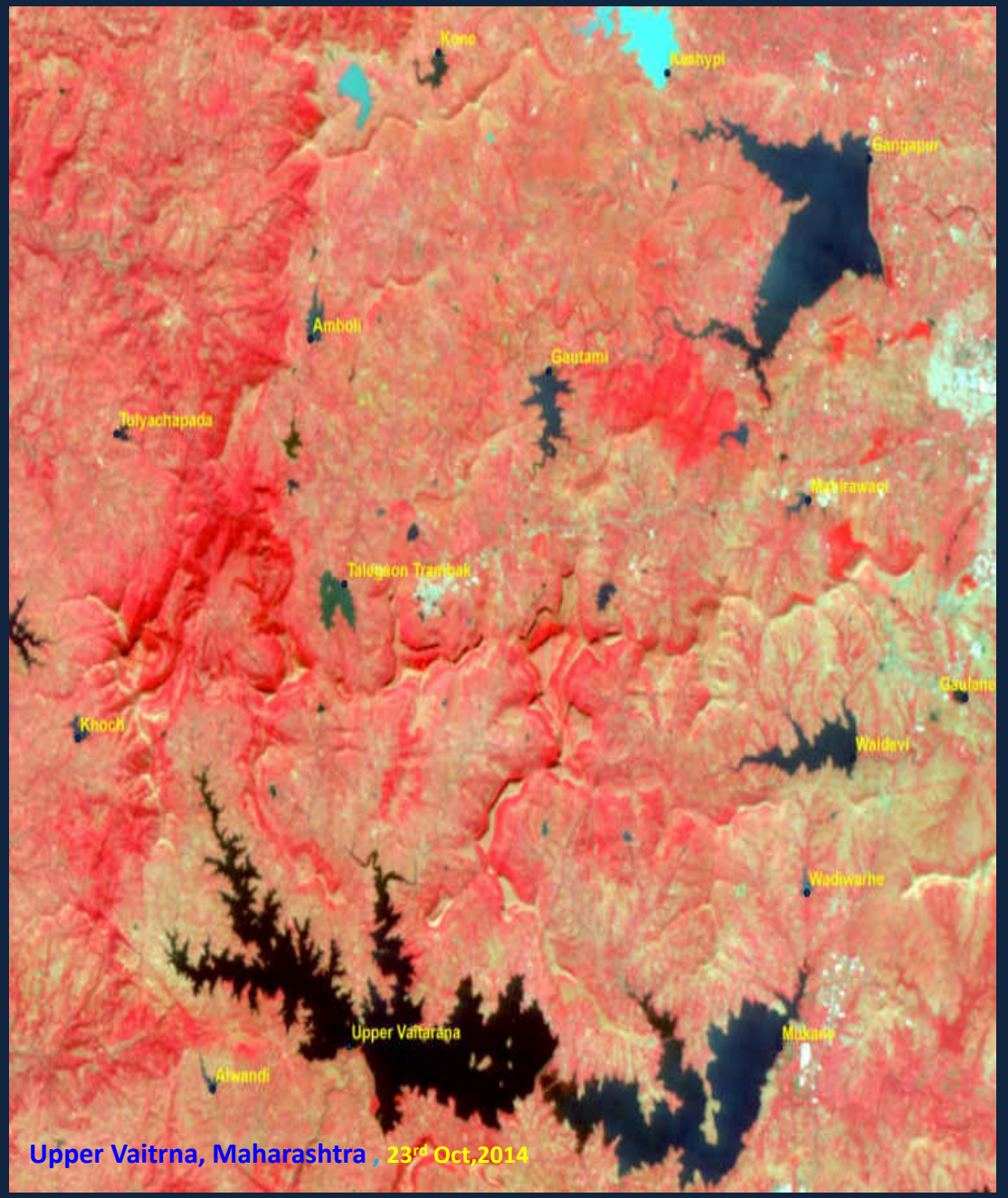

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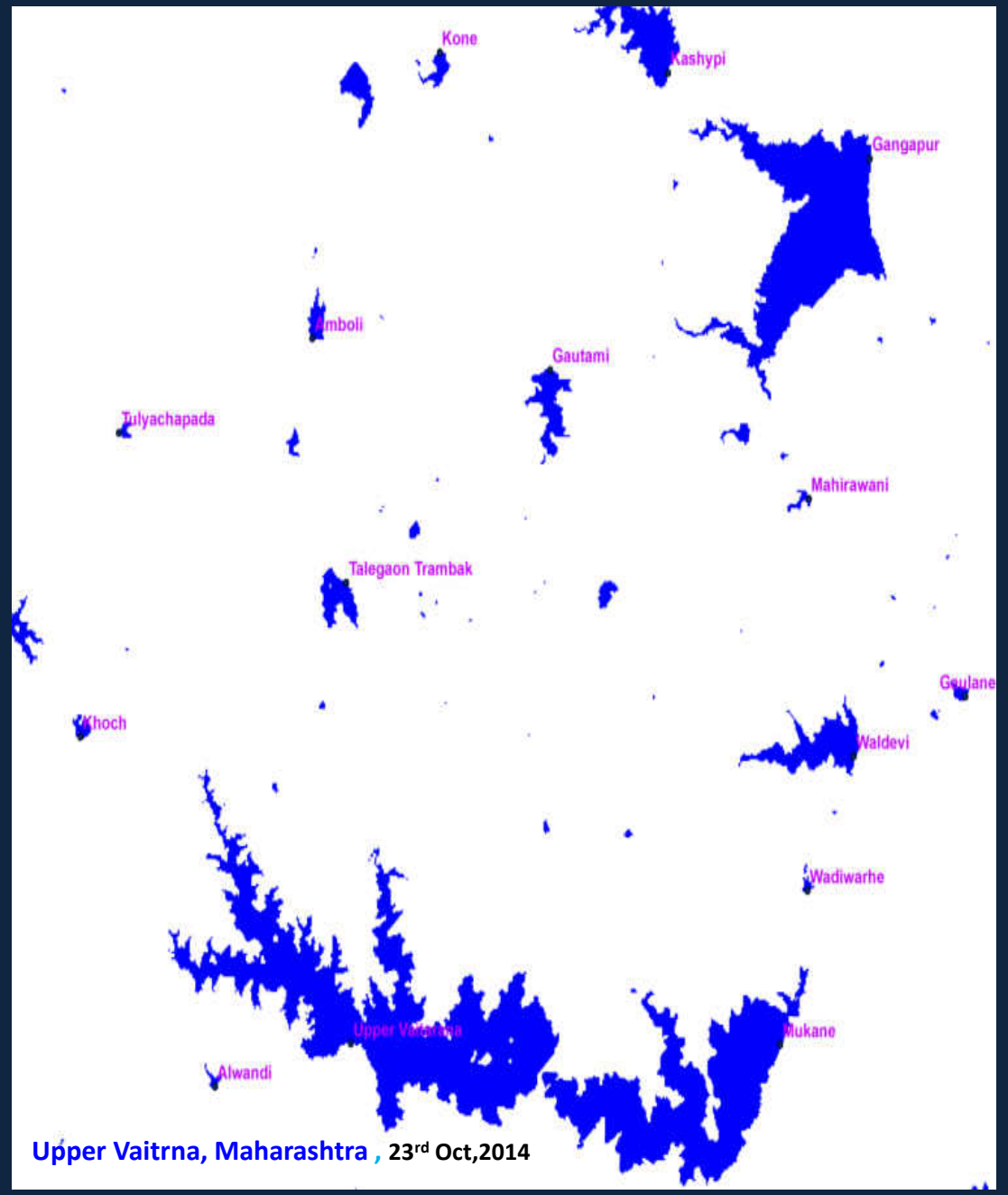

Upper Vaitrna, Maharashtra , 23rd Oct,2014

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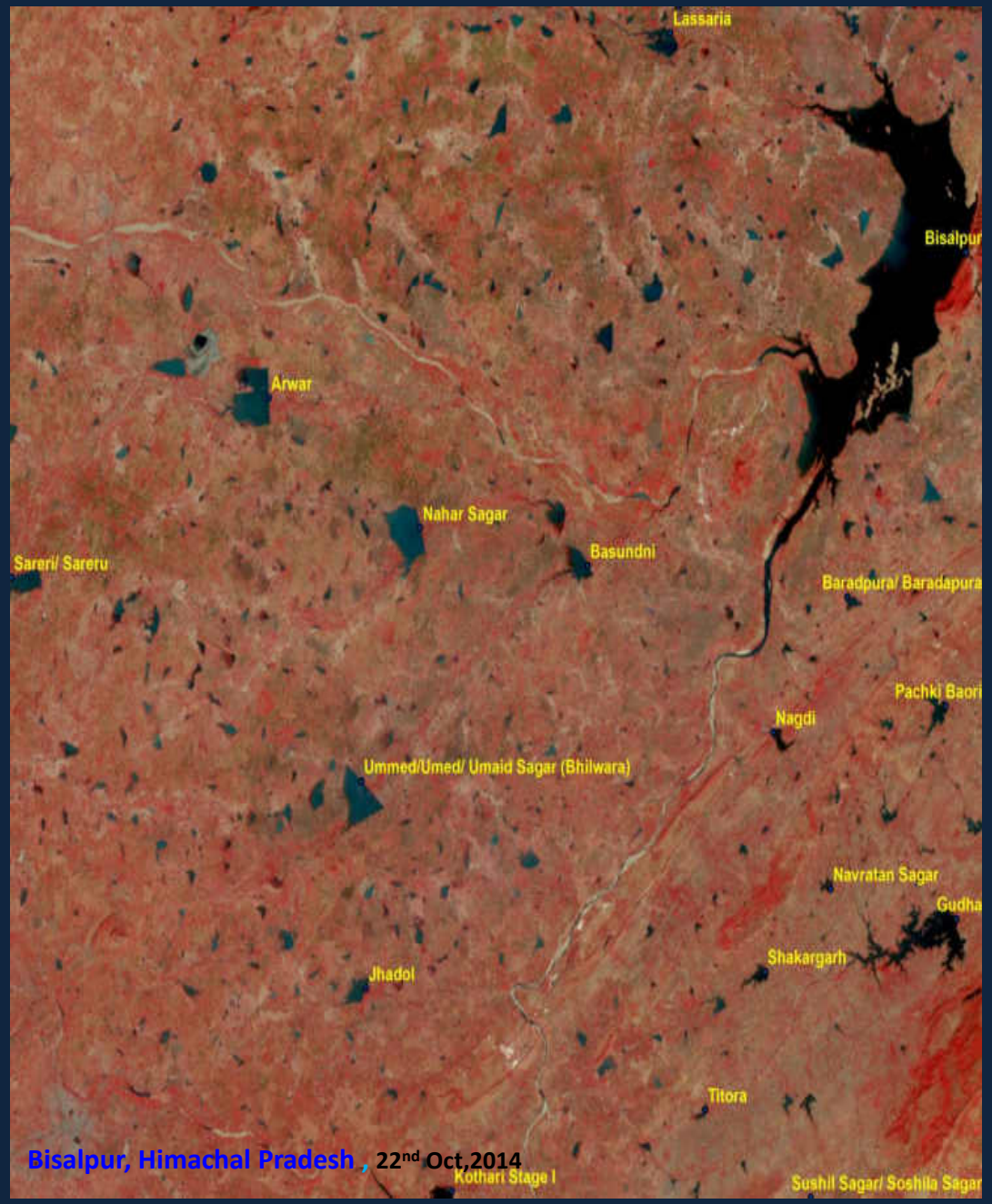

Bisalpur, Himachal Pradesh , 22nd Oct,2014

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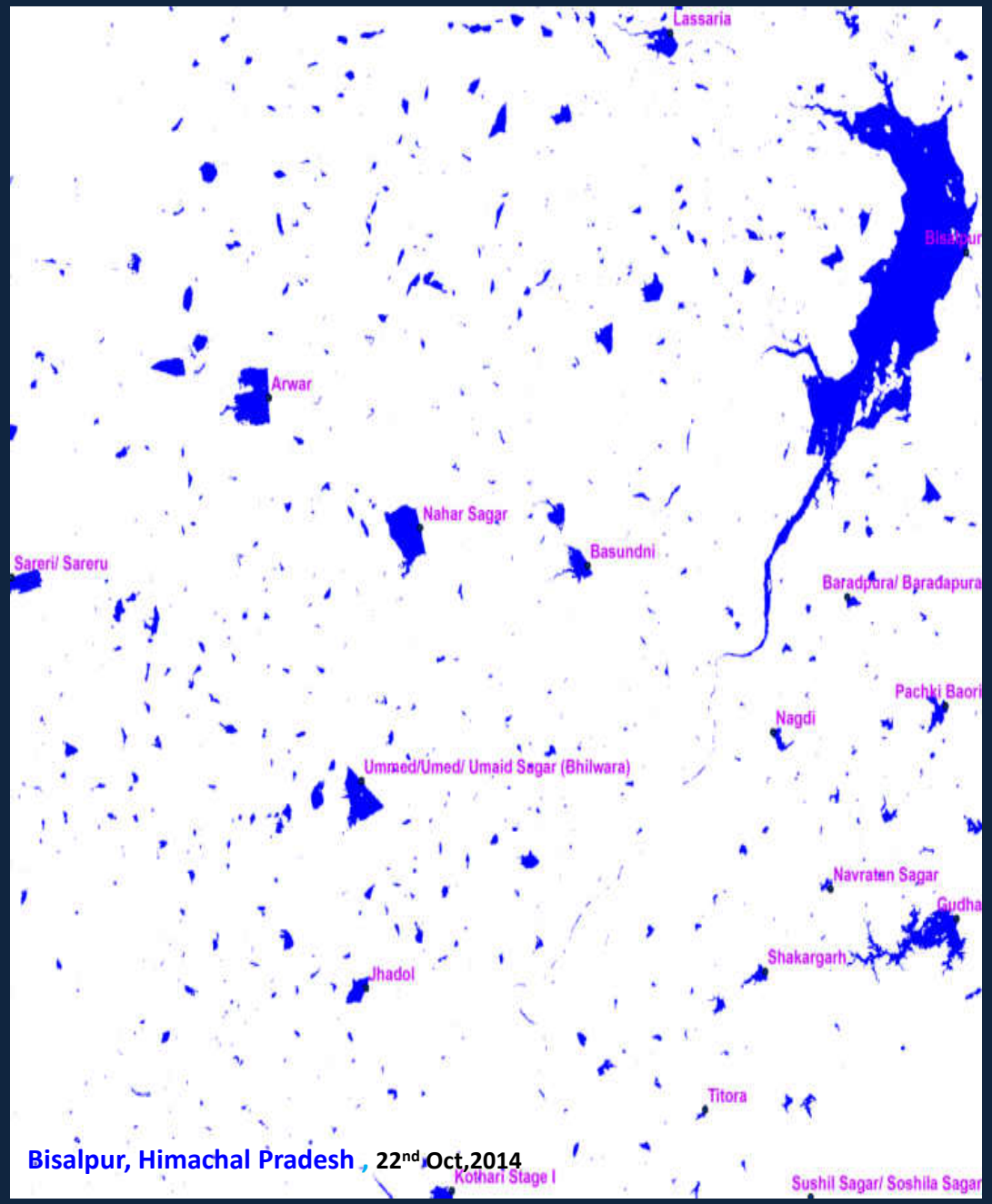

Bisalpur, Himachal Pradesh , 22nd Oct,2014

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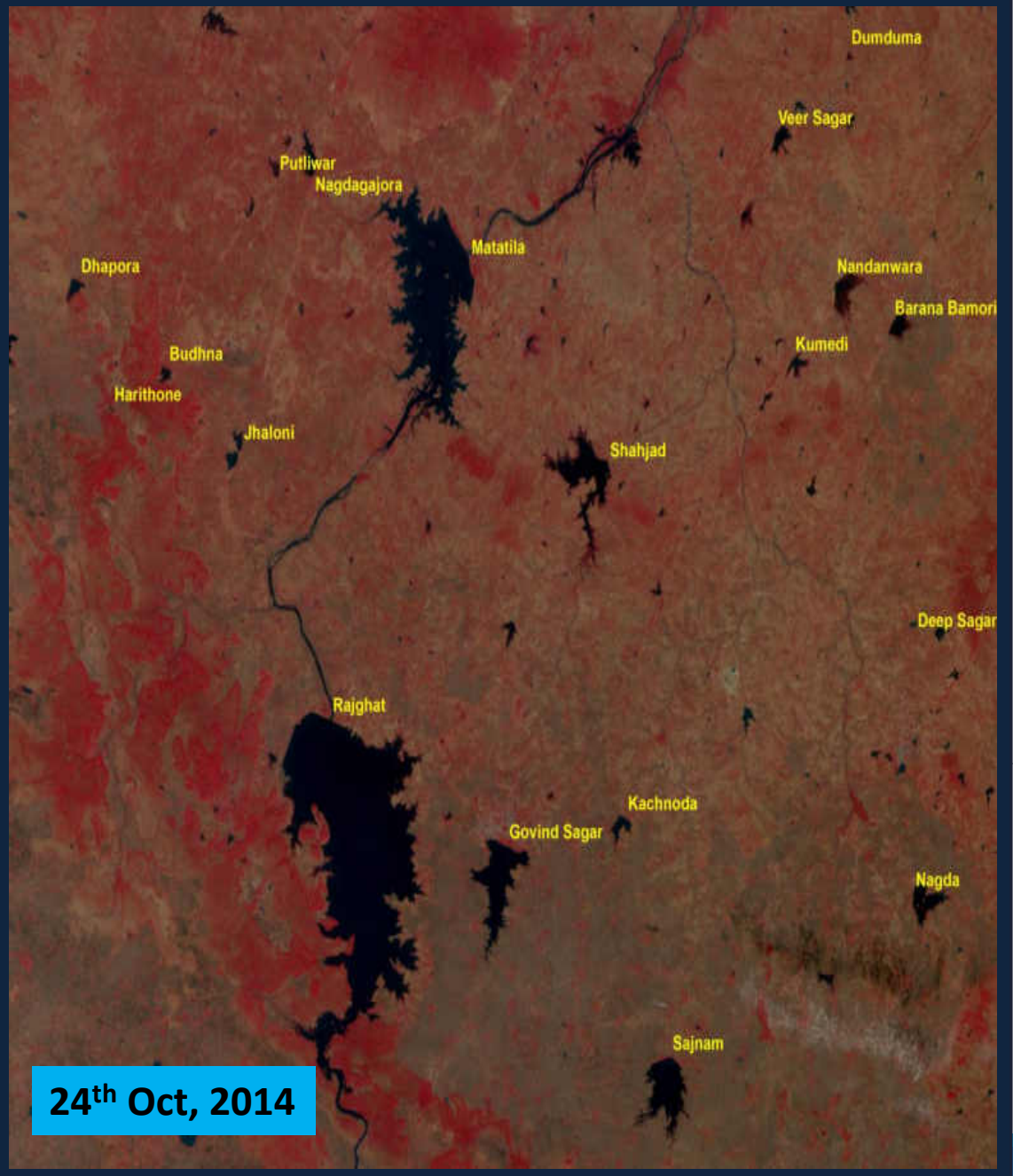

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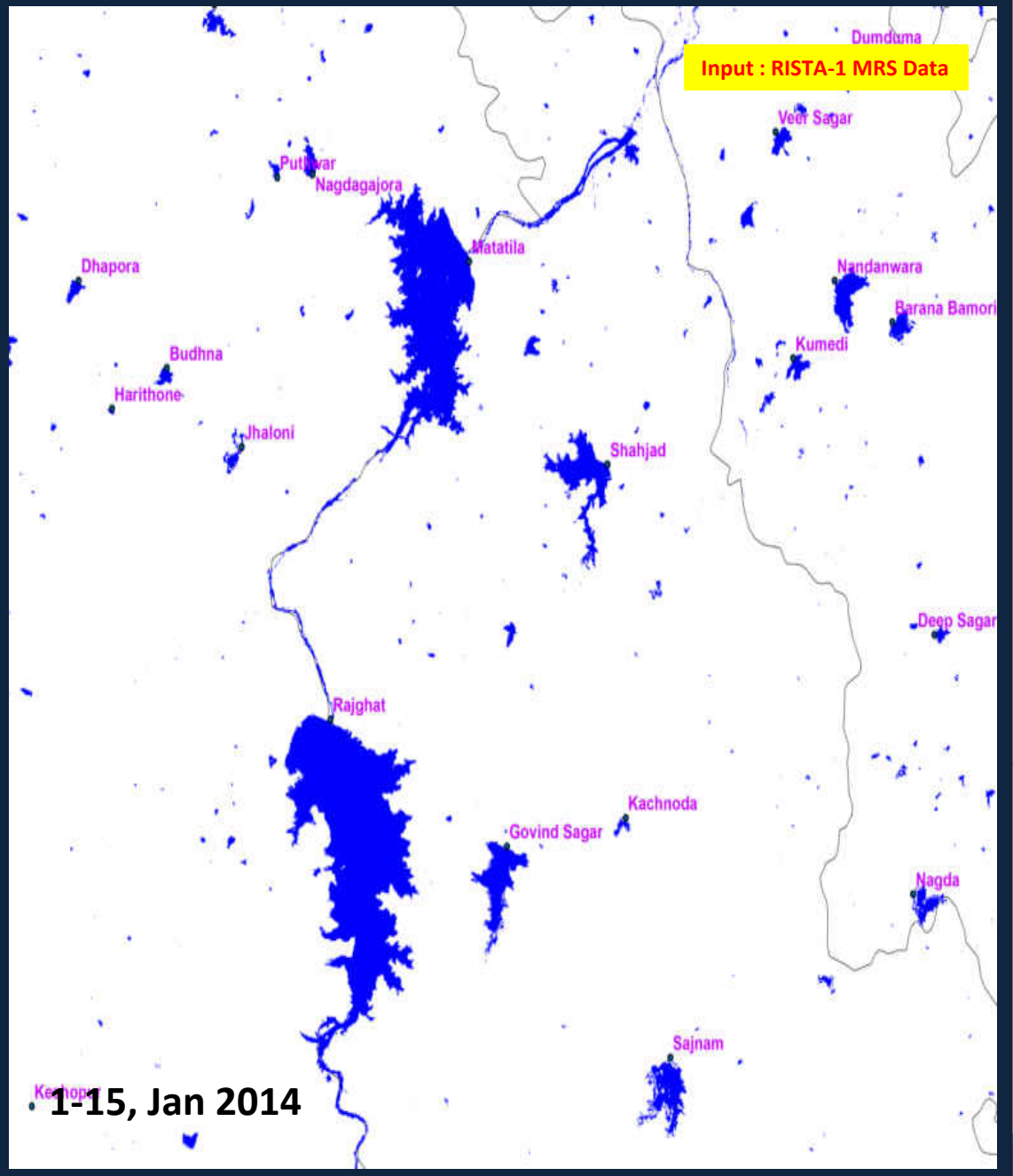

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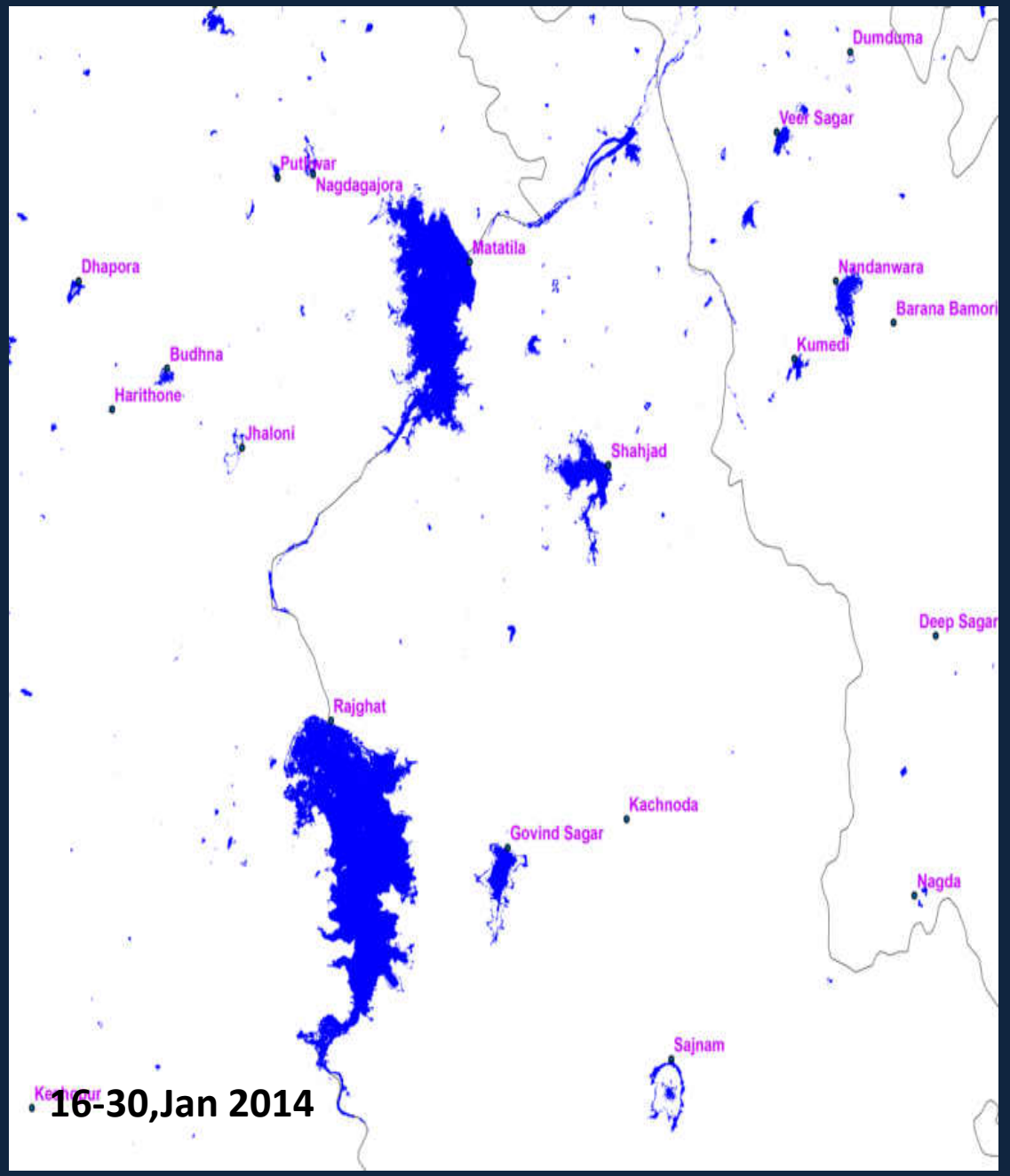

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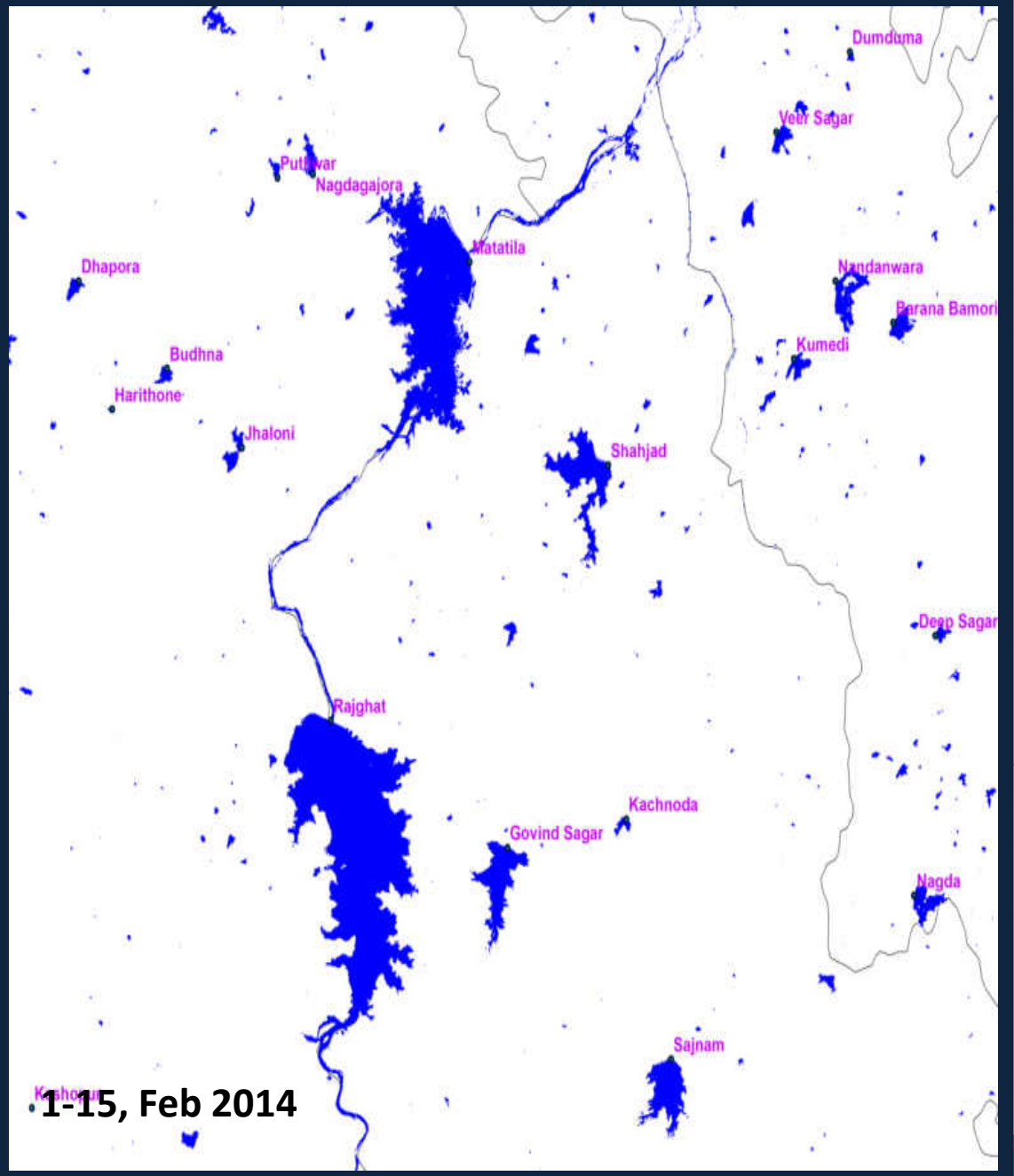

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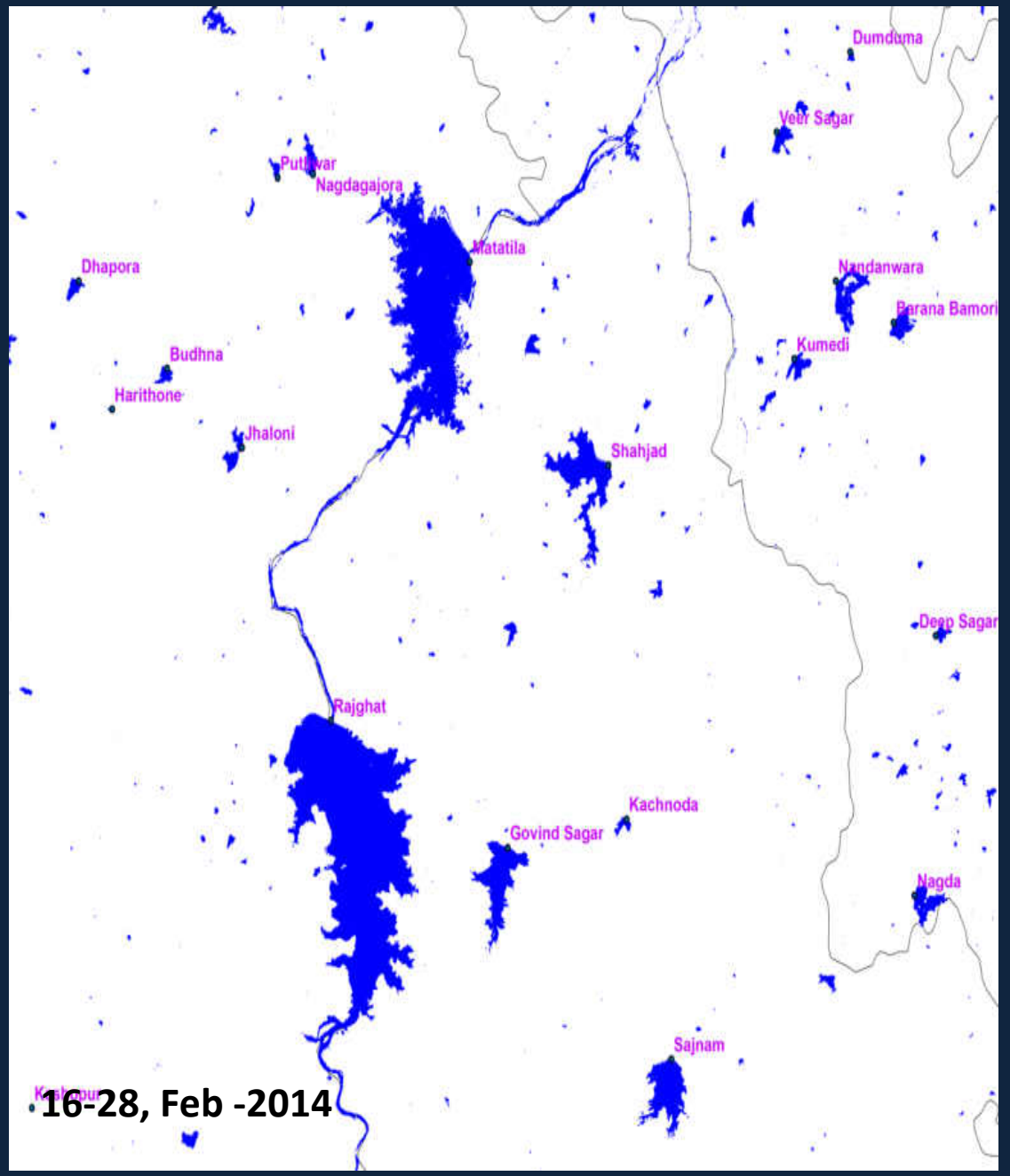

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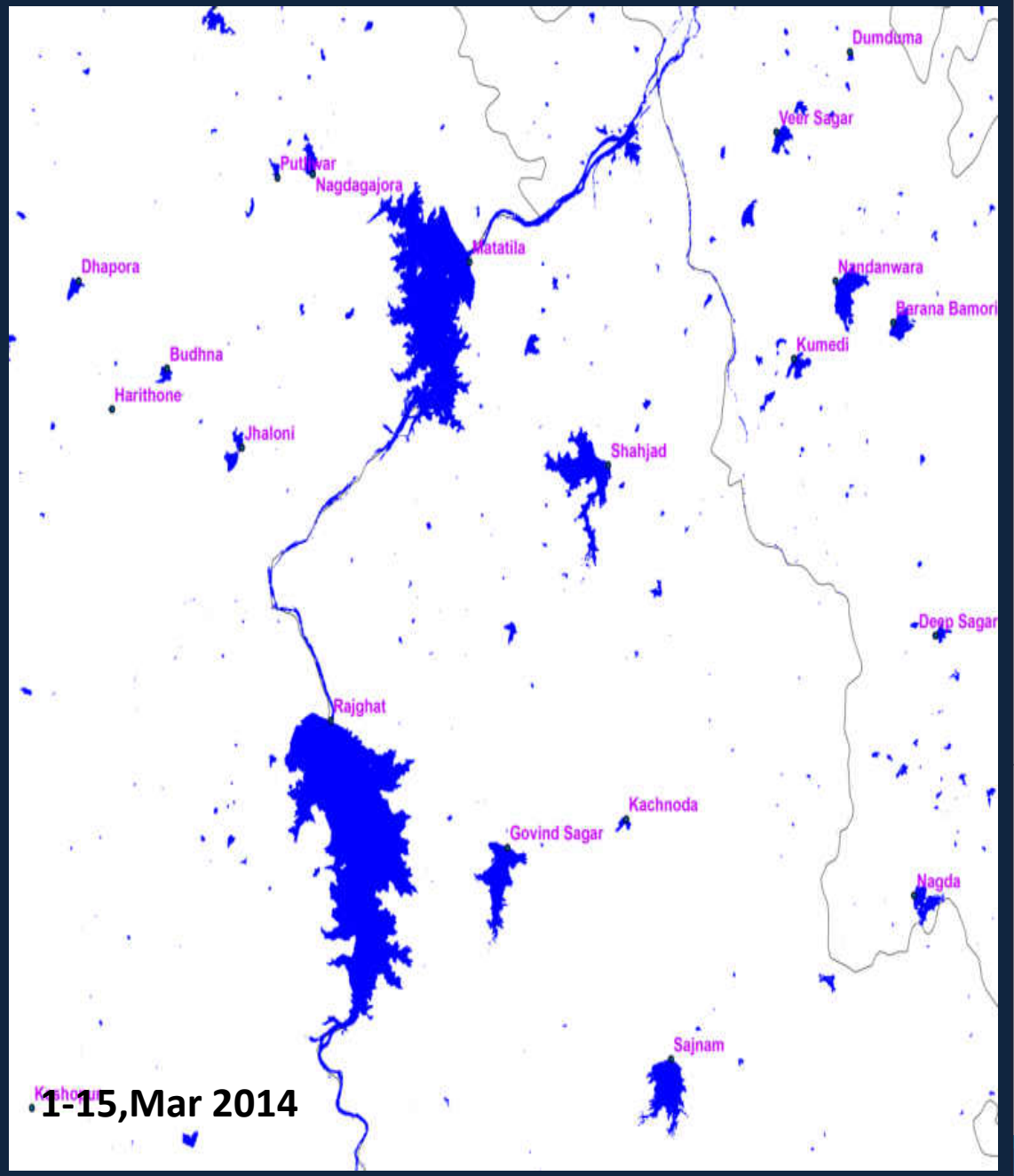

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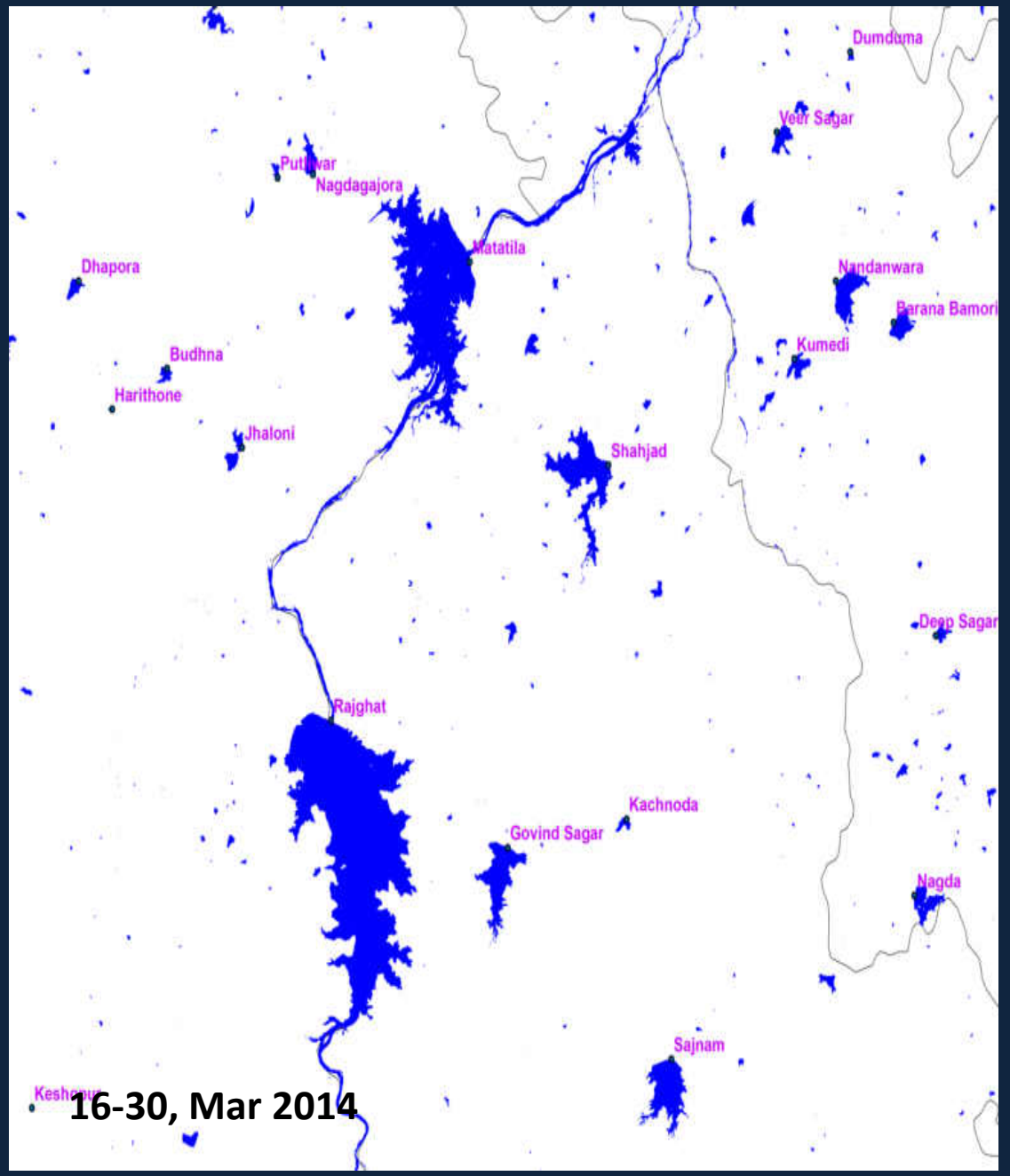

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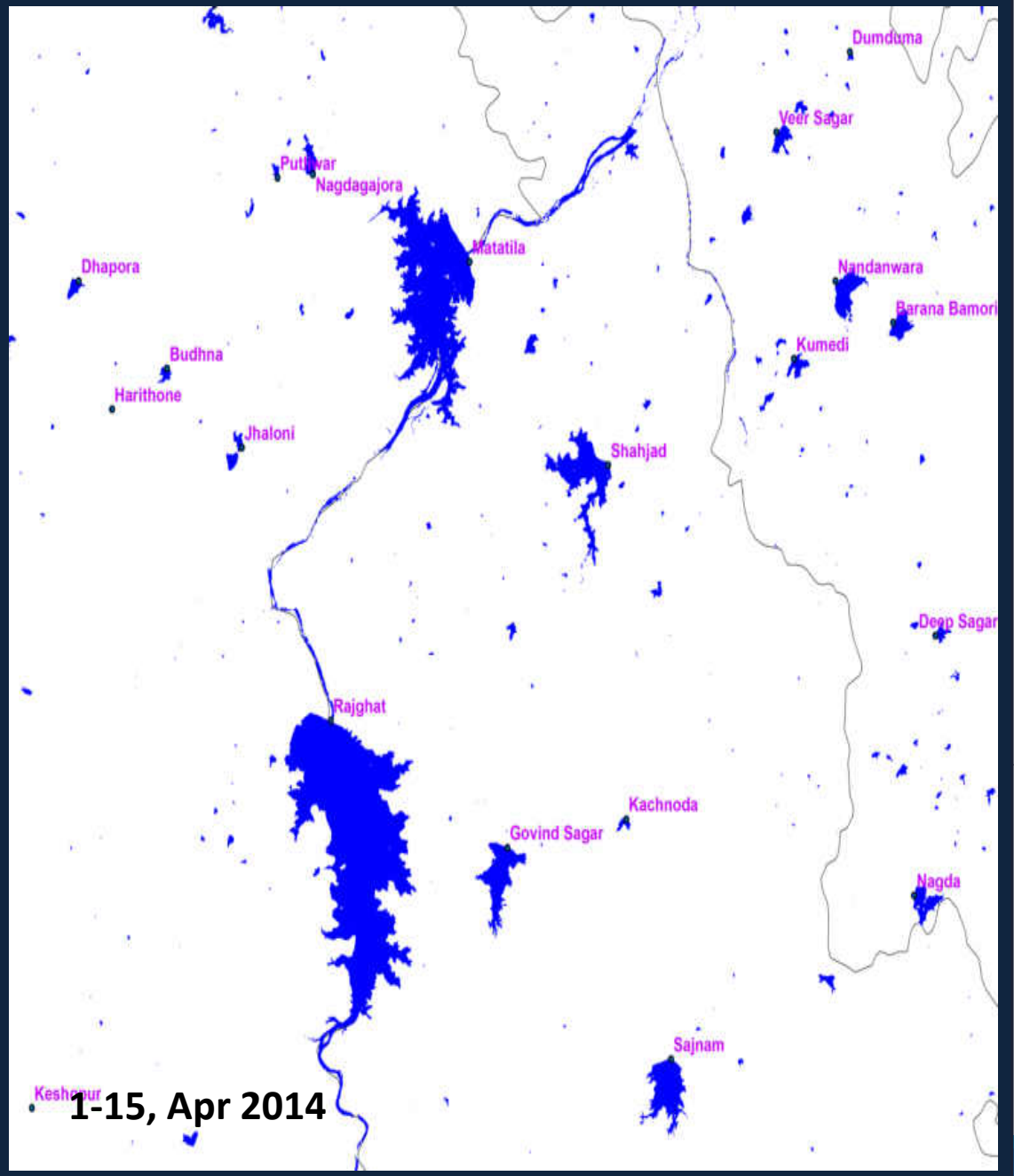

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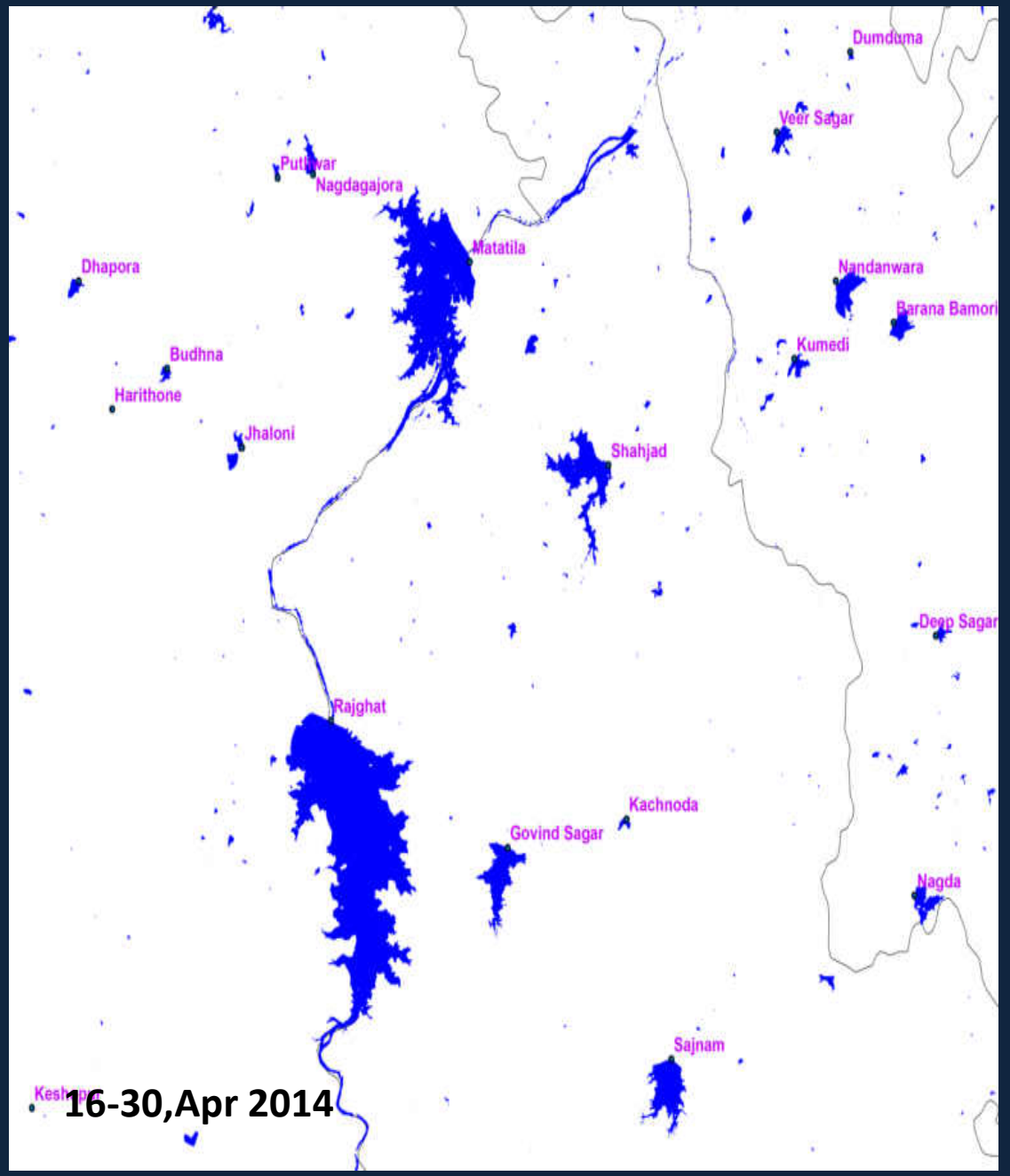

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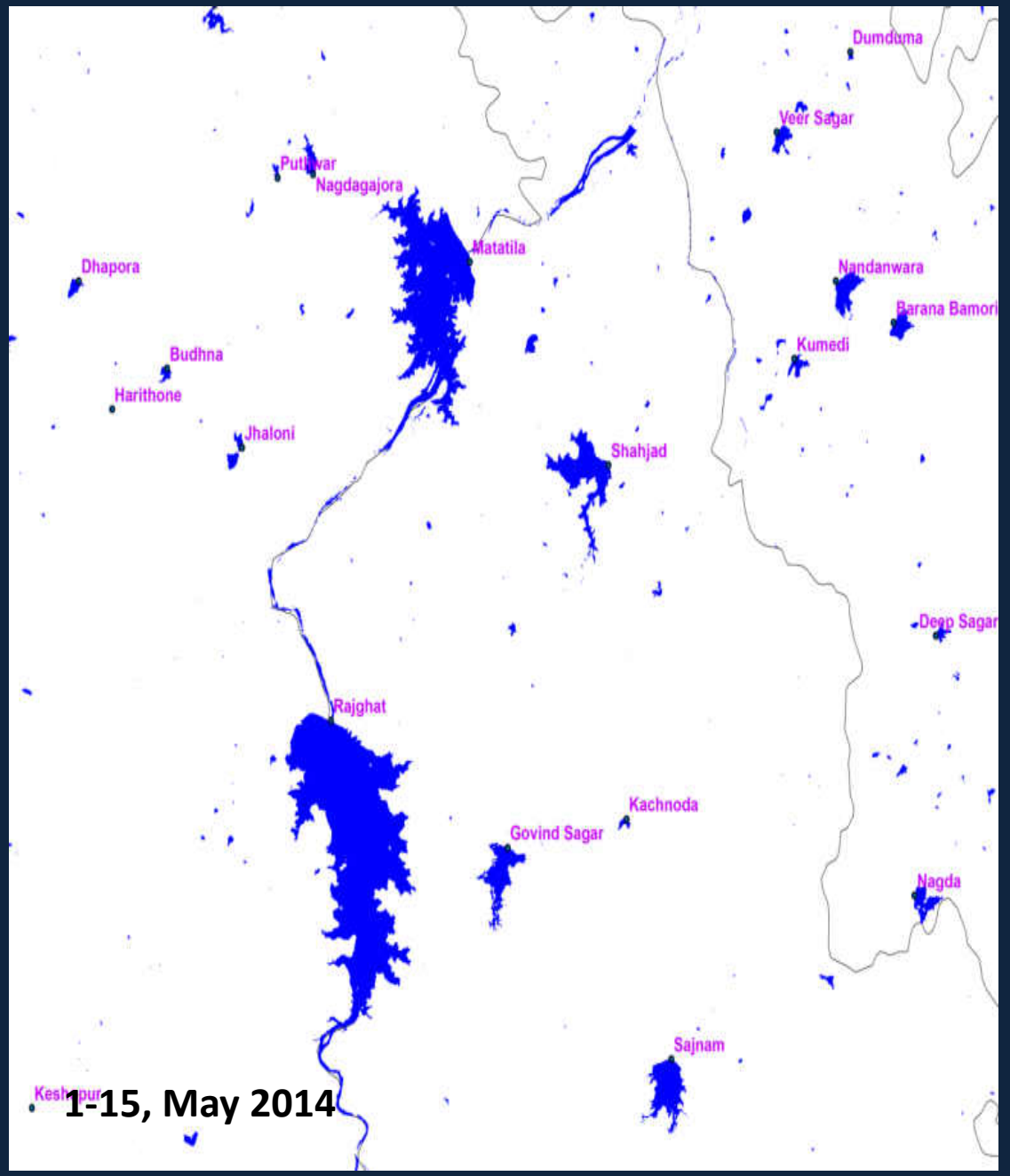

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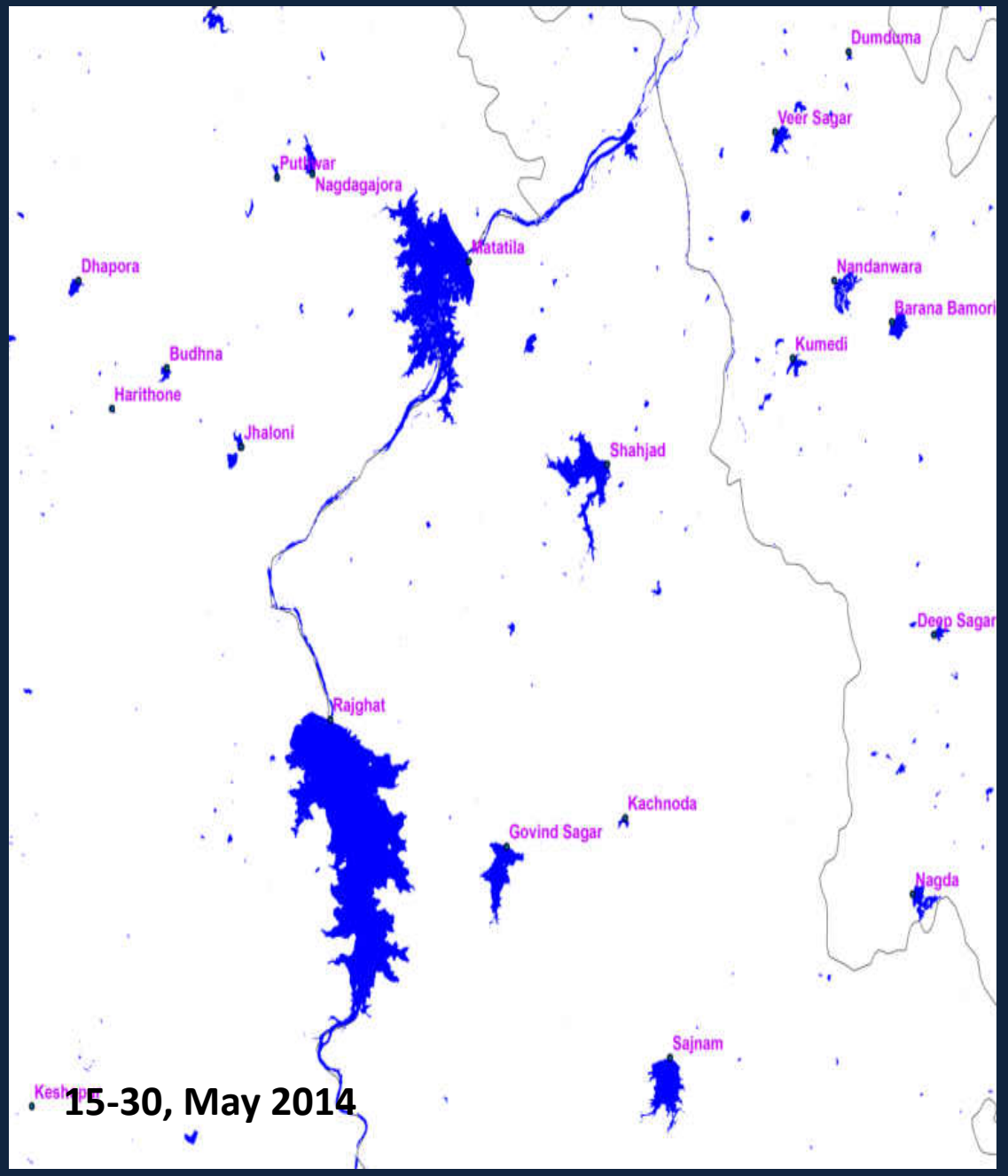

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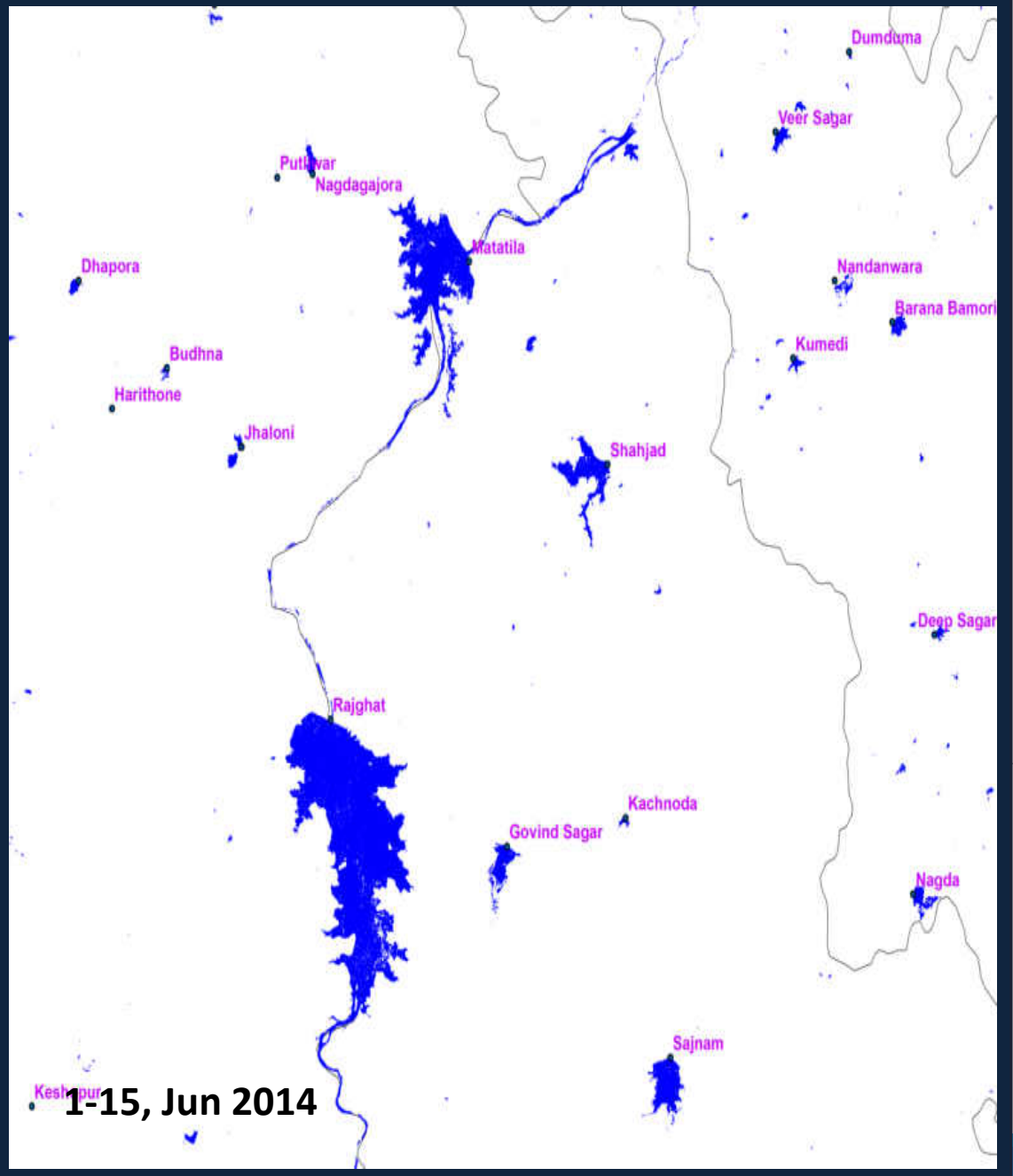

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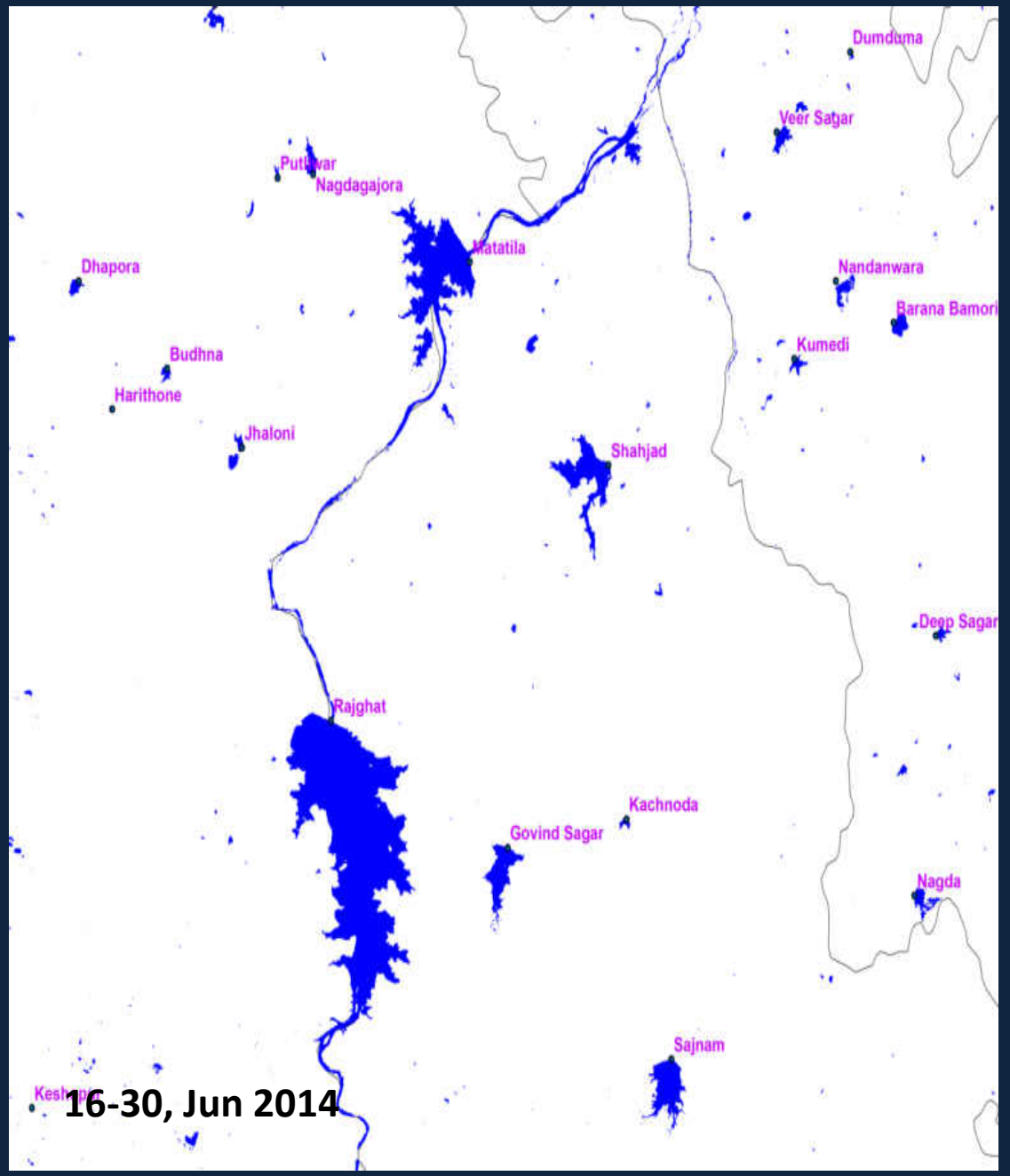

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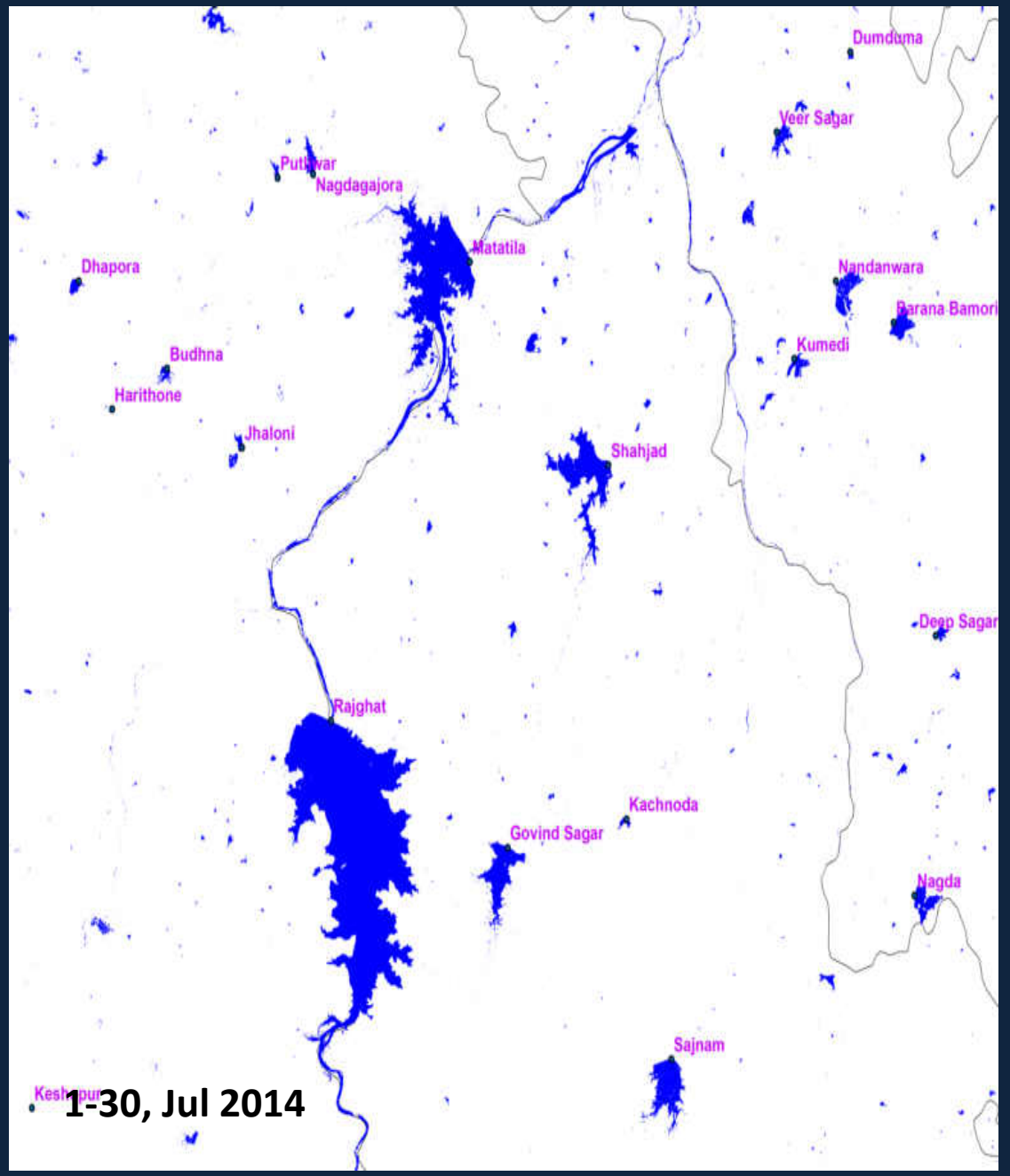

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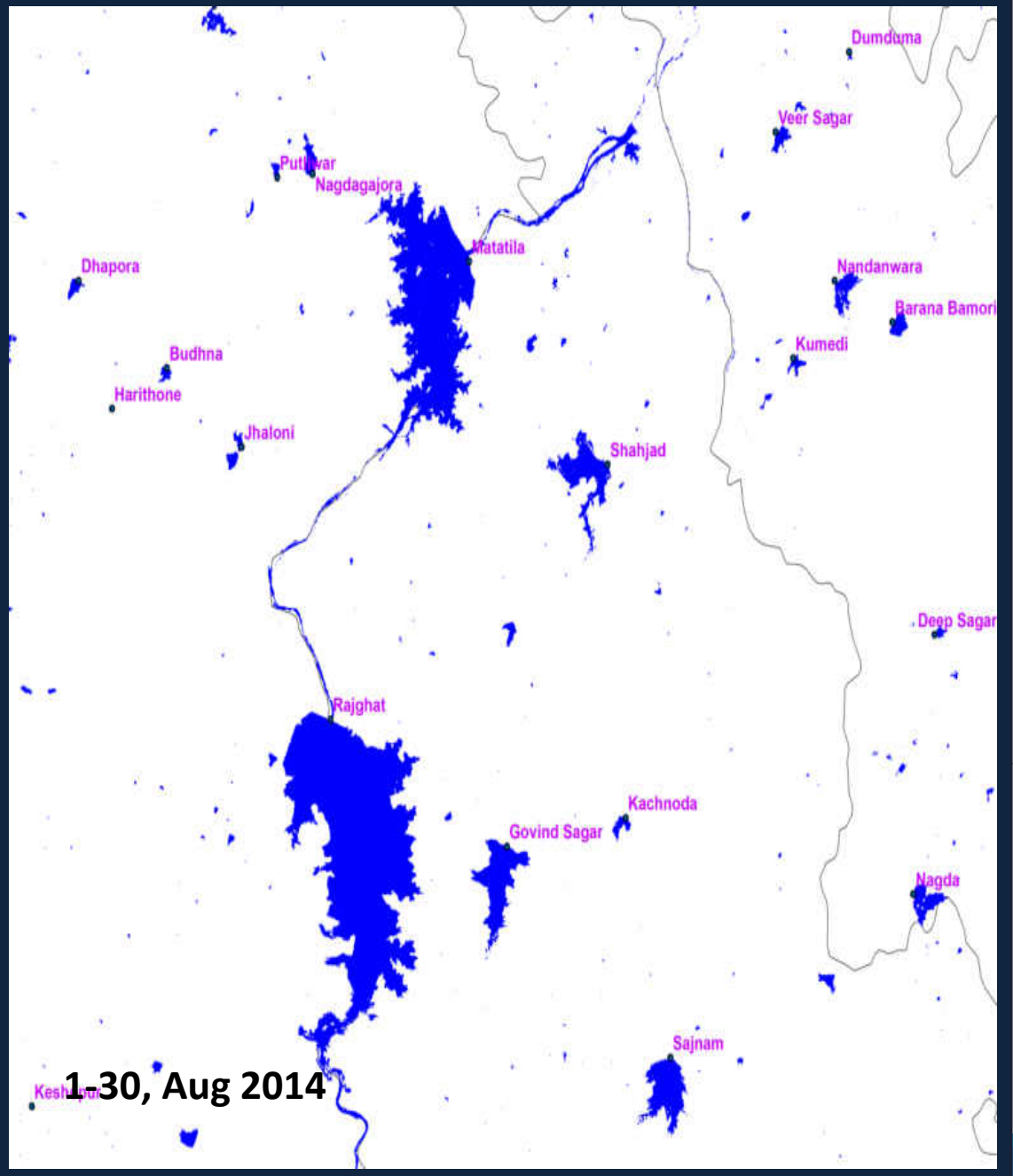

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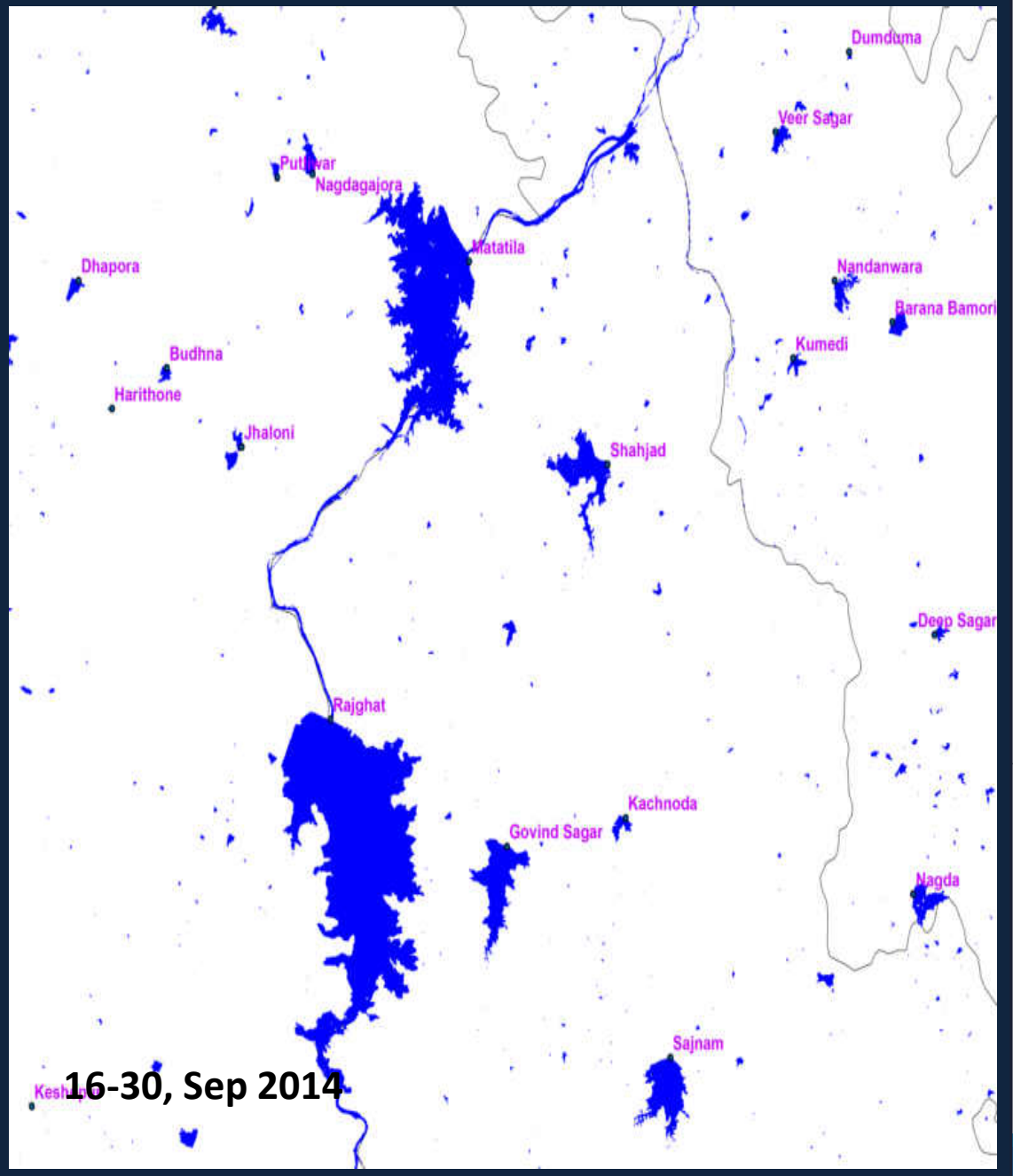

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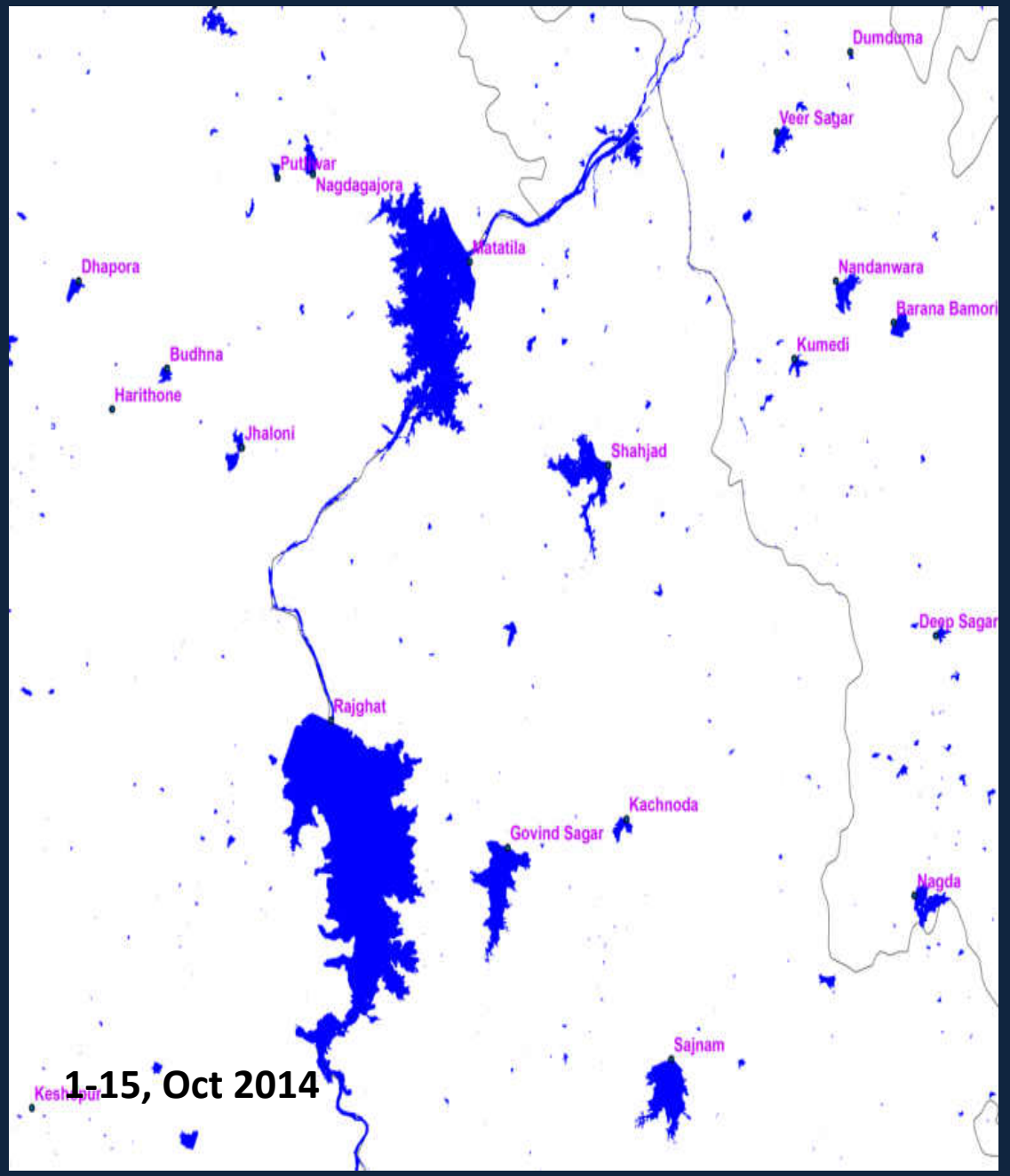

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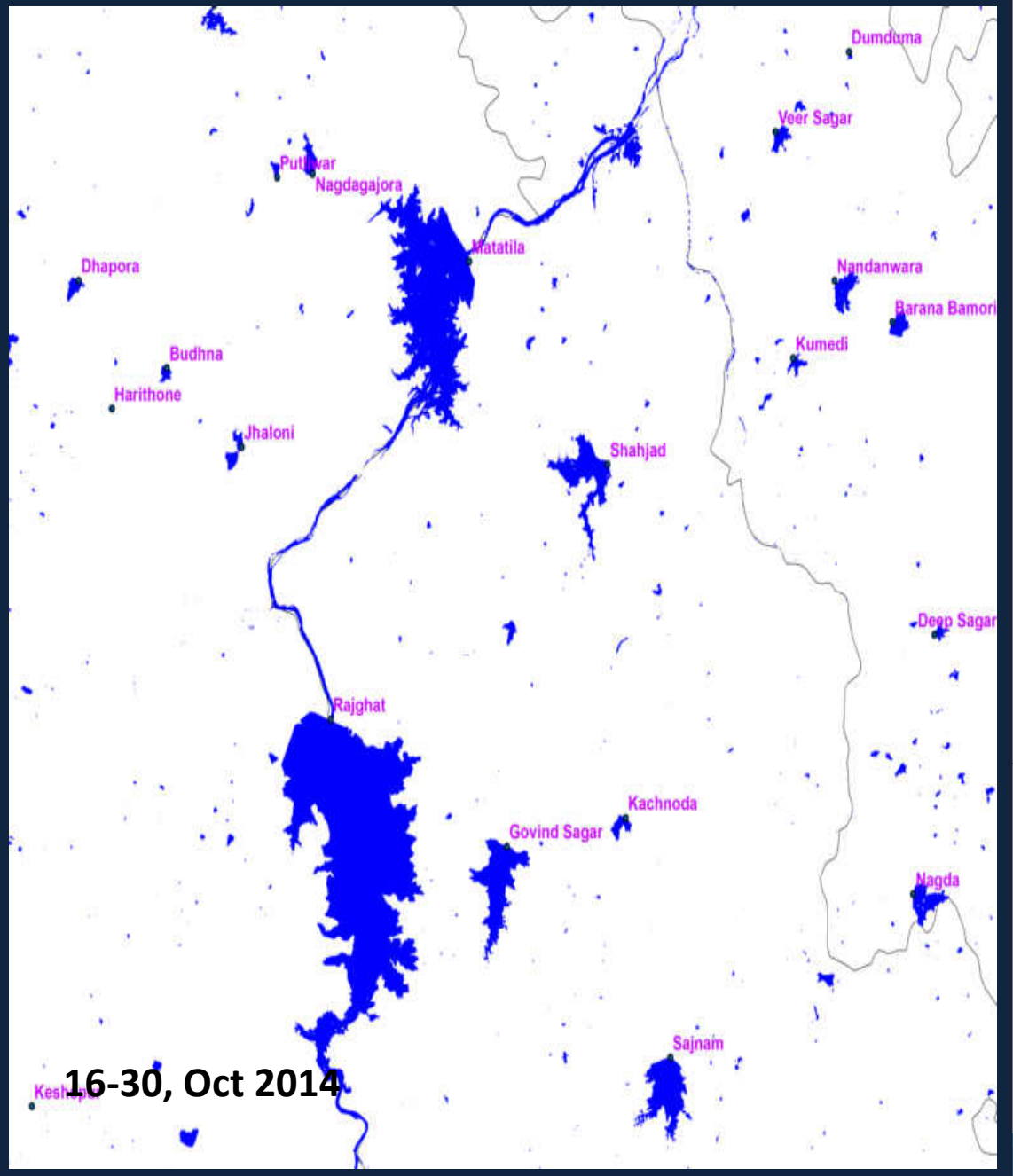

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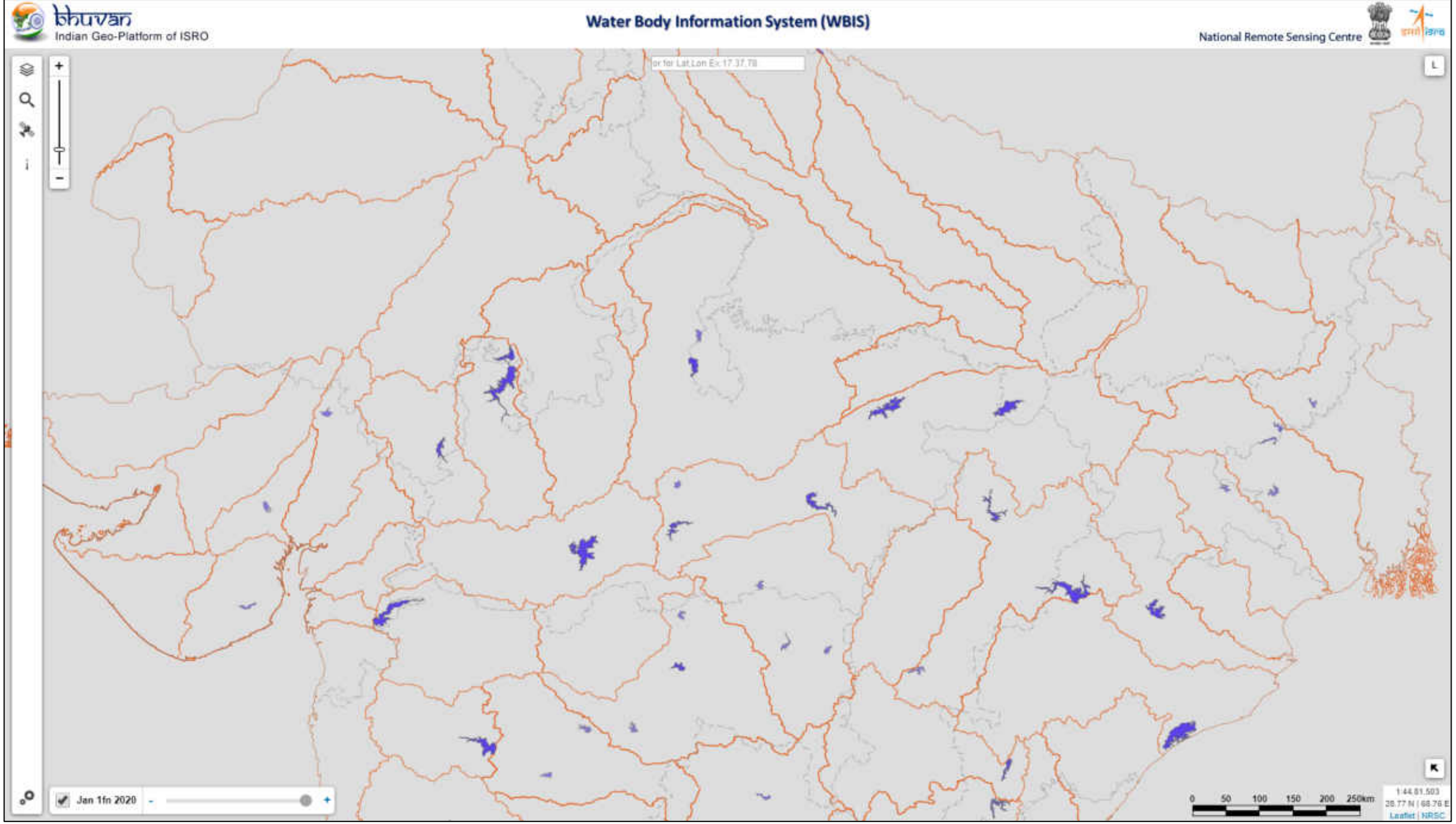
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Indian Geo-Platform of ISRO
Water Body Information System (WBIS)
National Remote Sensing Centre
Jan 1fn 2020
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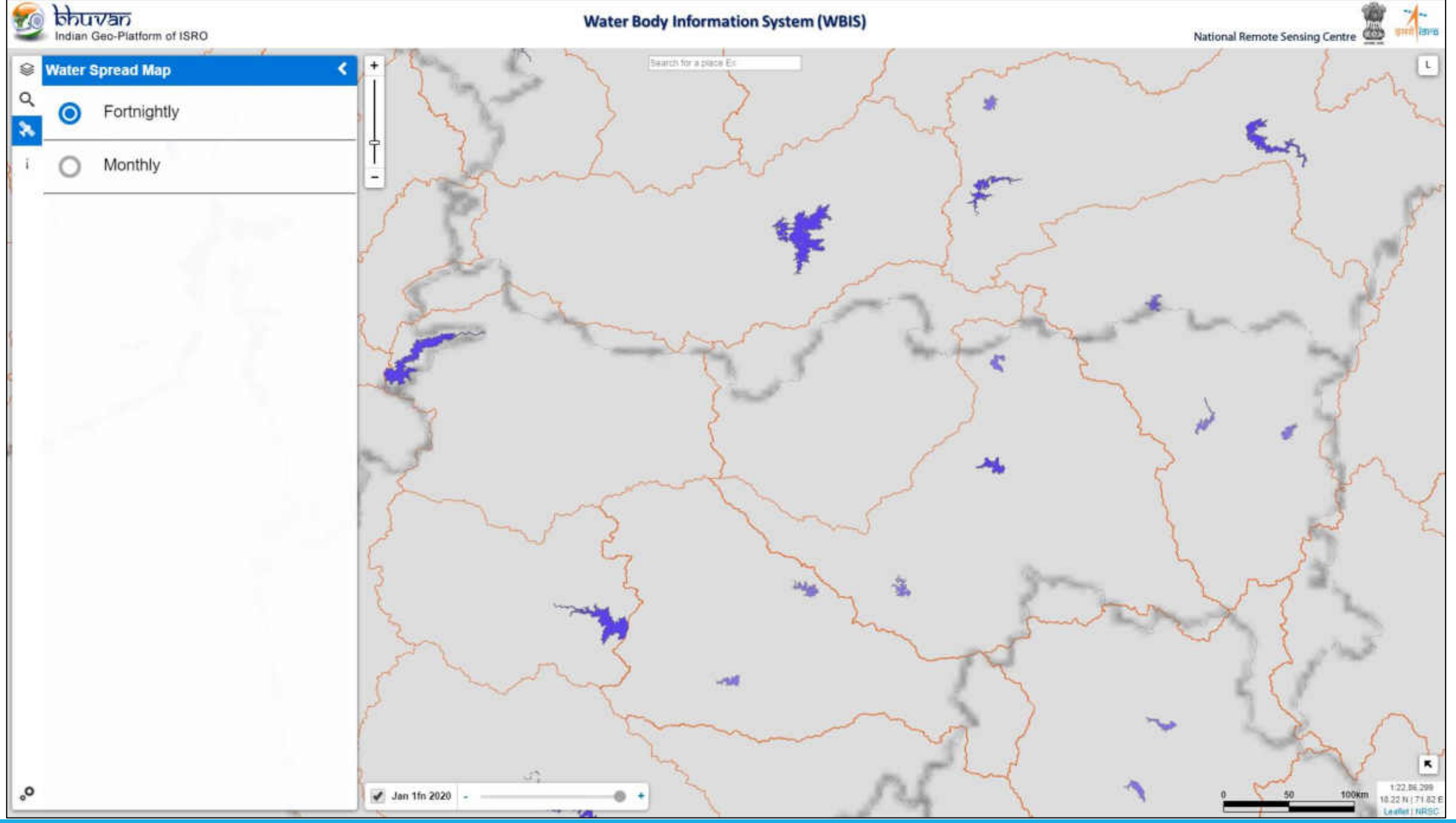
Leaflet | NRSC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Water Spread Map
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Monthly
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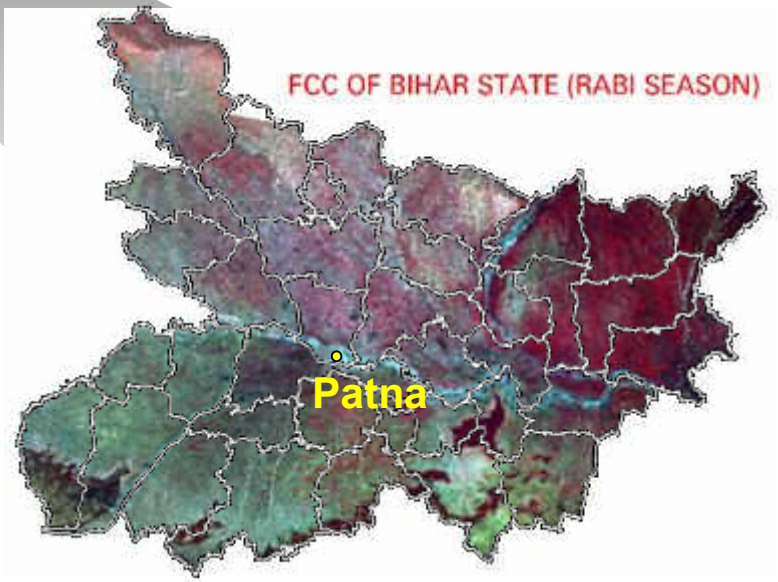
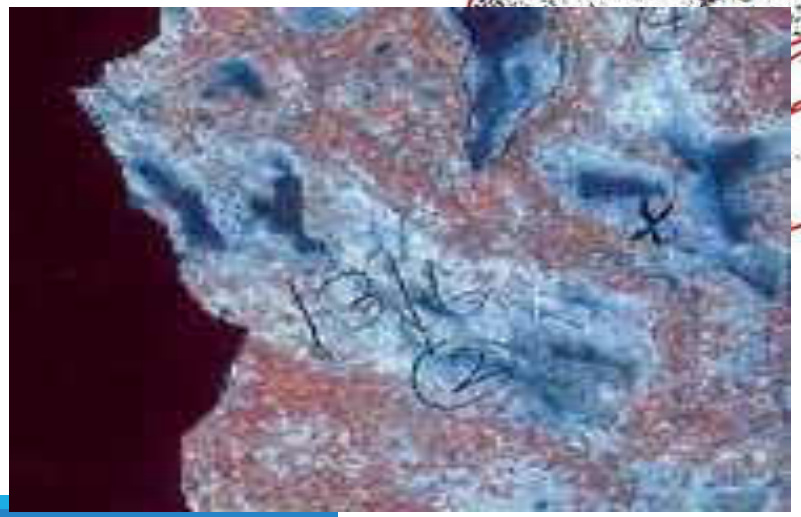
Assessment of waterlogging and salt effected areas for all the irrigation command areas of Bihar state

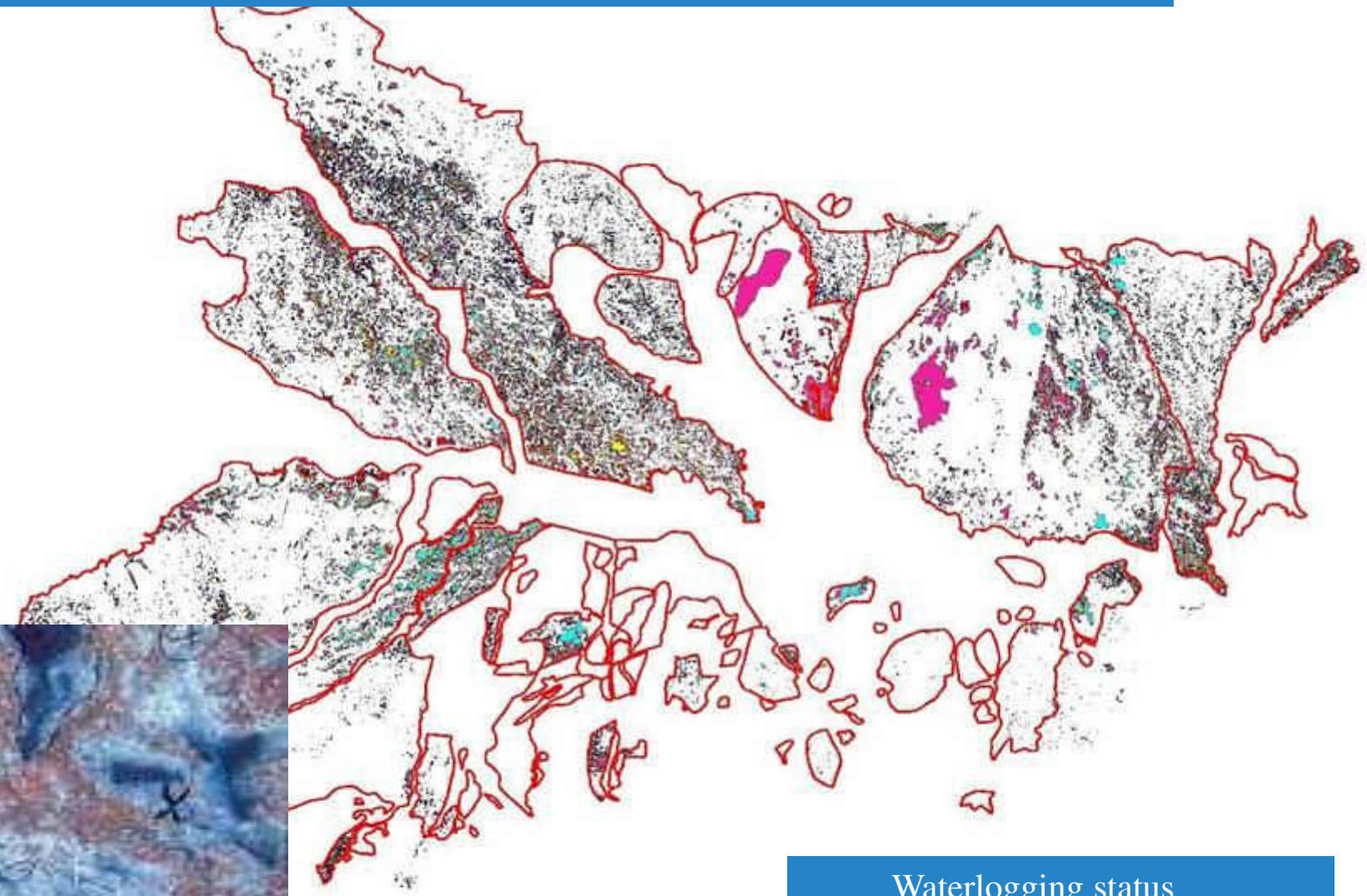
Sponsored	: Central Water Commission
Role	: Principal Investigator



IRS LISS III image of December 2003

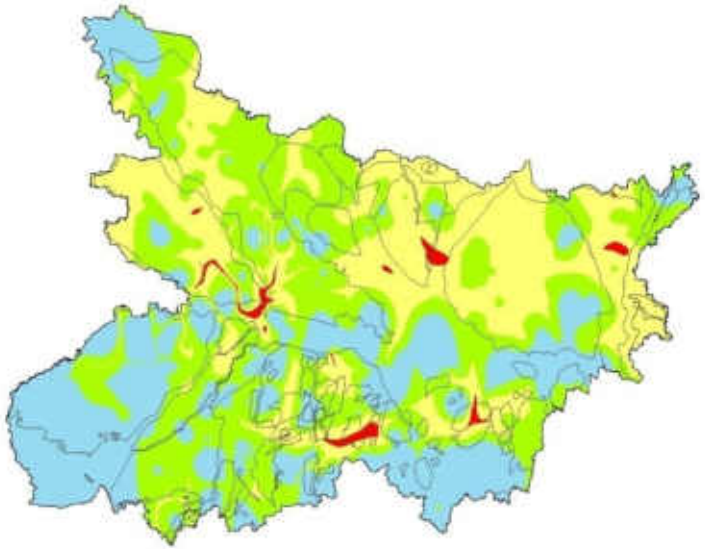
Spatial distribution of surface waterlogging areas in the Bihar state





Spatial distribution of sub-surface waterlogged areas for pre and post monsoon seasons (In terms of depth of ground water)

POST- MONSOON, November 2002



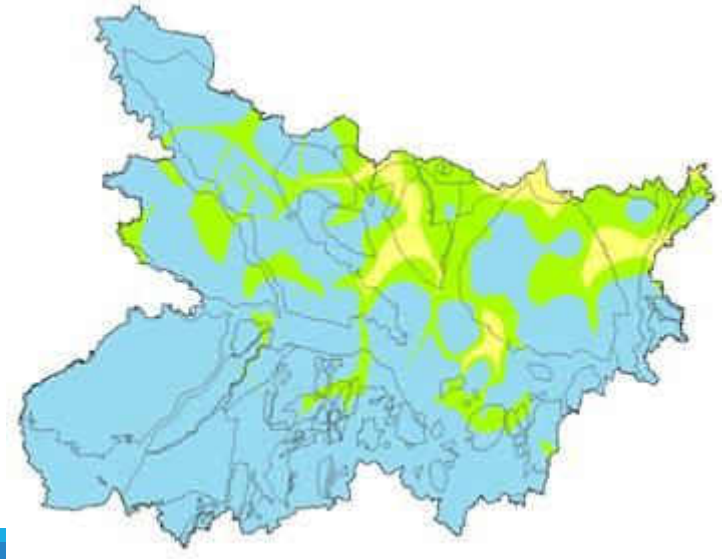
Most Critical

Critical

Less Critical

Non Critical

PRE- MONSOON, May 2003



Thank You