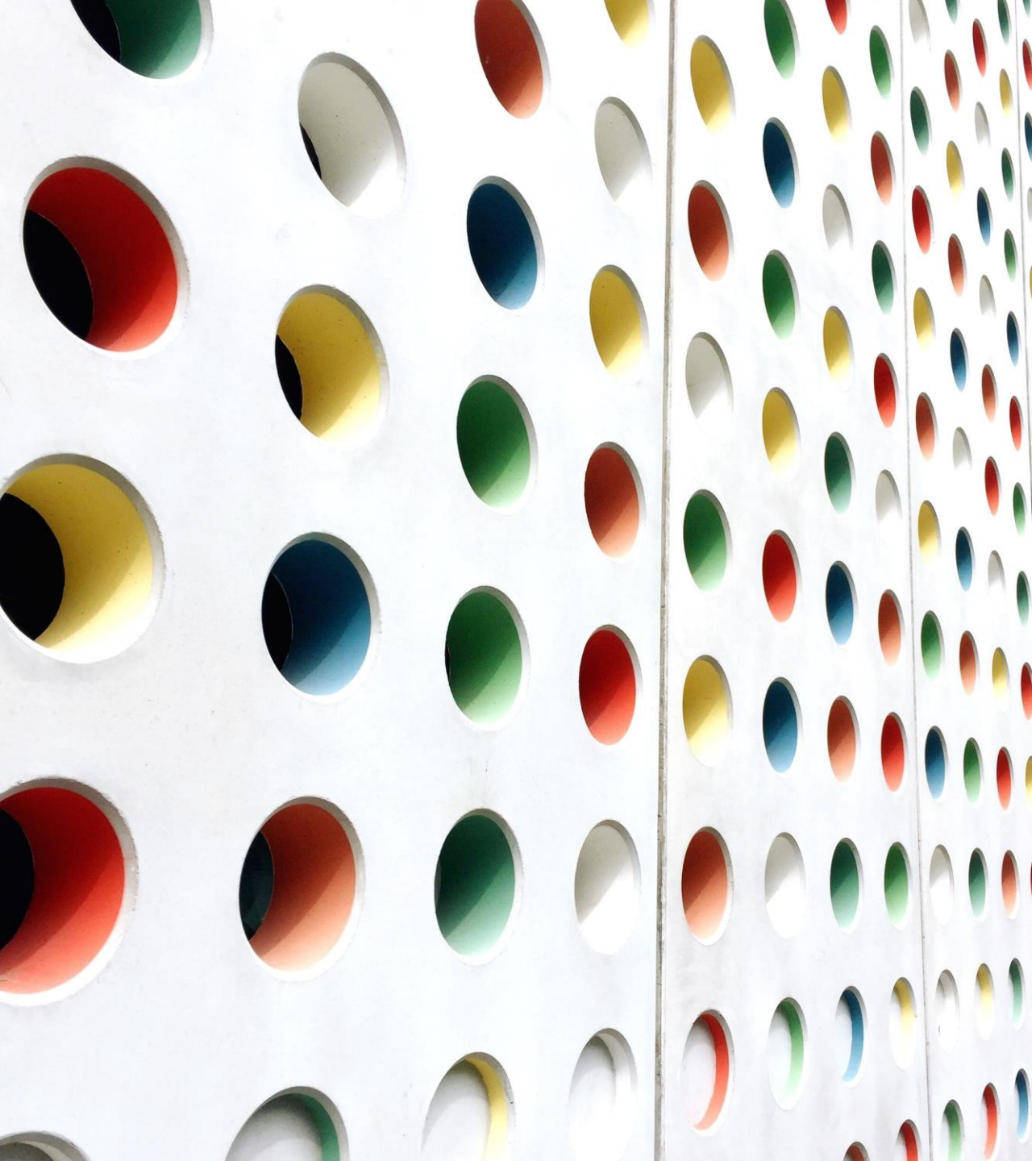


APPLICATIONS

DR. APARNA S. BHASKAR

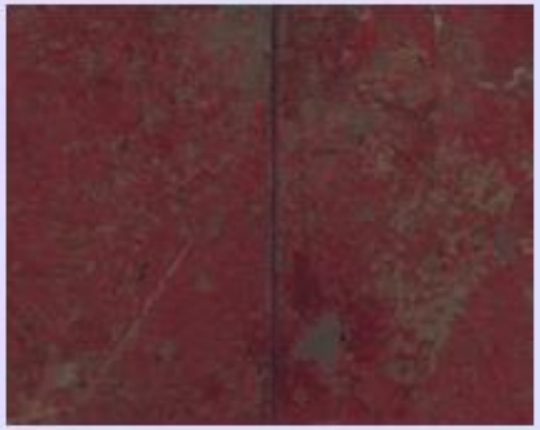
Application in water resource

(Source: IIRS)

Remote Sensing provides..

- Precipitation
  - Cloud Cover, CTT, CMV, OLR etc.
- Evapotranspiration
  - LST, Albedo, LAI, NDVI
- Water Body
  - Reservoir, Lake, ponds, flood mapping and monitoring
- Soil Moisture
  - Surface Soil Moisture
- Topography
  - DEM, Slope, Aspect, Flow Direction, Flow Accumulation
- Water Demand
  - Crop Acreage, CWR, IWR

RS Applications in Irrigation Command Area Mapping

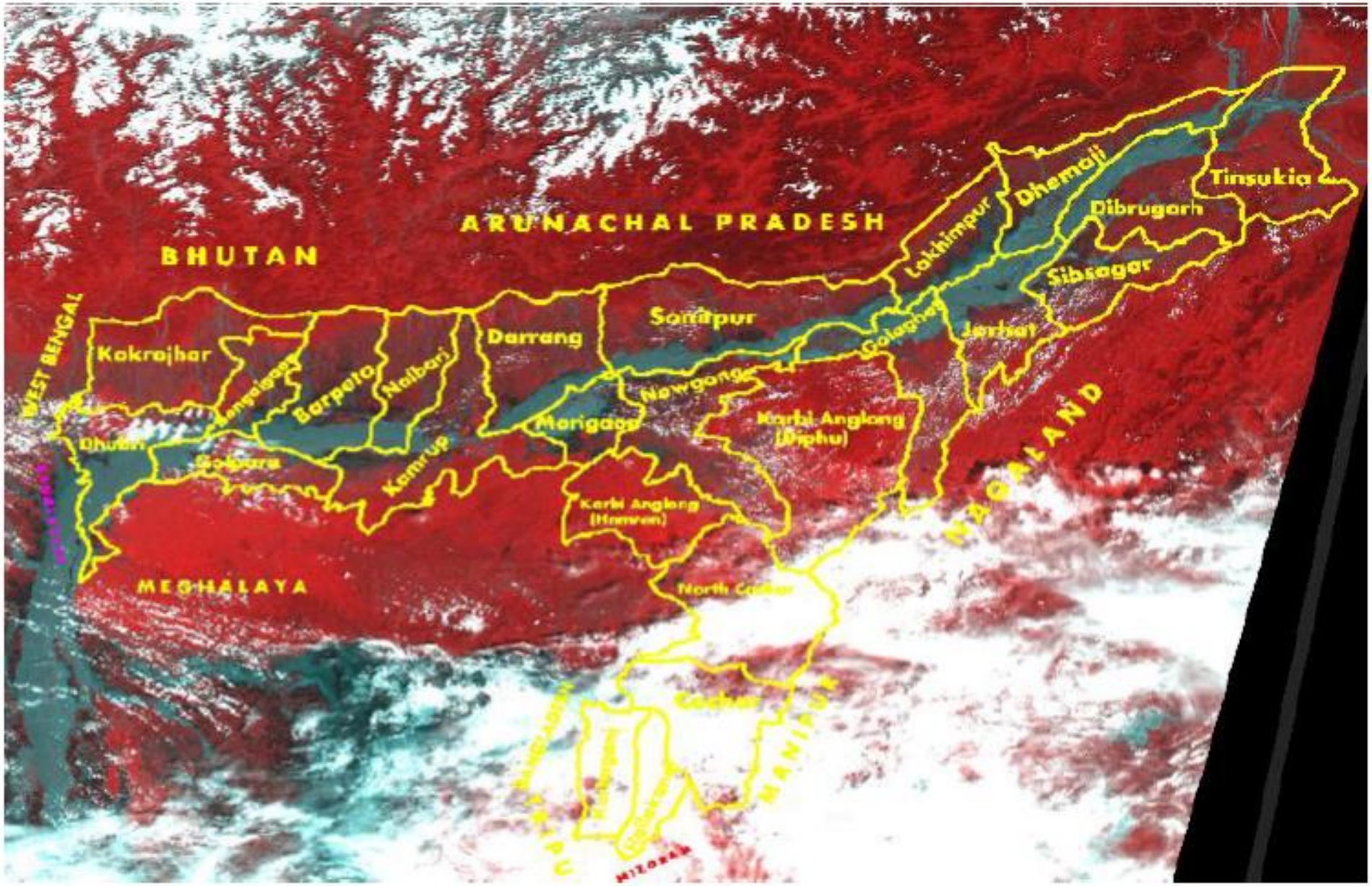
Sensor /Spatial Resolution		Suitability for Mapping
AWiFS **(56 m × 56 m)** Satellites : Resourcesat 1,2 Swath: 740 km		❖This sensor gives high coverage and high temporal resolution so, may be best suitable for monitoring crop area and crop condition
LISS-III **(23.5 m × 23.5 m)** Satellites : Resourcesat 1,2 swath: 150 km		❖This sensor is best suitable for crop monitoring up to taluk or village level

Sensor /Spatial Resolution		Suitability for Mapping
LISS-IV (5.8m × 5.8 m) Satellites : Resourcesat 1,2 Swath: 23.9 km		❖ Main, Branch. Distributary, **Minor canal having width around 5 m or more** ❖Field level mapping
CARTOSAT-1 (2.5m × 2.5 m) Swath: ≈ 30 km		• Main, Branch. Distributary, Minor, **Sub-minor canal having width around 2 m or more** • **Infrastructure mapping**
CARTOSAT-2 and 3 1m, 65 cm, 25 cm		• Main, Branch. Distributary, Minor, Sub-minor, **field channels canal having width even less than 1 m** • **Infrastructure mapping**

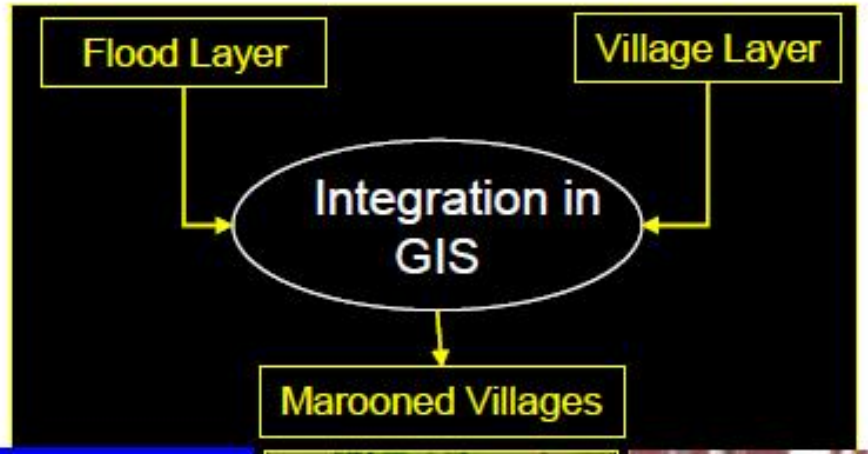
Flood Inundation Mapping and Damage Assessment

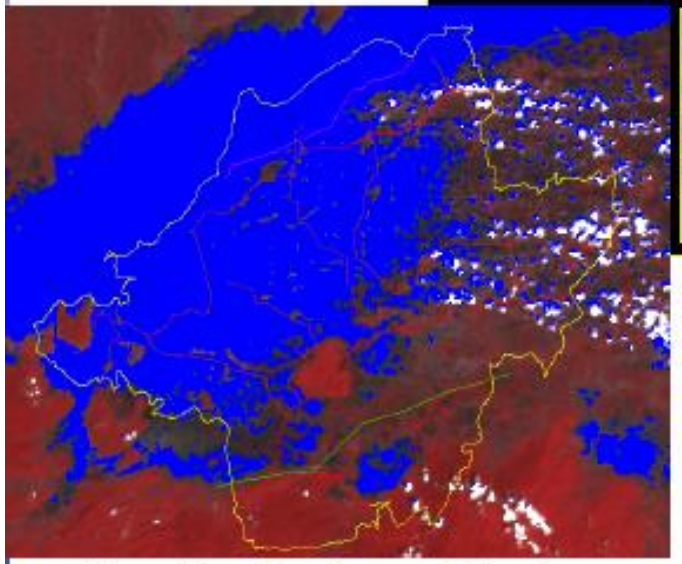
(Source: IIRS)

Integration of Satellite Image and GIS layer



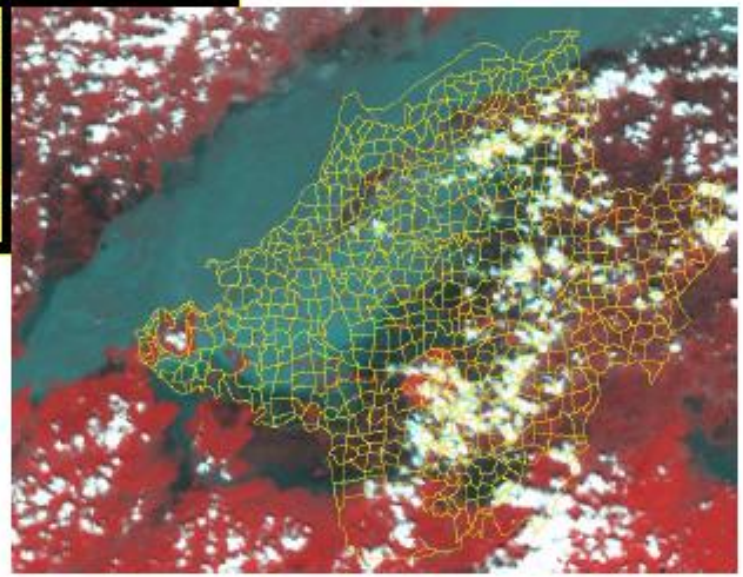
District wise inundation mapping





Flood in Marigaon District

Inundated area 34,240 ha



Marooned villages in Marigaon district

Villages affected 465

Geospatial Technology for Urban & Regional Planning

(Source: IIRS)

DEFINING URBAN & REGIONAL AREAS

Urban: characterized by higher population density and infrastructure in comparison to areas surrounding it. It may be cities, towns or conurbations excluding rural settlements.

a) All statutory places with a municipality, corporation, cantonment board or notified town area committee, etc.
b) A place satisfying the following three criteria:
   i. a minimum population of 5,000,
   ii. at least 75% of male working population engaged in non-agricultural pursuits, and
   iii. a density of population of at least 400 persons per sq. km. City/town with population of 100,000 and above.

Census of India (2001)

REGION: Any portion of earth's surface where physical conditions are homogeneous. It ranges from a single feature region to compage, depending on criteria used for delineation.

(Woolfgang & Joerg)

URBAN AREAS: TYPES

- **Statutory Towns (ST)**: All places with a municipality, corporation, cantonment board, notified town area committee, etc.
- **Census Towns (CT)**: All villages with a minimum population of 5,000 persons in preceding Census, at least 75% of male main working population engaged in non-agricultural activities and a population density of at least 400 persons per sq. km.
- **Urban Agglomerations (UA)**: A continuous urban spread comprising one or more towns and their adjoining out growth(s).
- **Out Growths (OG)**: Areas around a core city or town e.g., Railway colony, Univ. campus, Port area, etc. lying outside town limit.

Source: India - Census of India 2011 & Primary Census Abstract

URBAN UNITS IN INDIA

Urban Unit	2001 Census	2011 Census
1. Towns:	5,161	7,935
(a) Statutory Towns	3,799	4,041
(b) Census Towns	1,362	3,894
2. Urban Agglomerations	384	475
3. Out Growths (OGs)	953	981

Source: Census of India

2011

- 31% population
- 63% of GDP

2030

- 40% population
- 75% of GDP

- 80% of Urban India of 2030 yet to be built
- A new city of Chicago dimensions to be built every year

IMPORTANCE OF URBAN PLANNING

Urban areas

- Engines of growth, provide services & economies of scale
- Contribute significantly in country's economy and employment
- Pull factor

Issues with Urban Areas

- Lack of open space
- Inadequacy of infrastructure
- Overcrowding, congestion
- Mushrooming of slums (61.8 million in 2001)
- Lack of drinking water and sanitation
- Insufficient solid waste disposal
- Poor environmental quality

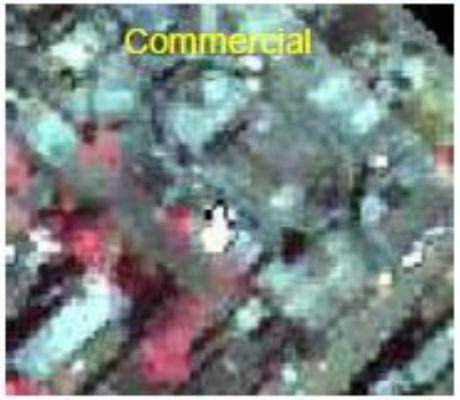
Needs timely and updated geospatial information for better management and planning of available resources…

INNOVATIVE TECH. FOR URBAN PLANNING

- **REMOTE SENSING**
  - Range of satellite data available: IRS series (Resourcesat, Cartosat, RISAT, etc.), Worldview, Sentinel, Quickbird, Geoeye…
- **PHOTOGRAMMETRY**
  - Areal
  - Digital (Cartosat-1, Pleiades, ALOS PALSAR, SPOT-5…)
  - Close range Photogrammetry
- **LiDAR**-Terrestrial Laser Scanner
- **GEOGRAPHIC INFORMATION SYSTEM (GIS)**
  - Facilitates data generation, integration and analysis
- **GLOBAL POSITIONING SYSTEM (GPS)**
  - Facilitates geo-referencing, asset mapping..
- **UNMANNED AERIAL VEHICLE (UAV)**- mapping of urban areas
- **GROUND PENETRATING RADAR (GPR)**- underground utilities, etc.

DATA REQUIRED FOR URBAN PLANNING

- **PHYSICAL PARAMETERS**
  - Land use/ land cover
  - Road Infrastructure….



- **LEGAL FRAMEWORK**
  - Master Plan
  - Govt. policies…..

- **SOCIAL UNDERSTANDING**
  - Types of developments:

    a) HIG, b) MIG & c) LIG & squatter….

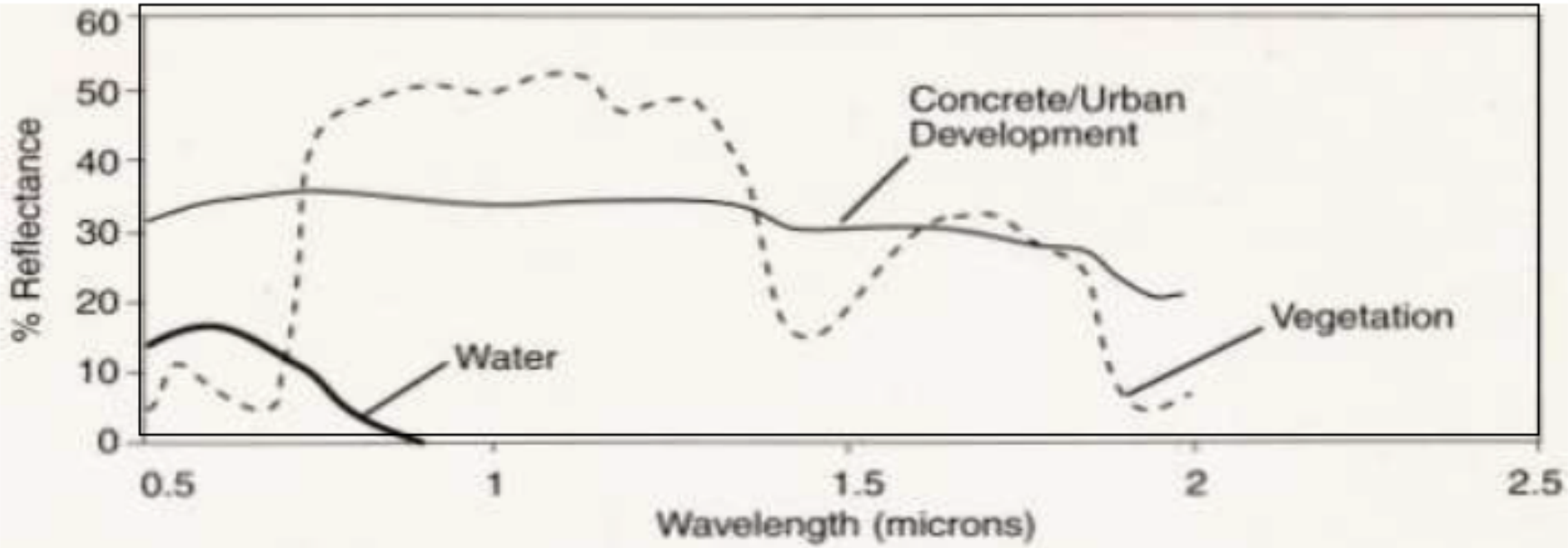
Interpretation key:
Shape, Size, Pattern, Tone, Texture, Association…

- **FISCAL MANAGEMENT**
  - **Taxation:** Unit area method…

Why should we use Geospatial Technology for Urban & Regional Planning ?

1. Wealth of information
2. Advantages of digital data
3. Urban and regional information extraction
4. Planners & Engineers can use spatial query and mapping functions of GIS to analyze existing situations
5. Identify behavior of a land over a specified time
6. Data integration..

Reflectance Curve



REQUIREMENTS FOR URBAN MAPPING

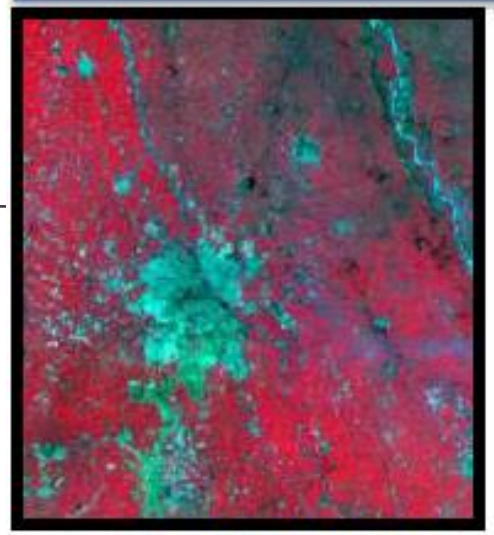
- **Spatial Resolution:** higher spatial resolution desirable as most of urban areas are densely built and features are comparatively small in size.
  - Minimum of four pixels within an object to identify
  - Role of shape, size, texture, orientation, pattern, shadow, association, etc.
  - Land use *vs.* land cover.
- **Spectral Resolution:** Multispectral data enhances ability to discern features but interpreter's intervention is must to discriminate among various urban features.
  - Hyperspectral data to distinguish urban features
- **Temporal Resolution:** e.g., land use transformations, urban sprawl, change in socio-economic characteristics.
- **Radiometric Resolution:** enhances capability to distinguish features and interpretation

SPATIAL RESOLUTION

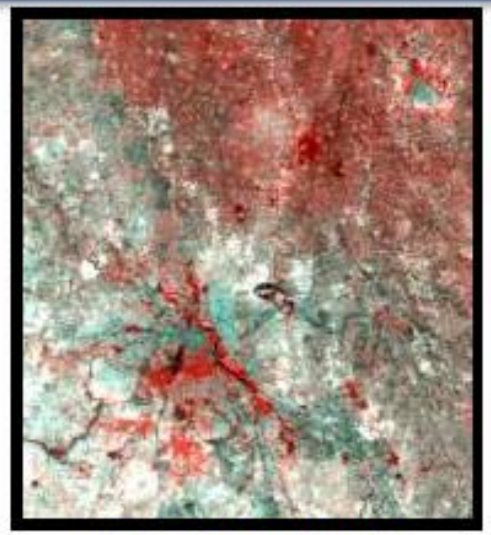
- **HIGH SPATIAL RESOLUTION** (<= 4m)
  - GeoEye-1, WorldView-1, WorldView-2, QuickBird, IKONOS, FORMOSAT-2, ALOS, CARTOSAT-1, CARTOSAT-2, 2A, 2B, SPOT-5, IRS-P6 LISS-IV, etc.
- **MEDIUM SPATIAL RESOLUTION** (4 m - 30 m)
  - Resourcesat, LANDSAT, ASTER, etc.
- **LOW SPATIAL RESOLUTION** (30 m - > 1000 m)
  - Resourcesat AWiFS, SeaWiFS, GOES, Oceansat OCM, etc.

Source: Yang, C., Wong, D., Miao, Q. and Yang, R. eds., 2010. Advanced Geo-Information Science. CRC Press.

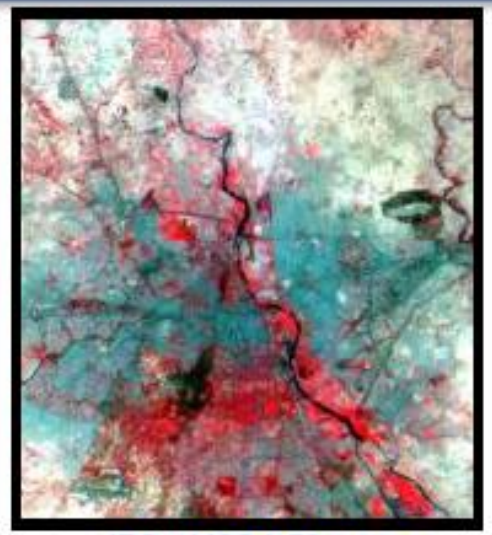
Improvements in Spatial/ Spectral Resolutions of IRS Sensors: Delhi and its Environs



IRS – OCM 360 meters



IRS – WIFS 188 meters

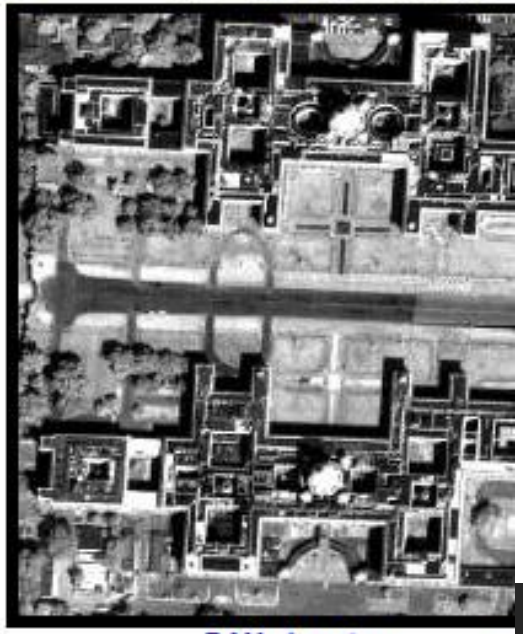


IRS – LISS-I 76 meters

IRS – LISS-II 36 meters

IRS – LISS-III 23 meters

IRS – PAN 5 meters

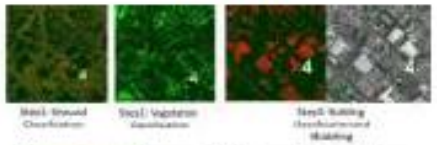


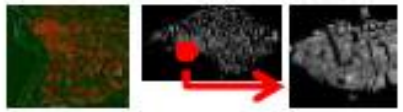
PAN 1 meter

UPCOMING GEOSPATIAL TECH. FOR URBAN PLANNING

LiDAR

Toronto, Canada





Classification and Modeling Results

Skyline Of Toronto

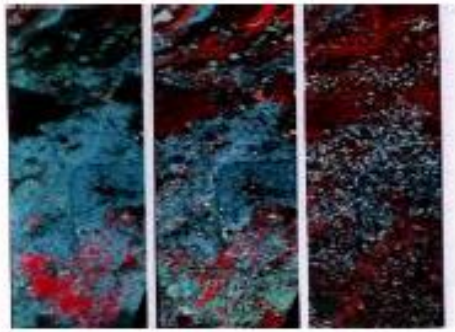
- LiDAR data- Good source for 3D models of urban areas.
- Extracted building heights- Accurate within 0.2 m - 1 m.

MICROWAVE R.S.

RISAT-1 FRS-1 image

- Building footprint, land use, building height, etc.

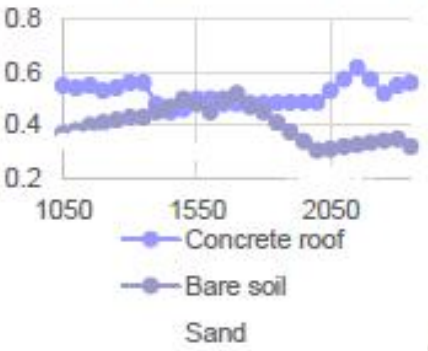
HYPERSPECTRAL R.S.



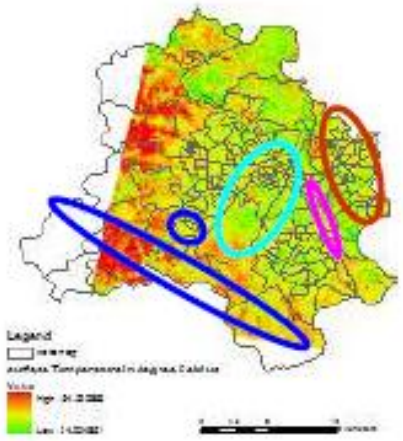
Satellite images: (a) Hyperion (b) ALI and (c) IKONOS

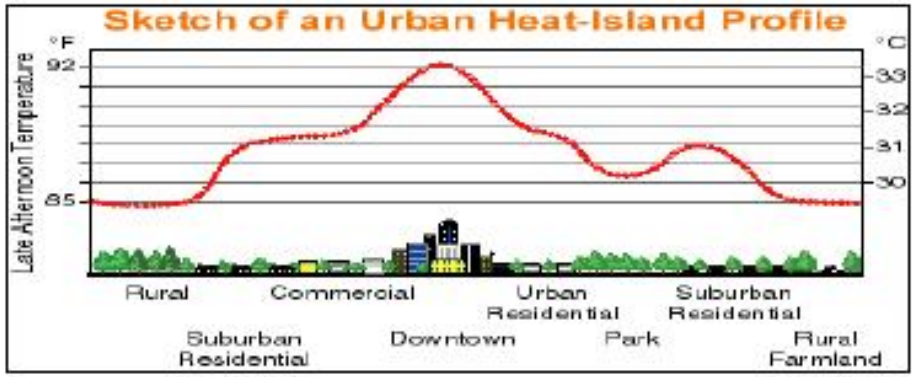
Urban Material	Suitable spectral configuration
Brick	1658:1718:1728 and 1335:1476:1486
Concrete roof	1123:1143:1153 and 1002:1073:1083
Road surface	688:699:709 and 658:719:729
Bare soil	688:719:729 and 2031:2041:2051
Sand	992:1083:1093

SWIR Spectral Library



THERMAL REMOTE SENSING





Dataset used: LANDSAT-7 ETM+, Terra ASTER (Aster level-1B, LANDSAT-7 ETM+ level-1G)

GROUND PENETRATING RADAR (GPR)

- GPR (also known as Ground Probing Radar/Geo-radar) is a non-invasive geophysical technique for sub-surface exploration.
- GPR sends EM energy through a Transmitter Antenna, and transmitted energy gets reflected based on Dielectric Contrast between subsurface layers.
- Operates in specific frequencies ranging from 15 MHz to 2 GHz.

Frequency	Depth of penetration
100 MHz	20m
200 MHz	7m
270 MHz	6m
400 MHz	4m
900 MHz	1m
1600 MHz	0.5m

Data Logger/Viewer
Electronic device records data and displays on monitor

Antenna
Transducer for transmission and reception of electromagnetic waves

D = (5.9t)/sqrt of (Er)

D = depth of target (in)
t = wave travel time (nanosec)
5.9 = a constant incorporating speed of light and unit conversions
Er = dielectric constant of subsurface material

Material	Er
Air	1
Pure water	81
Fresh water (ice)	4
Granite (dry)	5
Clay (saturated)	8-12
Sand (dry)	4-6
Sand (saturated)	30

Remote Sensing and GIS Applications in Geology & Geomorphology

(Source: IIRS)

- Geomorphological Mapping
- Lithological Mapping
- Geological Structure Mapping
- Mineral & Hydrocarbon Exploration
- Groundwater Targeting and Flow Modelling
- Construction Material Exploration
- Engineering Geological Investigations
- Environmental Impact Assessment
- Geo-hazard Mapping and Monitoring
- Many more …

Remote sensing is more effective and powerful in synergy with complementary datasets such as Geophysical data, Geochemical data, Subsurface geological information and Ground truths…

An image of the earth surface represents a STACK of many thematic layers:

- Layer of Topographic Information
- Layer of Vegetation Information
- Layer of Landuse/Infrastructural Information
- Layer of Soil Information
- Layer of Geomorphological Information
- Layer of Lithological Information
- Layer of Structural Information

From all these information we need to separate geological information from direct and indirect signatures, which includes Geomorphology, Lithology and Geological Structure.

We do it by -

Visual Image Interpretation

Digital Image Enhancement and Feature Extraction

Interpretation Elements

The objects of our interest are expressed in the image in terms of Direct and Indirect Interpretation keys …

***Photo/Image Elements* (Direct Interpretation Elements)**

- *Tone or Hue*
- *Texture*
- *Shape or Form*
- *Size*
- *Pattern*
- *Association*

***Terrain Elements* (Indirect Interpretation Elements)**

- *Landform*
- *Drainage*
- *Vegetation*
- *Landuse*

Convergence of Information from Photo/Image Elements and Terrain/Geotechnical Elements is the Key to a Successful Visual Interpretation …

Remote Sensing of Rock Types…

IGNEOUS Rocks

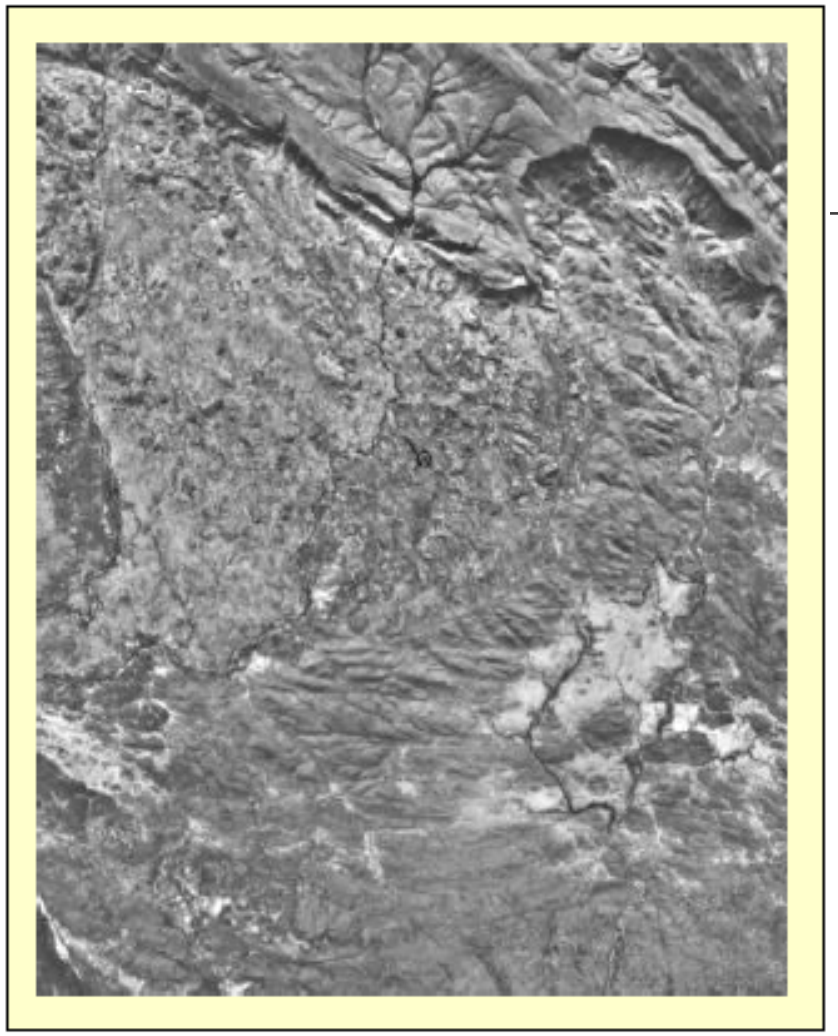
- Homogeneous, Massive, Hard, Compact and Resistant. Lacks Bedding. Course textures. Characteristic Joint Patterns and Landforms.

SEDIMENTARY Rocks

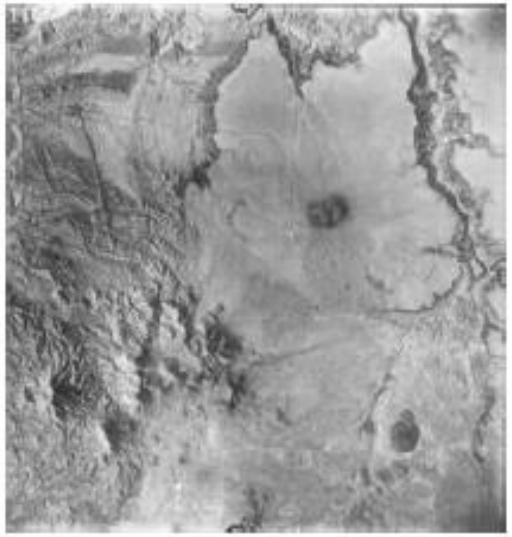
- Soft and Bedded. Vulnerable to more dissection. Fine Texture. Differential resistance to weathering and erosion yield Ridge-and-Valley Topography. Characteristic Landforms.

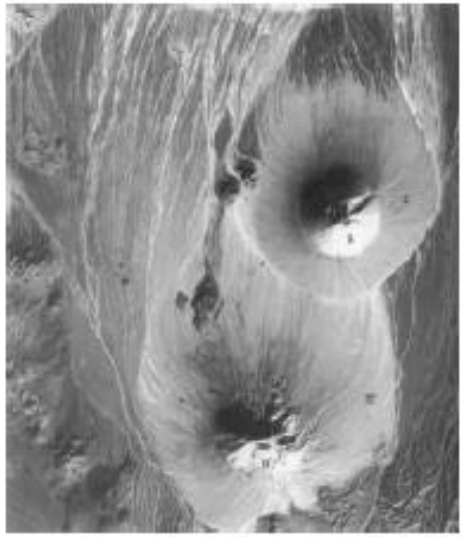
METAMORPHIC Rocks

- Regional Foliation gives striated appearance in the rock mass due to differential weathering along the weak planes. Presence of deformational structures.

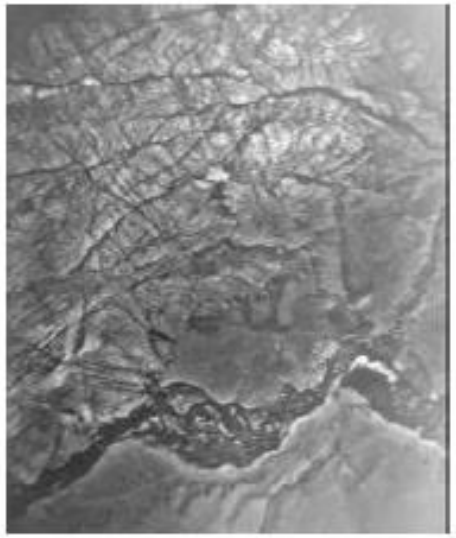


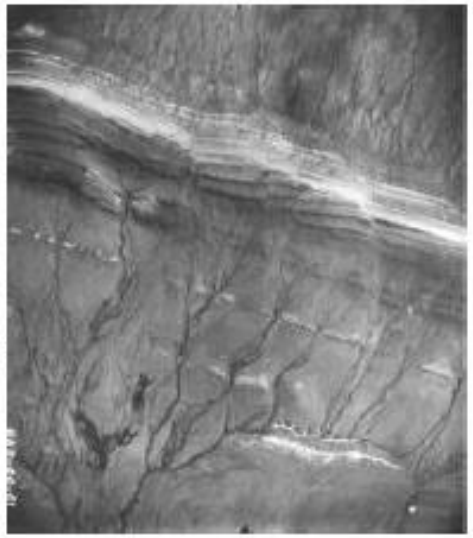
Remote Sensing of Rock Types…





Igneous Rocks (Volcanic)



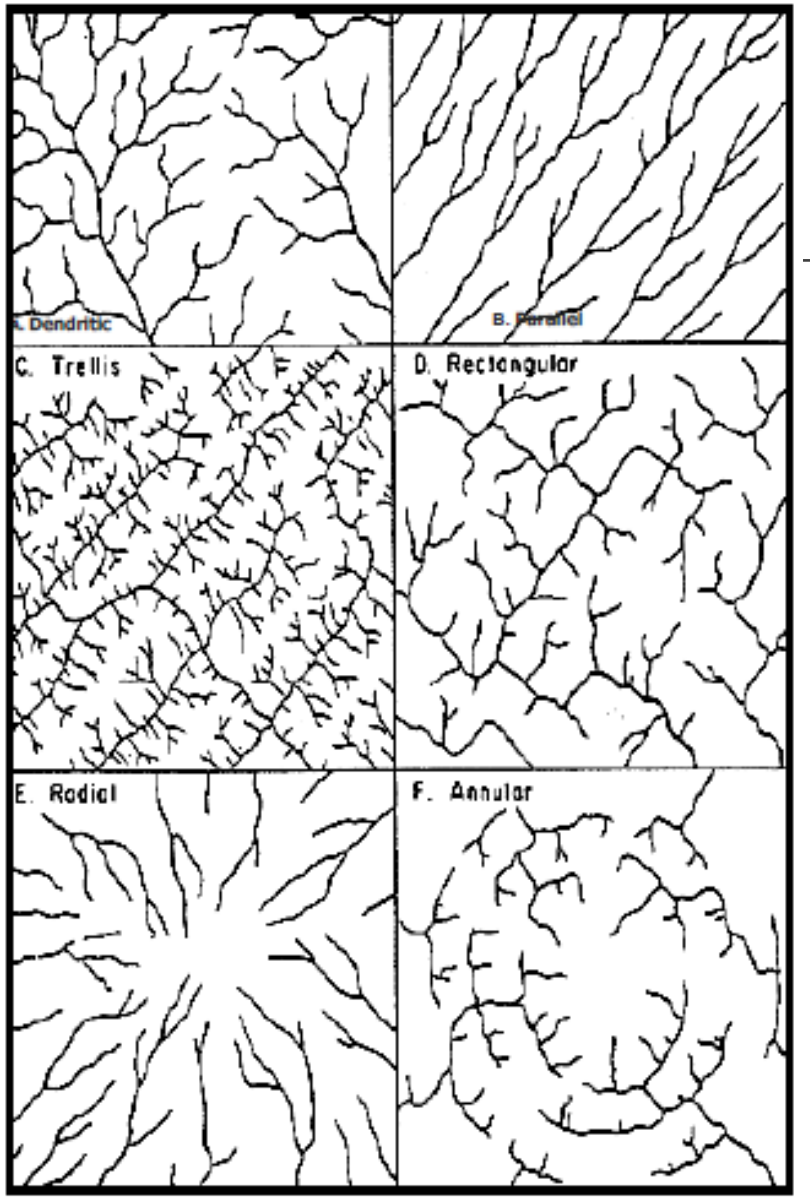


Sedimentary Rocks (Sandstone-Shale)

Metamorphic Rocks

Visual Image Interpretation Elements: *Terrain/Geotechnical Elements …*

Drainage Pattern	Significance
Dendritic	Horizontal sediments or uniformly resistant crystalline rocks; Gentle regional slope at present or at the time of drainage inception
Parallel	Moderate to steep slopes or areas of parallel elongate landforms
Trellis	Dipping or folded sedimentary, volcanic, or low-grade metasedimentary rocks. *Develops mostly in interbedded dipping sequence.*
Rectangular	Streams lack regional continuity; Controlled by orthogonal fracture system.
Radial	Volcanic domes or Residual dome-like landforms
Annular	Structural domes and basins: *Erosion exposes rocks of varying resistance*



Visual Image Interpretation Elements: *Terrain/Geotechnical Elements …*

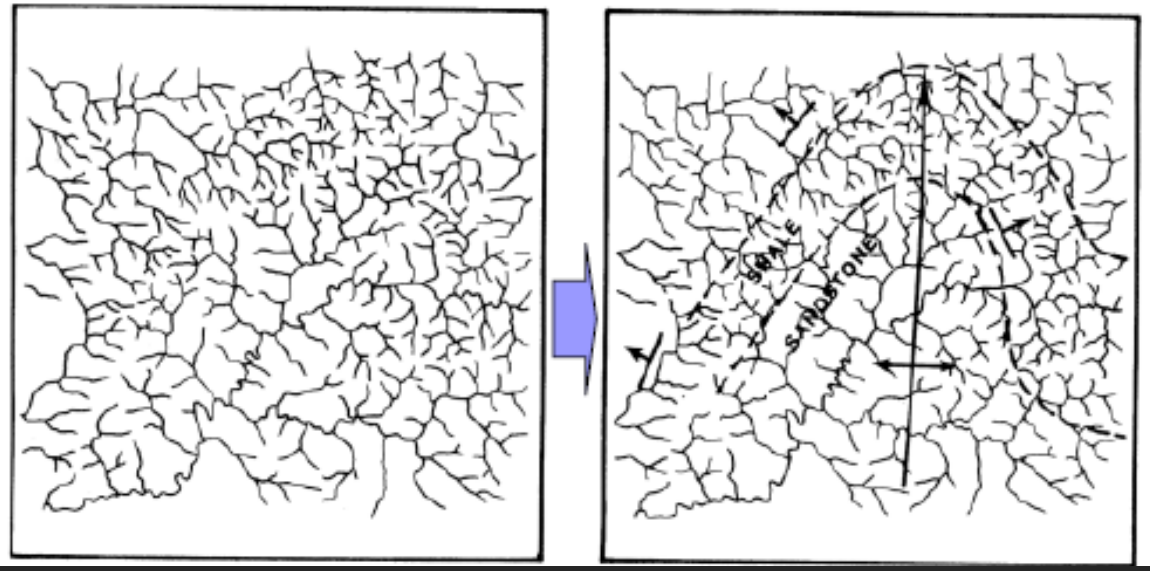
Drainage Density and Significance …

- Drainage density can be estimated as the ratio of total drainage length divided by area.
- It describes the hardness and infiltration capacity of surface materials. It can be used to differentiate rock types based on hardness and/or infiltration capacity.

Drainage Density depends on the following factors:

- Resistance of rock formation: Harder rocks – Low; Softer rocks – High
- Permeability of rocks: Permeable rocks – Low; Impervious rocks – High
- Topographic slope: Gentle slope – Low; Steep slope – High
- Climate (Rainfall & Temperature)

- ***Drainage density is useful to identify rock units as well as folded structure.***

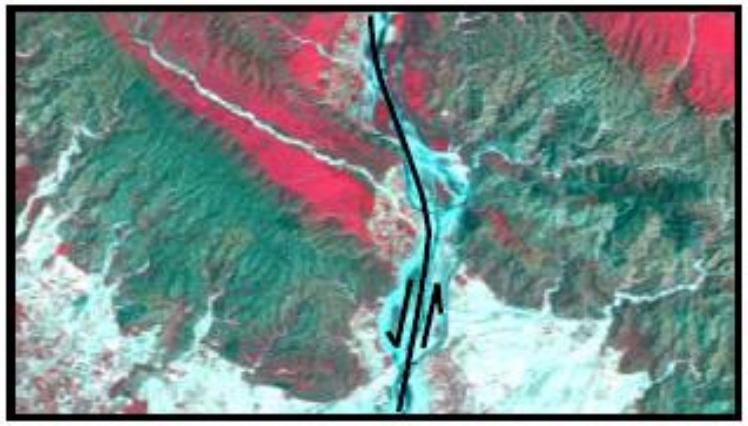


Geological structures such as folds, faults, lineaments and unconformities can be mapped from remote sensing images using tonal and physiographic expressions.

Remote Sensing images show the synoptic view of the outcrop pattern of the exposed regional folds. Buried folds are identified by indirect signatures such as topographic and drainage anomalies.

Geological faults and lineaments can be identified as linear tonal and/or physiographic signatures with or without displacement. Geomorphic signatures such as topographic break, drainage segment anomaly and stream migration are useful indicators.

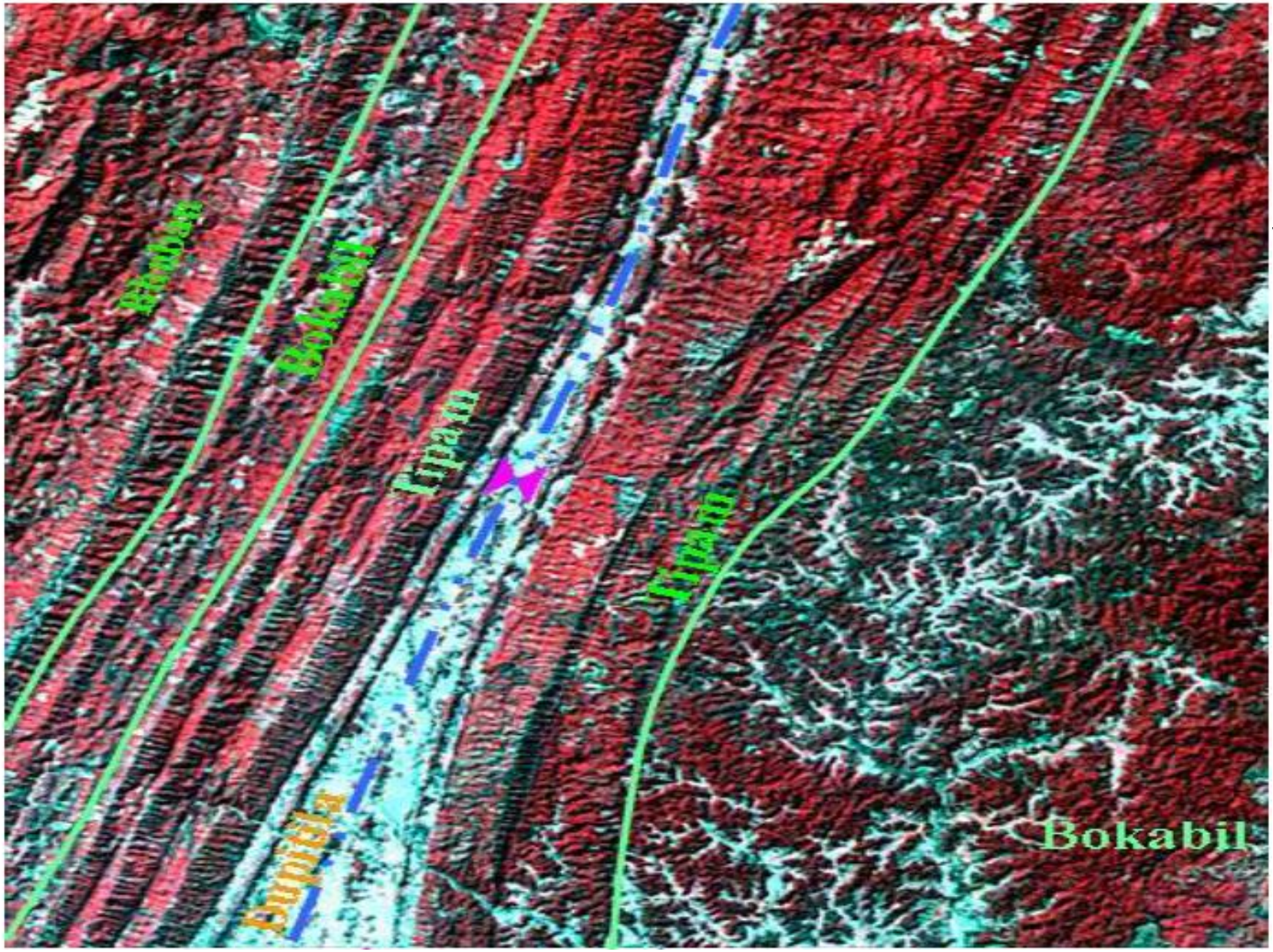
Exposed plunging antiform fold (dome ?) in aerial photo



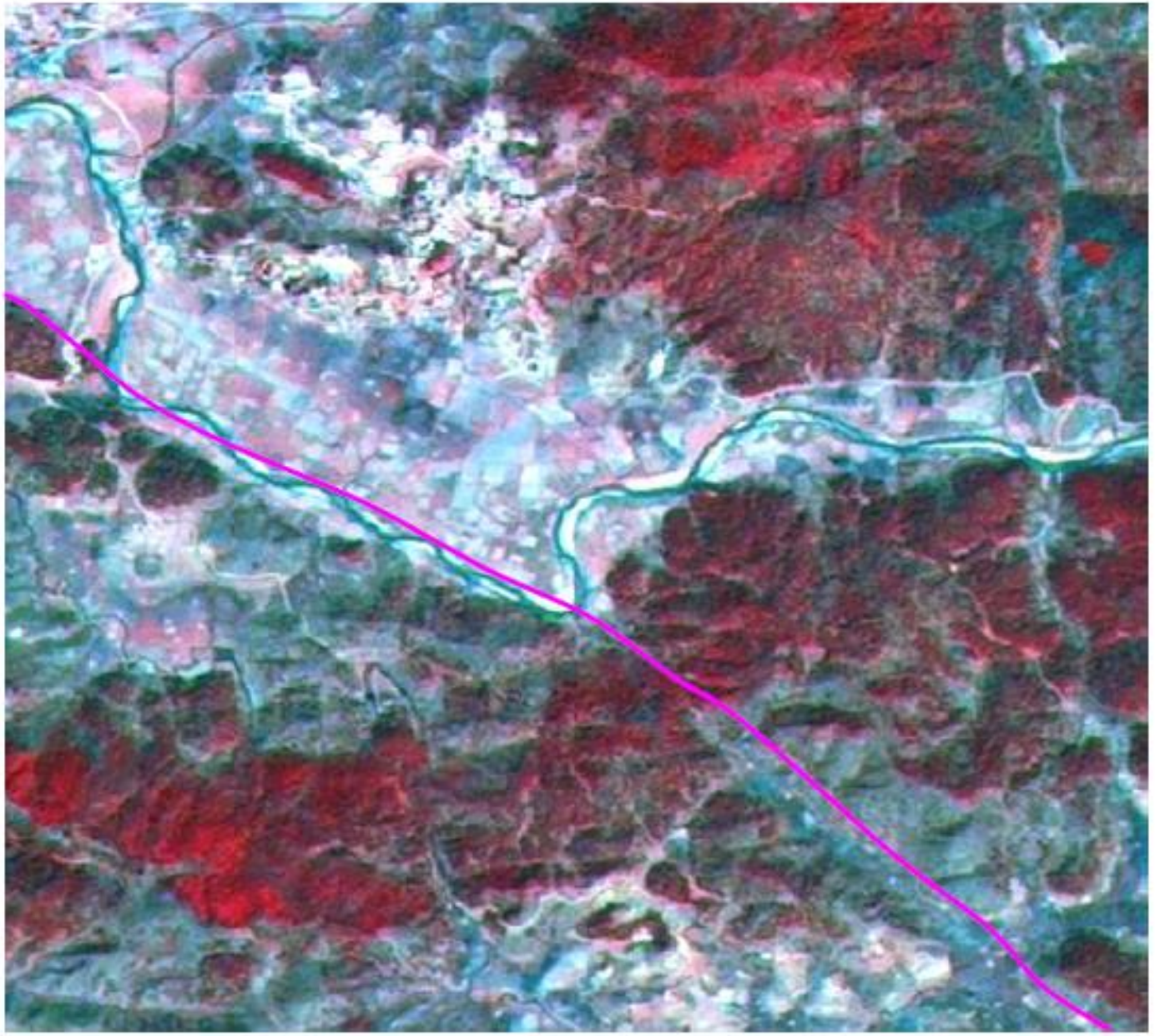
Yamuna tear fault (strike slip fault) in Optical Mx image

Remote Sensing based Information on geological structures and their analysis provide important input for Groundwater Prospecting, Geological Hazard Assessment, Engineering Geological Projects, Mineral Exploration etc.

Remote Sensing in Geology & Geomorphology: *Geological Structures*

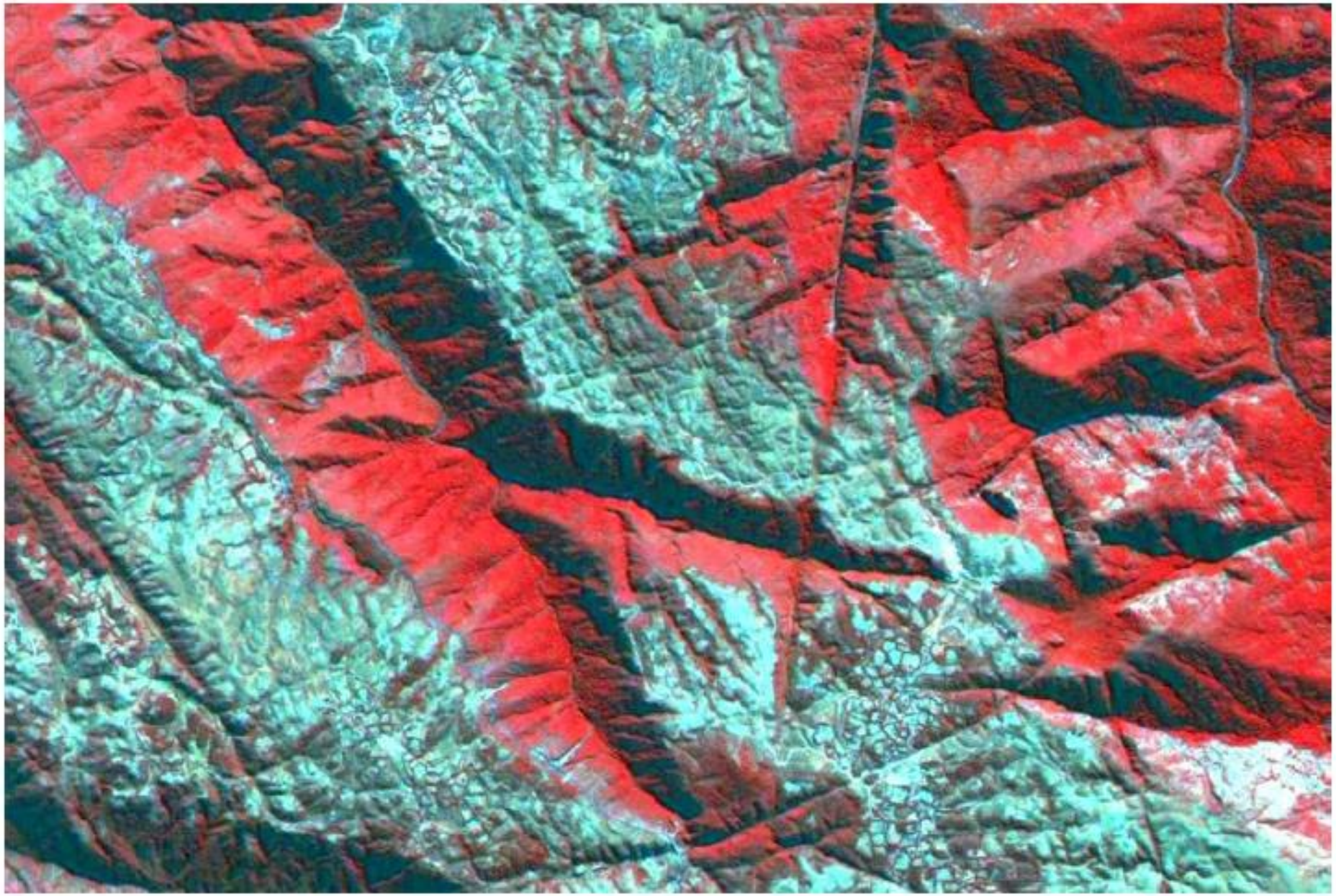


Remote Sensing in Geology & Geomorphology: *Geological Structures*



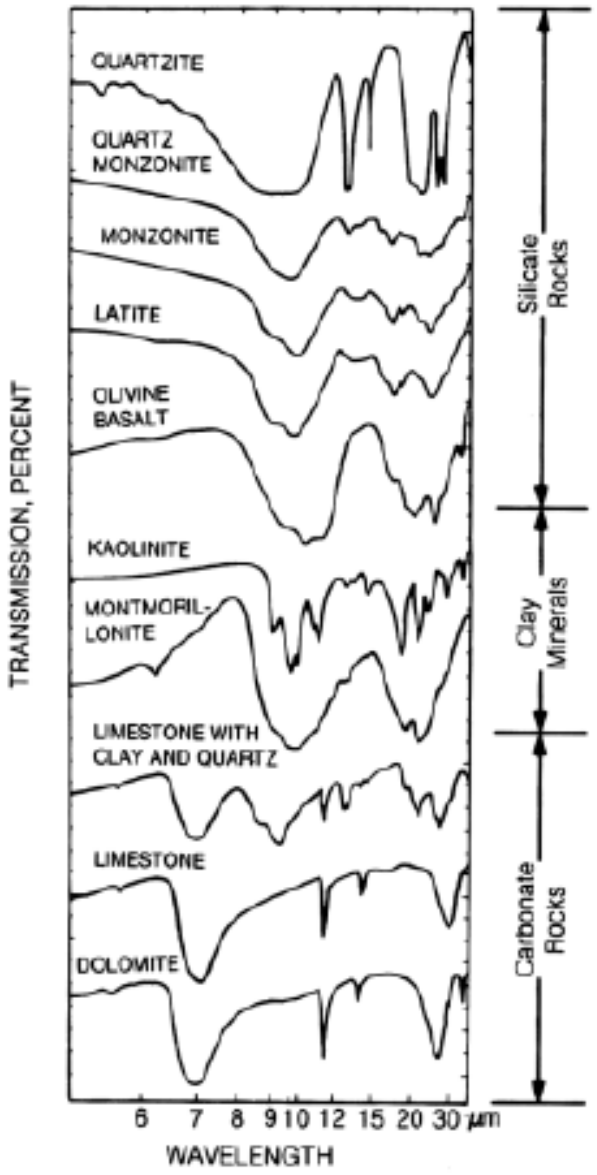
Kynshi Fault in East Khasi Hills District, Meghalaya

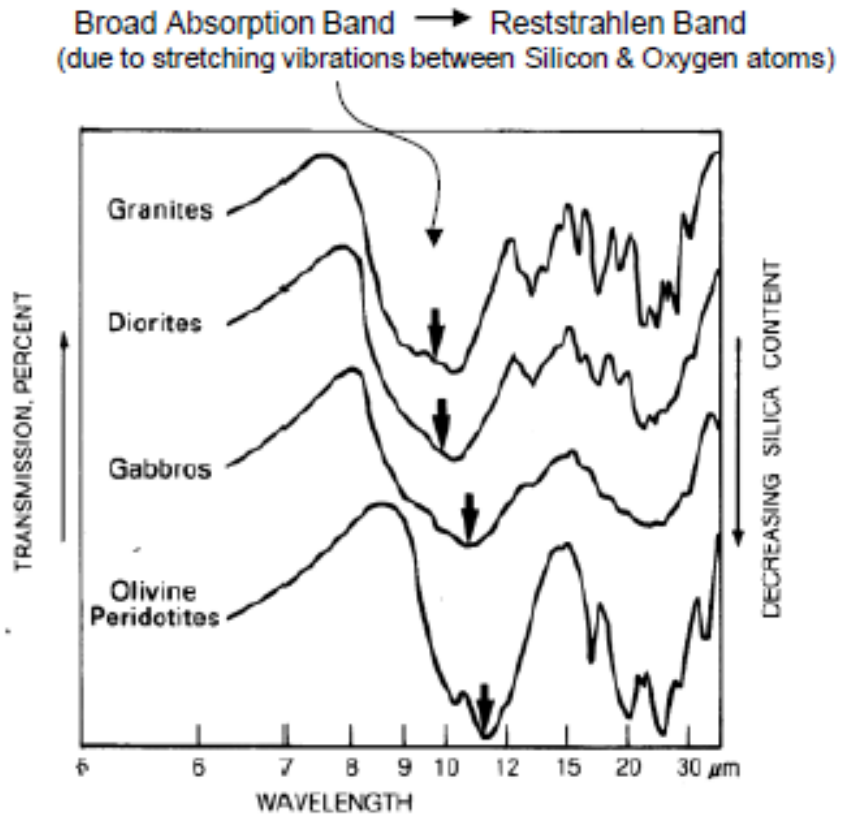
Remote Sensing in Geology & Geomorphology: *Geological Structures*



South of Laitlyngkot showing prominent faults (Nongkshaid Fault) and lineaments

Thermal Spectra of Geological Materials





Thermal IR spectra of Igneous Rocks
The centre of the absorption band shifts towards higher wavelength with decreasing silica content

Remote Sensing in Geology & Geomorphology:

Radar Remote Sensing

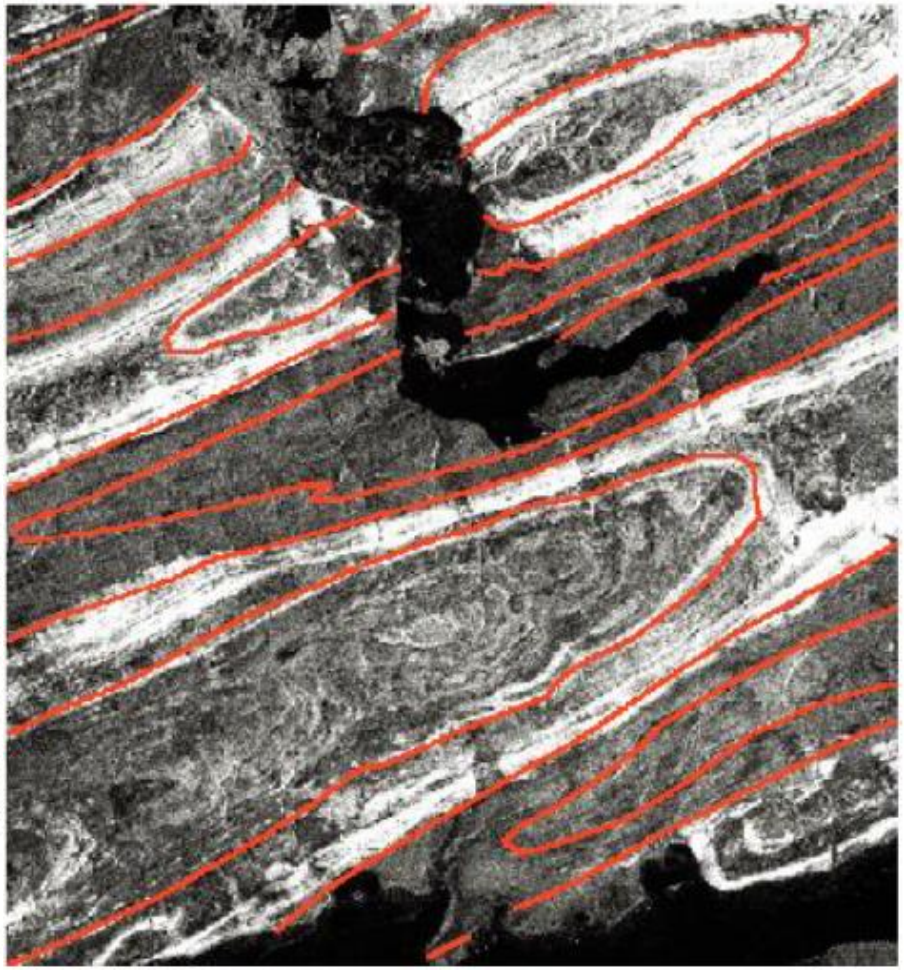
–

Sensitivity to Surface Geometry provides information on Geomorphology and Geological Structures.

Sensitivity to Surface Roughness in non vegetated terrains provides information on Lithology.

Sensitivity to Moisture Content provides information on Unconsolidated Materials and Soils.

Radar Remote Sensing – Surficial Bedrock Mapping



Study Area: 22km. x 25km.

Bathurst Island, Canada
RADARSAT S7, Descending Node
March 6, 1996

Radar Remote Sensing – Geomorphological Mapping

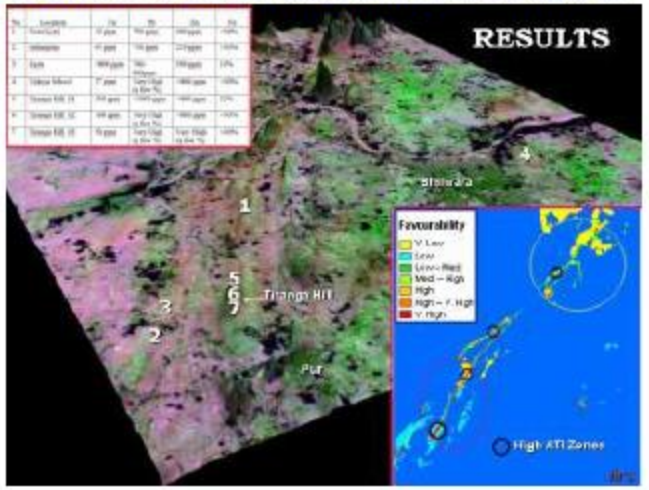
Roter Kamm Meteorite Impact Crater in Namibia

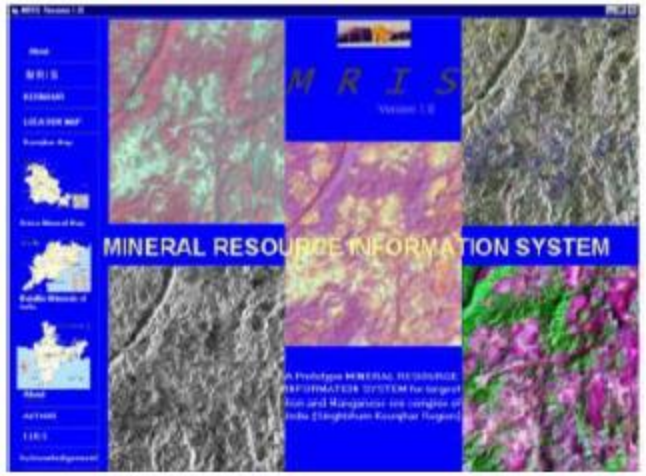
- Fused product of SIR-C and Optical remote sensing data.
- Lithological discrimination is clear from optical multispectral data.
- Geomorphology and Structural features are highlighted by the radar data.
- Buried channels can be identified due to surface penetration of radar wave.
- Crater boundary is distinct.
- Aeolian landforms are prominent.

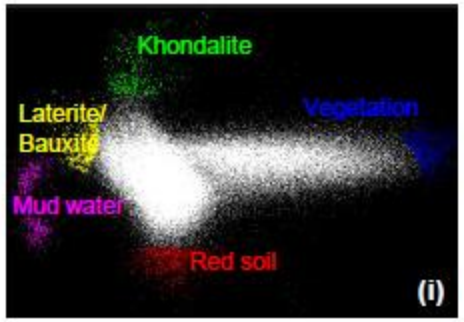
Remote Sensing in Geology & Geomorphology: *Geol. Resource Exploration*

- Base metal exploration and GIS based predictive modelling, Pur Banera, Rajasthan.
- Mineral Resource Information System (MRIS), Keonjhar, Orissa.
- Prospecting of Bauxite Deposits by Spectrometric Analysis, Koraput, Orissa.

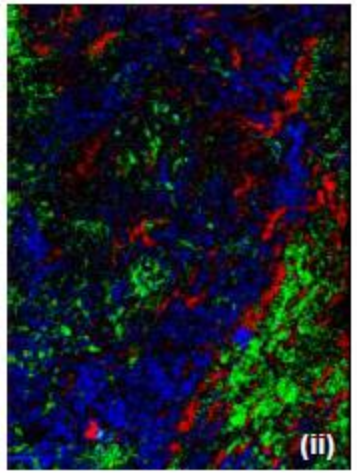
Remote Sensing & GIS-based Exploration of Base Metal Deposits in Pur-Banera Area, Bhilwara District, Rajasthan



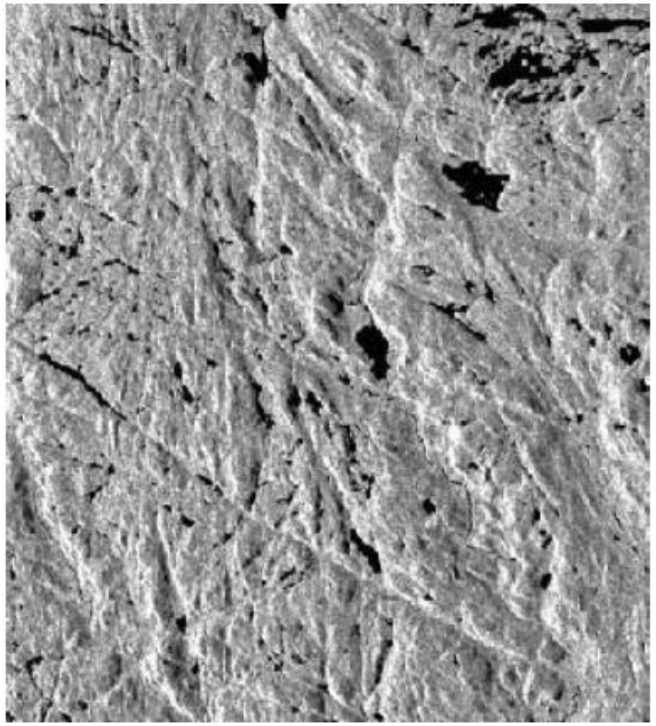


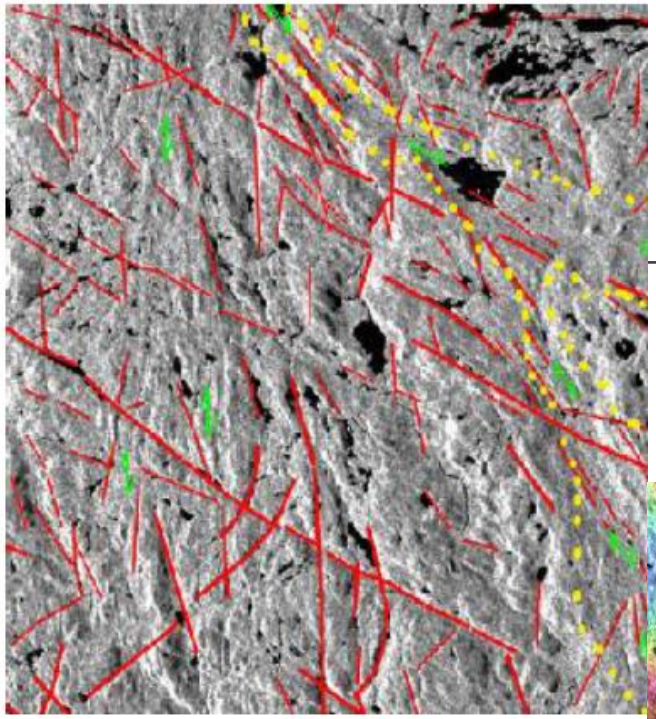


End member selection by spectral unmixing (i) and FCC of Laterite/Bauxite (red), red soil (blue) and vegetation (green) end members (ii)

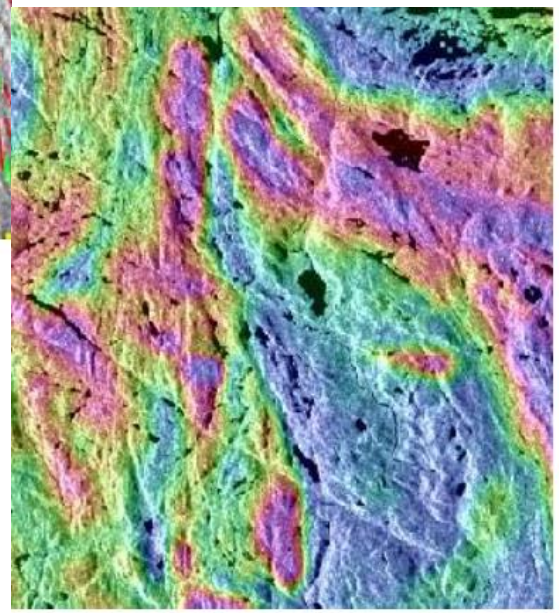


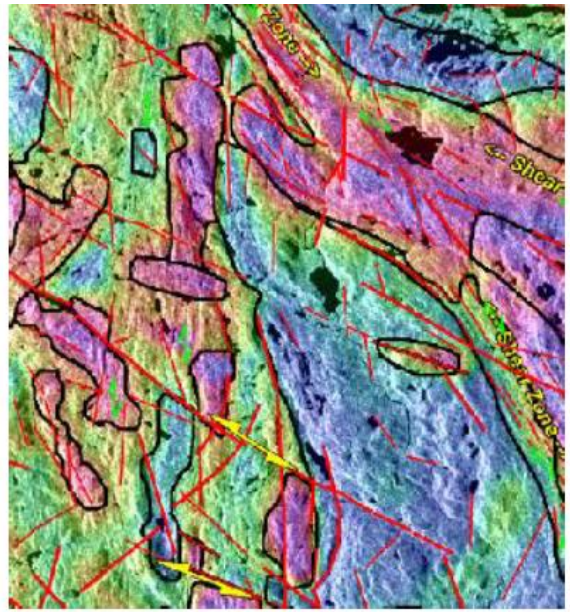
Radar Remote Sensing – Mineral Exploration





Interpretation from Radar Data Alone …





Interpretation from the Fused Product of Optical and Radar Data …

Landslide Identification Characteristics

Identification of Active Landslides

- Scar on the earth surface
- No vegetation

Visual Interpretation, Image Segmentation and Multi-temporal Change Detection

Identification of Old and Dormant Landslides

- Break in slope
- Accumulation of thick soil below rocky hill slope
- Differences in pattern and density of vegetation

Identification of Potential Landslides

- Steep slopes
- Landmasses undercut by streams/waves
- Areas of drainage concentration or seepage
- Areas of concentration of weak structural planes
- Areas surrounding recent landslides
- Areas of old landslides

RS and GIS Applications in Forest Resources & Ecosystem Analysis

(Source: IIRS)

Forest Ecosystem Studies with Geospatial Technologies

- Synoptic coverage
- Systematic revisit
- See things invisible to humans
- Multiple scale observations
- Cost effective

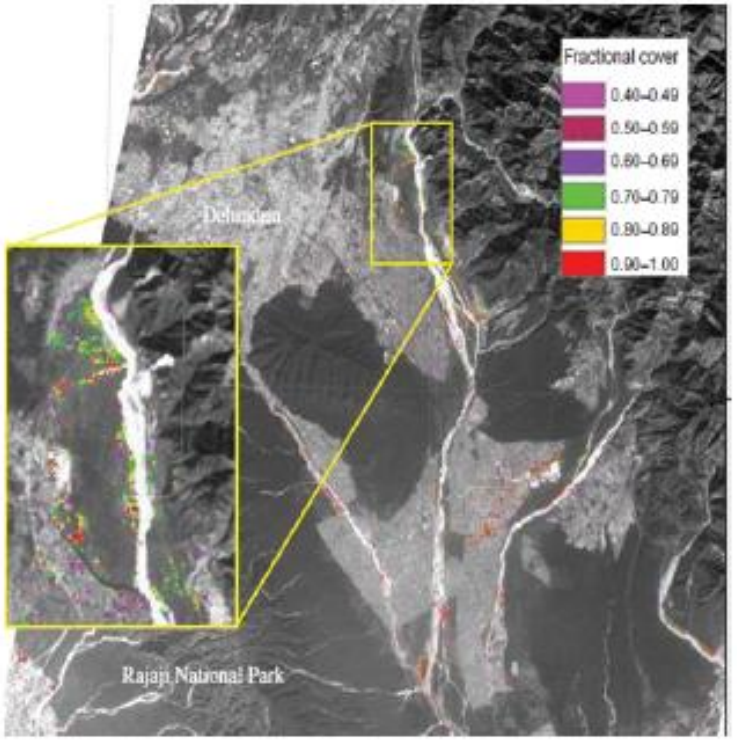
- Location information
- Navigation
- Time information
- Communication
- Observations

- Visualization, archival, retrieval and analysis data
- Linking of spatial to non-spatial data
- Integrated analysis

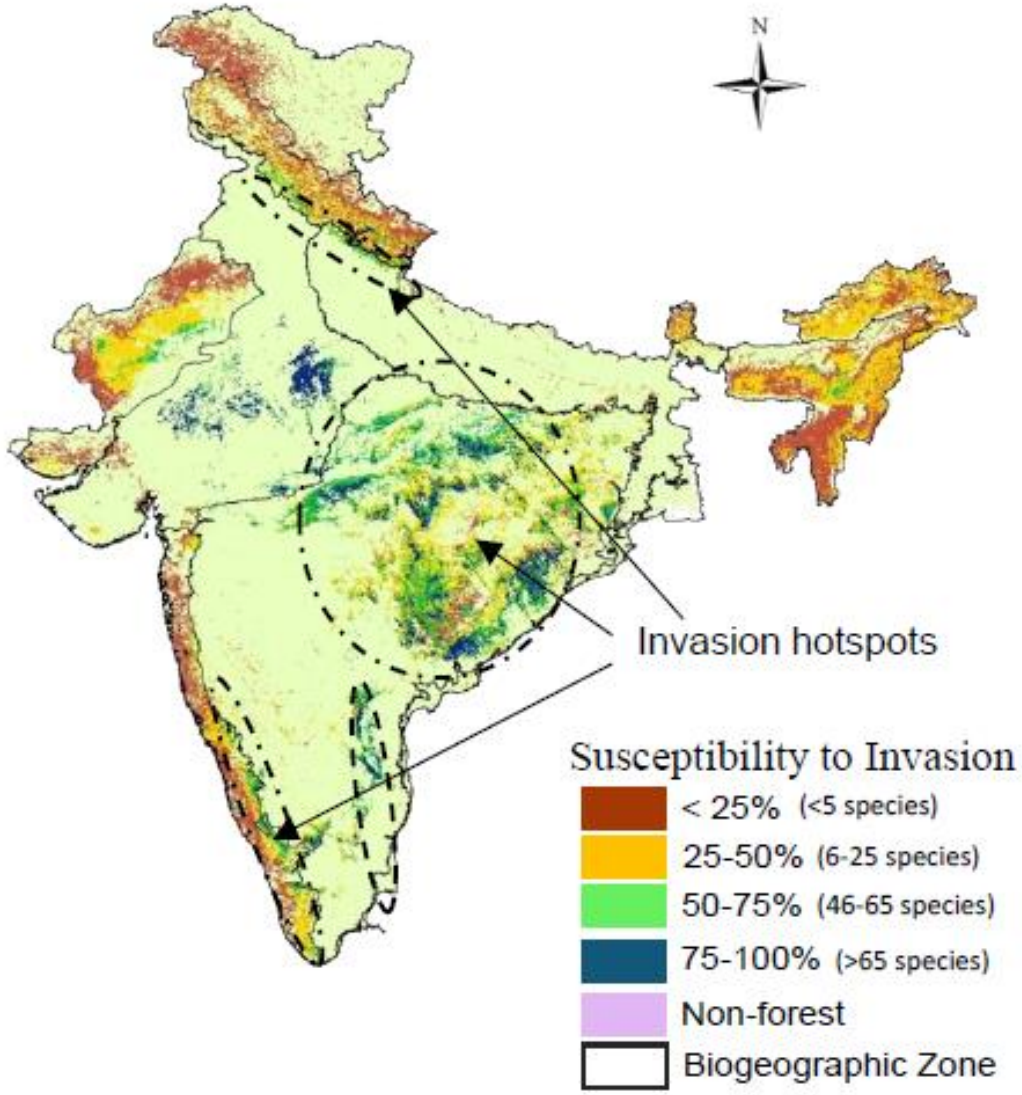
Alien Invasive Plants Mapping & Risk Assessment

Vilayati Tulsi
In flowering

Phenology during monsoon (left) and early winter (right)

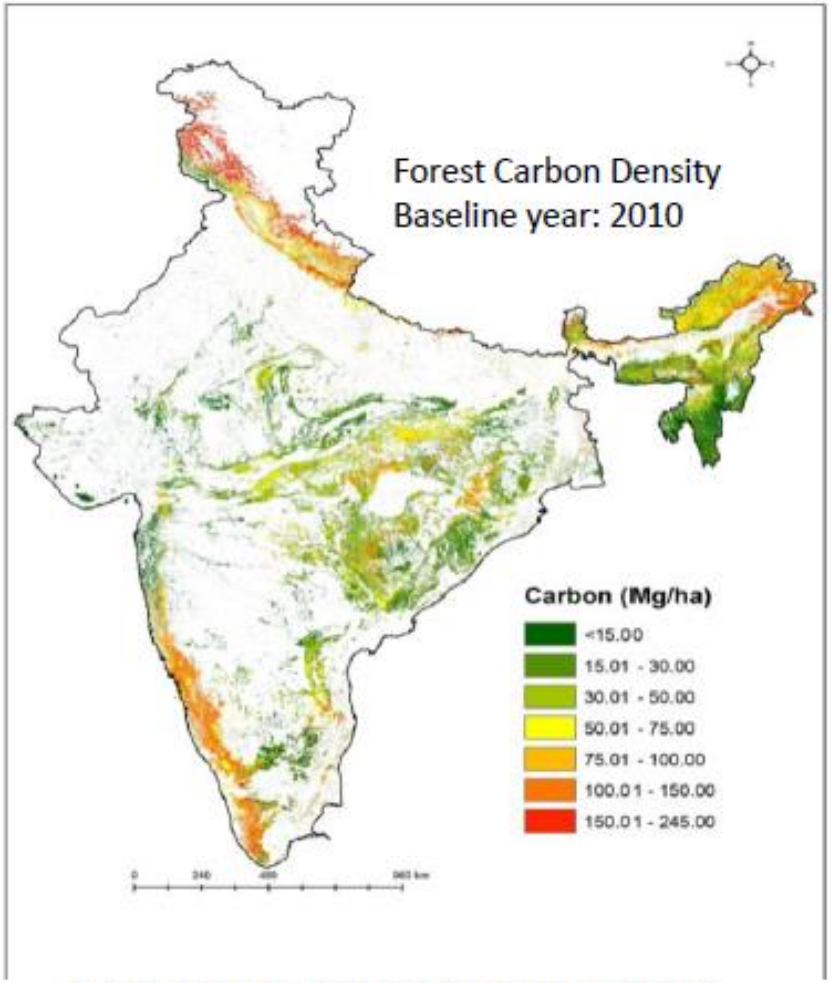


Vilayati Tulsi's fractional cover (colored pixels) mapped in Doon Valley using ALI satellite data (Superimposed on grey scale ALI red band)



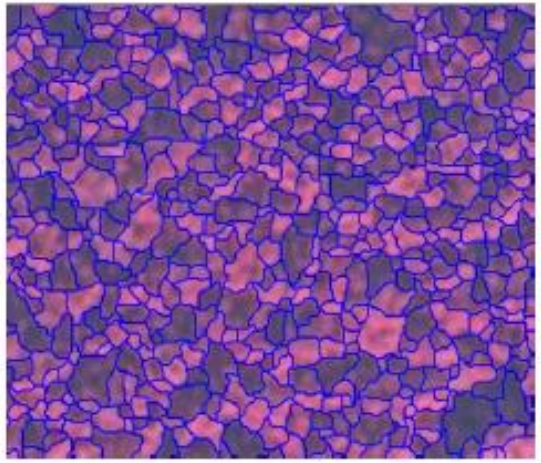
Forest Biomass/Carbon Stock Mapping

Medium resolution biomass/carbon stock mapping

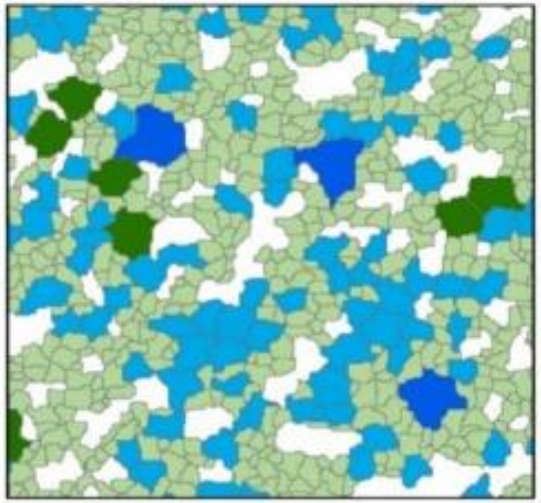


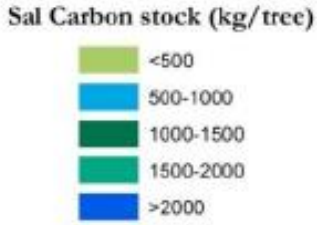
ISRO-GBP National Carbon Project

High resolution biomass/carbon stock mapping

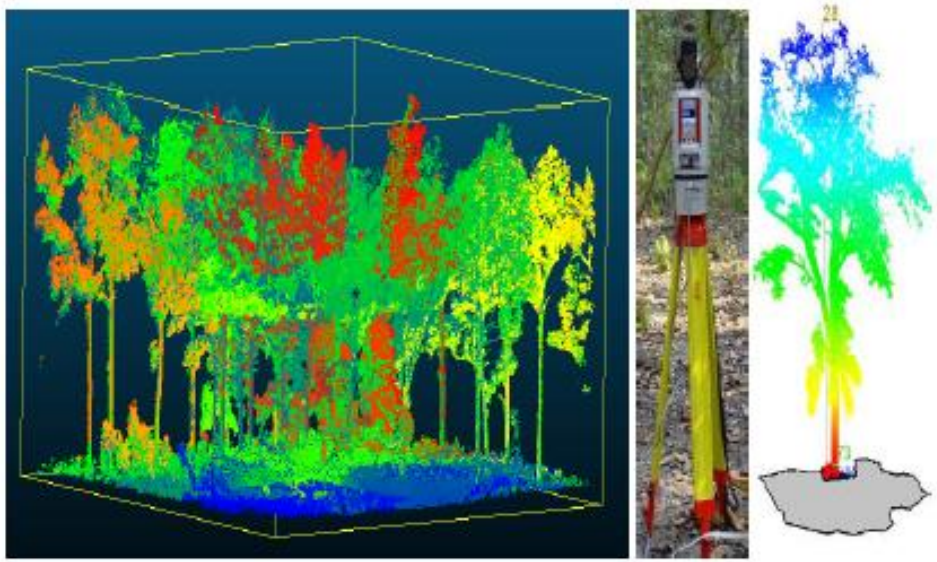


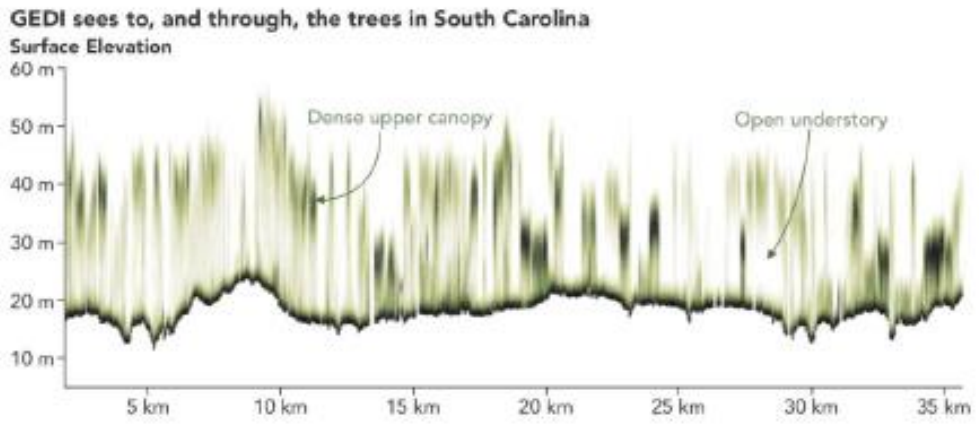
Individual tree crown delineation on VHR satellite image





Forest Biomass/Carbon Stock Inventory using LiDAR



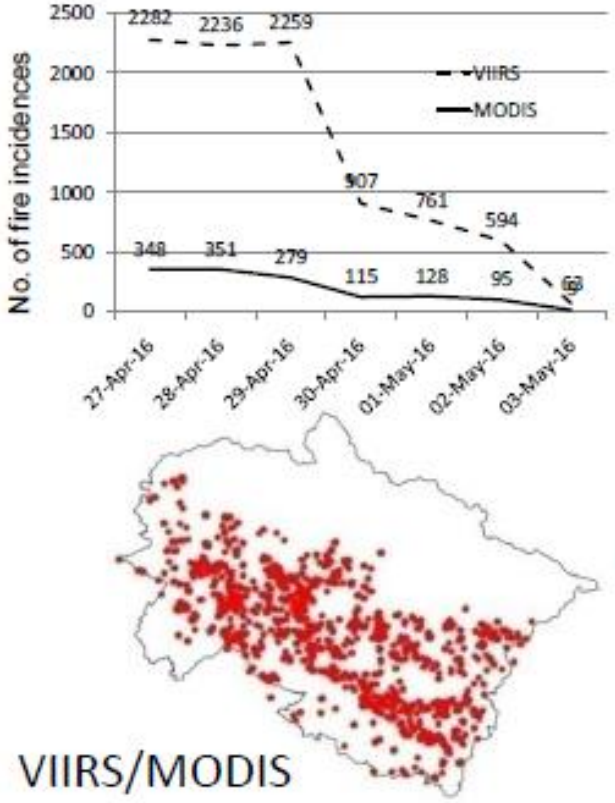


- Space borne LiDAR Observations from ICESAT-2 and GEDI (on board ISS) would provide global LiDAR footprints for forest height and biomass studies.

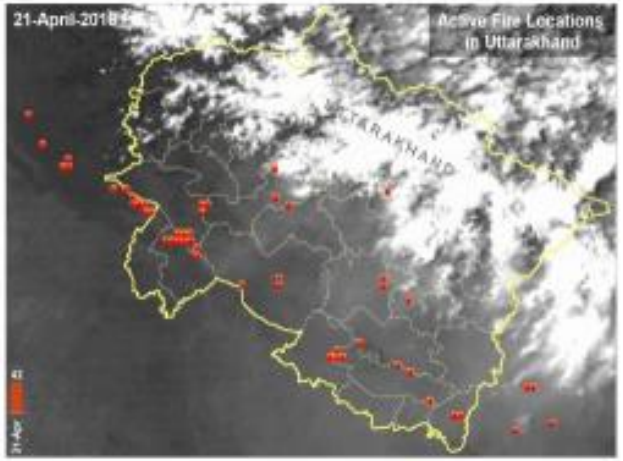
- Terrestrial Laser scanner (TLS) use for intensive site characterisation and validation of Space based LiDAR outputs.

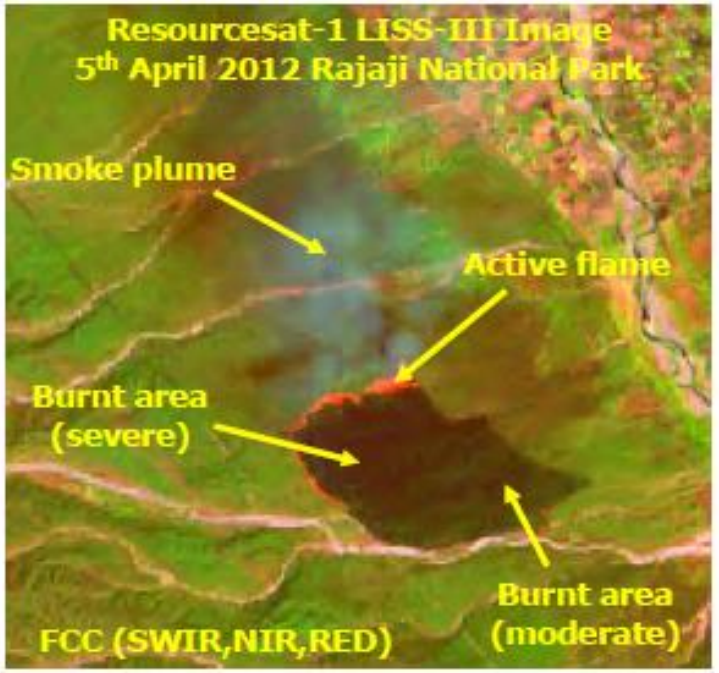
Forest Fire Prevention & Management

- Forest fire risk assessment & danger rating
- Active fire detection and monitoring
- Burnt area assessment
- Recovery assessment
- Quantification of emissions from forest fires
- Ecological Impacts of forest fires



VIIRS/MODIS

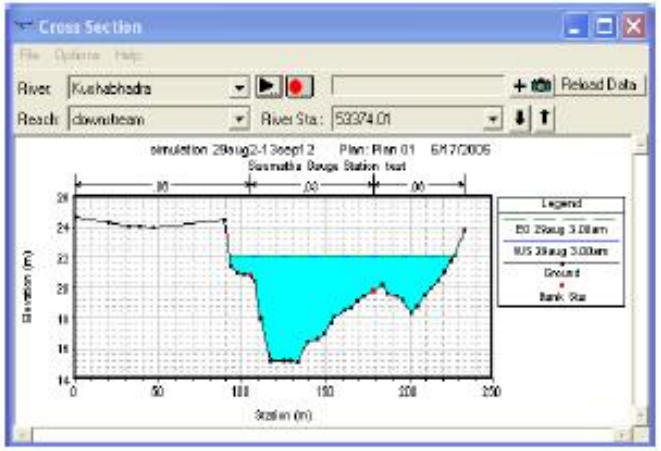




SAR APPLICATIONS IN FLOOD MAPPING AND MONITORING STUDIES

Flood Definition

- A flood is an unusual high stage in a river – normally the level at which the river overflows its banks and inundates the adjoining area



Causes of Floods

- Heavy Rainfall
- Dam Break
- Breaching of embankment
- Drainage congestion
- Storm Surge
- Glacial Lake outburst

Natural hazards to Disaster

- Can we stop…?
- Can we predict….?
- Can we manage and mitigate…?

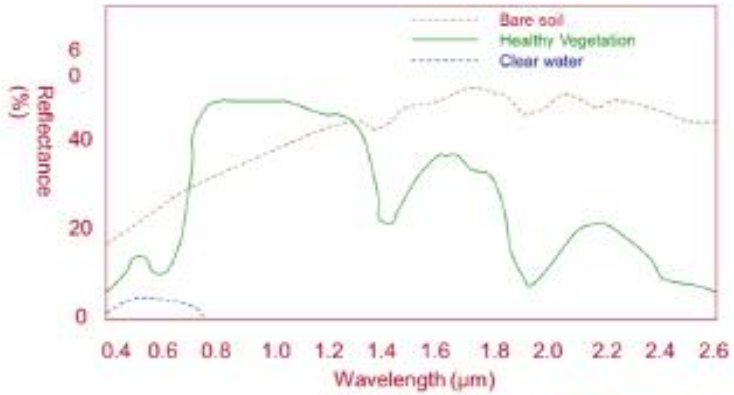
Gap Areas

- Communication
- Real time information
  - Extent
  - Damage
  - Road connectivity
- Day to day monitoring
- Alternatives routes for rescue and re
- *Forecasting and prediction….operationalization*

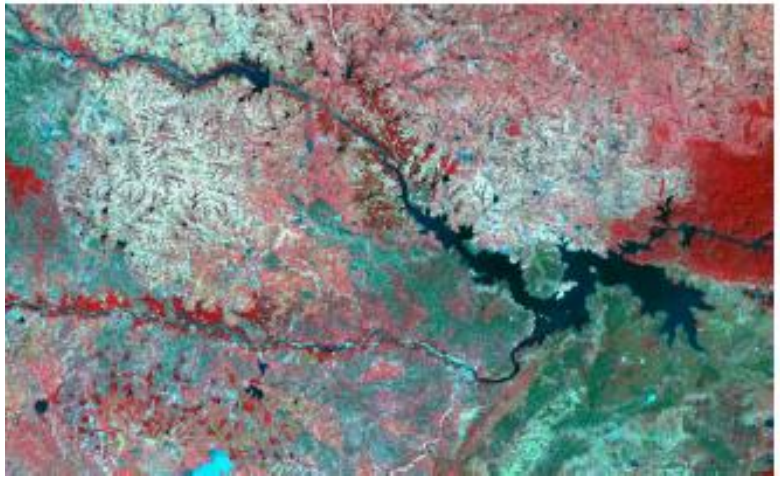
Rambara(Pre Disaster)

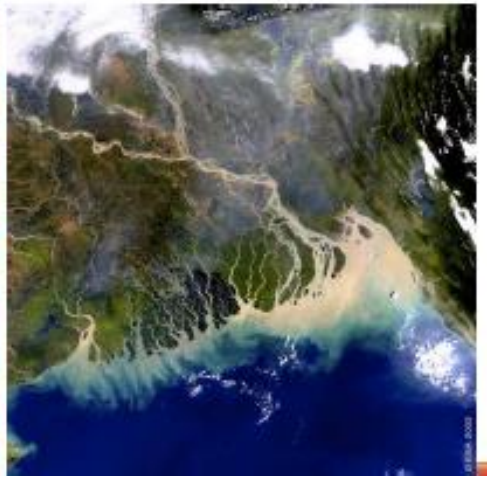
Rambara after flood disaster

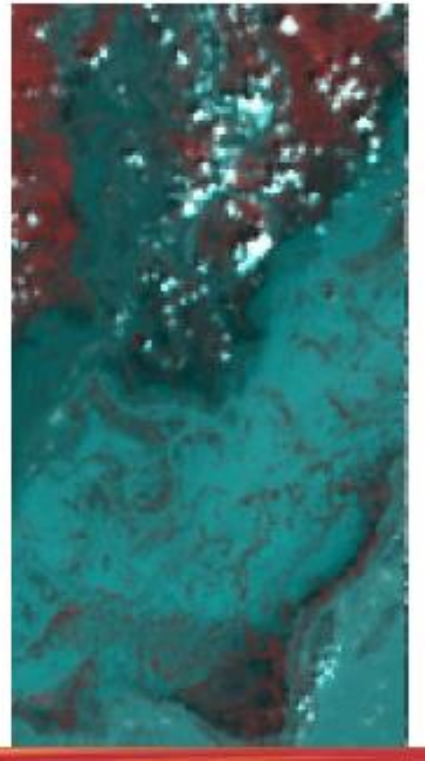
Flood Inundation Mapping: Principle



- **Spectral Characteristics**
  - Optical
    - ✓ Almost 100% absorption in NIR band
    - ✓ In FCC it appears black (if deep) or blue or cyan or brown (if shallow..a case of inundated water



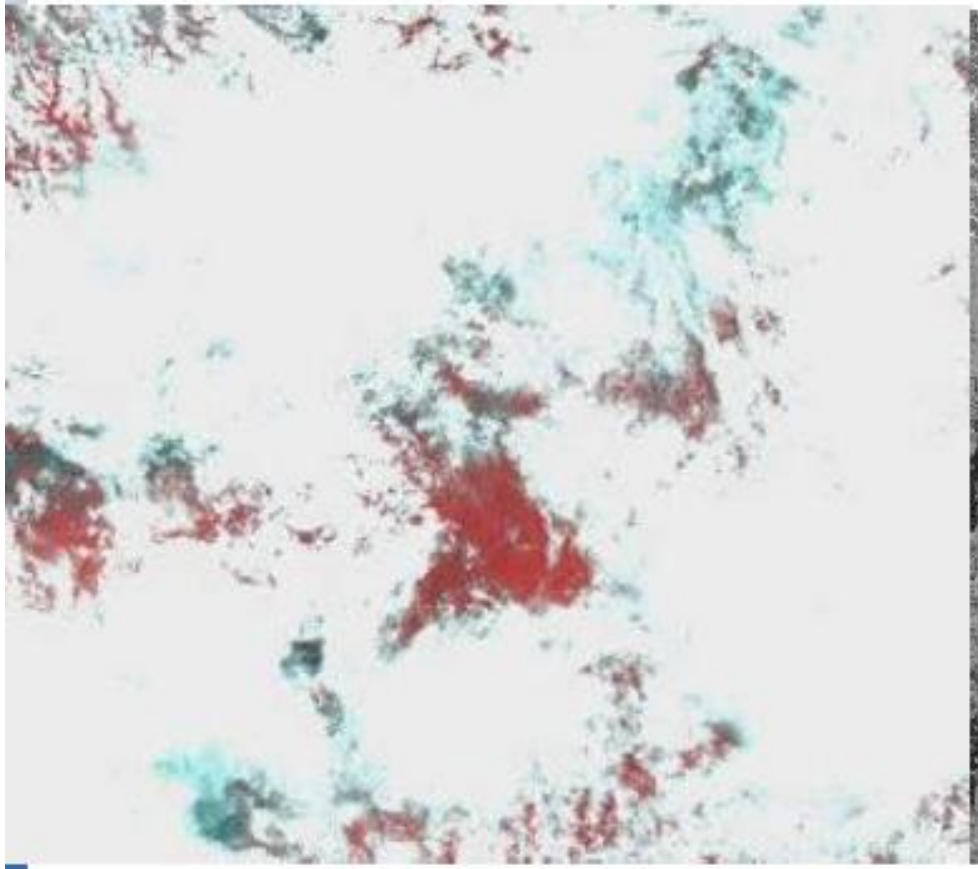


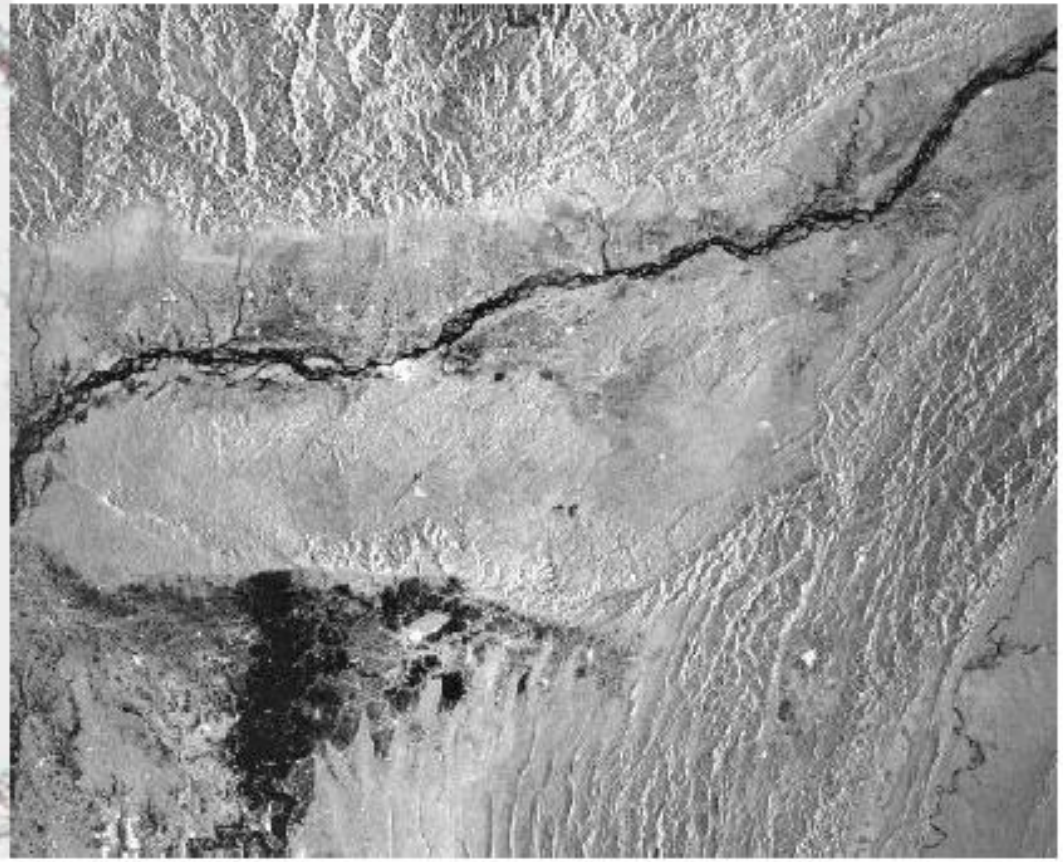


Optical and Microwave SAR data during flood season and cloud cover

Optical image, Clouds everywhere

SAR data penetrates clouds



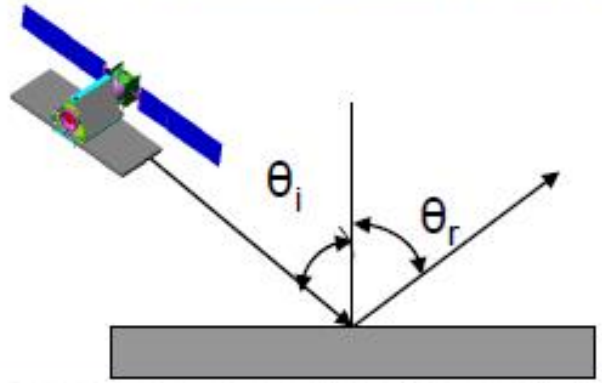


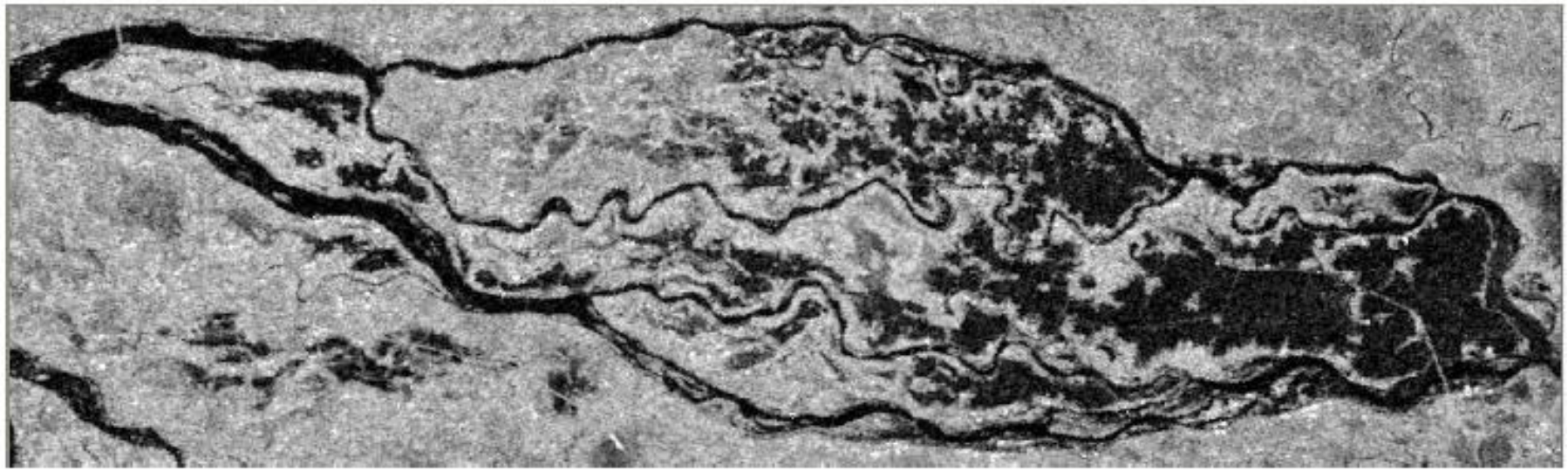
IRS data of 10-Jul-2002

Radarsat data of 10-Jul-2002

Flood Inundation Mapping: Principle

- **Microwave Region**
  - **Due to specular reflectance water appear black**





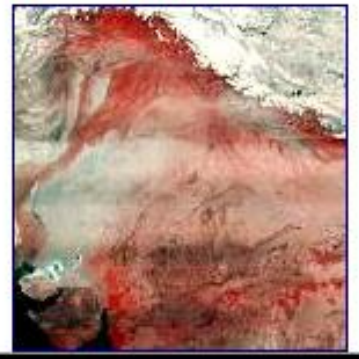
Present Capabilities

High temporal resolution
Large swath

Low spatial resolution
Global level information

- Communication
- Weather

Medium temporal resolution
Large swath



Coarse spatial resolution
Regional level information

- Regional scale flood Mapping, monitoring and assessment

Low temporal resolution
Limited swath

Medium spatial resolution
Local level information

- elements under Flood inundation

Low temporal resolution
Very limited swath

High spatial resolution
Location specific information

Damage Assessment

Depends on
- **Phase of the disaster**
- **Type of the disaster**
- **Extent and severity**

Source: DSC, NRSC Hyderabad

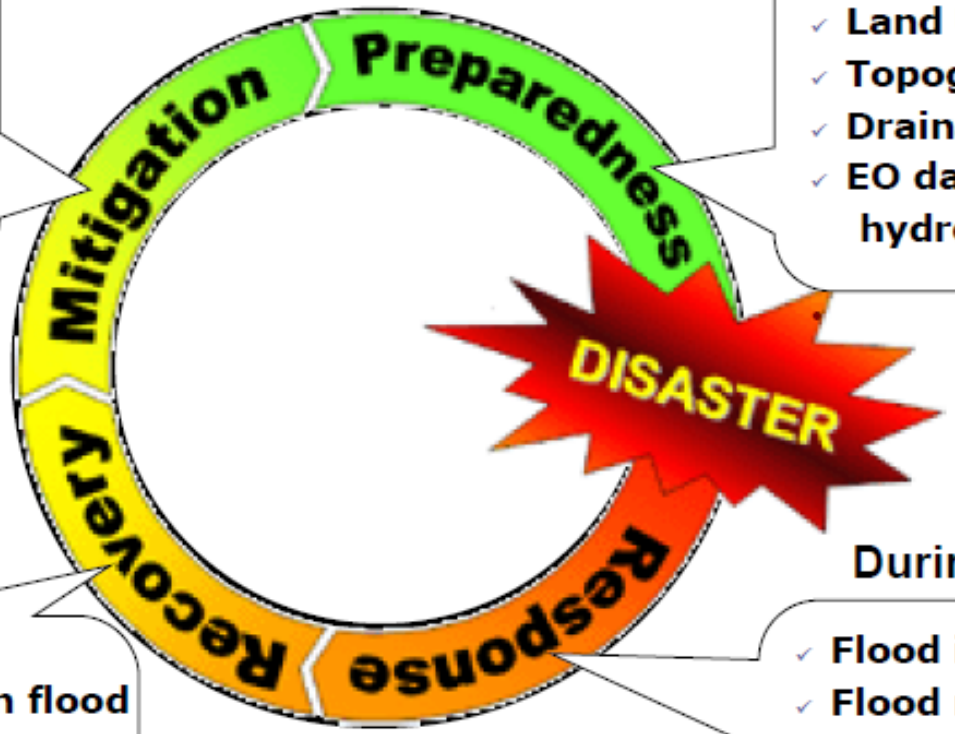
Flood Disaster Phases – Support from EO Systems

Long-term

- Flood Hazard Zoning
- Vulnerability & Risk analyses;
- Public Education
- Location of Shelters

Prior to a disaster

- Precipitation
- Land Use/ Land cover
- Topographic parameters
- Drainage
- EO data supported hydrological simulation



Following a disaster

- Socio economic loss assessment based on flood damages & crowd sourcing
- Rehabilitation & Reconstruction;
- Counseling
- ... 12

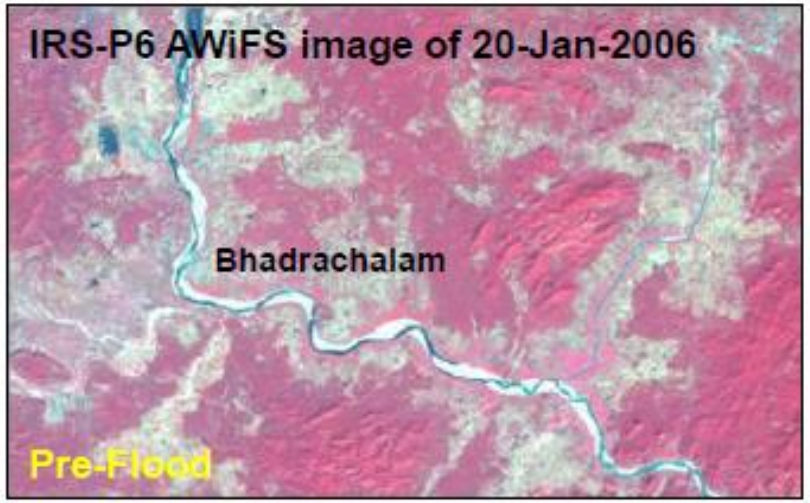
During a disaster

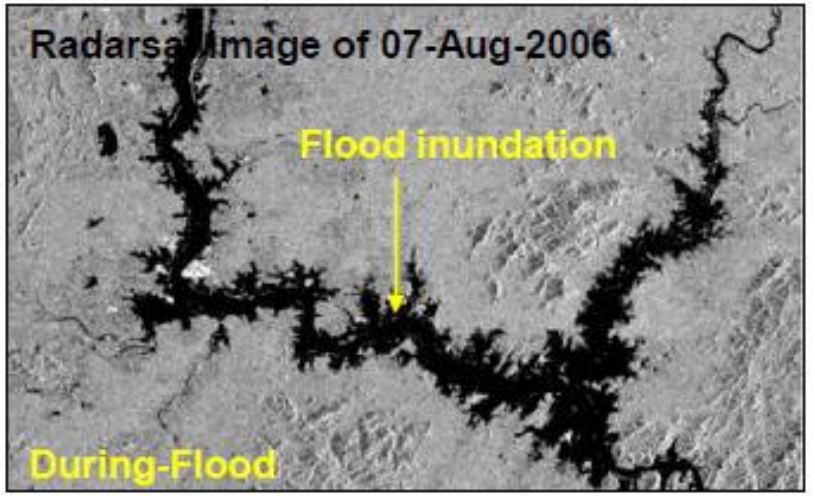
- Flood inundation map
- Flood monitoring
- Infrastructure damage
- Flood evacuation route
- Relief and rescue
- Communication

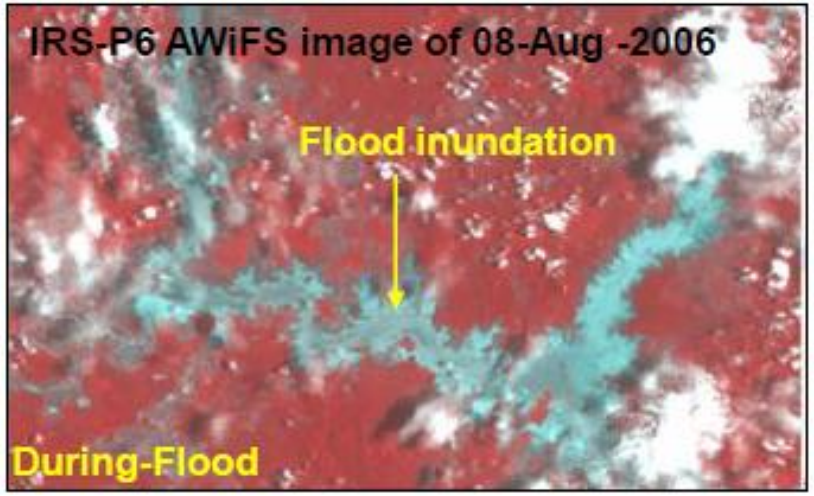
Source: DSC, NRSC Hyderabad

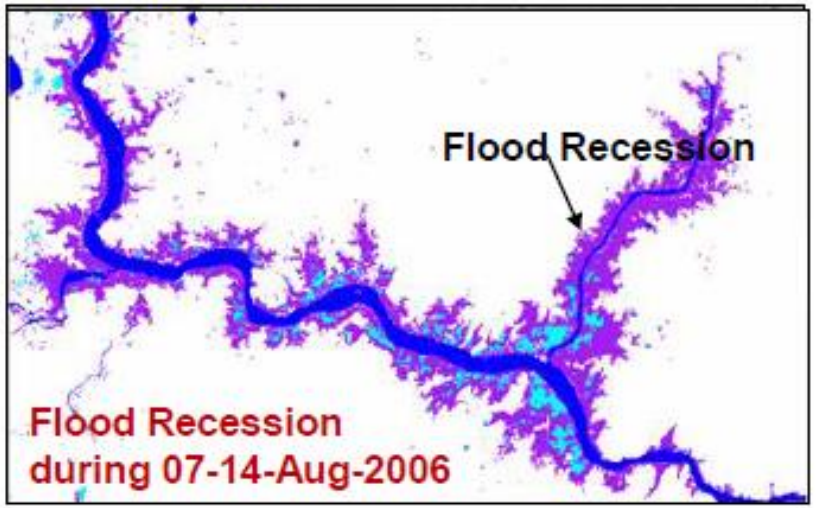
Flood Inundation Mapping

Part of Khammam District









Indian RS satellites in support of flood disaster management

Satellite	Sensor	Spatial Resolution (Meters)	Revisit time (days)	Service period
IRS 1 A/1 B	(LISS-I & LISS-II)	36.5 and 72.5	22	March 1988-1992 August 1991 -1990
IRS 1 C/D	PAN,	5.80,	22	December 1995 - 2001
	LISS 3,	23.5,	22	September 1997 - 2005
	WIFS,	188.	5	
IRS P 3	WiFS	188	5	March 1996 - 2002
RISAT-1	C-band SAR	1-50 m	11 to 90	April 2012 – operating
RISAT-2	X-band SAR	1-5 m		April 2009 - operating
Resourcesat-1	LISS 4,	5.8,	22	October 2003 - operating
& Resourcesat-2	LISS 3,	23.5,	22	
	AWIFS.	56.0.	5	2011 - operating
IRS – P 5 (Cartosat – 1)	Stereo pan	2.5	5	June 2005 - operating
(Cartosat – 2)	Pan	1	5	Jan 2007 - operating

More RS satellites in support of flood disaster management

Satellite	Sensor/instrument	Spatial resolution	Revisit time	Service period
TERRA /AQUA*	MODIS	250, 500, 1000m	2 days	1999/2002-present
IKONOS 1/2	PAN,MS	1m,4m	3 days	1999-present
LANDSAT	ETM+	30m,80m	16 days	1999-present
NOAA*	AVHRR	1-5km	1 day	1978-present
Orbview 2/3	SeaWiFS	1-4m	1 day	1997-2010& 2003-2011
Quickbird	PAN, MS	65cm,1m	1-3.5 days	2001-present
SPOT 1-5	HRG,PAN,MS	10m,2.5m,30m	4-5 days	1978-present
TRMM*	PR, TMI, VIS, LIS	4km	0.5 day	1997-2015
TERRASAR-X	Active X- band Microwave	1m,3m,18m	11 days	2007-present
ENVISAT	ASAR	25-100 m	35 days	2002- 2012
RADARSAT 1	C Band SAR	10-100 m	24 days	1995-2013
RADARSAT 2	C Band SAR	10-100 m	24 days	2007- present
ERS 1, 2	C Band SAR	25 m	24 days	1991-2000 & 1995-2011
Sentinel 1 A/B*	C Band SAR	5-40 m	12 days	2014- present
ALOS -1	PALSAR	10-100 m	46 days	2006-2011
ALOS -2	PALSAR	3-100 m	46 days	2014-present
DMSP*	OLS,SSM/I, SSM/T, SSM/T-2, SSJ/4, SSIES2, SSM, SSB/X and SSZ	2.7 ,174 km	101 min	1995-present

* Free data availability