Application of Remote Sensing Techniques and GIS for Forest Cover Mapping

Meenakshi Joshi, IFS
Joint Director (FGD)
Forest Survey of India
Dehradun
Email: jdnfdmc@fsi.nic.in

A National Organisation with the Mandate of Assessment and Monitoring of Forest Resources of the Country

EVOLUTION OF THE ORGANIZATION

- A National Organization under the MoEF&CC, GOI
- Undertakes Forest Resource Assessment at the National Level
- In service of the Nation since 1965

1965 – PISFR

- Assess availability of raw material for establishment of wood based industries in selected forest rich regions (FAO/UNDP/GOI project)

NCA Report, 1976

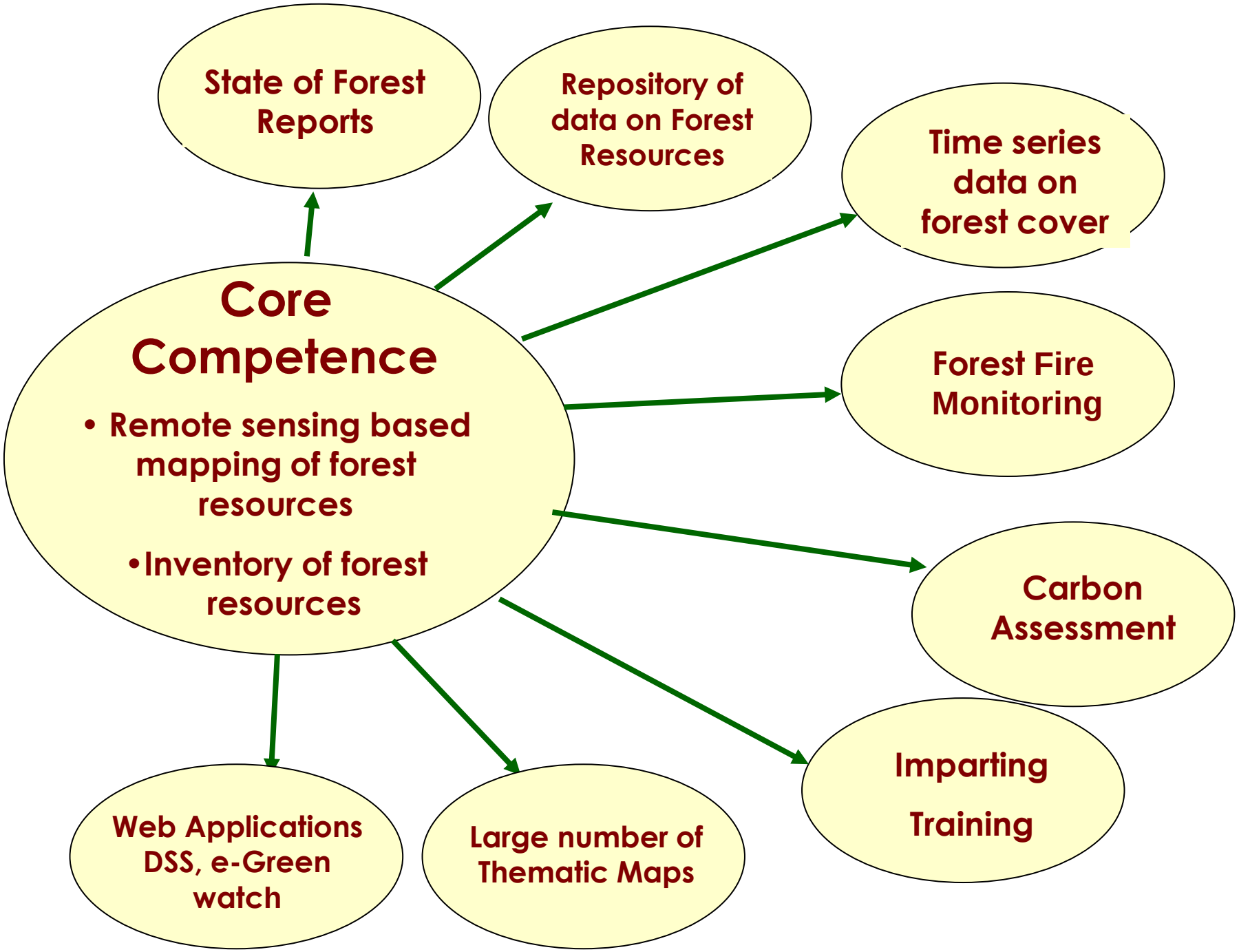
1981 – FSI

- Periodic monitoring of the forest resources
- Serve the data needs of development planning
- Serve as nucleus for the technological advancement and consultancy in the field of forest mapping and inventory
- Training of forestry personnel
- Provide institutional base for international cooperation and training

NRSA Report, 1984

1986 – FSI – New Mandate

- Biennial forest cover mapping & preparation of SFR
- Inventory of forests and trees outside forests
- Impart training to forestry personnel in modern forest survey and inventory techniques
- Support and oversee techniques/inventory work undertaken by State/UT forest department.
- Undertake project based activities of the State Forest Departments and central government organizations.


State of Forest Reports
Repository of data on Forest Resources
Time series data on forest cover
Core Competence
• Remote sensing based mapping of forest resources
• Inventory of forest resources
Forest Fire Monitoring
Carbon Assessment
Imparting Training
Web Applications DSS, e-Green watch
Large number of Thematic Maps

Forest Geoinformatics Division

- ✓ Forest Cover Mapping
- ✓ Forest Fire alert system
- ✓ Forest Type Mapping and Biodiversity assessment
- ✓ E-Green Watch
- ✓ Decision Support System
- ✓ Very High Resolution Data
- ✓ SAR (WIP)
- ✓ Special Projects
- ✓ UAV/Drone (WIP)
- ✓ Legal cases

What is the need of FCM??

- To provide inputs for policy and planning
- Generate data &statistics on forest cover, its changes& density classes for planning and scientific management of forests
- To provide base data for forest carbon assessment in the country
- To provide inputs for international reporting and tracking progress on forestry related parameters
- To monitor progress towards achieving forest policy goals related to forest and tree cover
- Devolution of funds under finance commission
- Broad evaluation of the forest related policies, legislations, programmes and activities across various levels in the country

Definitions

➨ Recorded forest area

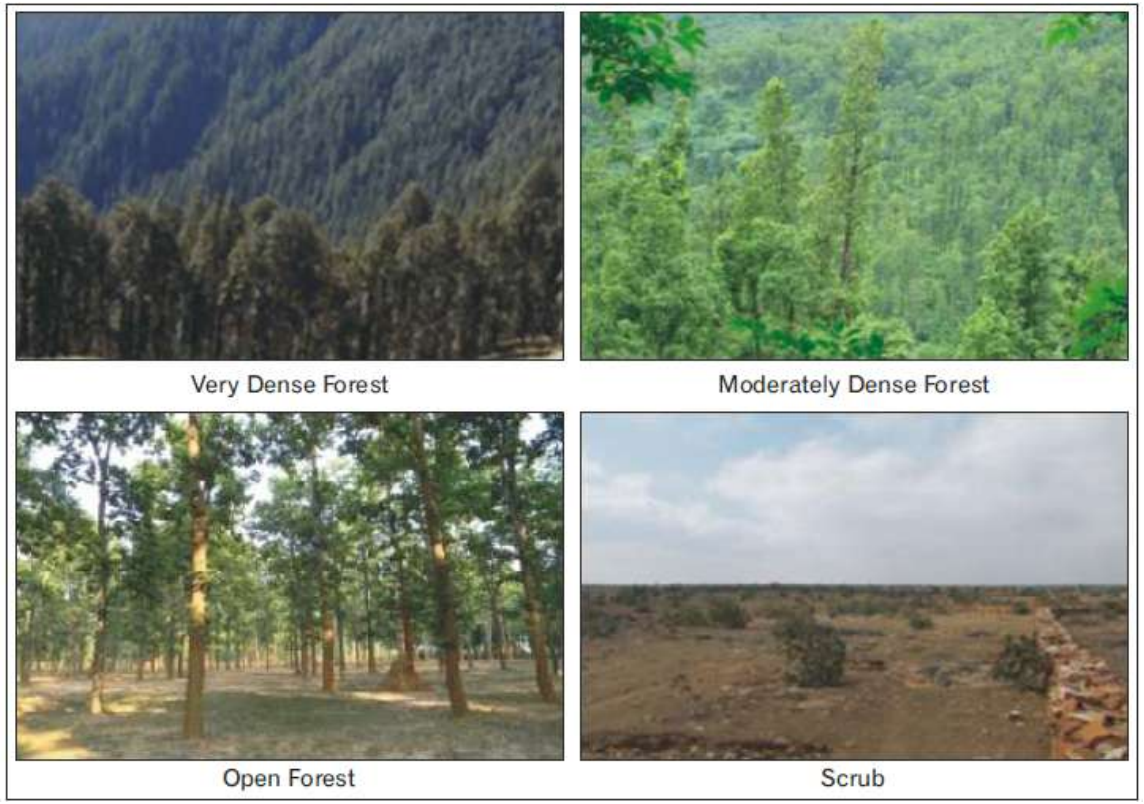
The area recorded as a forest in the government records.

Forest Cover

- ✓ All lands, more than **1 hectare** in area, with a tree canopy density of more than 10 % irrespective of ownership and legal status.
- ✓ Such lands may not necessarily be a recorded forest area.
- ✓ It also includes Orchards, Bamboo and Palm.

CLASS	DESCRIPTION
Very Dense Forest (VDF)	Having canopy density ≥70%
Moderately Dense Forest (MDF)	Having canopy density 40% to <70%
Open Forest (OF)	Having canopy density 10% to < 40%
Scrub	Having canopy density < 10%

Legend



Definitions

Trees Outside Forests (TOF)

Trees growing outside recorded forest areas.

- If tree patch is > 1 ha then it is part of forest cover

Tree Cover

- It comprises of tree patches < 1 ha and upto 0.1 ha.
- Such small patches comprising of block, linear and scattered trees are not delineated as forest cover during interpretation of satellite data.
- The areas of scattered trees are computed by notional numbers.

Linear plantation along Canal

Block plantation

Trees in village woodlots

Trees on Farm Bunds

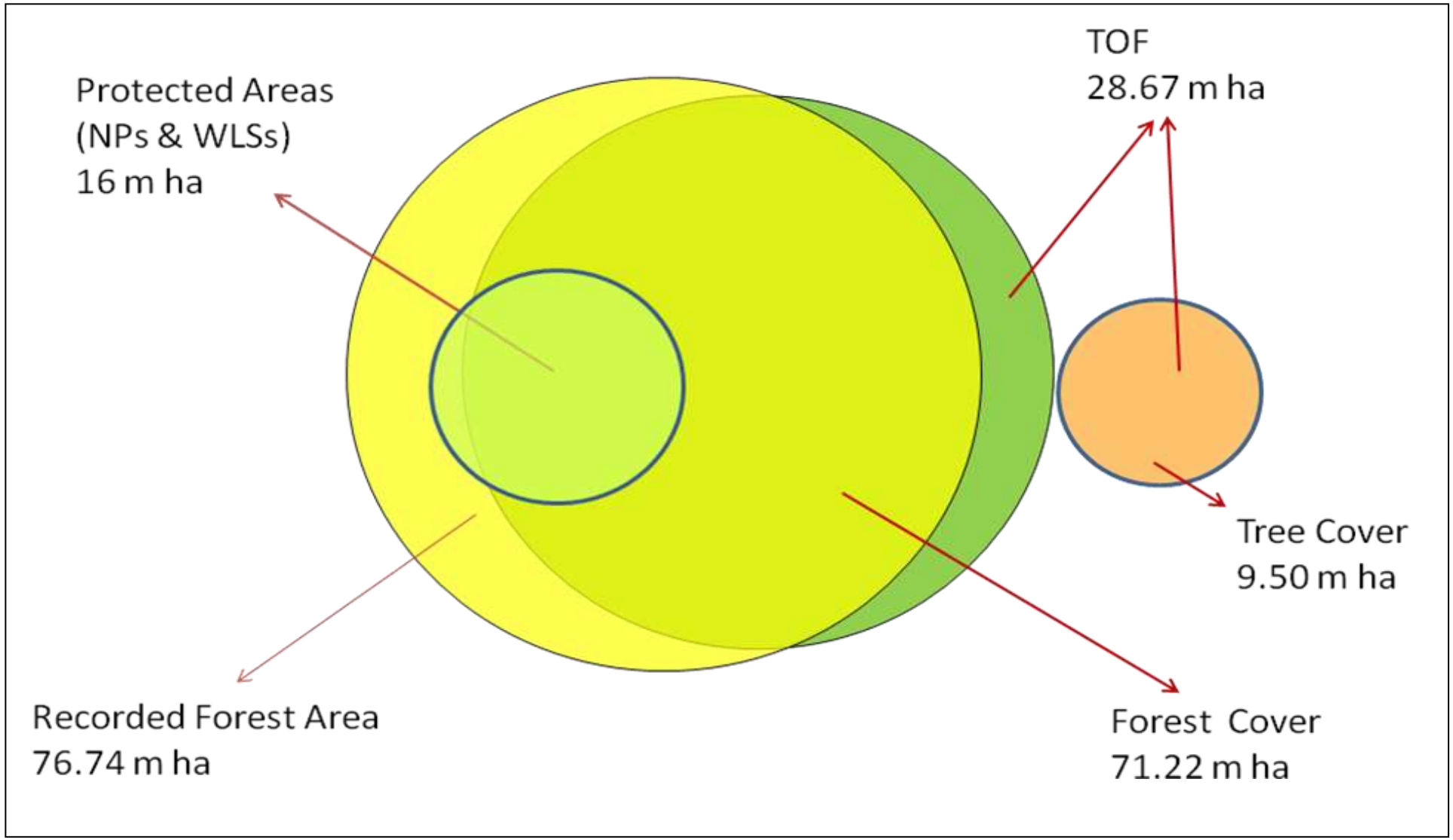
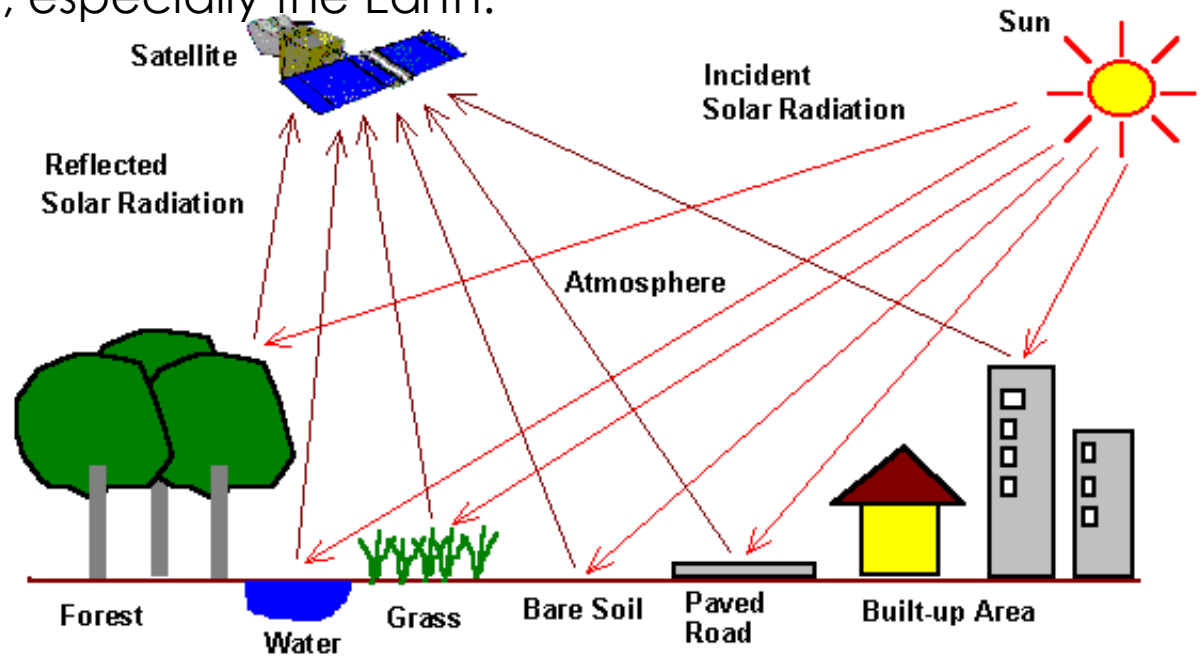


Diagram showing relationship between RFA, Forest Cover, TOF and Tree Cover

Remote Sensing

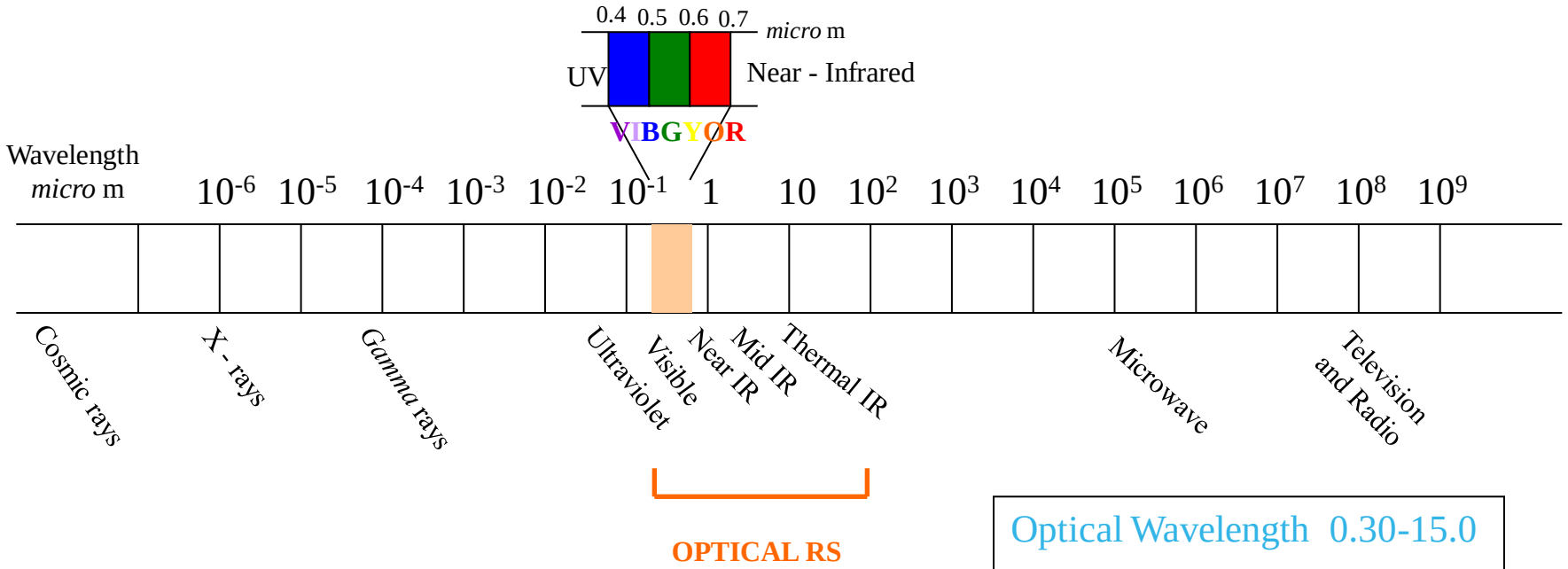
Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation, especially the Earth.



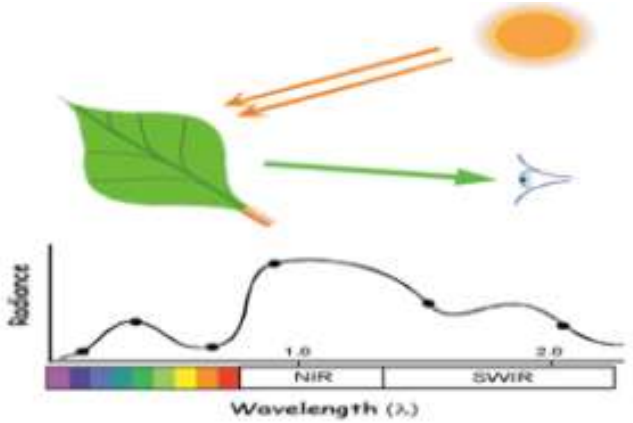
GIS

A geographic information system (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

Electromagnetic Spectrum



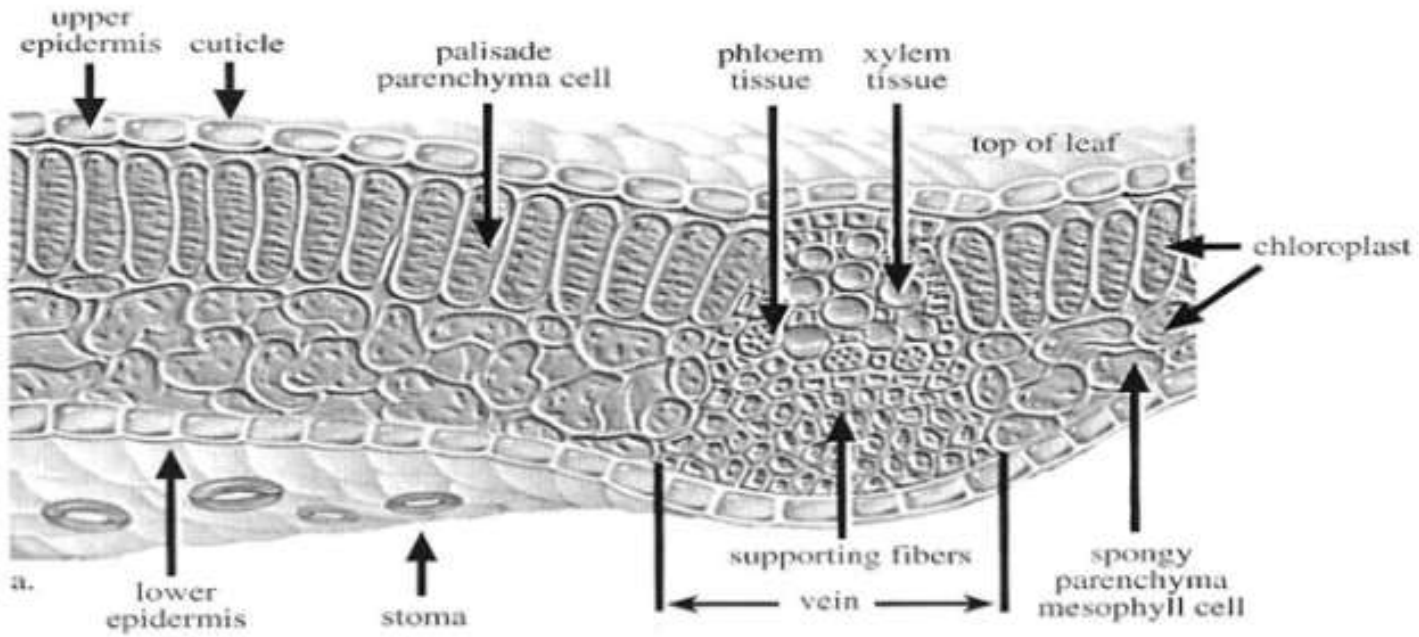
Optical Wavelength	0.30-15.0
Reflective Portion	0.38-3.00
visible	0.38-0.72
near IR	0.72-1.30
middle IR	1.30-3.00
Far IR (thermal)	7.00- 15.0



Vegetation:

Pigment in Plant Leaves (Chlorophyll) strongly absorbs visible light (0.4 to 0.7 μm)

Cell Structure however strongly reflects Near-IR (0.7 - 1.1 μm)



KEY REFERENCE:

Kidwell, K.B., 1990, Global Vegetation Index User's Guide, U.S. Department of Commerce/National Oceanic and Atmospheric Administration/National Environmental Satellite Data and Information Service/National Climatic Data Center/Satellite Data Services Division.

Normalized Difference Vegetation Index (NDVI).

The index compares reflected near-infrared light to reflected visible red light, and is calculated simply with the following equation:

$$NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$$

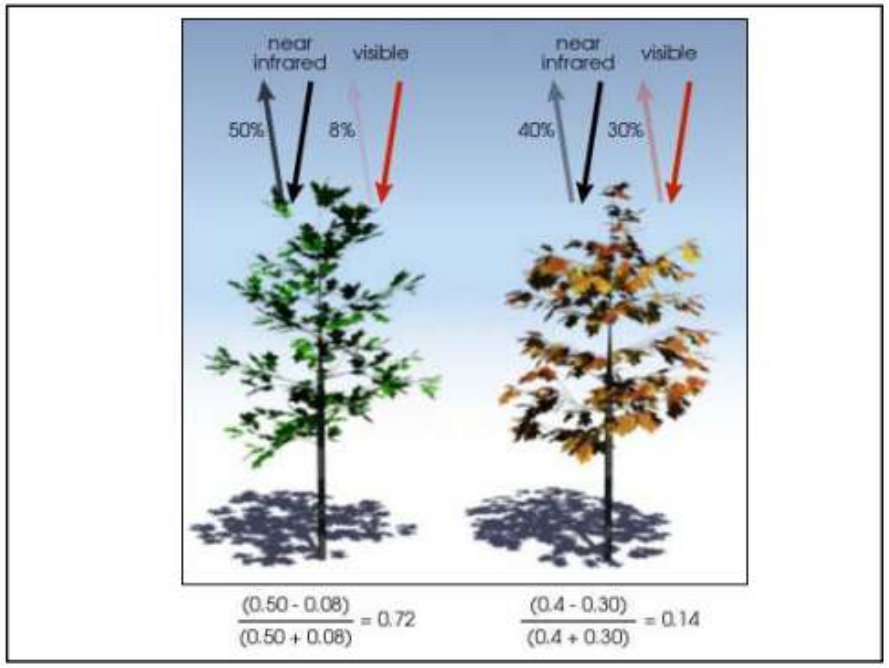
IR 750-1300 nm
Red 600-700nm

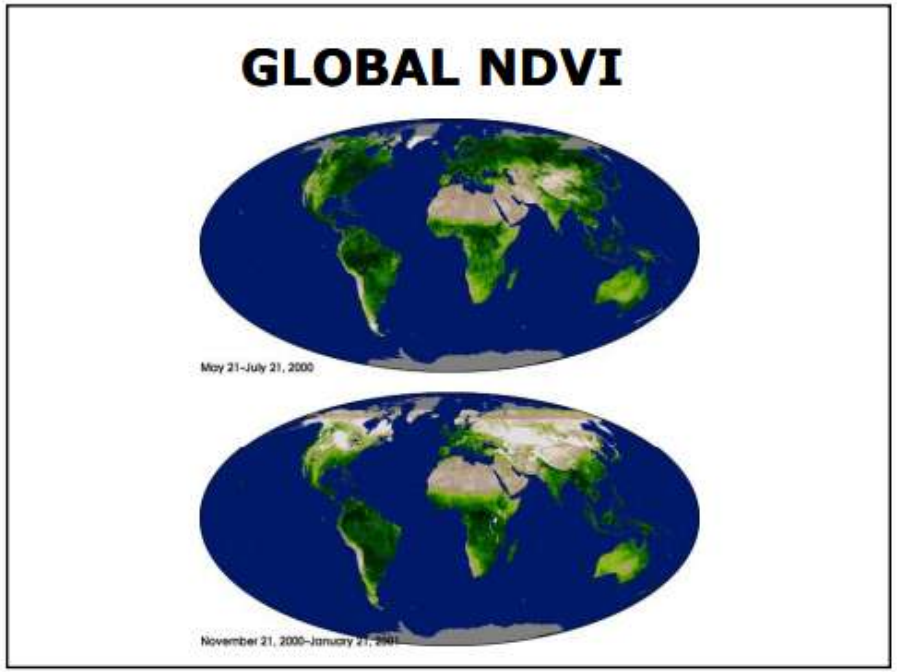
Vegetation reflects high amounts of near-infrared light, so the vegetation index will be greater for images with a greater density of vegetation

The scale for NDVI is -1 to 1, with values near -1 representing water and those near 1 representing dense and healthy vegetation.

What does NDVI measure?

- "greenness" i.e. chlorophyll content
- correlated with biomass
- Water Stress/drought
- Disease /health of vegetation
- Phenology etc





Parameters of Satellite Data

Spatial Resolution :

Measure of the smallest linear separation between two objects that can be resolved by the sensor - length of the side of the area on the ground represented by a pixel.

Spectral Resolution :

Number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive.

Temporal Resolution :

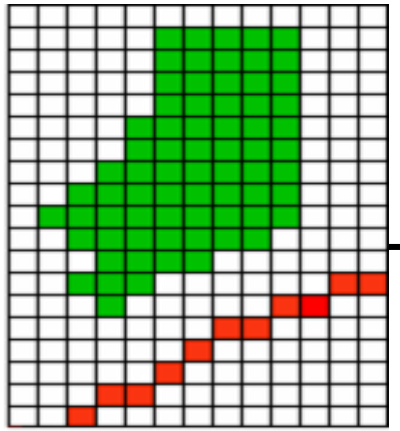
It refers to how often a sensor records imagery of a particular area.

Radiometric Resolution :

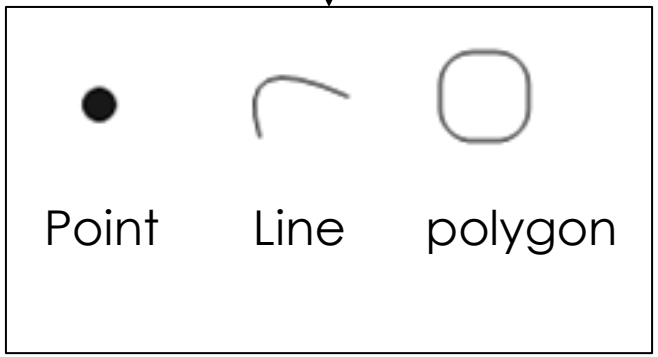
The capability to differentiate the spectral reflectance from various objects - number of quantization levels within the spectral bands.

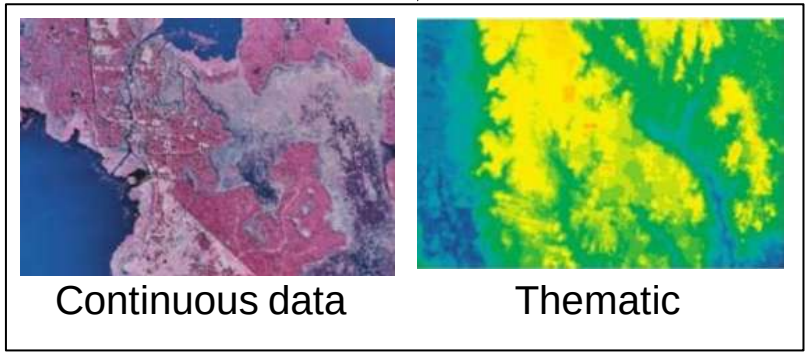
Types of Spatial Data

Vector

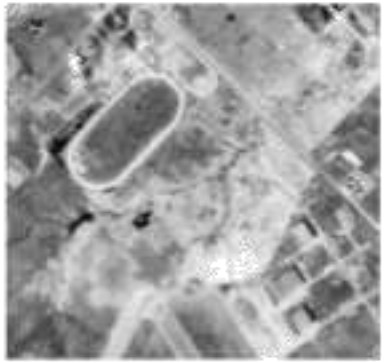


Raster





Elements of Image Interpretation

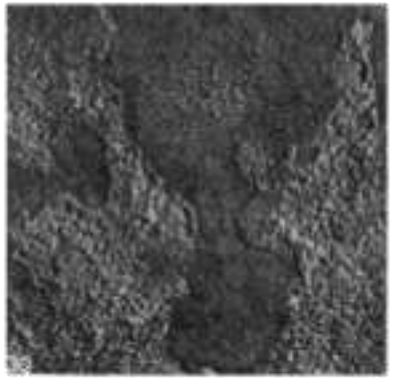


Shape
(depends on the object outline)

Size
(relative to one an other)

Tone
(brightness-hue, color)

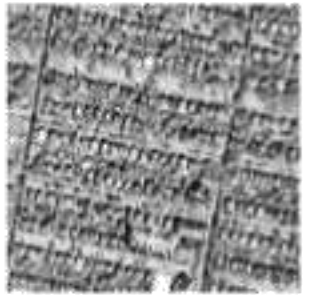
Site
(location helps recognition)



Texture
(smooth or coarse)

Shadow
(helps to determine height)

Association
(features that are normally found near object)



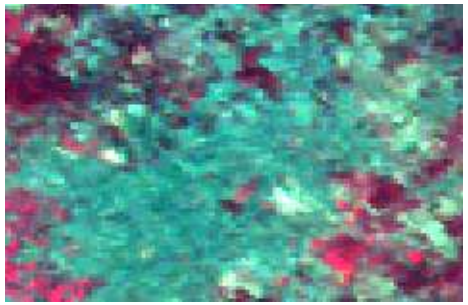
Pattern

Tone and Texture of some Common Features

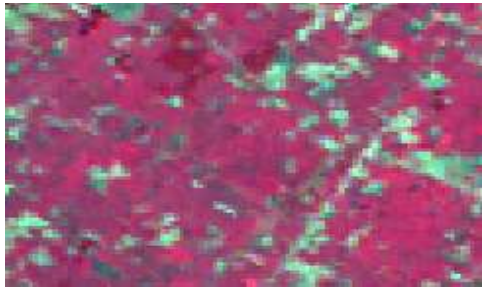
Dense Forest

River

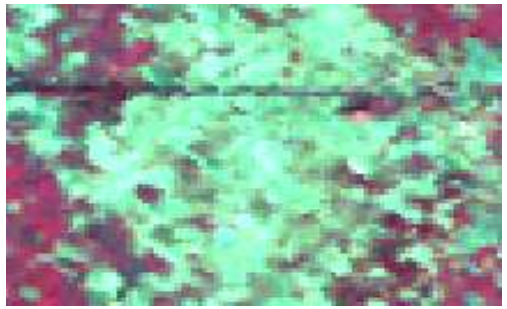
Water Body



Settlement

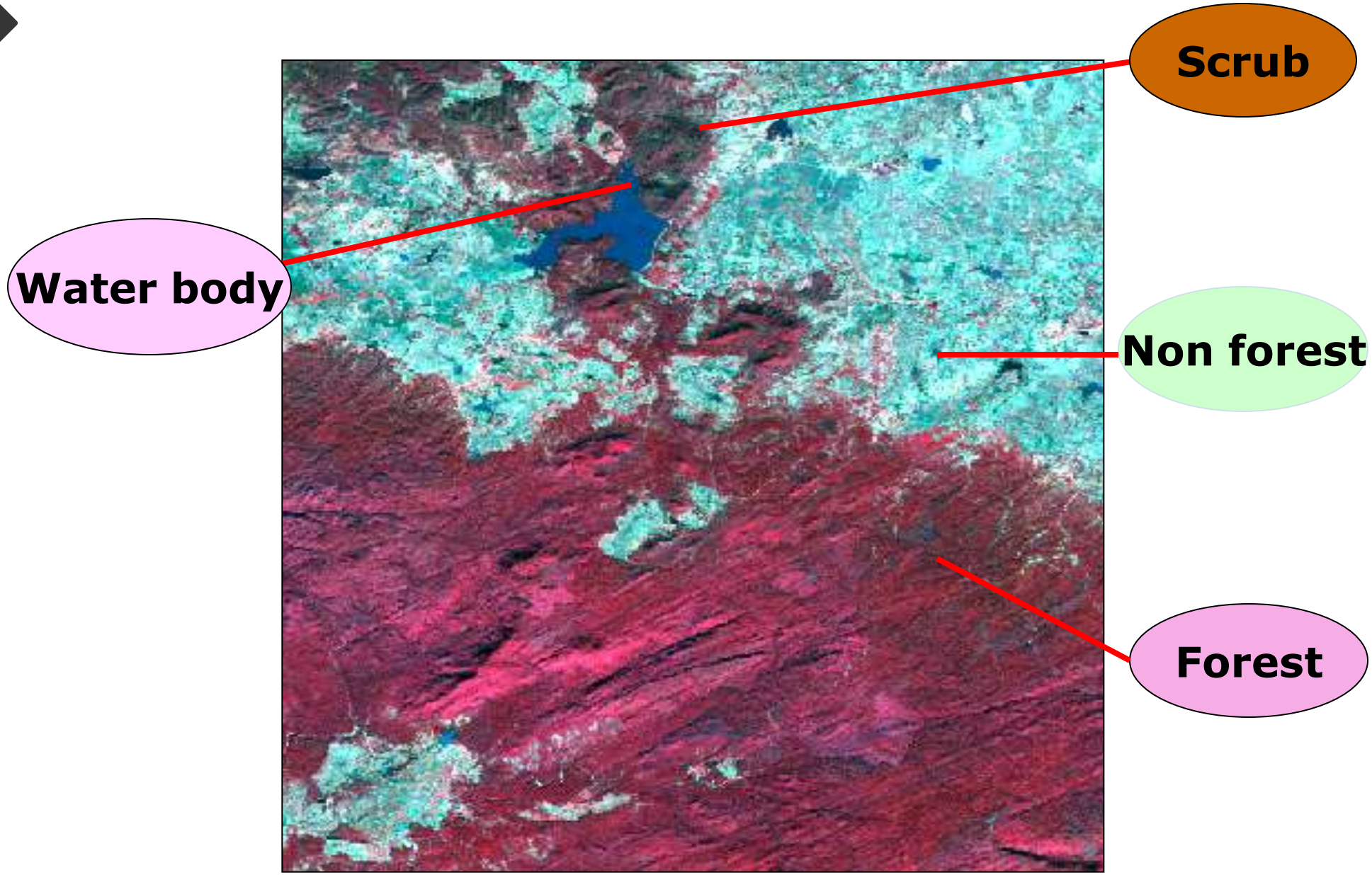


Agriculture



Fallow Land

Satellite Imagery

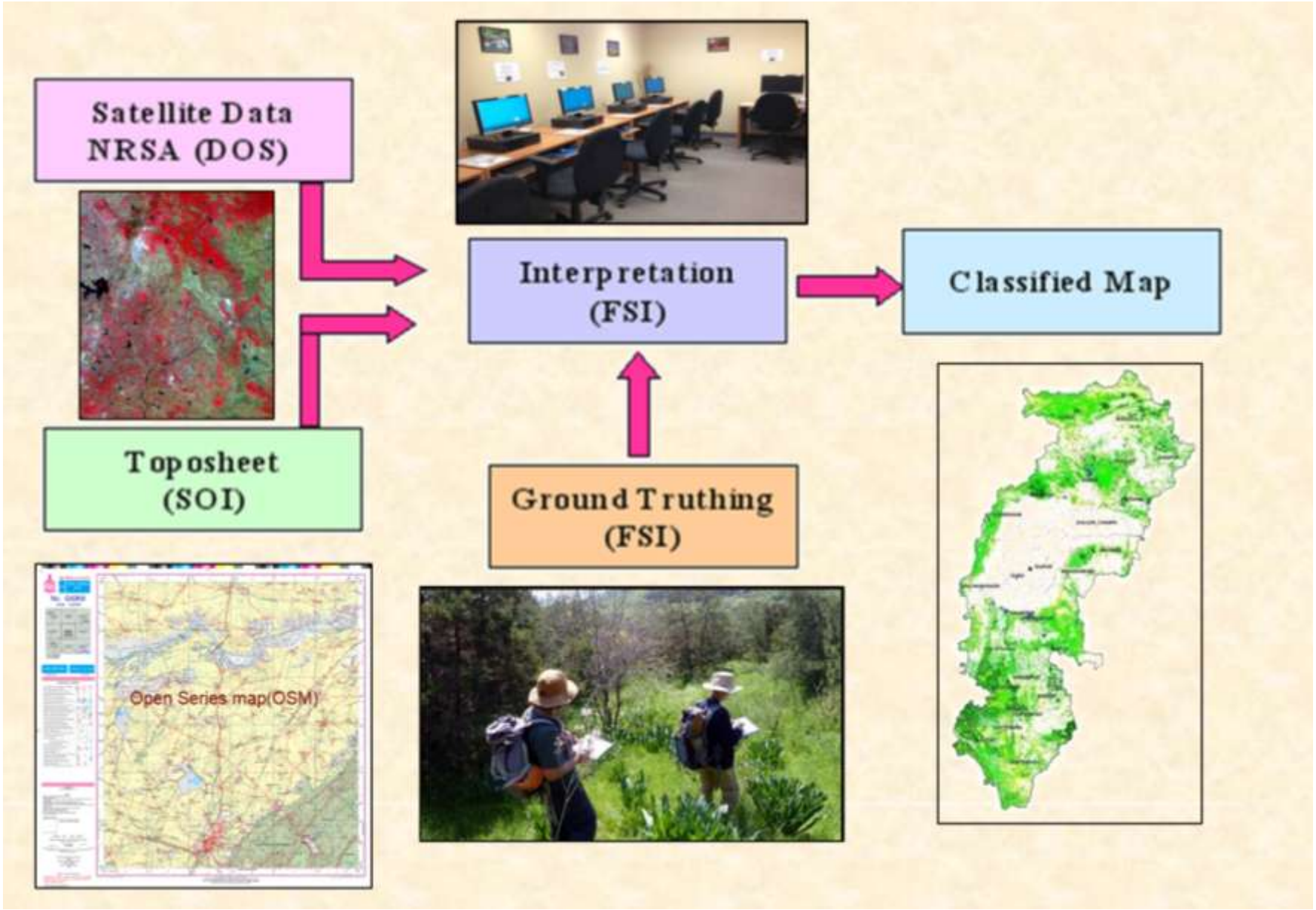


Timeline of Forest Cover Mapping

Cycle of Assessment	Year	Data Period	Sensor	Spatial Resolution	Scale	Minimum Mapping Unit (ha)	Mode of Interpretation
I	**1987**	**1981-83**	**LANDSAT MSS**	**80 m**	**1:1 million**	**400**	**Visual**
II	**1989**	**1985-87**	**LANDSAT TM**	**30 m**	**1:250,000**	**25**	**Visual**
III	1991	1987-89	LANDSAT TM	30 m	1:250,000	25	Visual
IV	1993	1989-91	LANDSAT TM	30 m	1:250,000	25	Visual
V	**1995**	**1991-93**	**IRS-1B LISS II**	**36.25 m**	**1:250,000**	**25**	**Visual & Digital**
VI	1997	1993-95	IRS-1B LISS II	36.25 m	1:250,000	25	Visual & Digital
VII	**1999**	**1996-98**	**IRS-1C/1D LISS III**	**23.5 m**	**1:250,000**	**25**	**Visual & Digital**
VIII	**2001**	**2000**	**IRS-1C/1D LISS III**	**23.5 m**	**1:50,000**	**1**	**Digital**
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
X	2005	2004	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
XI	**2009**	**2006**	**IRS-P6 LISS III**	**23.5 m**	**1:50,000**	**1**	**Digital**
XII	2011	2008-09	IRS-P6 LISS III & IRS-P6 AWiFS	23.5 m 56 m	1:50,000	1	Digital
XIII	2013	2010-12	IRS P6 LISS III IRS-Resourcesat2 LISS III	23.5 m	1:50,000	1	Digital
XIV	2015	2013-14	"	"	"	"	"
XV	**2017**	**2015-16**	"	"	"	"	"
XVI	**2019**	**2017-18**	"	"	"	"	"

FSI's approach for Forest Cover Mapping

- Biennial Wall-to-wall mapping on 1:50,000 scale using IRS Resourcesat 2 Satellite data
- 306 scenes each covering approx. 20,000 sq km
- Forest cover information up to district level
- Marked improvement in the methodology (yet compatible with previous assessments)



Satellite Data Requirements

Resourcesat-2/IRS P6	:	**LISS III/LISS-IV**
Spatial Resolution	:	**23.5 mt.**
Swath	:	**141 x 141 (Sqkm)**
No. of scenes used	:	**316**
Scale of mapping	:	**1:50,000**
ERDAS Imagine	:	**2011/13**
Data Period	:	**2017-18**

Satellite data of only a limited period of the year is suitable for forest cover assessment.

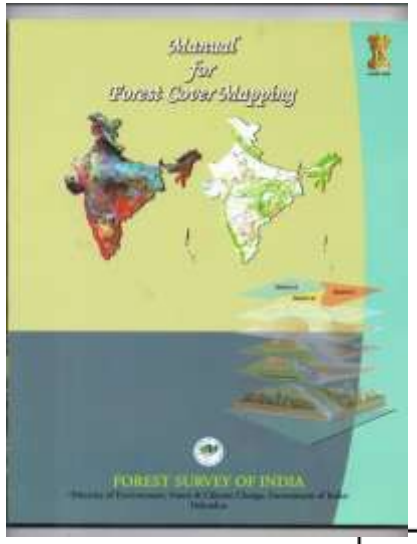
- Period preferred: October to December
- Leaflessness in summer season
- Clouds in rainy season
- Shadows

Advantages

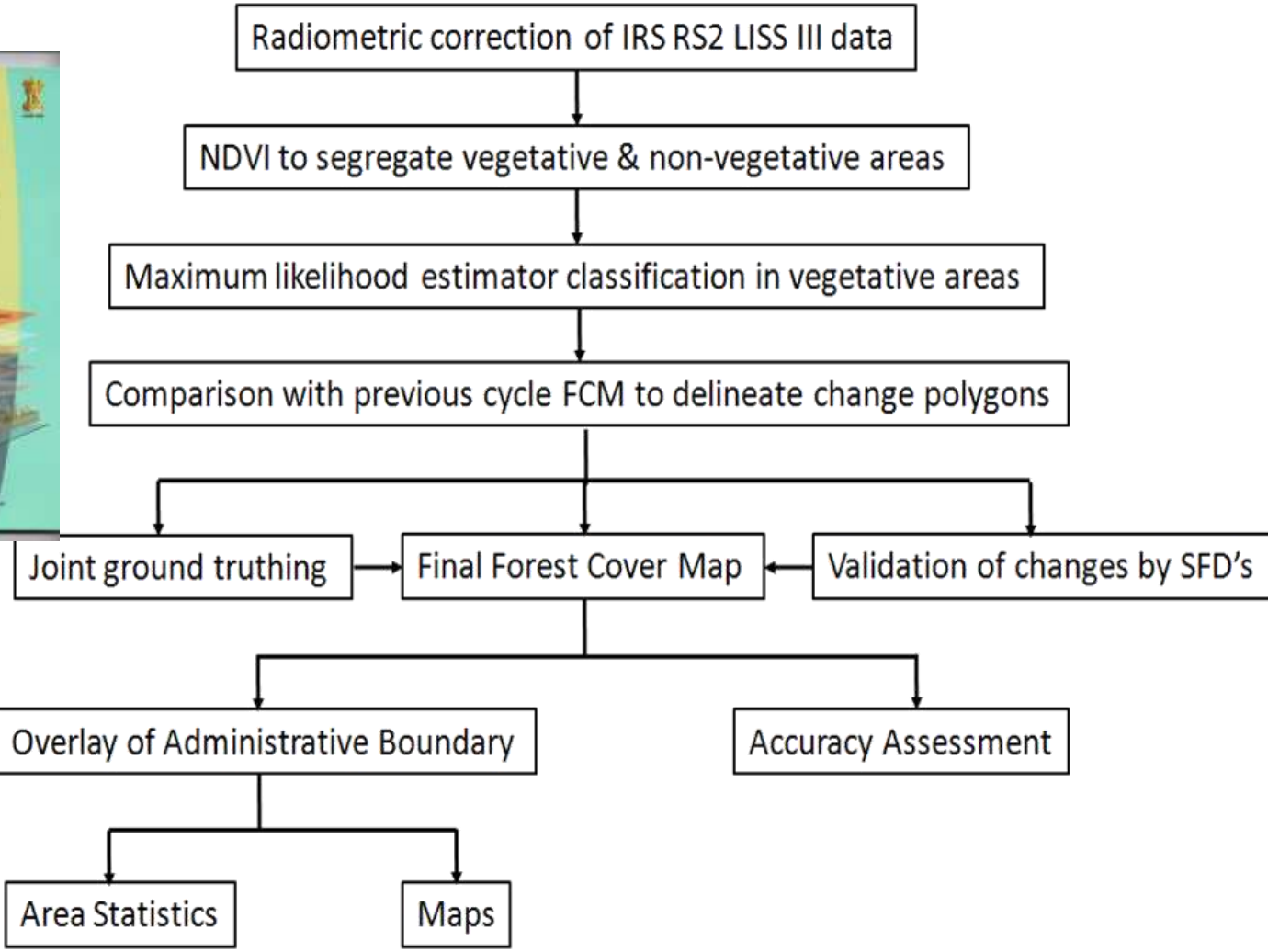
- Unobtrusive
- Systematic- removes sampling bias
- Large geographic areas
- Cheaper
- Faster

Steps involved in Forest Cover Classification

1. Data Browsing (Biennial data, Data period , Data quality)
2. Data Ordering (With NDC, NRSC)
3. Geometric Correction(Geo-Referencing)
4. Digital Image Processing
5. Sheet-wise classification/change detection
6. Ground Truthing
7. Post field corrections
8. Change maps generation
9. Edge Matching
10. Calculation of area statistics, QC&QA, error matrix
11. Finalizing the area figures
12. Report preparation

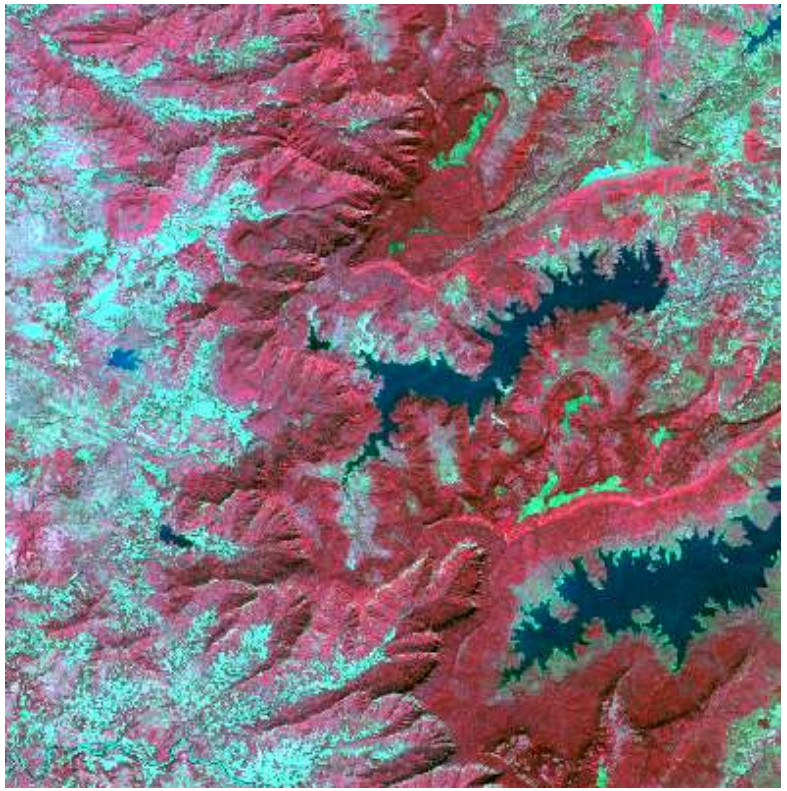


FCM-Methodology



Geometric Correction

(Using SOI toposheet)



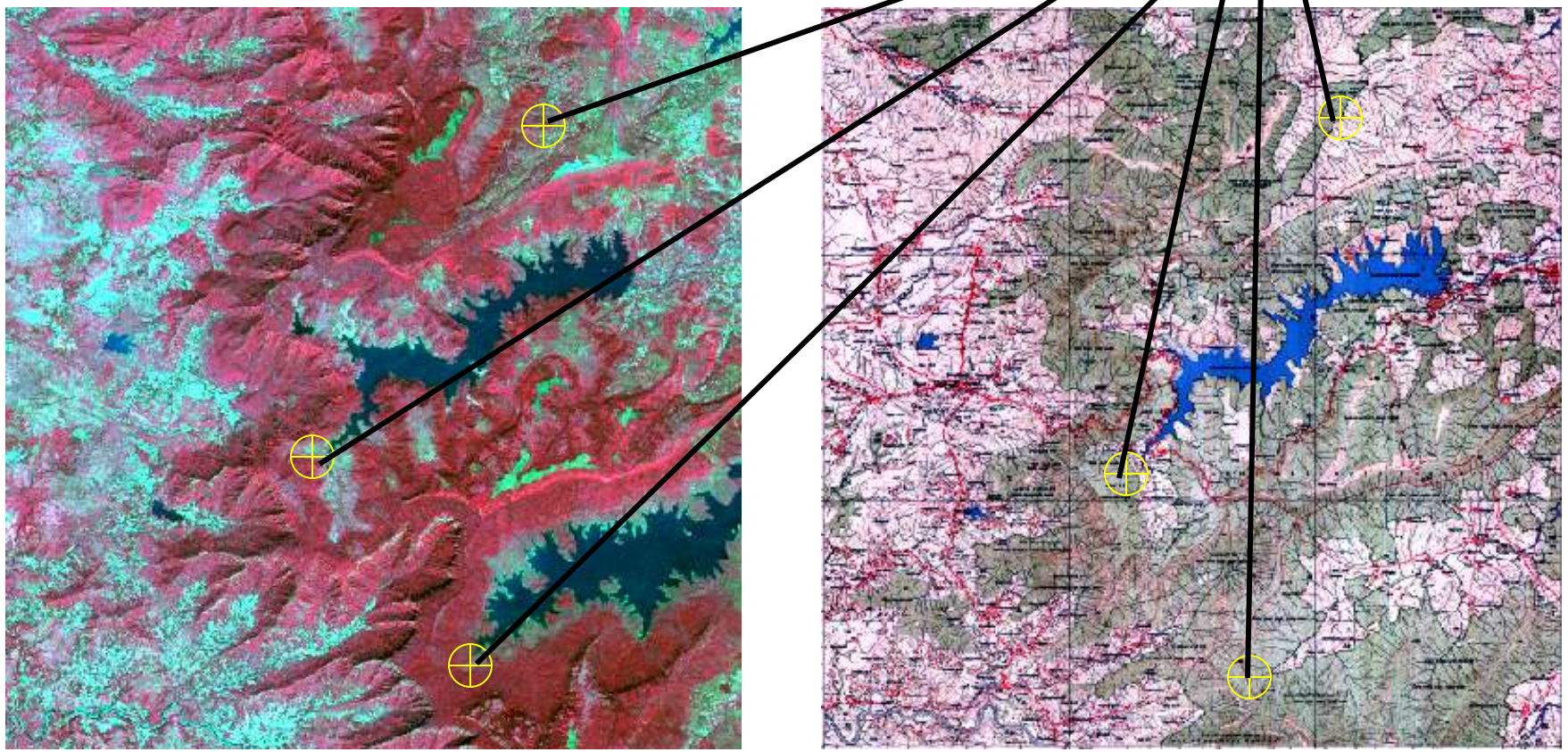
About 50 GCPs are recommended

RMS error < 0.5

Projection/Re-projection : Geographic (lat-long)/UTM

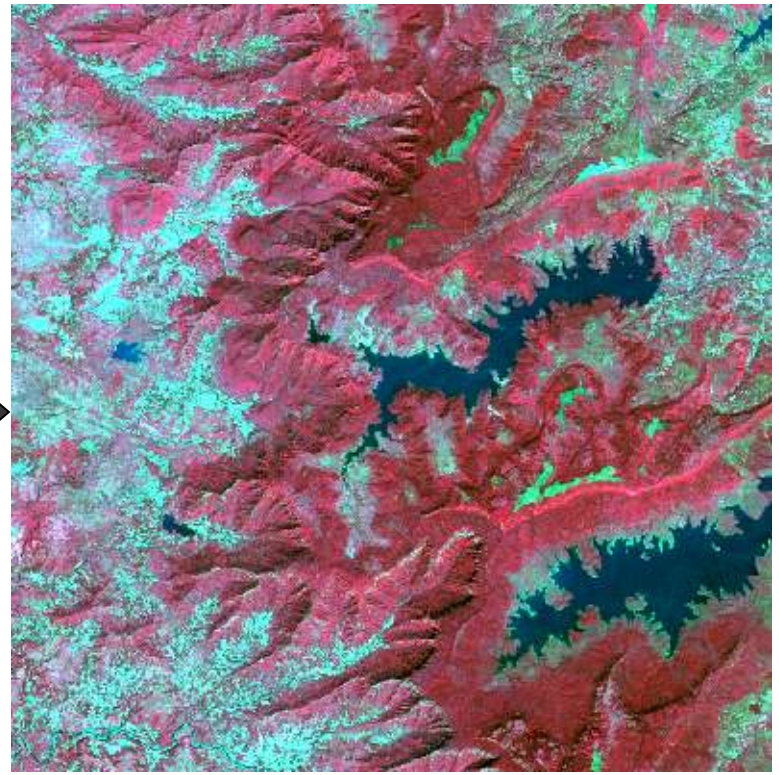
Datum : Indian (Bangladesh)/WGS 84

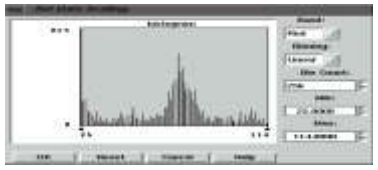
Geometric Rectification of Raw Scene with the help of toposheets



- **Contrast Enhancement**

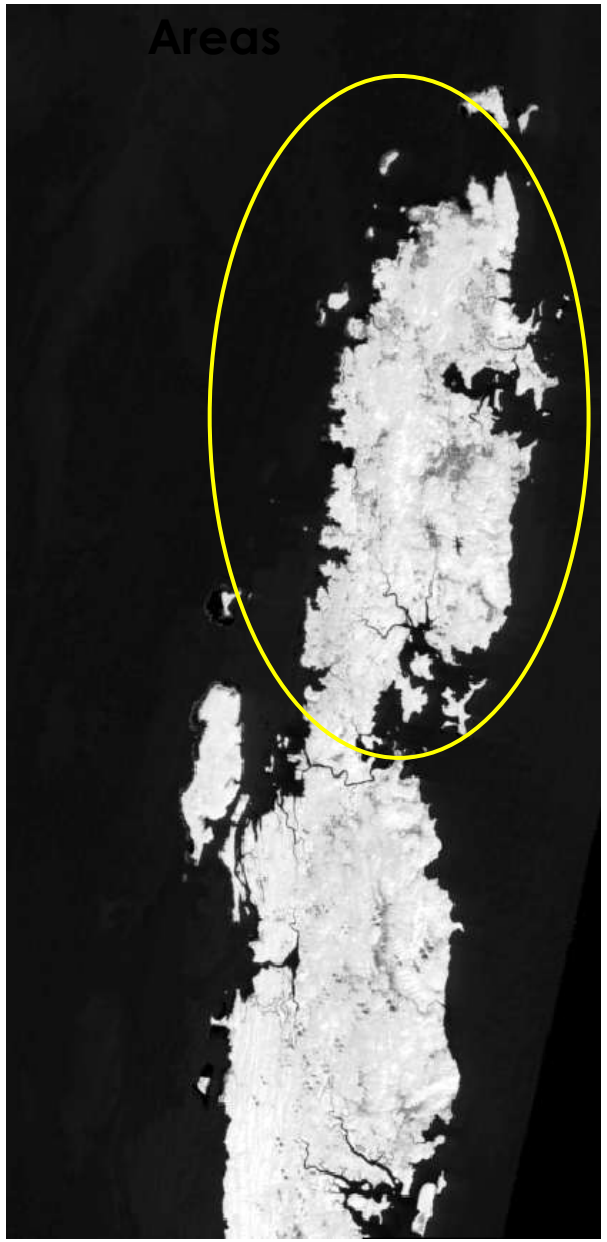
  - to improve visual impact of the imagery





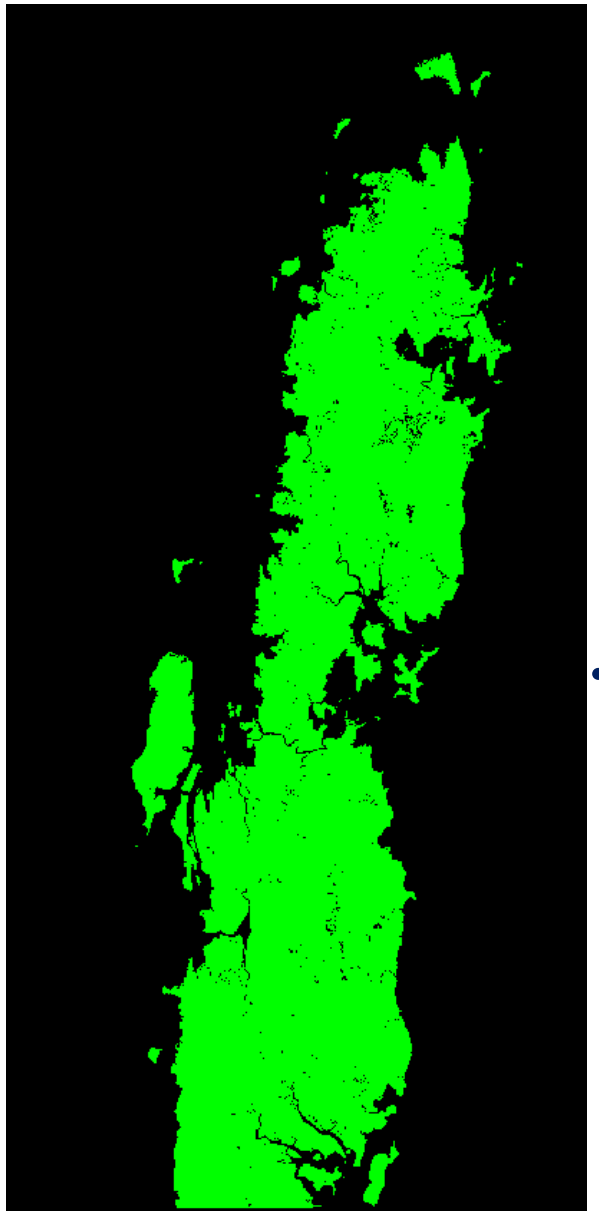
- Histogram equalization
- Standard deviation stretch
- LUT contrast stretch

NDVI Transformation of Satellite Data for segregation of Vegetated and Non-Vegetated Area

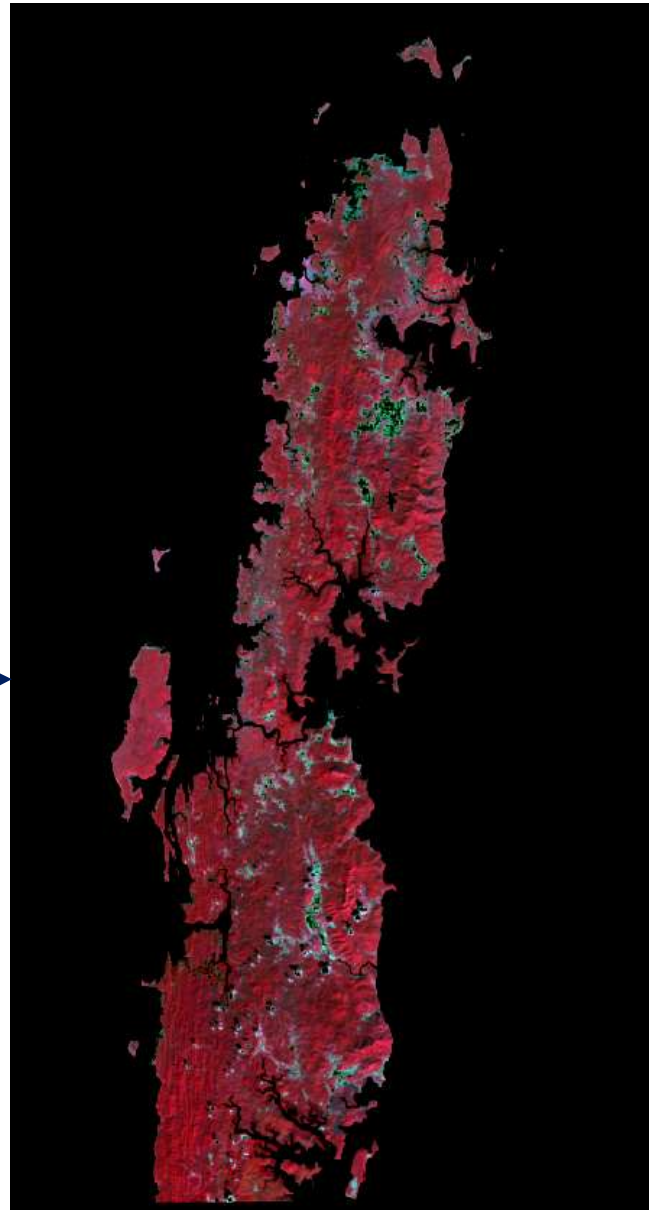


16th Cycle NDVI Imagery of A &N Islands

The lighter region shows the Vegetated Part of the Imagery

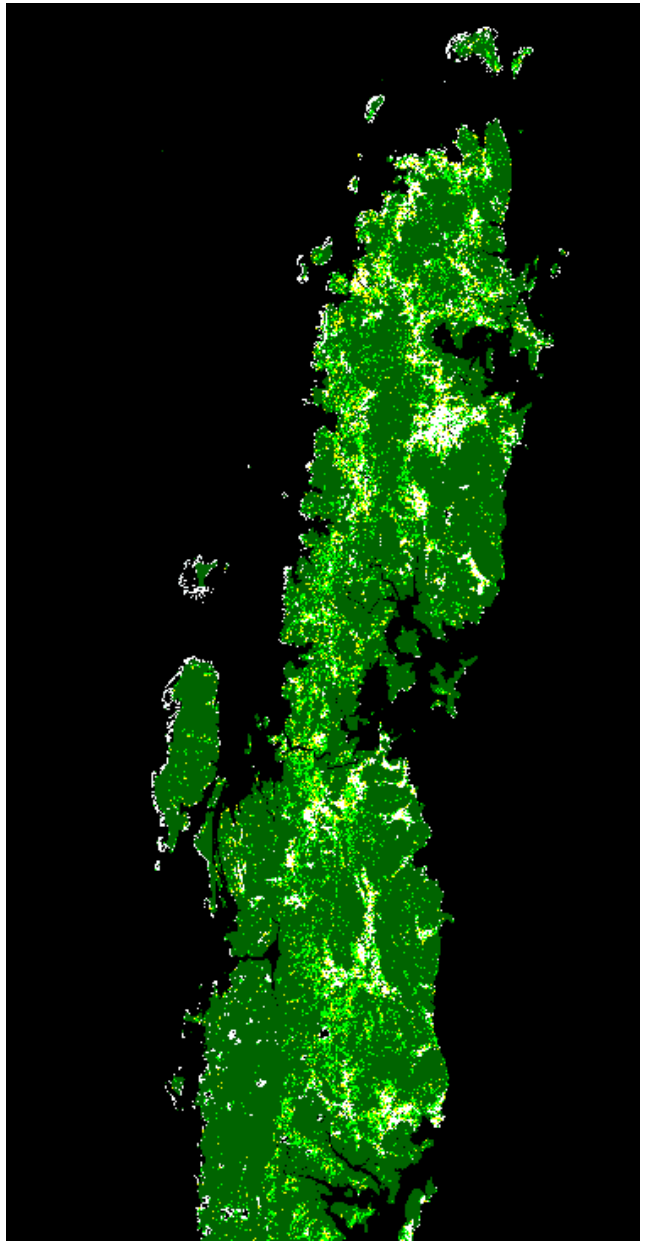


16th Cycle Mask File for Culling out Vegetated Part



16th Cycle FCC after masking out Vegetated Part

Classification of Satellite Imagery using Unsupervised Classification



16th Cycle Unsupervised Imagery (A&N Islands)

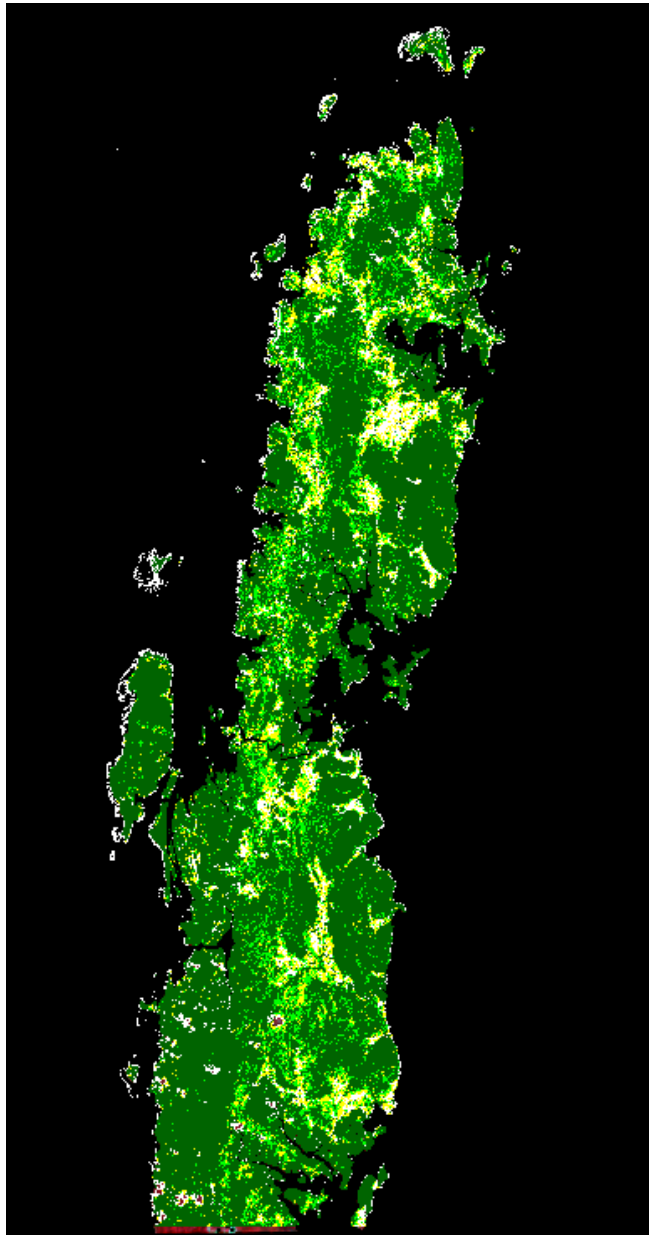
Raster Attribute Editor - unsup_30_

File Edit Help

Layer N

Row	Class Names	Color
0	Unclassified	
1	Water	
2	Water	
3	Water	
4	NF	
5	MDF	
6	VDF	
7	VDF	
8	VDF	
9	MDF	
10	MDF	
11	MDF	
12	MDF	
13	MDF	
14	Scrub	
15	OF	
16	TOF Open	
17	OF	
18	MDF	
19	MDF	
20	OF	
21	OF	
22	OF	
23	NF	
24	NF	
25	NF	
26	TOF Dense	
27	NF	
28	NF	
29	NF	
30	NF	

Recoded Image



Raster Attribute Editor - reco_58e_unsup30.img(:Layer_1)

File Edit Help

Row	Class Names	Color	Histogram	Red	Green	Blue	Opacity
0			0	0	0	0	0
1			0	1	1	1	1
2	VDF		461112	0	0.392157	0	1
3	MDF		1890293	0	1	0	1
4	OF		1186566	1	1	0	1
5	SCRUB		227236	1	0	0	1
6	TOF VD		146182	1	0.752941	0.796078	1
7	TOF MD		352165	0.627451	0.12549	0.941176	1
8			0	1	1	1	1
9			0	1	1	1	1
10			0	1	1	1	1
11			0	1	1	1	1
12	WATER		266644	0	0	1	1
13	NON FOREST		1050889	1	1	1	1

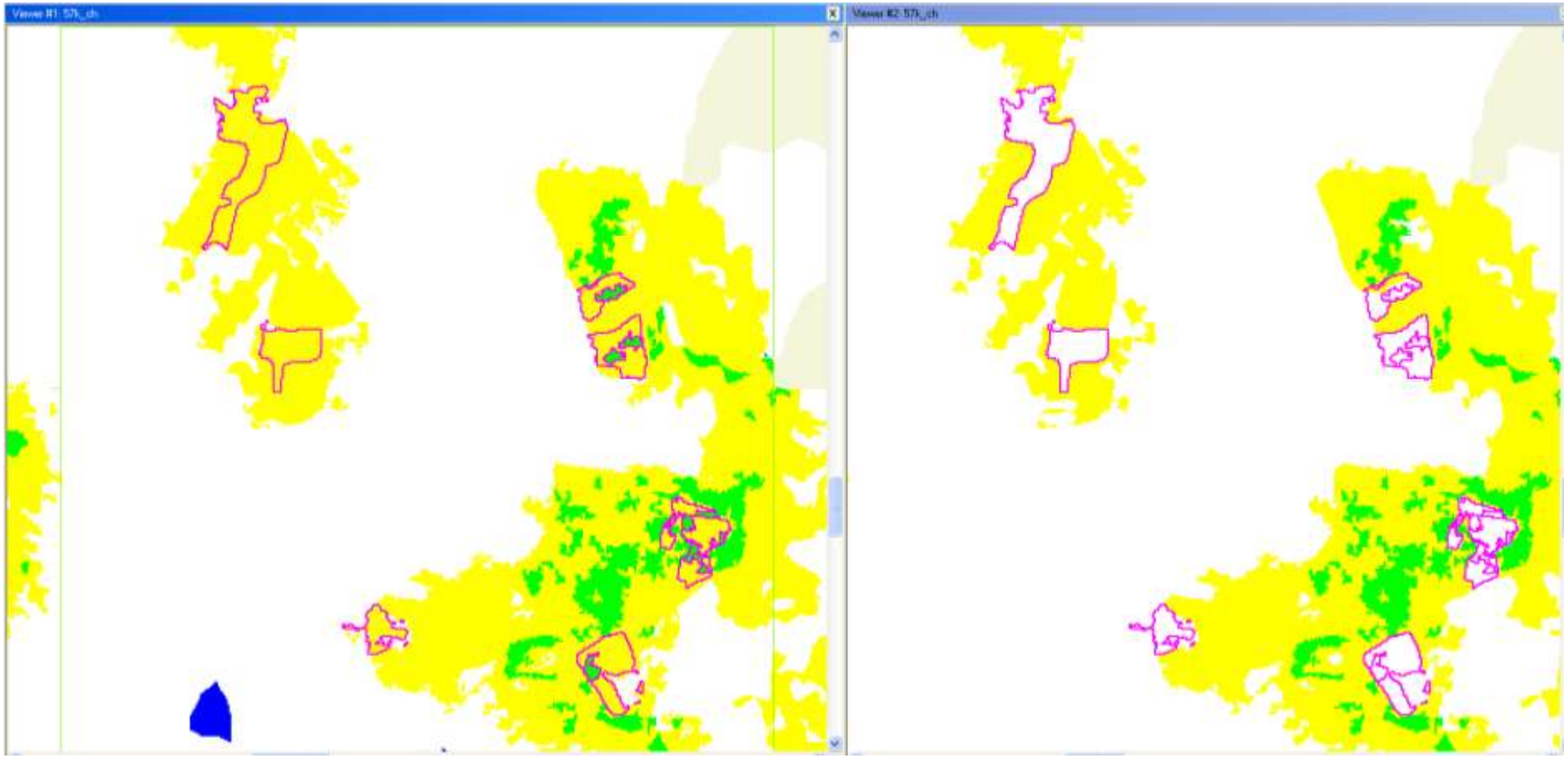
16th Cycle Supervised (Final Classified) Imagery

Change Detection between two successive Assessment Periods(FCC)

State : Karnataka , District : Kolar, Sheet No. : 57K

Changes observed in satellite imagery b/w two cycle

Change Detection (Classified)



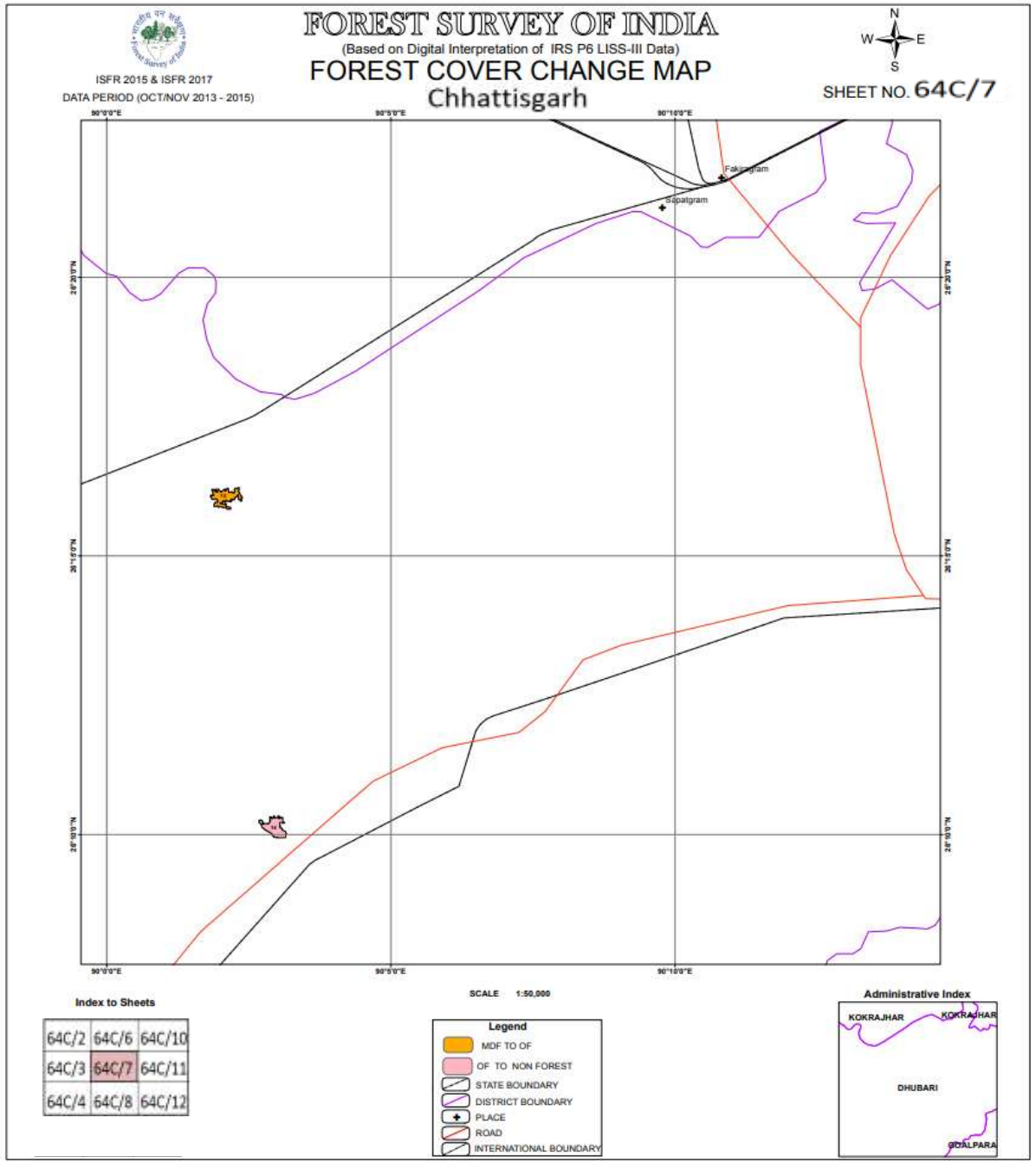
Changes made in classified image b/w two cycles

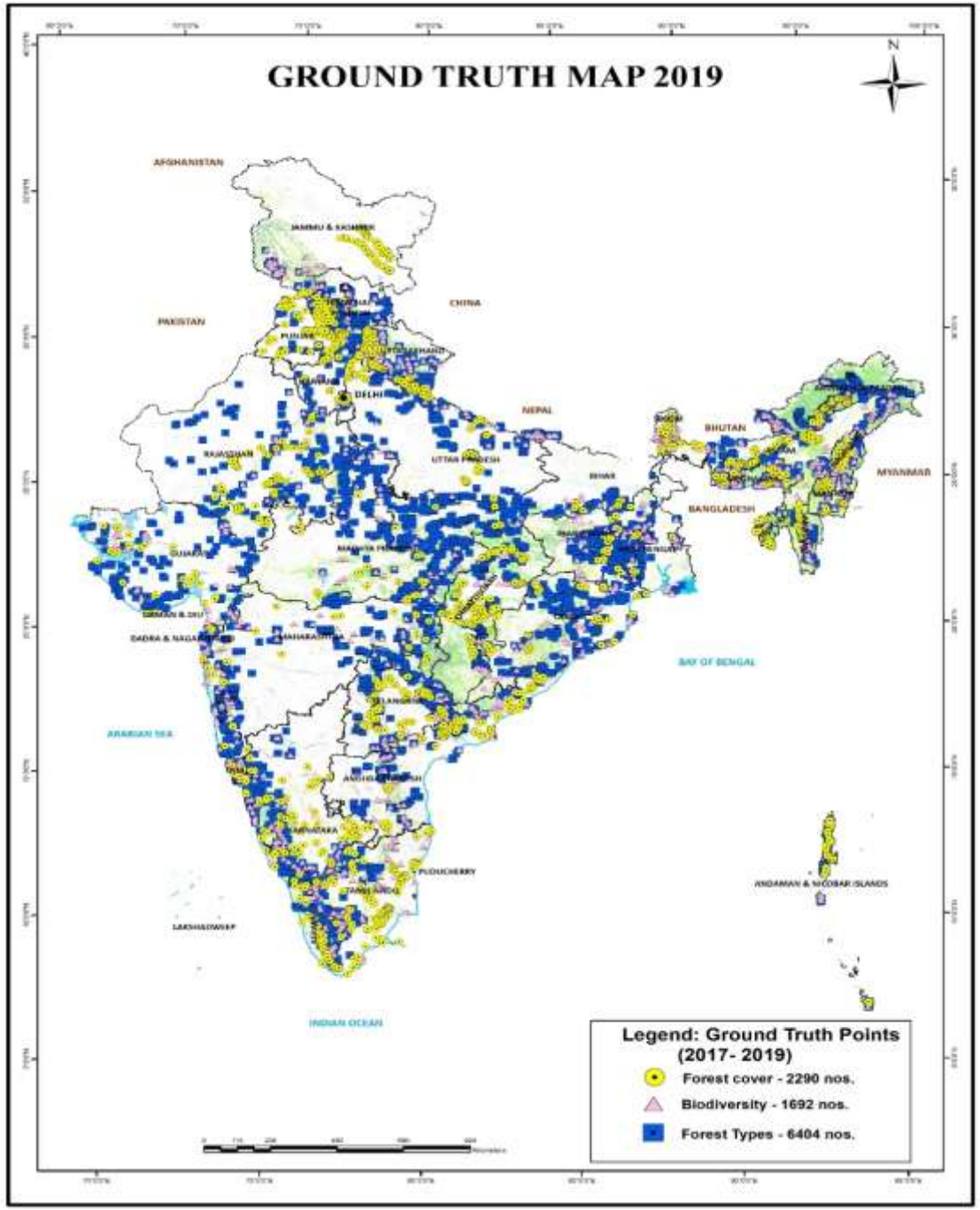
State : Karnataka , District : Kolar, Sheet No. : 57K

Validation of Change

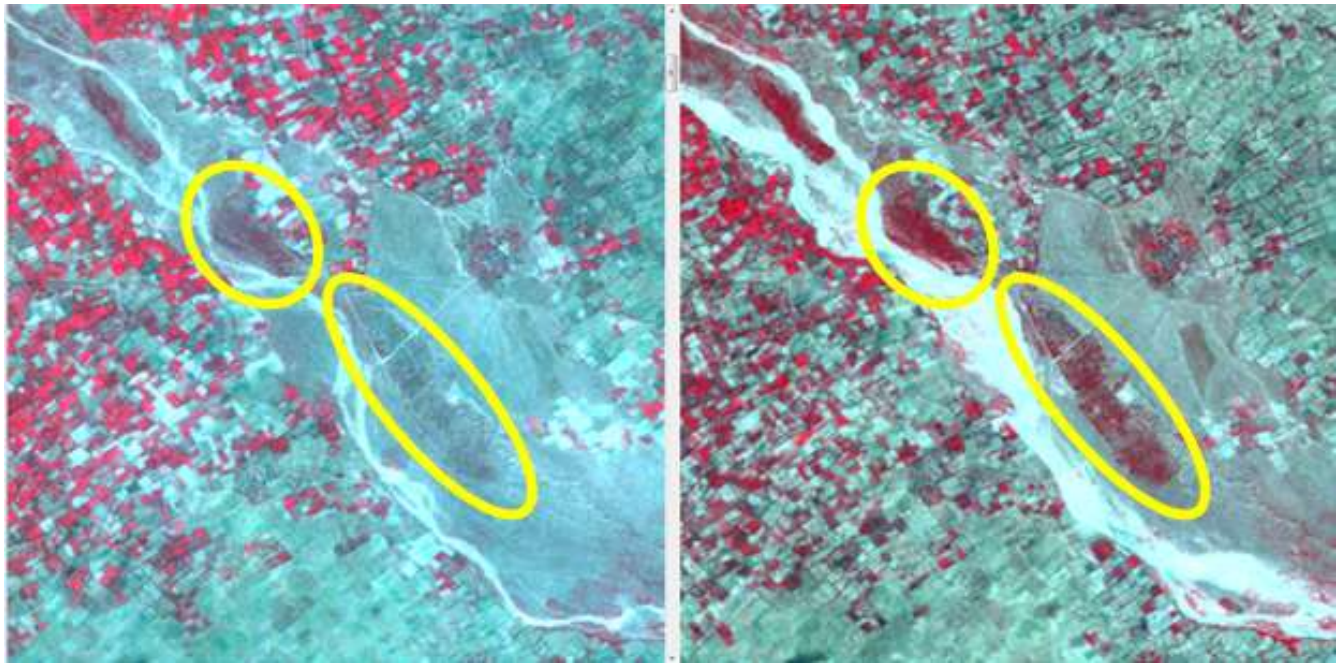
• The change patches of more than 5 ha are mapped on 1. 50,000 scale,along with the other supporting GIS layers like rail, road, location, state and district boundary.

• An additional details of the Patch ID, Patch area (in ha),Positional Coordinates (Latitude and Longitude of the centroid), Change Class name is. These change maps are then shared with the respective State Forest Department (SFD) for validation.




GROUND TRUTH MAP 2019
N
AFGHANISTAN
PAKISTAN
CHINA
NEPAL
BHUTAN
MYANMAR
BANGLADESH
DELHI
RAJASTHAN
UTTAR PRADESH
BIHAR
GUJARAT
MAHARASHTRA
DADRA & NAGAR HAVELI
ARABIAN SEA
BAY OF BENGAL
TELANGANA
KARNATAKA
PUDUCHERRY
TAMIL NADU
LAKSHADWEEP
ANDAMAN & NICOBAR ISLANDS
INDIAN OCEAN
Legend: Ground Truth Points
(2017- 2019)
Forest cover - 2290 nos.
Biodiversity - 1692 nos.
Forest Types - 6404 nos.

Example – Positive Change
District Jalore, Rajastan



14th Cycle

15th Cycle

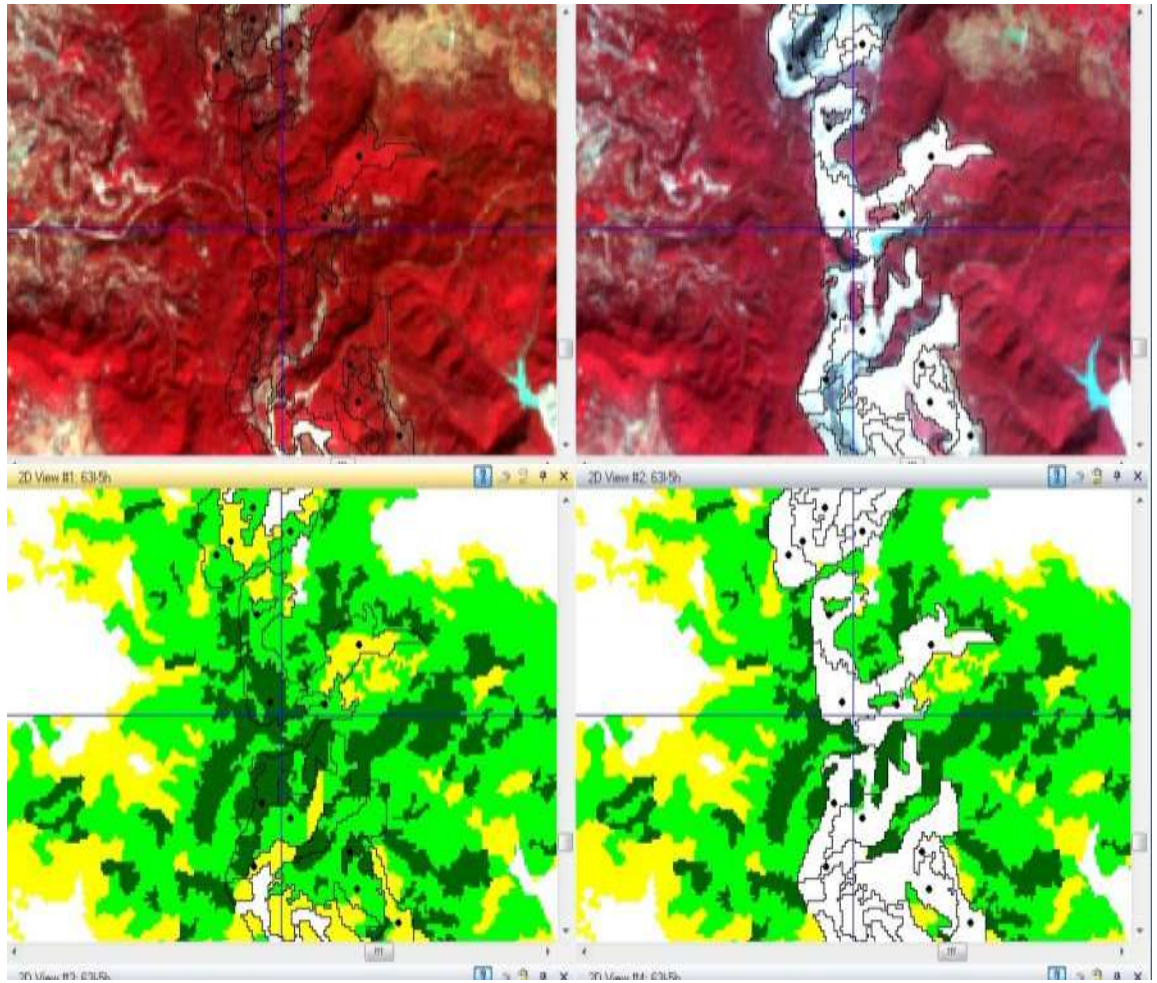
Field Photograph taken during Ground Truthing

REAL CHANGE OF MADHYA PRADESH

13 th FCC

14 th FCC

Google Earth Image



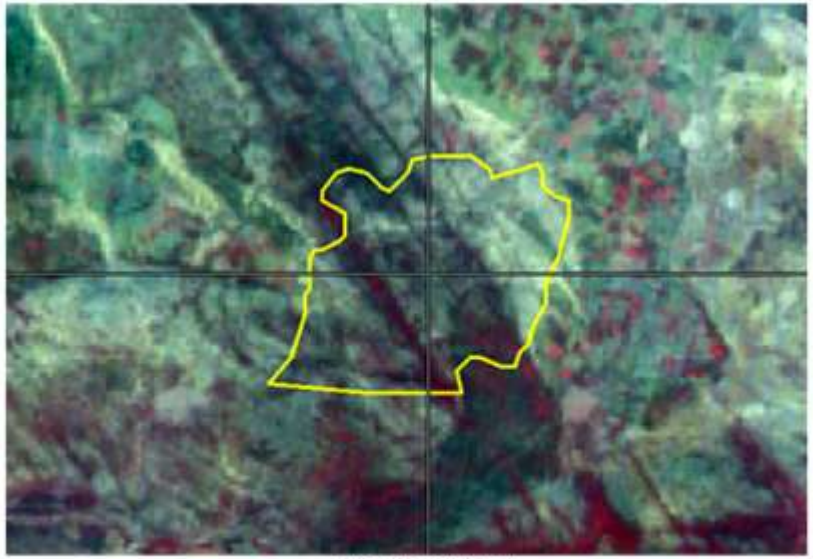
13 th Classified(2011)

14 th Classified(2013-14)

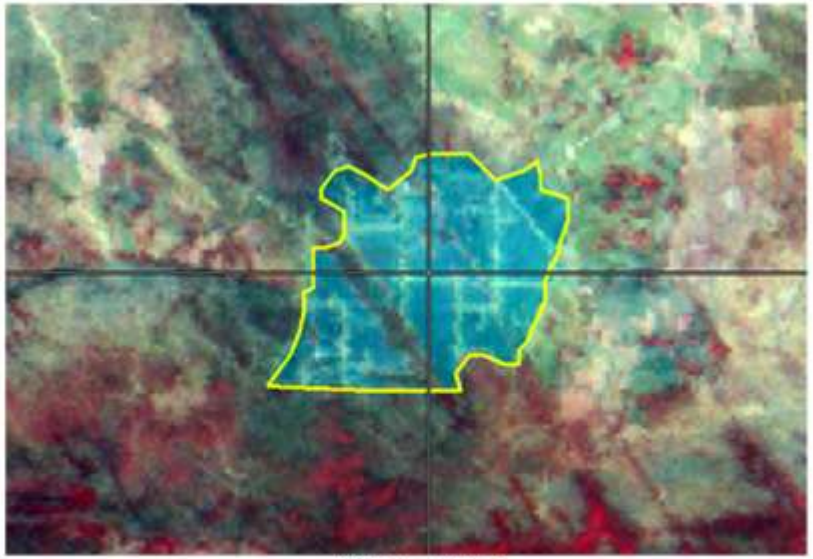
Ground truthing (January2015)

STATE – MADHYA PRADESH DISTRICT – SINGRAULI
LOCATION –SINGRAULI LAT LONG - 24° 9'7.69"N 82°33'7.56"E
SHEET NO. – 63L/12
CHANGE- VDF/MDF TO NON FOREST
REASON –RELIANCE MINING ACTIVITIES.

Establishment of solar power plant in Mirzapur District (UP) as seen on satellite image

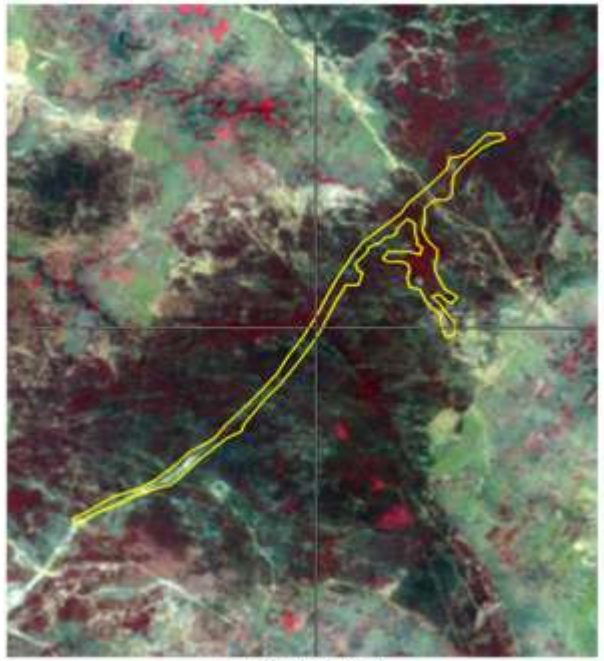


ISFR 2017

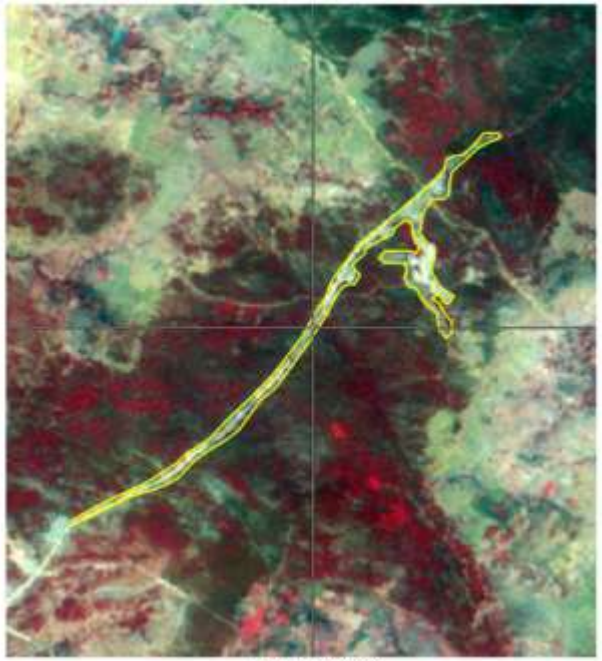


ISFR 2019

Canal construction in Mirzapur district, Uttar Pradesh as seen on satellite image



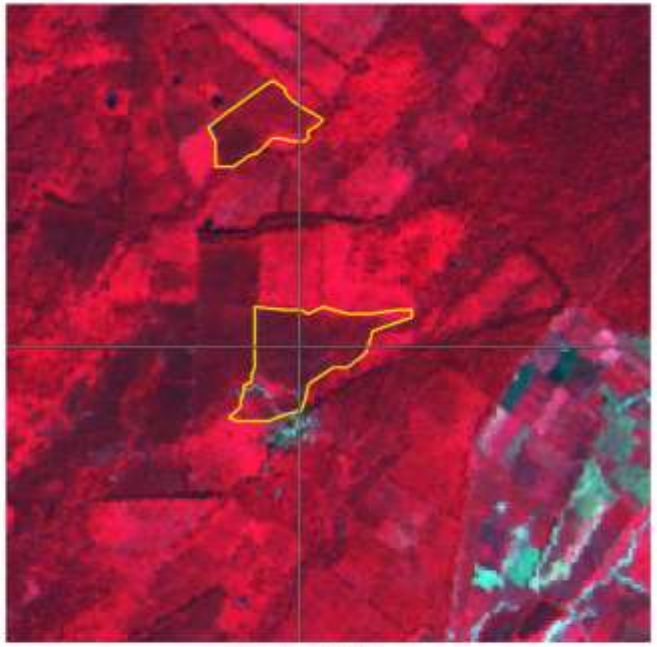
ISFR 2017



ISFR 2019

Afforestation in Bijnor District (UP) as seen on the satellite image

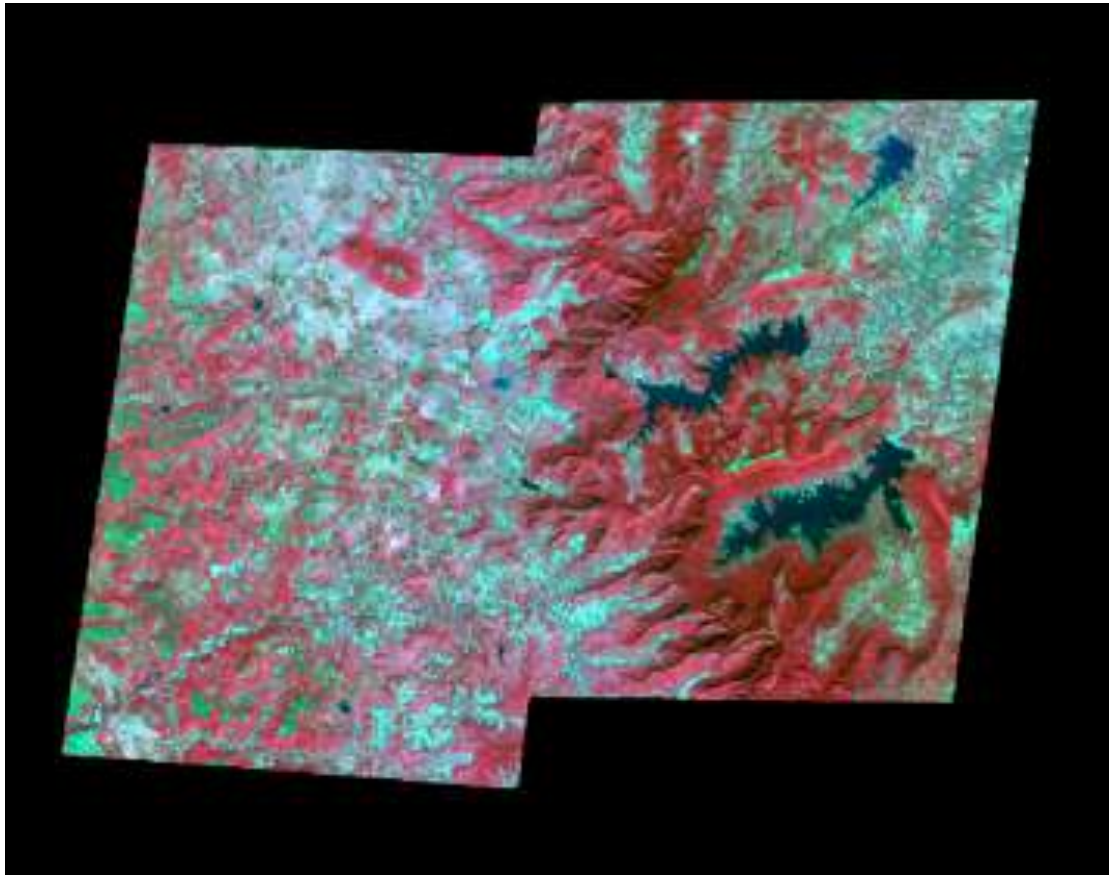
ISFR 2017

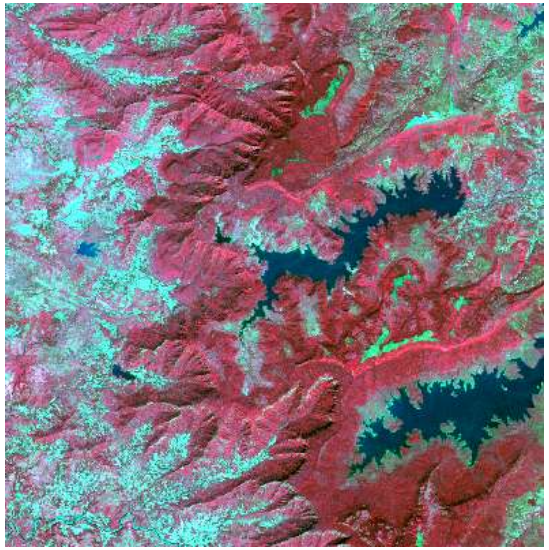


ISFR 2019

Mosaicing of scenes

Extraction of scene

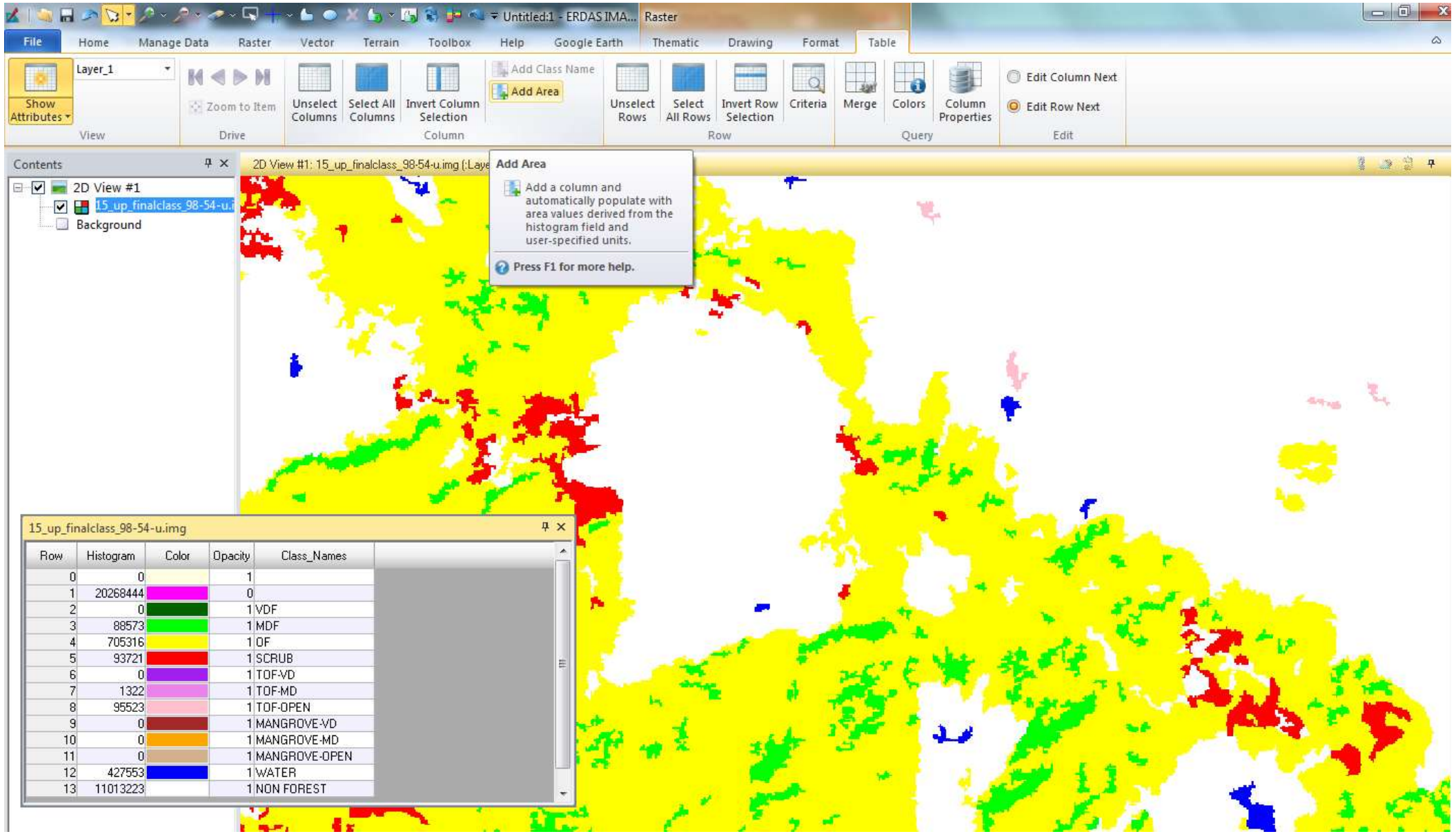




- equal to topo sheet

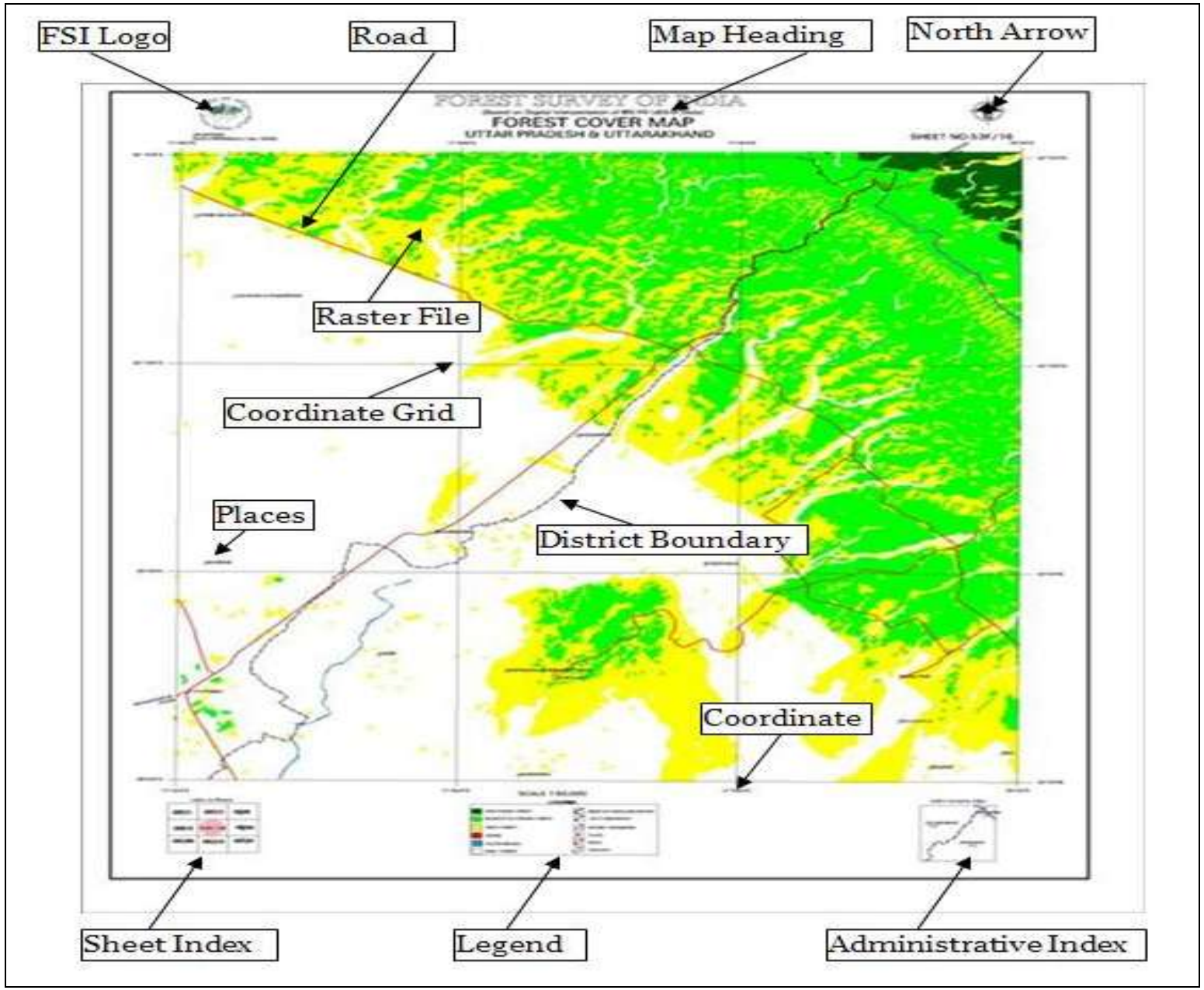
on 1:50000

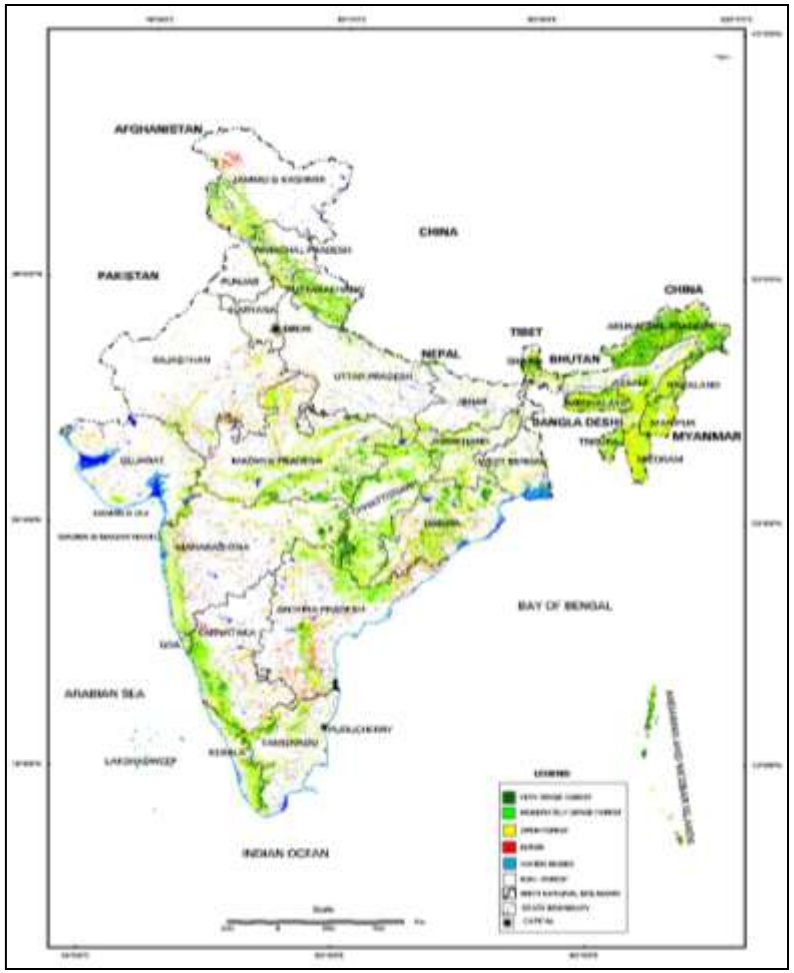
Area Calculation of different density classes



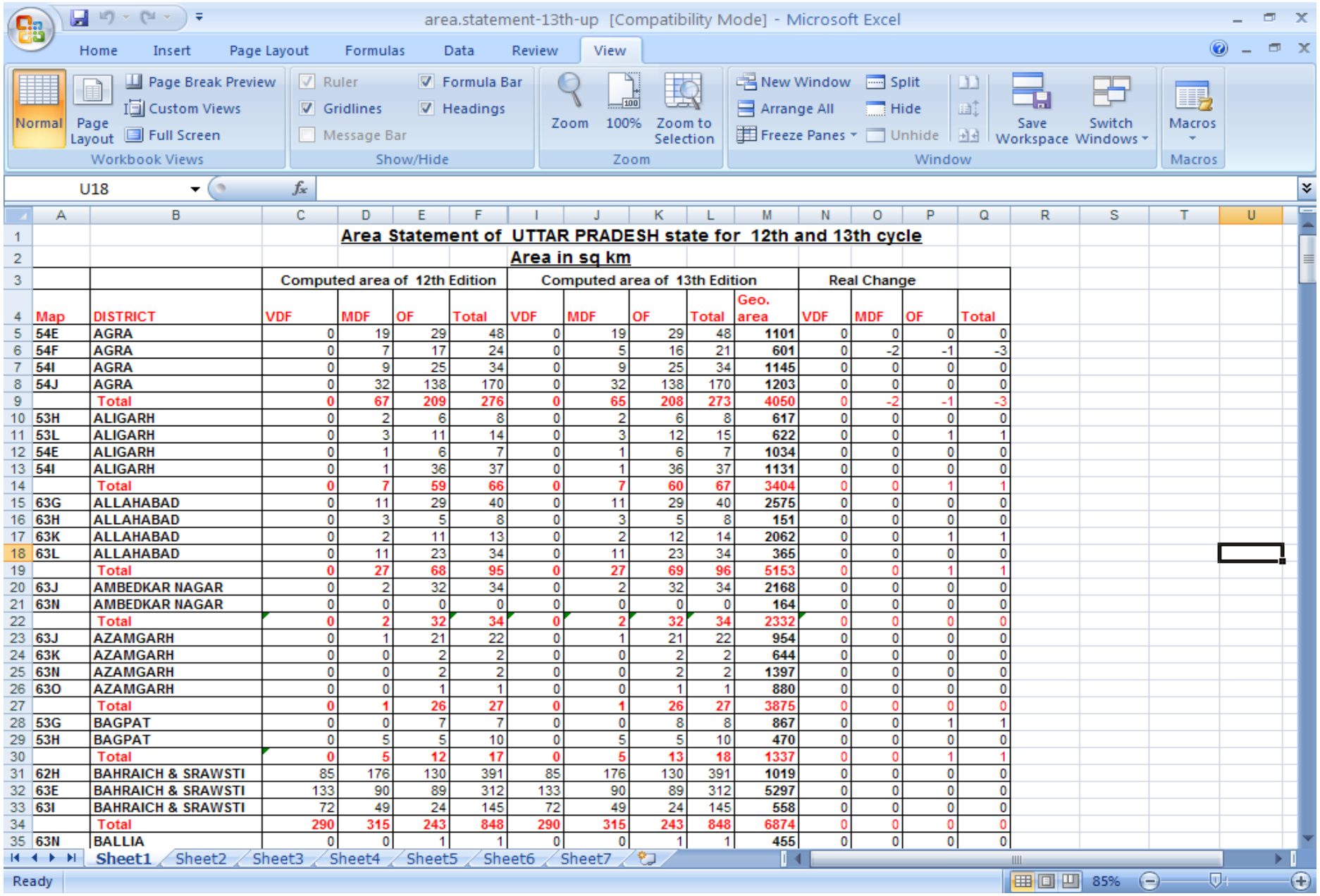
Row	Histogram	Color	Opacity	Class_Names
0	0		1	
1	20268444		0	
2	0		1	VDF
3	88573		1	MDF
4	705316		1	OF
5	93721		1	SCRUB
6	0		1	TOF-VD
7	1322		1	TOF-MD
8	95523		1	TOF-OPEN
9	0		1	MANGROVE-VD
10	0		1	MANGROVE-MD
11	0		1	MANGROVE-OPEN
12	427553		1	WATER
13	11013223		1	NON FOREST

Final Forest Cover Sheet Wise Map





Generation of Area Statistics



Forest Cover Change Matrix for India between 2017 and 2019 assessments.

Class	VDF	MDF	OF	Scrub	Non Forest	Total Forest Cover 2017
Very Dense Forest	97309	626	50	2	171	**98,158**
Moderately Dense Forest	1755	303781	699	109	1,974	**308,318**
Open Forest	127	2,244	2,89,358	1,069	8,999	**301,797**
Scrub	2	48	1732	41831	2366	**45,979**
Non Forest	85	1773	12660	3286	25,15,413	**25,33,217**
Total Forest Cover 2019	**99,278**	**3,08,472**	**3,04,499**	**46,297**	**25,28,923**	**32,87,469**
Net change	1,120	154	2,702	318	-4,294	

Gain Loss

- QC & QA
- Accuracy Assessment
- Error and confusion matrix (for Forest Cover classes and Forest and Non Forest Classes)

Classification Classes	Ground truth (based on field inventory data)			User's Accuracy (%)
	Forest	Non-Forest	Total	
Forest	3,451	50	3,501	98.57
Non-Forest	98	1,684	1,782	94.50
Total	3,549	1,734	5,283	
Producer's Accuracy (%)	97.24	97.12		
Overall Accuracy	97.20 %			
Overall Kappa Statistics	0.94			

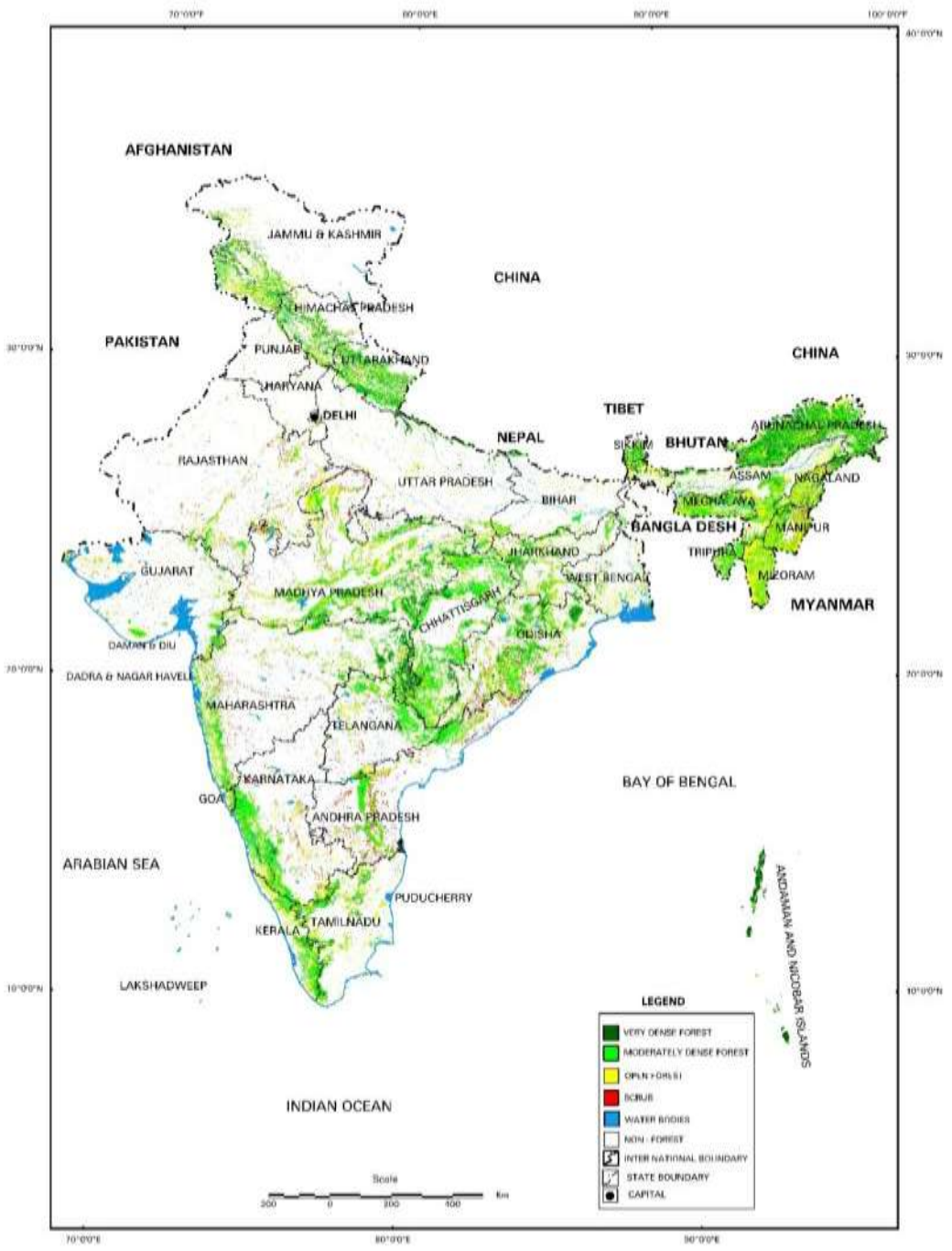
Outcome of FCM

- Inputs for the publication of ISFR on a biennial basis
- National and state level forest cover with district wise figures
- Change matrix: Change as compared to last assessment
- Mangrove Cover
- Forest cover in hill & tribal districts
- Forest cover in Northern Eastern States
- Slope wise and altitude wise
- Widely used primary data

Forest and Tree Cover of India - ISFR 2019

CLASS	AREA (SQ KM)	% OF GEOG. AREA
Forest Cover		
Very Dense Forest	99,278	3.02
Moderately Dense Forest	3,08,472	9.39
Open Forest	3,04,499	9.26
Total Forest Cover	**7,12,249**	**21.67**
Tree Cover	**95,027**	**2.89**
Total Forest and Tree Cover	**8,07,276**	**24.56**
Scrub	46,297	1.41
Non Forest	2,528,923	76.92
Total Geographical Area	**3,287,469**	**100.00**

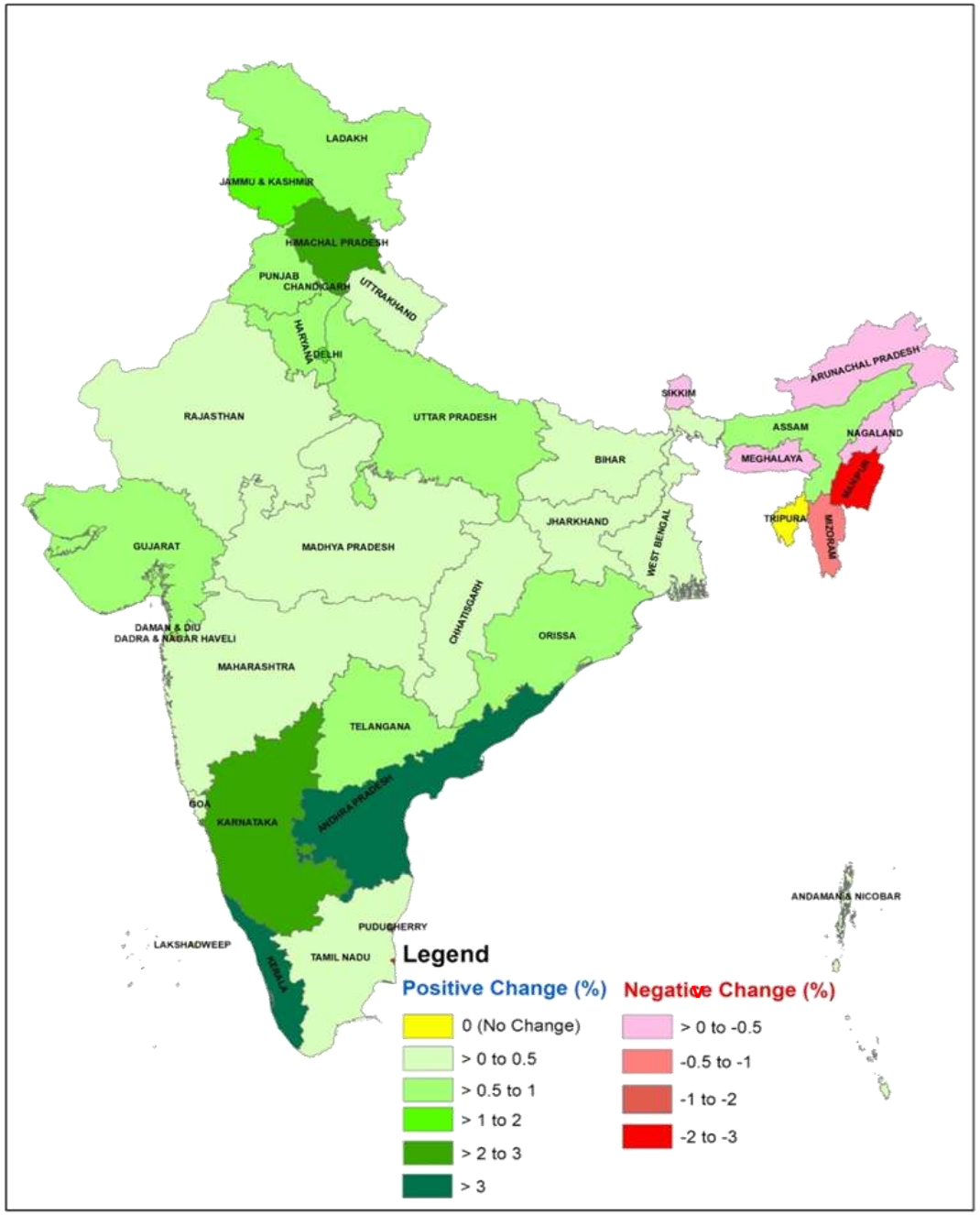
- ✓ Total growing stock of India's forest and Trees Outside Forest is **5915.76 million cu m**
- ✓ Total Carbon Stock in India's forest is estimated to be **7124.6 million tonnes**
- ✓ **Total Forest and Tree cover in Uttarakhand is 47.01 percent of State's geographical area (53,483 sq km.)**



Map Showing Gains and Losses in Forest Cover (%) in States & UTs

Top 5 States/UTs Showing Gain in Forest Cover

Karnataka	1025 sq km
Andhra Pradesh	990 sq km
Kerala	823 sq km
UT of J&K	348 sq km
Himachal Pradesh	334 sq km



5 States/UTs Showing Loss in Forest Cover

Manipur	- 499 sq km
Arunachal Pradesh	- 276 sq km
Mizoram	- 180 sq km
Meghalaya	- 27 sq km
Nagaland	- 3 sq km

Mapping of Forest Cover in and outside Recorded Forest Areas of Bihar at High Resolution

(Using LISS-IV Satellite Data of IRS Resourcesat-2)

Methodology

Objective of the Study

Objective

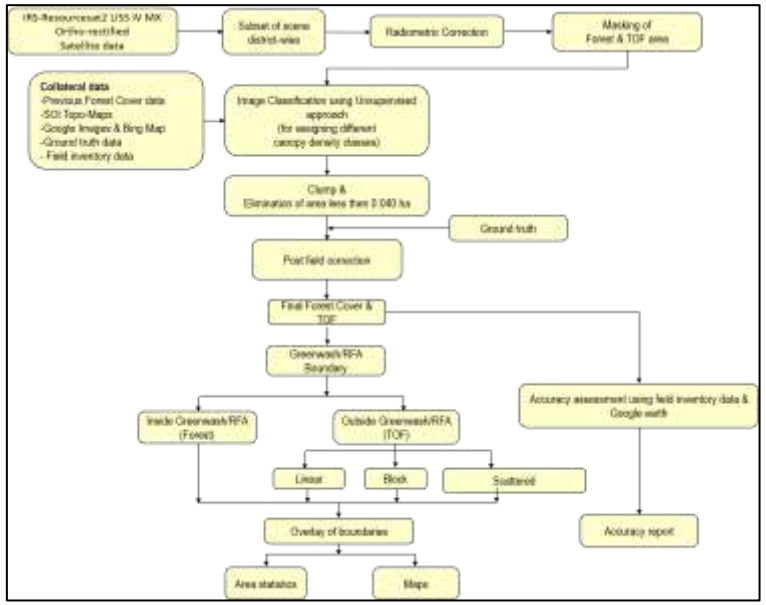
The objective of the study is to assess the Forest Cover in and outside Recorded Forest Areas in terms of canopy density classes using LISS-IV (Multispectral) data.

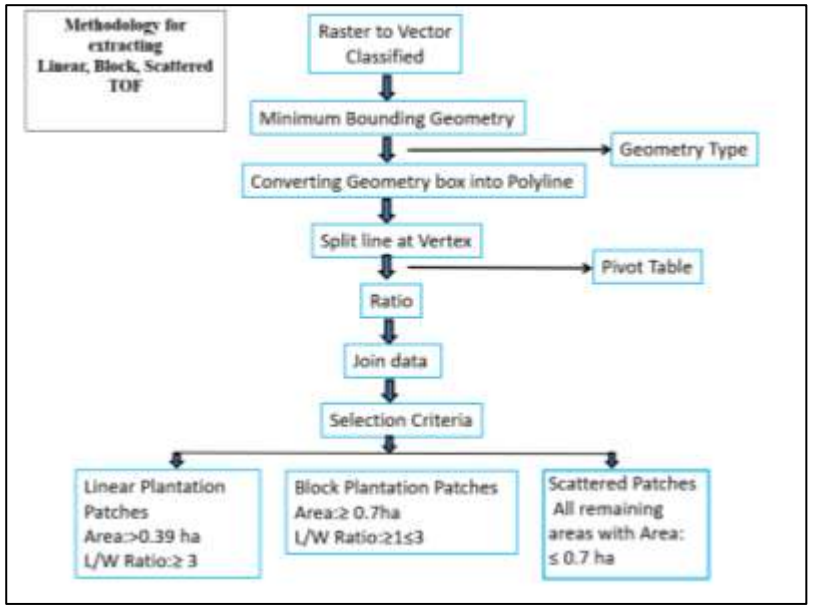
- Very Dense Forest (canopy density ≥ 70%),
- Moderately Dense Forest (canopy density 40% to < 70%),
- Open Forest (canopy density 10% to <40%)
- Scrub (canopy density < 10%).

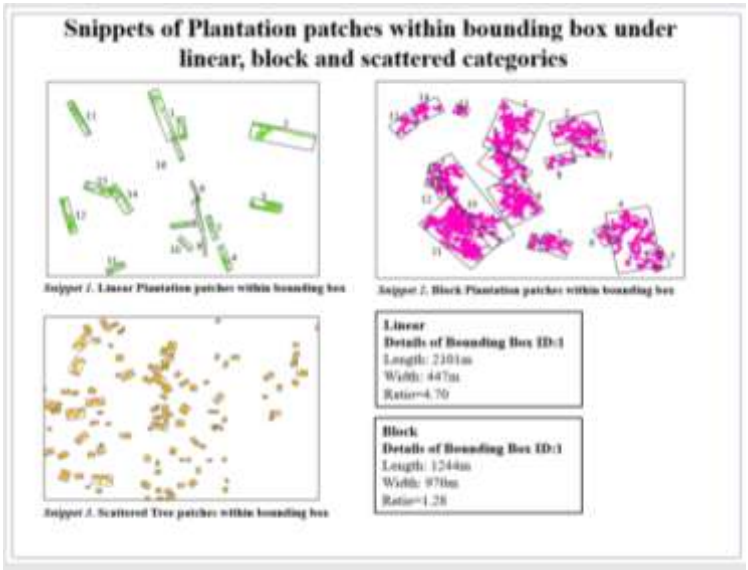
The study includes TOF assessment for 38 districts of the State and includes Sacred Grove, plantation along rivers, road, railway track, canal, ponds and reservoirs.

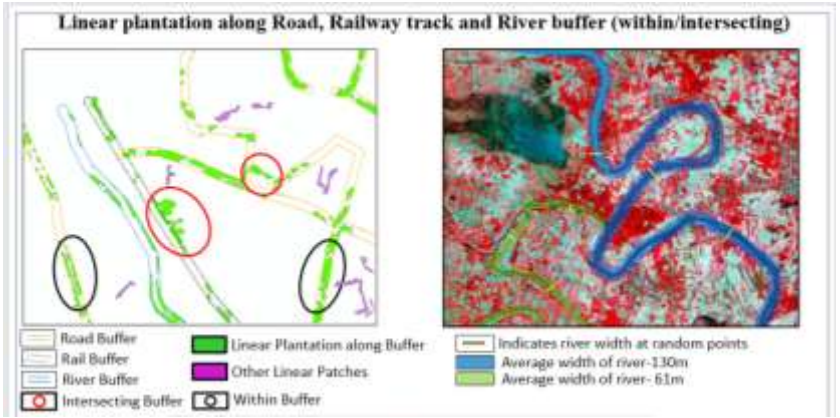
MMU (Minimum mapping unit)

The MMU (minimum mapping unit) is the size of the smallest feature of a class that can be reliably mapped on a given scale. In the present mapping MMU is 0.04 ha. at scale 1:10,000.



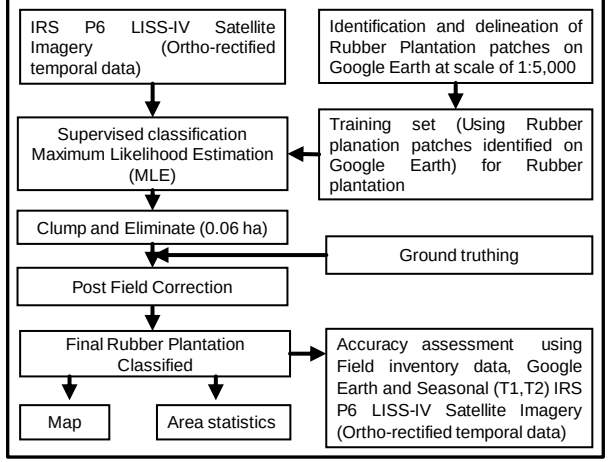






MAPPING OF RUBBER PLANTATIONS IN TRIPURA USING GEOSPATIAL TOOLS (LISS-IV DATA)

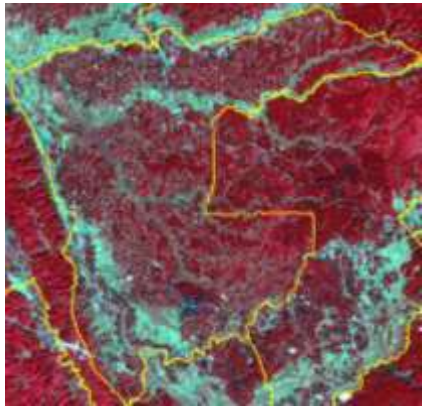
Methodology



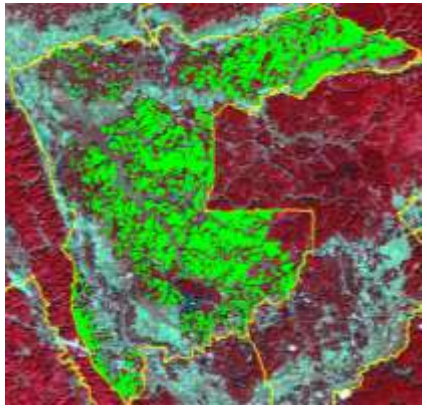
Study Area

Muhuripur Beat, South Tripura

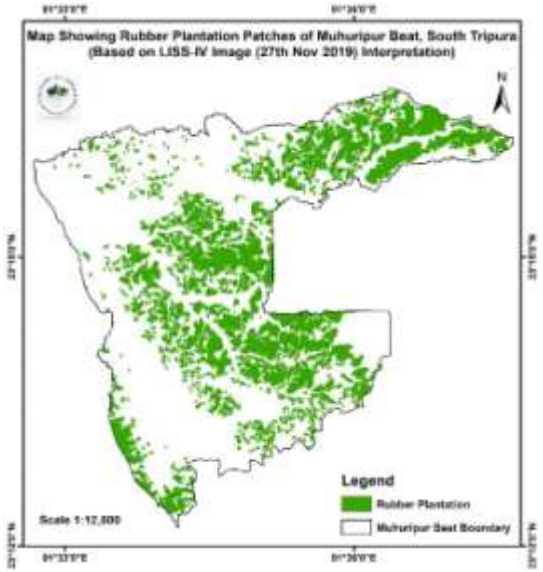
Identification and Delamination of Rubber plantation patches on Google Earth at scale 1:5000



Training set generation using identified and delineated Rubber patches with the help of Google Image



Supervised classification of Rubber plantations using Maximum Likelihood Estimation at scale 1:12,500

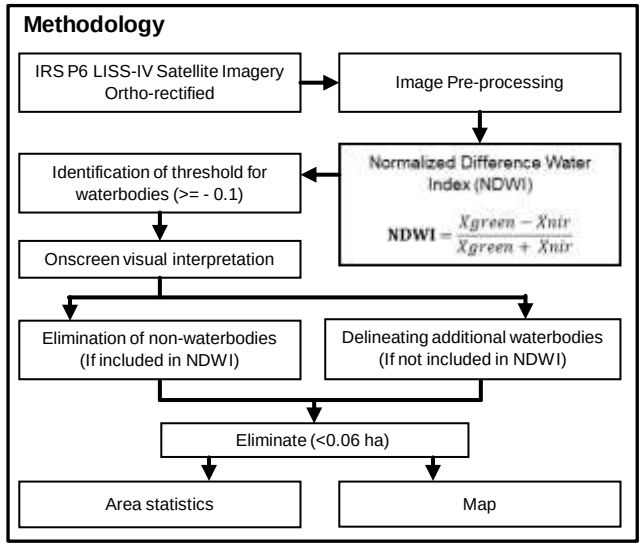


Map prepared at 1:12,500 scale for ground verification

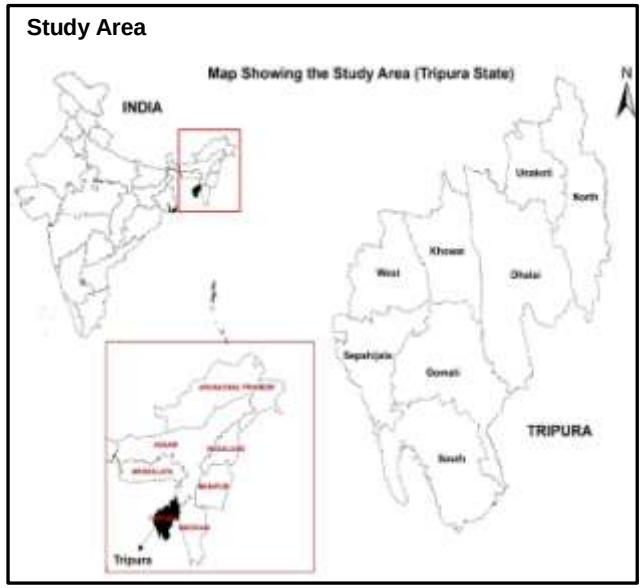
Rubber Plantation	Area (in sq. km)
Within RFA	3.32
Outside RFA	7.29
Total	**10.61**

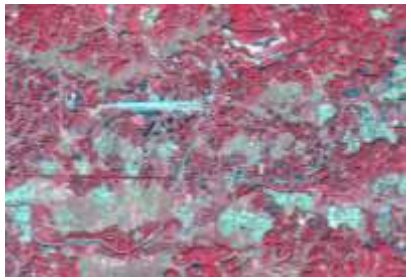
MAPPING OF WATERBODIES IN TRIPURA USING GEOSPATIAL TOOLS (LISS-IV DATA)

Methodology

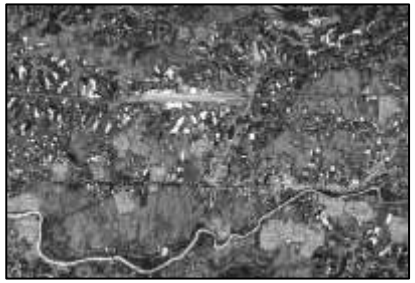


Study Area

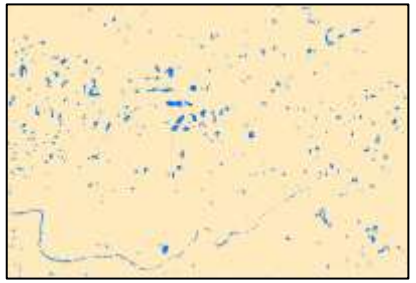




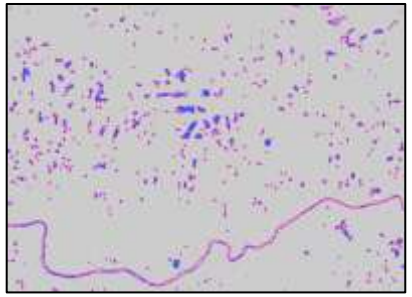
LISS-IV Image



Preparation of NDWI

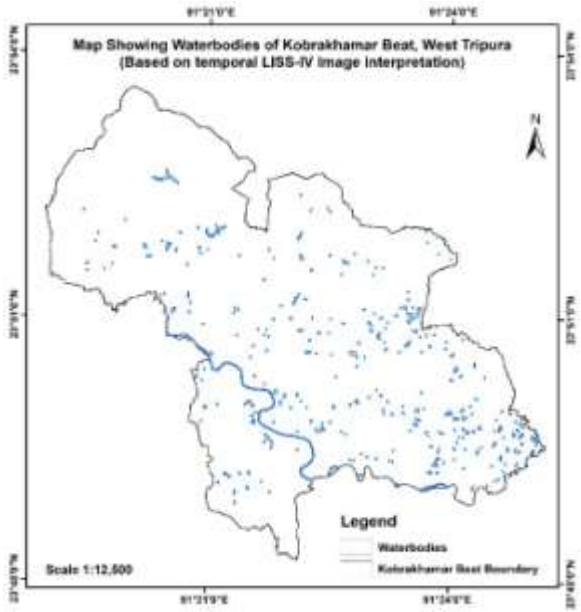


Raster Calculation for threshold identification of Water Bodies >= -0.1

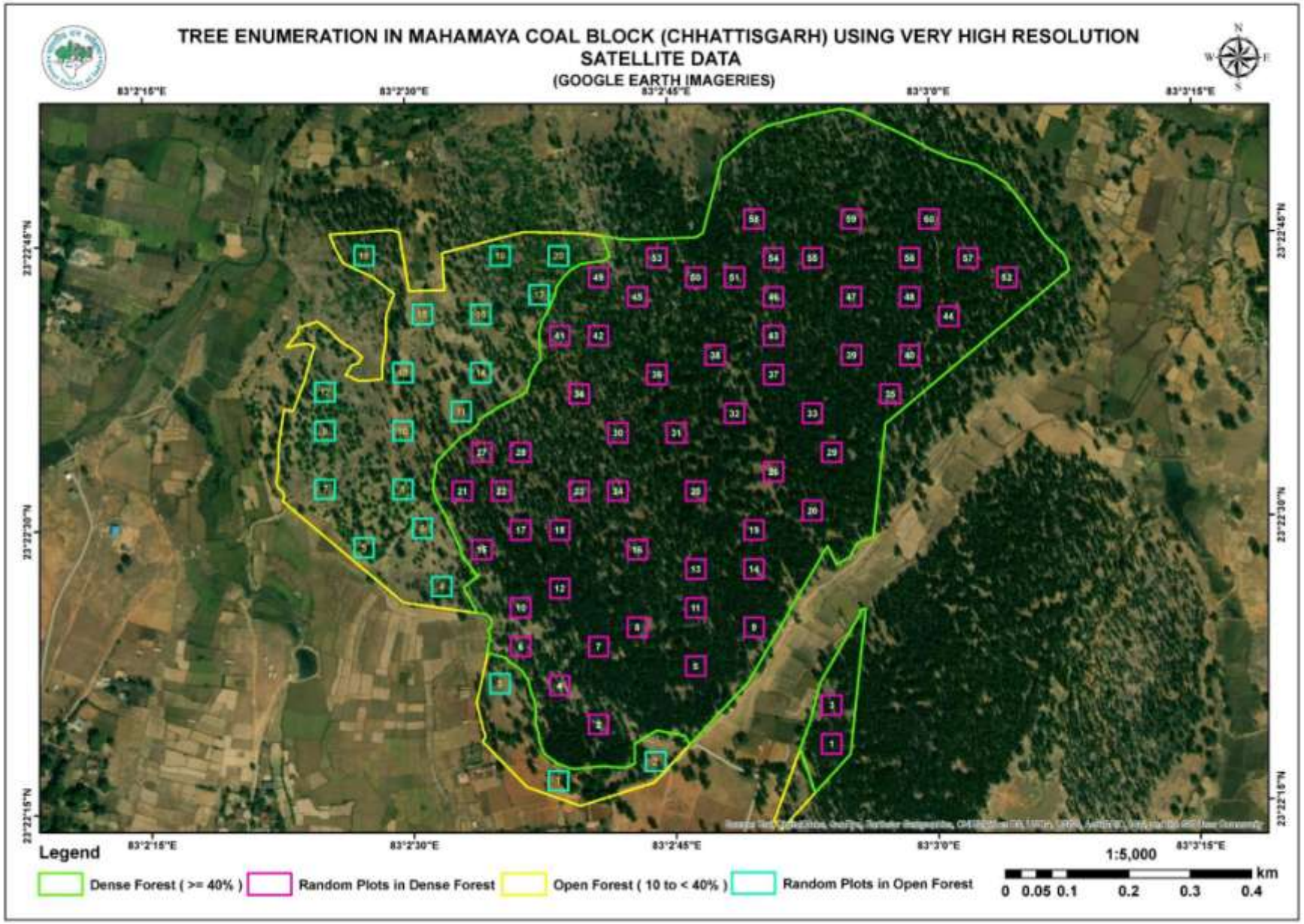


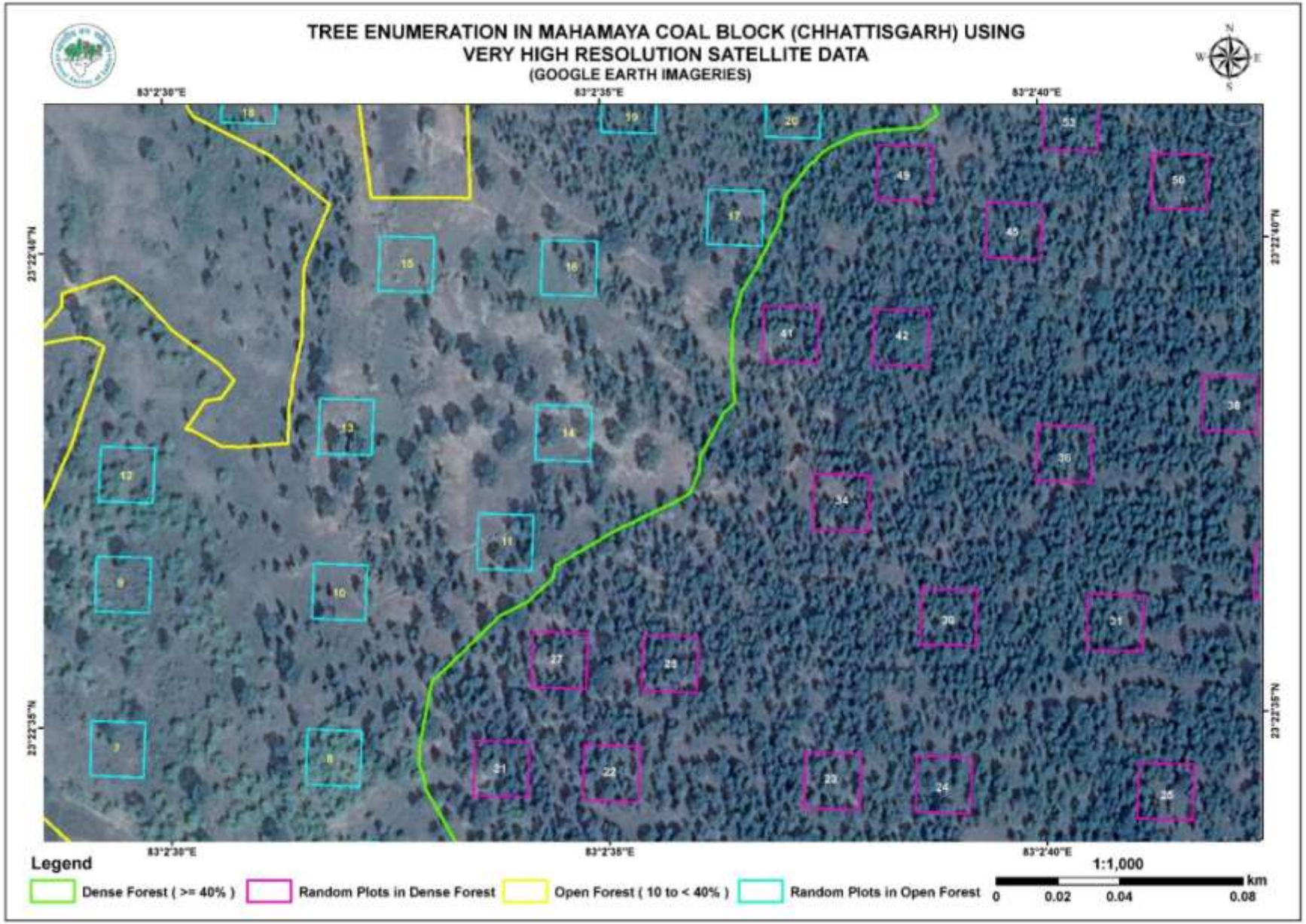
Raster to Vector conversion for visual interpretation

Final Water Bodies retained (>= 0.06 ha as per Minimum Mapping Unit)



Waterbodies	No. of waterbodies	Area (in ha)
< 1 ha	312	44.1
1ha - 5ha	5	11.2
> 5ha	1	8.34
Total	**318**	**63.64**


TREE ENUMERATION IN MAHAMAYA COAL BLOCK (CHHATTISGARH) USING VERY HIGH RESOLUTION SATELLITE DATA
(GOOGLE EARTH IMAGERIES)
N
W
E
S
83°2'15"E
83°2'30"E
83°2'45"E
83°3'0"E
83°3'15"E
23°22'45"N
23°22'30"N
23°22'15"N
Legend
Dense Forest (>= 40%)
Random Plots in Dense Forest
Open Forest (10 to < 40%)
Random Plots in Open Forest
1:5,000
0 0.05 0.1 0.2 0.3 0.4
km


TREE ENUMERATION IN MAHAMAYA COAL BLOCK (CHHATTISGARH) USING
VERY HIGH RESOLUTION SATELLITE DATA
(GOOGLE EARTH IMAGERIES)
83°2'30"E
83°2'35"E
83°2'40"E
23°22'45"N
23°22'40"N
23°22'35"N
Legend
Dense Forest (>= 40%)
Random Plots in Dense Forest
Open Forest (10 to < 40%)
Random Plots in Open Forest
1:1,000
0
0.02
0.04
0.08
km


Thank
You