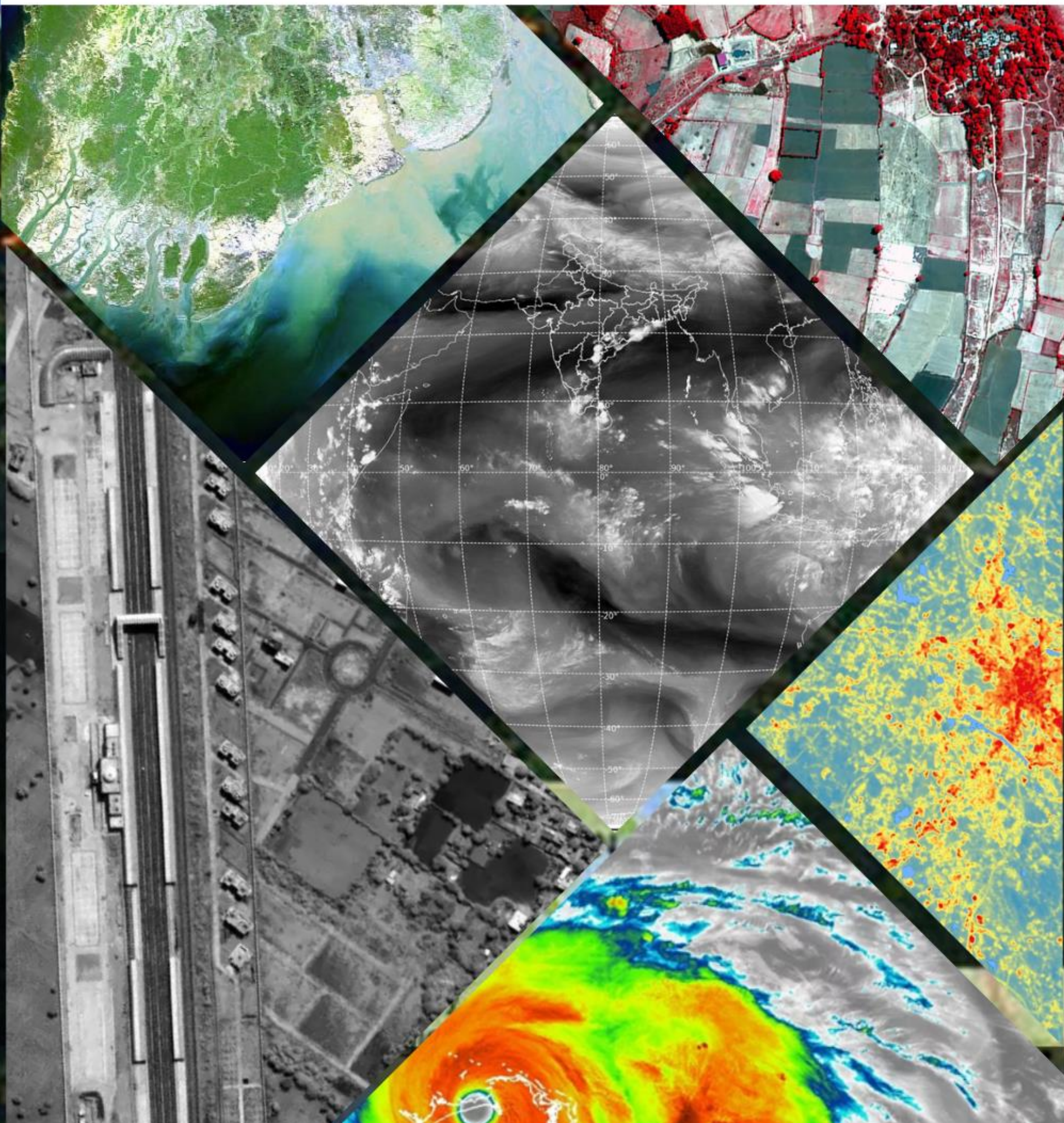
GEOSPATIAL

TECHNOLOGIES & APPLICATIONS (PRACTICAL)



GEOSPATIAL TECHNOLOGIES AND APPLICATION (PRACTICALS)

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List of Demonstrations

FOREWORD

Geospatial science is an interdisciplinary field that combines many technologies and has an impact on numerous fields. Geospatial technology has a wide range of applications in practically every domain of natural resources, including agriculture, forestry, industries, rural, urban, water, and marine, and contributes significantly to the development of national infrastructure. These technologies are vital for land revenue, banking and finance, resource mapping and management, social planning, disaster management, e-governance, food security, and other purposes.

The National Geospatial Policy, 2022 aims to make India a world leader in global geospatial map with the best in class ecosystem for sustainable growth and economy for the nation through the integration of geospatial data/technology/concepts with industry 4.0 revolutionary technologies by growing web, cloud, and network infrastructure. The demand for qualified human resources for adopting technology for social and economic development across the country is growing by the day.

To fulfil the ever-increasing need, there is a need to build capacity through effective training and raise awareness among the many stakeholders, which include state and central ministries, industry, academics, entrepreneurs, and educated youth.

ISRO has launched many space missions for Earth observation applications. The Resourcesat, Cartosat, Oceansat, RISAT, INSAT2D/3DR class of satellite are providing temporal, multi-platform, multi-sensor satellite data of earth surface. The satellite data are critical inputs for geospatial technology for different thematic applications.

I am pleased to see that a course material encompassing all important topics in geospatial technology and applications has been created by various ISRO centres / institutions. A few practical sessions are also planned to provide hands-on experience.

I am confident that knowledge sharing will assist students, academics, industries, and researchers in improving their capabilities in the geospatial area and capitalising on growth possibilities.

S Somnath

PREFACE

In a frame work of National Geospatial Policy-2022, DOS accorded in principle approval for conducting an integrated course on Geospatial Technology and its applications for various user ministries and NGEs as a part of capacity building in space domain. Subsequently, CBPO in consultation with ISRO centres SAC, NRSC, IIRS and NE-SAC brought out the course curriculum.

The book on Geospatial Technology and its applications covers the chapters on Fundamental of Remote Sensing, Geographical Information System (GIS), Digital Image Processing, Advances in Remote Sensing, Microwave Remote Sensing, UAV Remote Sensing, Agriculture and Soils, Water Resources, Forestry and Ecology, Geoscience, Urban Development, Marine Applications, Atmospheric Science and Disaster. To have hands on different tools on Geo Spatial Applications the five demonstration topics are also covered in this programme e.g. on Remote Sensing, Geographical Information System, Digital Image processing, Geo portals and data dissemination and Open-source platforms for Geo-data processing.

The topics are contributed by Scientists across above ISRO centres and two books comprising twenty (20) topics on theory and five (5) practicals are brought out for Geospatial Technologies and its Applications. This book will be a basis for conducting the one-week training programme for BE/B Tech in Engineering or equivalent, BSc in any discipline, BA in Geology/Environment studies or 3 years Diploma in Engineering or equivalent fields. The students should have proficiency with Windows, MS Word and Excel.

The course will be conducted at eight identified Outreach & Training Centres (OTCs) at NRSC-RRCS North Delhi, RRSC South-Bengaluru, RRSC East-Kolkata, RRSC West-Jodhpur, RRSC Central-Nagpur, MCF-Bhopal, IIRS Dehradun, NESAC-Shillong.

Online course will also be made available in collaboration with iGOT Karmayogi (Department of Personnel & Training, GoI) platform.

N Sudheer Kumar
Director CBPO

GEOSPATIAL TECHNOLOGIES AND APPLICATION (PRACTICALS)

Exercise 1

REMOTE SENSING VISUAL INTERPRETATION

1.1 Concept of Visual Elements of Image Interpretation

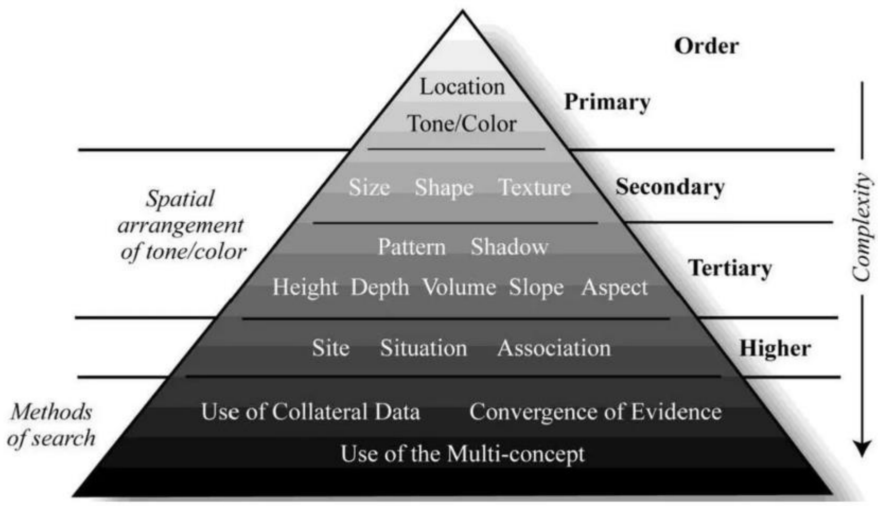
Learning Objectives

- Adapt to think how objects look from a vertical perspective and in different spectral regions.
- Apply the elements of visual image interpretation to identify objects in the images.
- To identify features and extract the useful information from the remotely sensed images based on the visual interpretation techniques.

Basic elements of interpretation

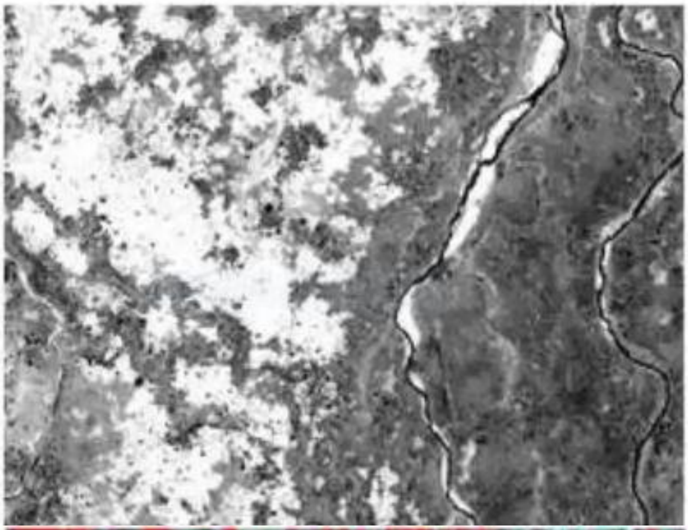
The interpretation of satellite imagery and aerial photographs involves the study of various basic characters of an object with reference to spectral bands which is useful in visual analysis. The basic elements are shape, size, pattern, tone, texture, shadows, location, association and resolution.

- Tone
- Size
- Shape
- Texture
- Association
- Shadow
- Site
- Pattern

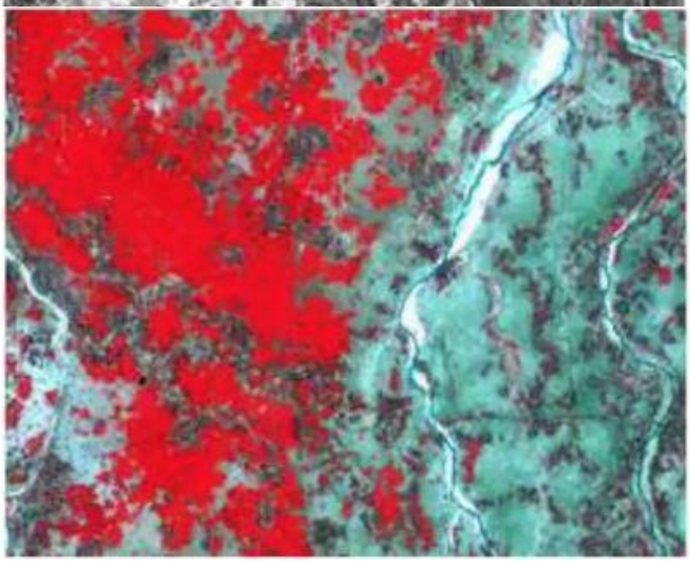


Tone: Refers to the colour or relative brightness of an object. The tonal variation is due to the reflection, emittance, transmission or absorption character of an objects. This may vary from one object to another and also changes with reference to different bands.

a



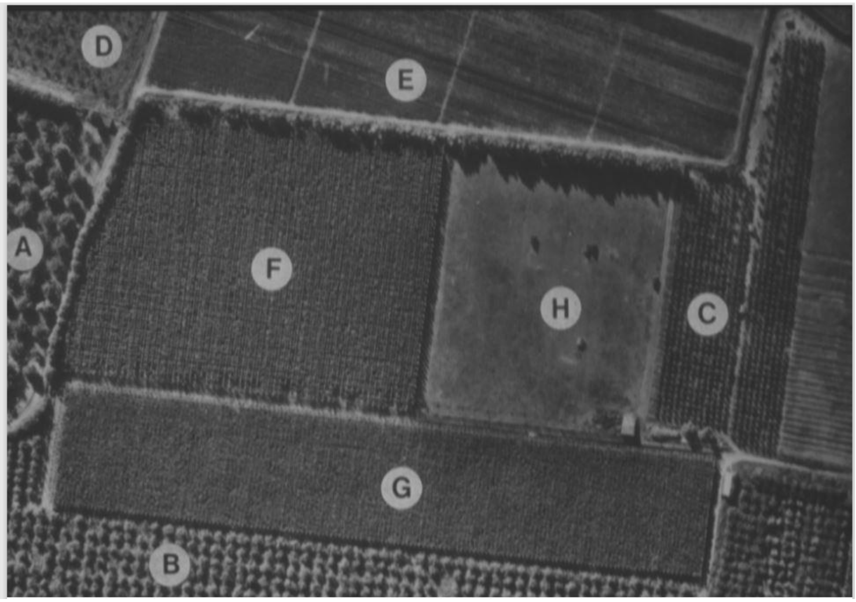
b



Questions:

1. Mark the different tonal variations (very dark, dark, light, very light etc.) in image chips a and b.
2. Correlate the grey tone with colour in corresponding areas. Try and identify the features on FCC based on the colour.

Texture: The frequency of tonal change. It creates a visual impression of surface roughness or smoothness.

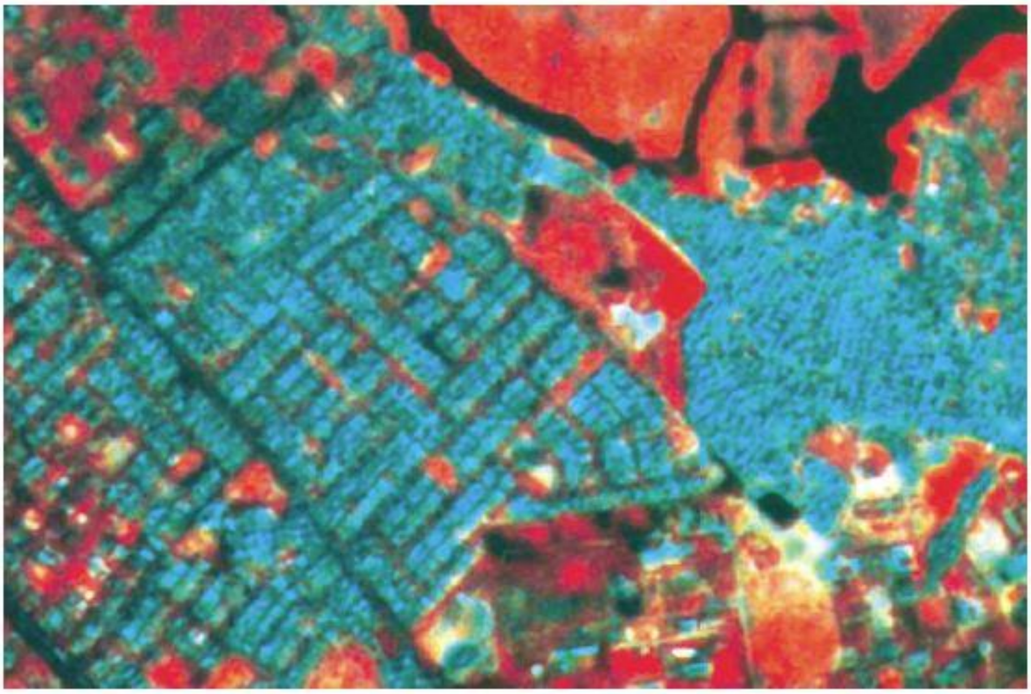


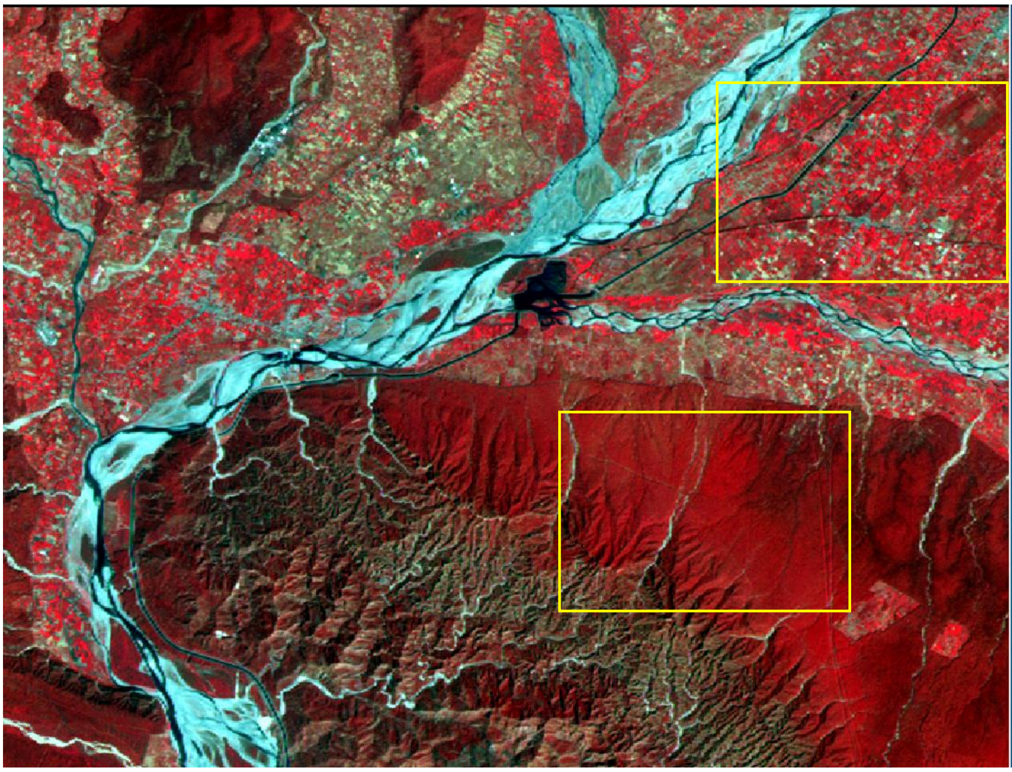
Questions:

a. Mark the different textural variations.

b. Correlate the texture with the type of vegetation. (Trees, bushes, grass. etc.)

Pattern: Spatial arrangement of an object into distinctive recurring forms.





Questions.

a. Mark the different patterns in both image chips.

b. Correlate the pattern with type of urban area and vegetation.

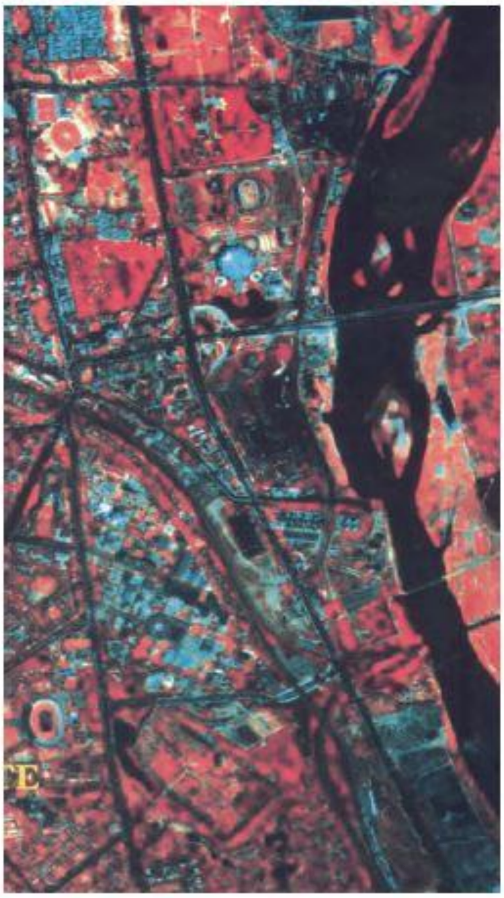
Question:

a. Mark the different patterns in the image chip.

b. Identify plantation area, planned housing, unplanned housing areas. What is the basis for your conclusion?

Shape: The external form, outline or configuration of the object. This includes natural features (Example: River), Man Made feature (Example: Stadium).

a



Questions: Observe and comment on:

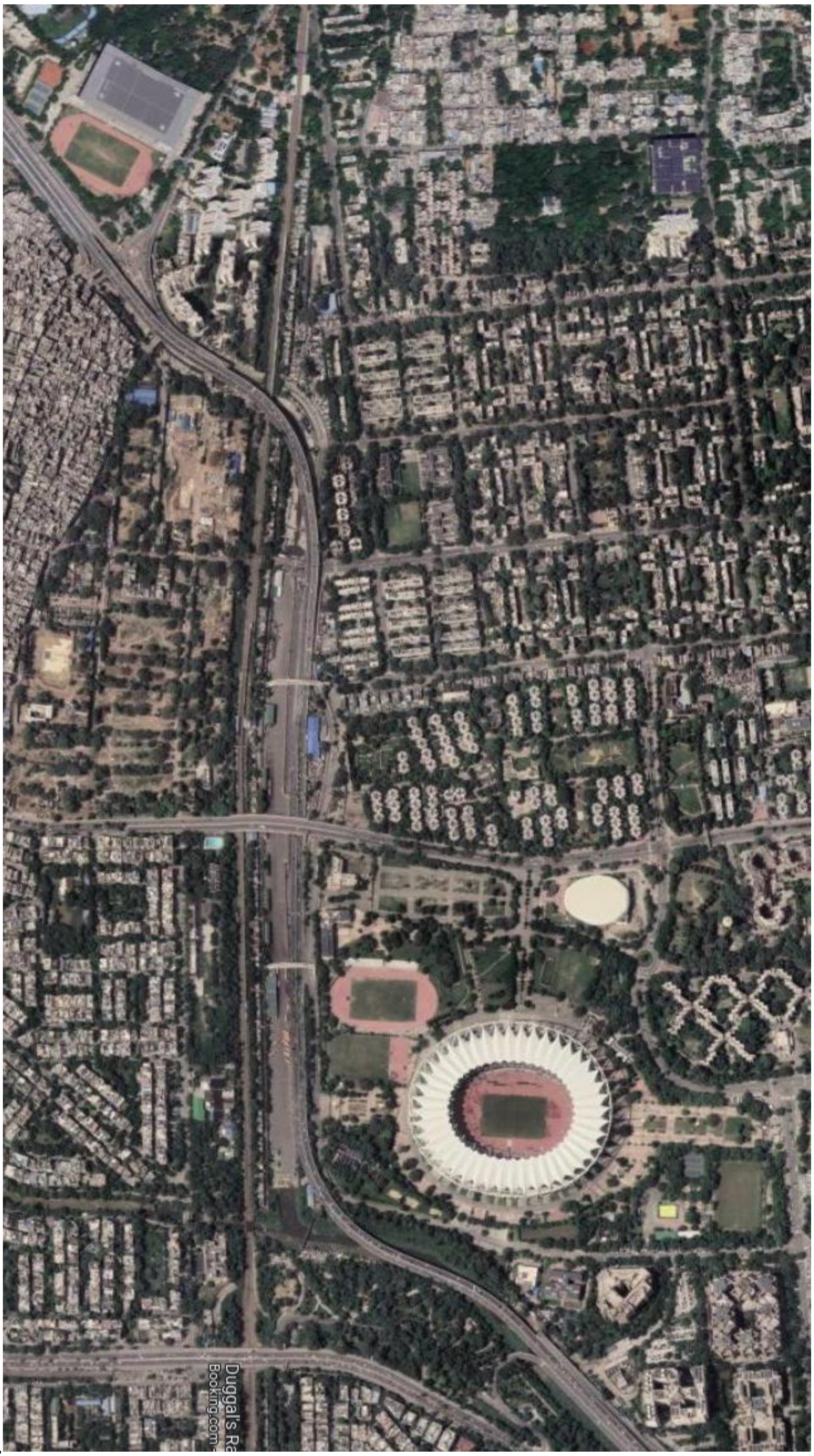
a. Shape of railway and road features

b

c

Questions: Observe and comment on:

b. Shape of river and c. Shape of agricultural fields



d.

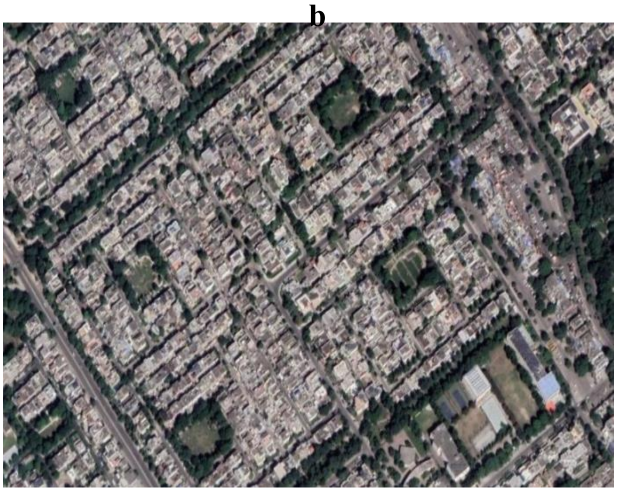
Questions: Observe and comment on image d:

d. Stadium, courts for various sports.
e. Identify the indoor stadium in image.

Size: This property depends on the scale and resolution of the image/photo.

a

b



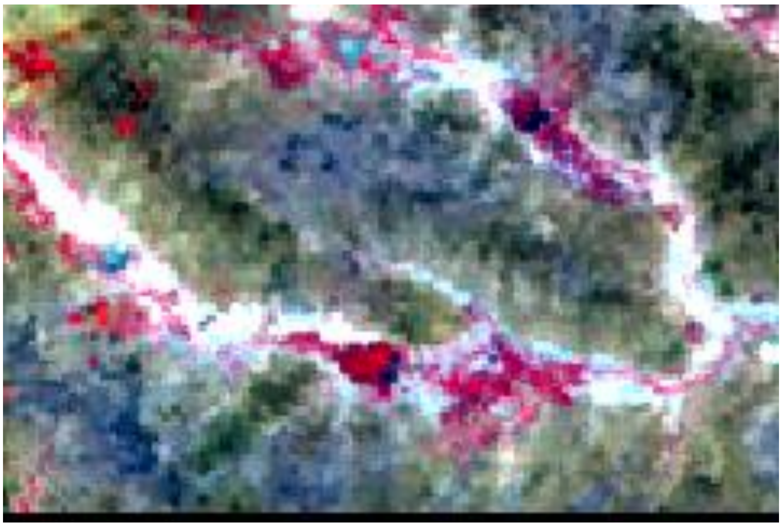
c

Questions:

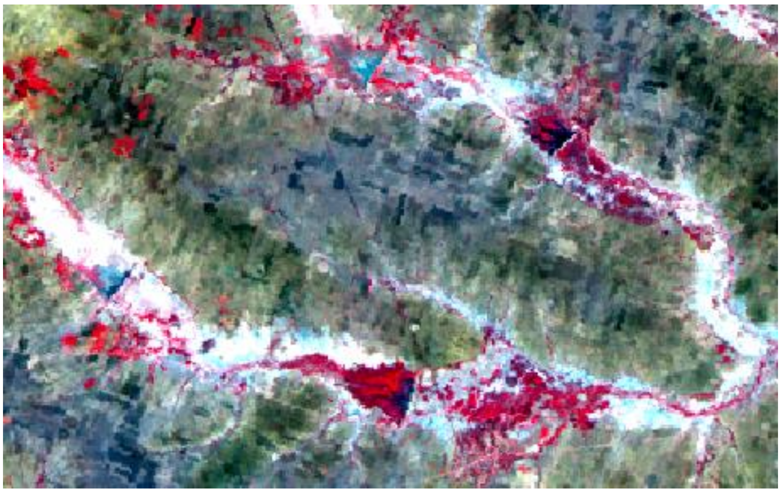
Observe and comment on:

1. In image chips a, b & c identify which has residential, industrial and institutional buildings.
2. Comment on the size of the buildings and how it helped you to categorize building types.

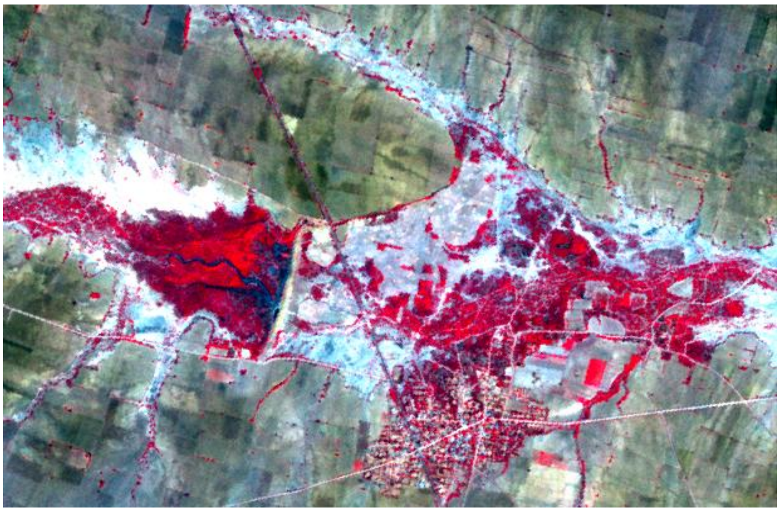
AWiFS FCC – 56 m



LISS-III- FCC – 24 m



LISS-IV FCC – 5.8m

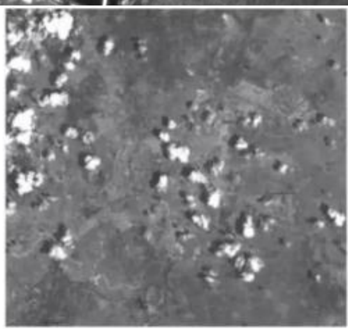


Observe and comment on:

3. Comment on the effect of spatial resolution and the effect it has on interpretation of details.

Shadow: Indicates the outline of an object on the ground and its length which is useful is estimating its height.




Observe and comment on:

Comment on the length of structures with the help of the shadow.

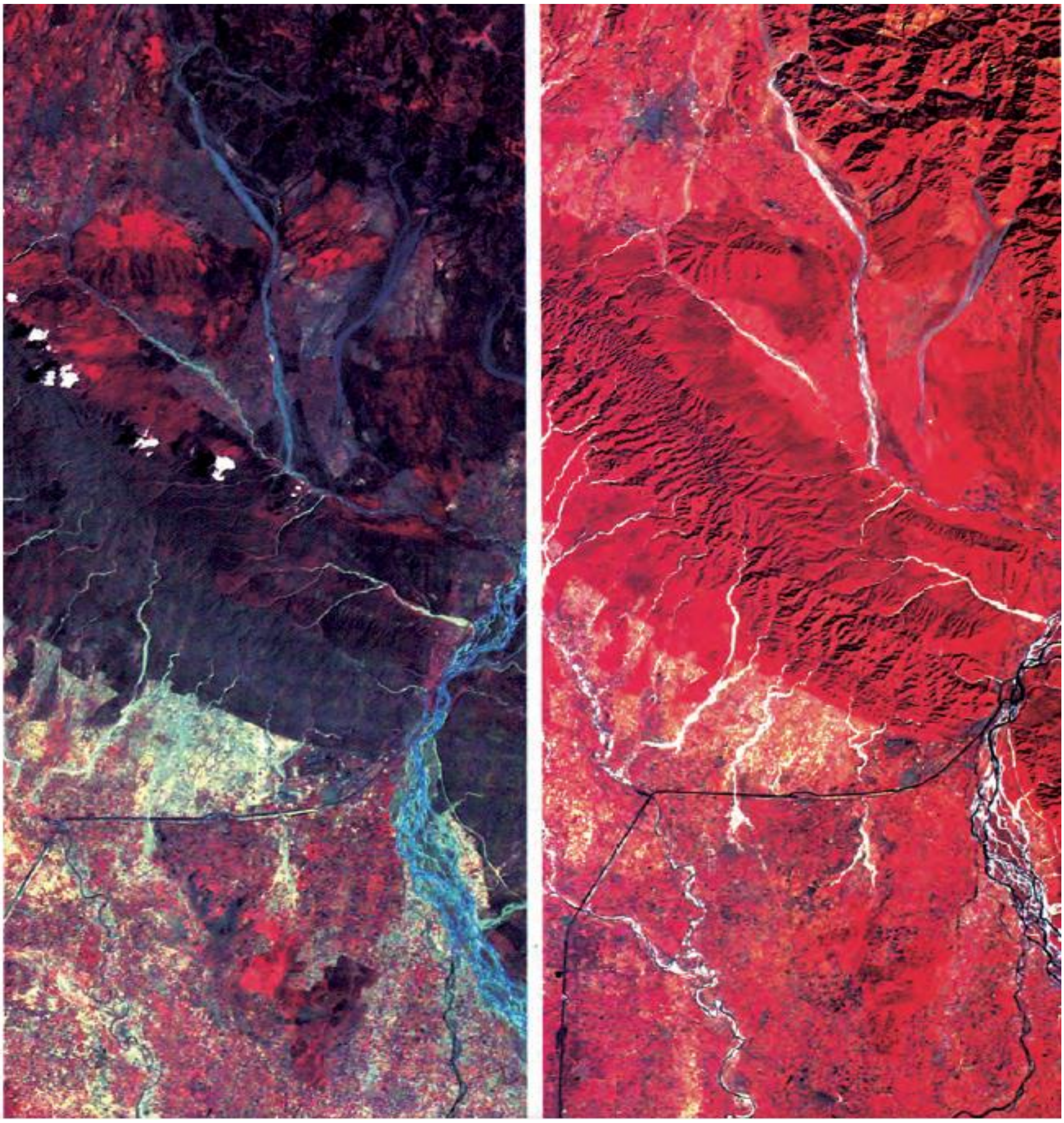
Association: Occurrence of features in relation to other features.

Question:

The screen print depicts an industrial area:

a. What are the features marked in yellow boxes?
b. How are they associated with industrial set up.

a. Images of Himalayas and Northern Indian Plain by IRS Satellite.



Question.

Identify the changes in both image chips and identify pre and post monsoon images in giving logical reasons.

b. True colour Composite IKONOS fused data

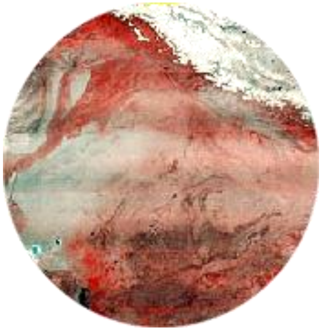
Question.

Identify the changes in both image chips and identify pre and post monsoon images in giving logical reasons.

1.2 Concept of visual image interpretation using RS data.

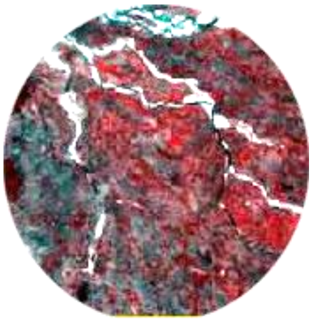
Objective:

- Familiarisation with different Remote Sensing data products in terms of differences in spatial, spectral, temporal characteristics
- Study and understanding of various land use/cover features based on image characteristics.
- Interpretation of relevant information from RS images.



1 km

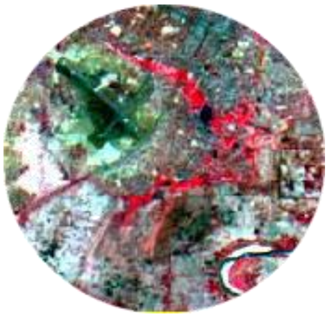
360 m



180 m

72 m

56 m



36 m

23.5 m

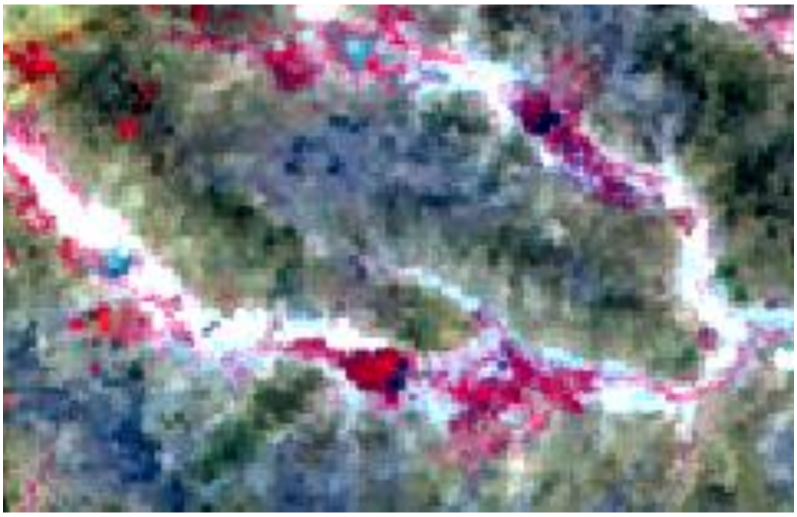
5.8 m

>1 m

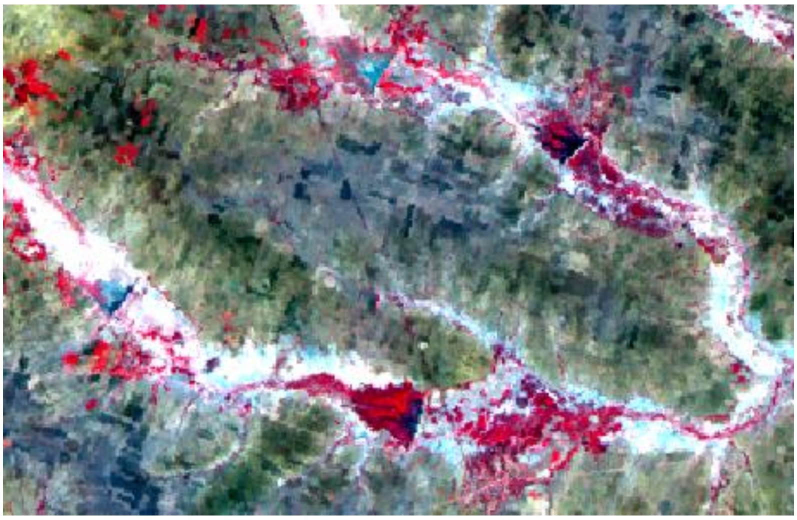
Questions:

1. Name the Indian sensors which provide data these spatial resolutions.
2. In which spectral bands does each one of them operate.

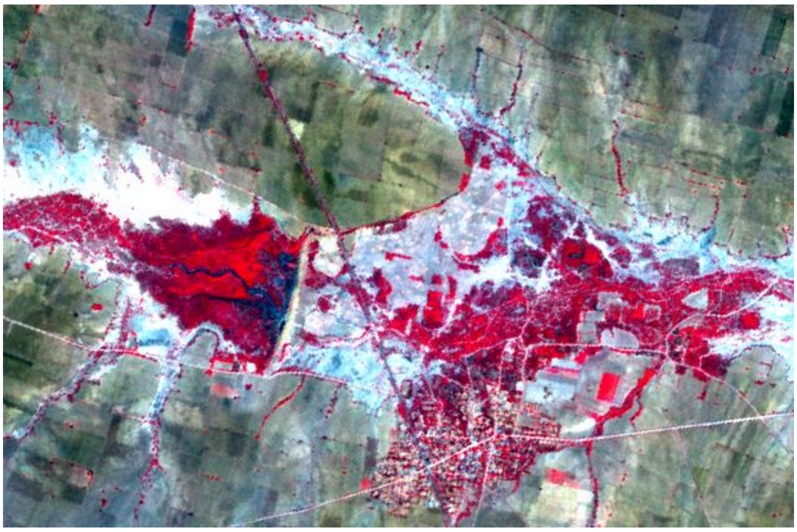
3. Comment on the effect of spatial resolution and the effect it has on interpretation of details.



AWiFS FCC – 56 m



LISS-III- FCC – 24 m

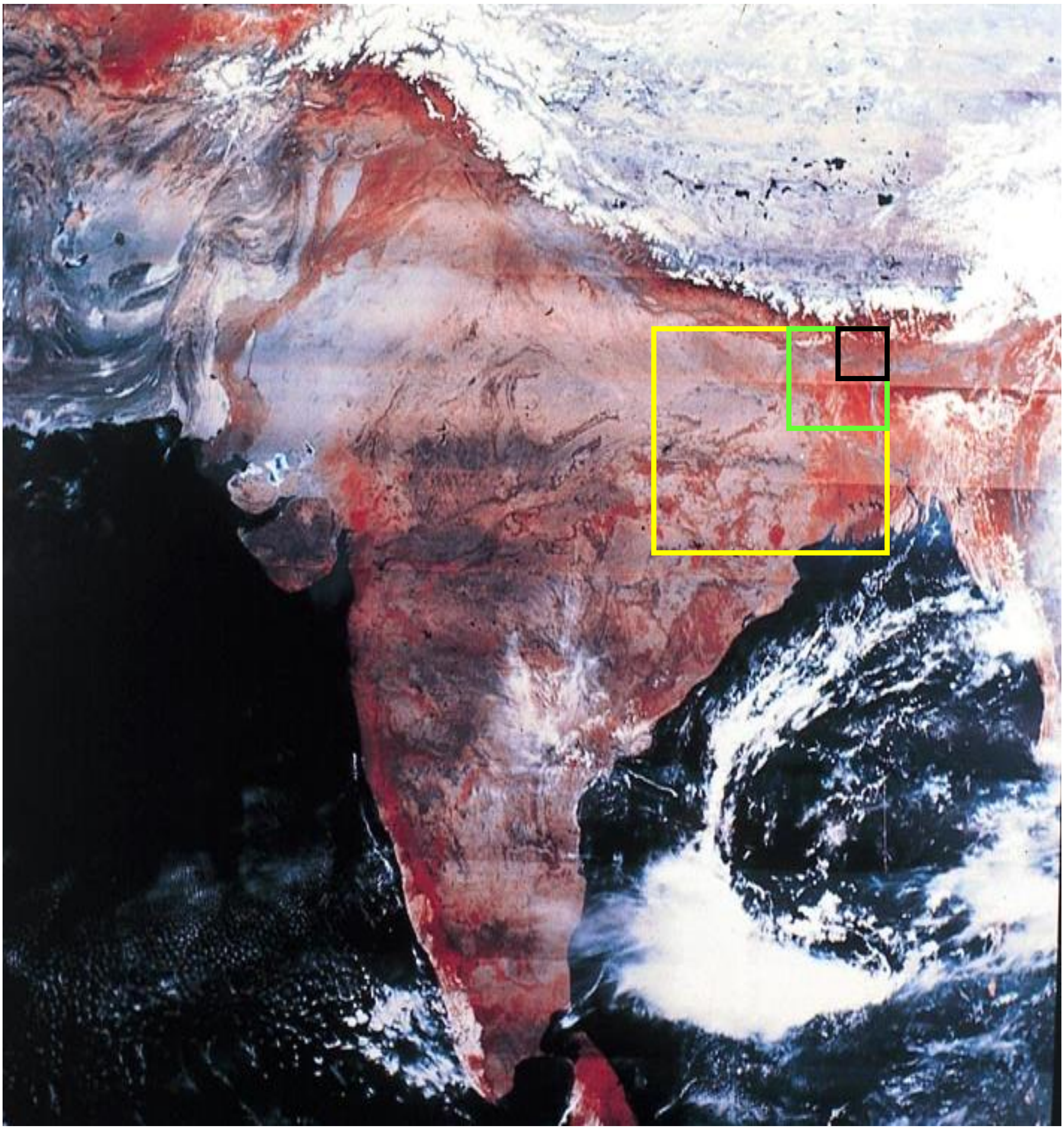


LISS-IV FCC – 5.8m

Comments:

4. Which box will correspond to area covered by

a. AWiFS -
b. LISS III -
c. PAN -

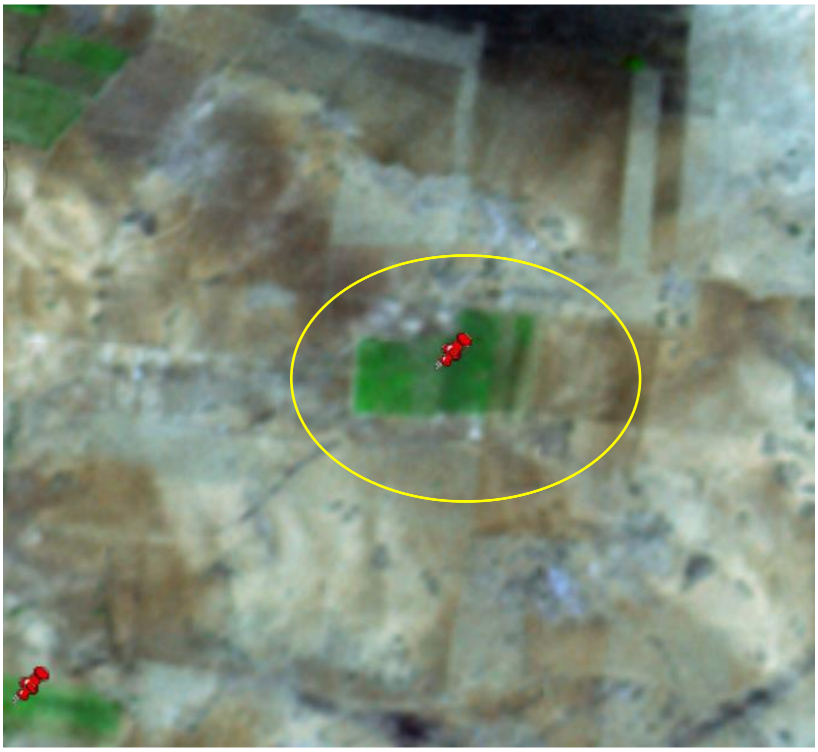


Cartosat & LISS IV data on BHUVAN

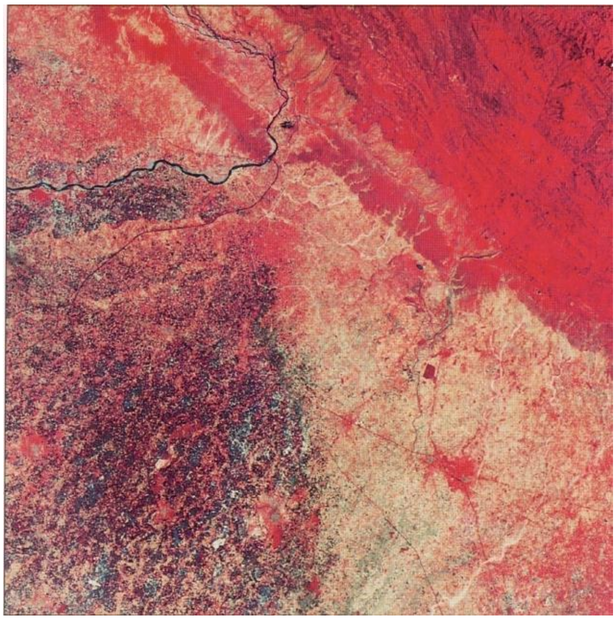
5. What are the changes observed in the area marked. Compare the features marked in the satellite data with respect to tone.

May 2011

March 2012

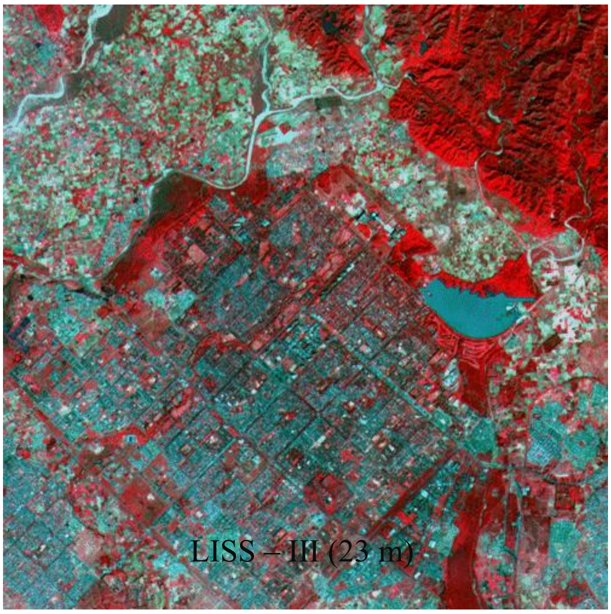


CHANDIGARH & ENVIRONS –NOTHERN INDIA



LISS – I (72 m)

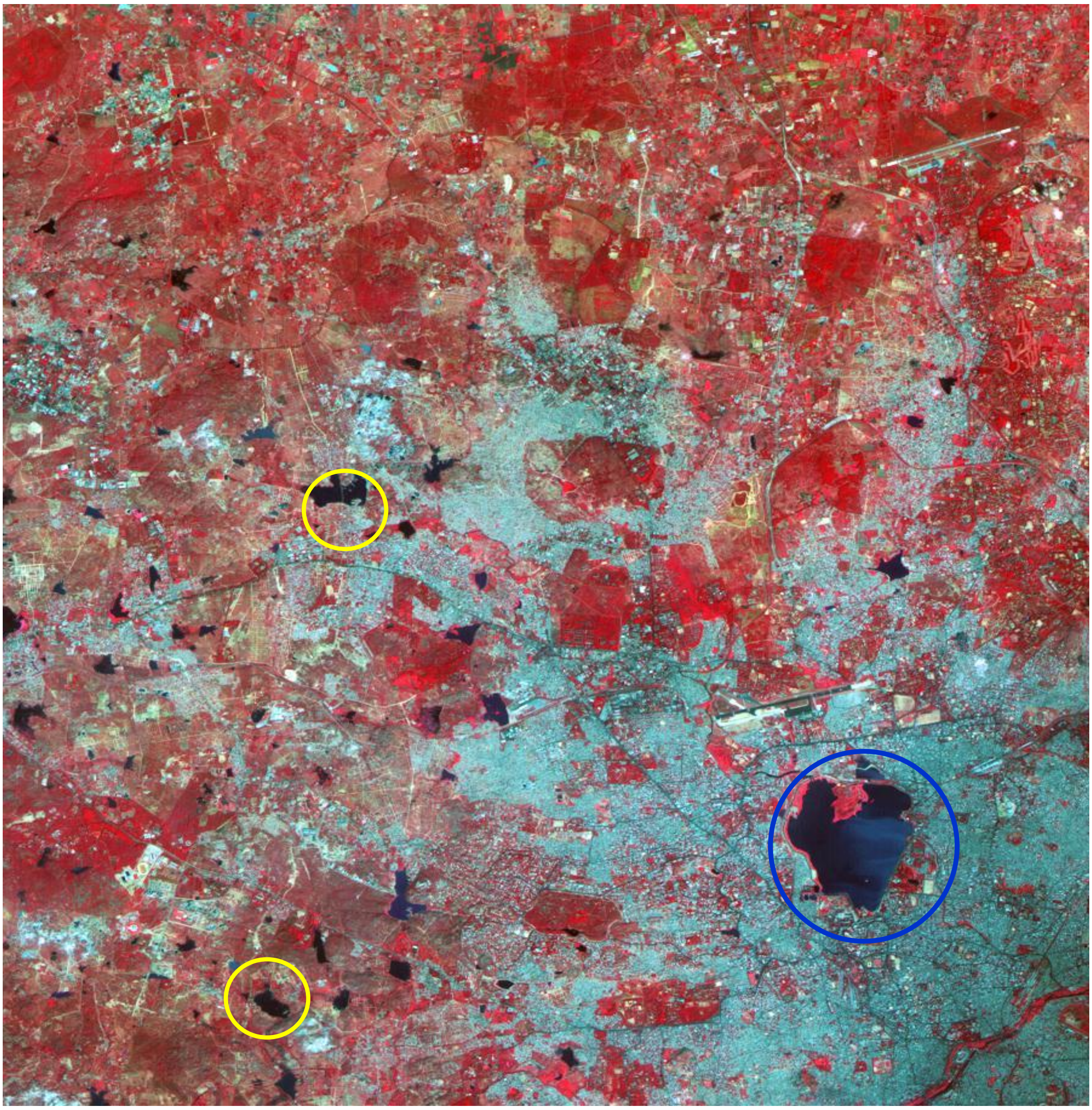
LISS – II (36 m)



6. With reference to above images, answer the following questions:

a. List out the land cover class that you feel can be visually interpreted from the four images.
b. Compare the data in terms of interpretable information with reference to spatial and spectral content.

Resourcesat –I LISS –III Image: Part of Hyderabad City



7. Interpret and mark the following features:

a. Airports.

b. How many airports are visible in the given image.

c. What are the features marked in yellow?

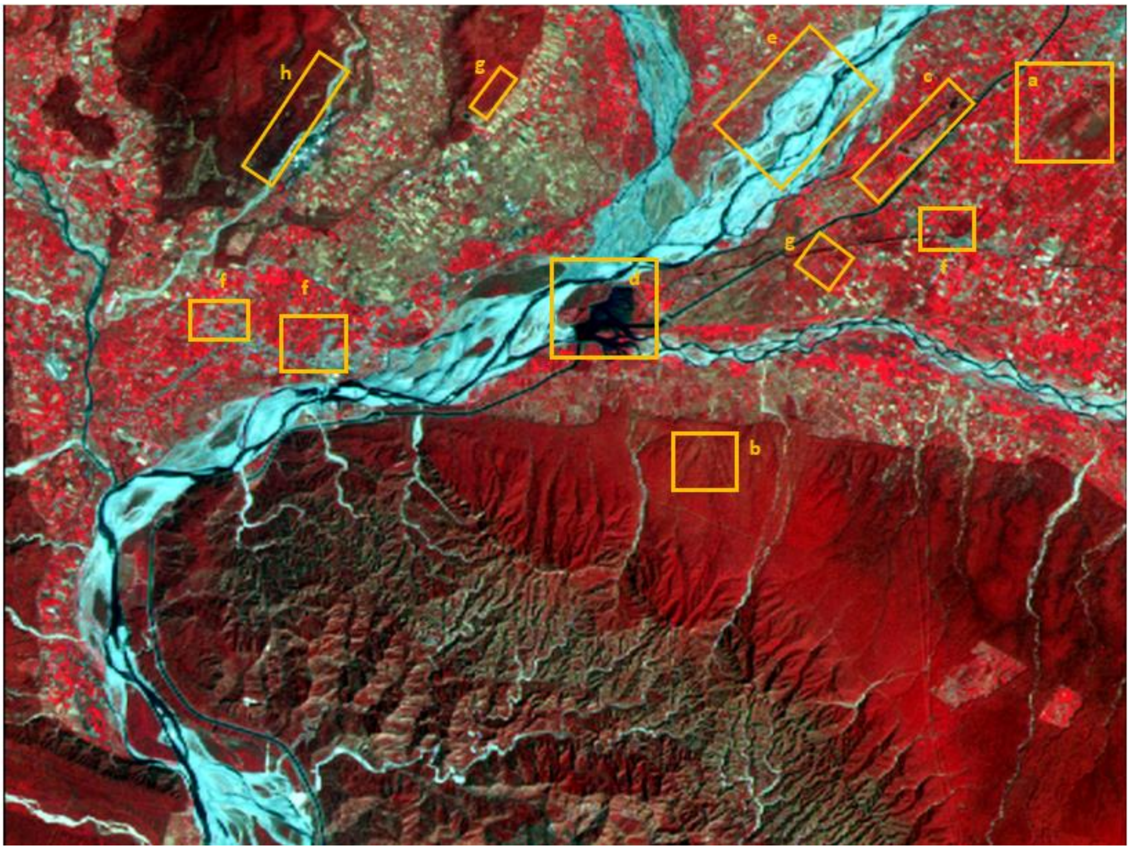
d. Name the object marked in blue.

e. What is the tone of the urban area

f. What is the spatial resolution of this data?

g. What are the spectral ranges of the dataset

LISS III image - Asan Barrage & surroundings



8. Questions:

a. Identify the features marked a – h.
b. Mention the elements of interpretation that helped you identify the feature.
c. Complete the following table:

#	Landcover/ use feature	Tone	Texture	Pattern	Shape	Size	Association

Exercise 2

GEOGRAPHICAL INFORMATION SYSTEM

2.1 Introduction:

QGIS is a free, open-source Geographic Information System (GIS) software used for viewing, editing, and analyzing geospatial data. It allows for the creation and styling of maps, the processing of geographic data, the analysis of spatial information, and the creation of interactive maps. It is available for a variety of platforms, such as Windows, Mac, and Linux, and can be used for a range of tasks, from basic data visualisation to advanced data analysis. This exercise provides a way to get brief hands-on on QGIS starting from digitisation to adding existing data, querying and finally visualising the map through making a map layout.

2.2 Digitisation

2.2.1 Data & Software/Tools

Image: Download any satellite image from Bhuvan (https://bhuvan-app3.nrsc.gov.in/data/download/index.php) or earthexplorer (https://earthexplorer.usgs.gov/))

QGIS: Digitizer toolbar, Advance digitizer toolbar and QuickMapServices plugin

Plugin installation steps can be followed from the link https://docs.qgis.org/3.28/en/docs/training_manual/qgis_plugins/fetching_plugins.html

2.2.2 Part 1: Steps for creating data

Adding Data to Canvas

- Add raster data layer which will be used for digitization.
- From the main menu choose ***Layer → Add Layer → Add Raster Layer.*** It open up a new pop up window, now browse to the ***satellite image*** and click ***Add***. (Figure 1 & Figure 2)

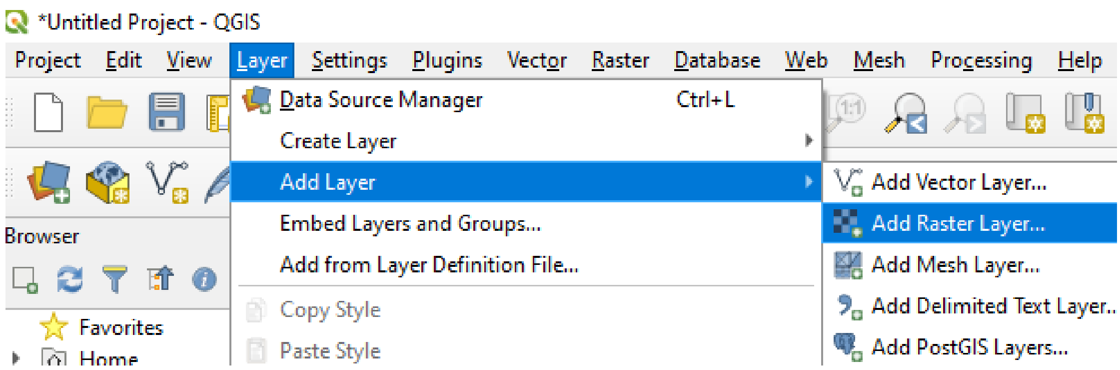


Figure 1

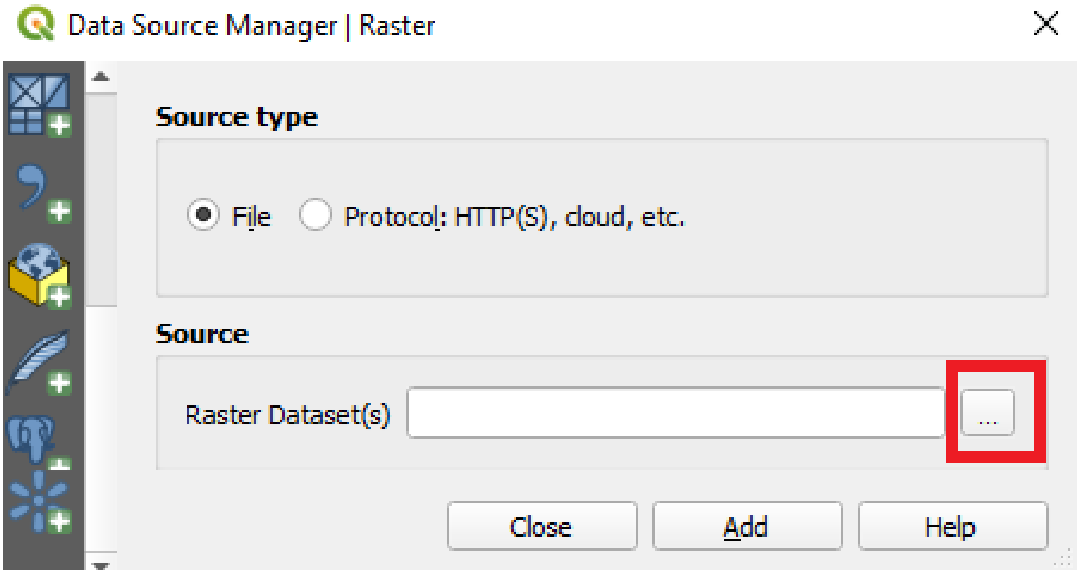


Figure 2

Optional step:

- If dataset is larger, then while zooming in or out you can notice that it takes some time to render the data. The simple solution to this problem is creation of pyramid layers. QGIS creates pre-rendered tiles at different resolutions, and these are presented to you instead of the full raster. This makes map navigation snappy and responsive.

- Right-click on the raster layer which you have opened earlier and choose ***Properties → Pyramids.*** Now select all the resolutions available in the Resolution panel then click on ***Build Pyramids.*** Click ok after process is finished (*Figure 3*).

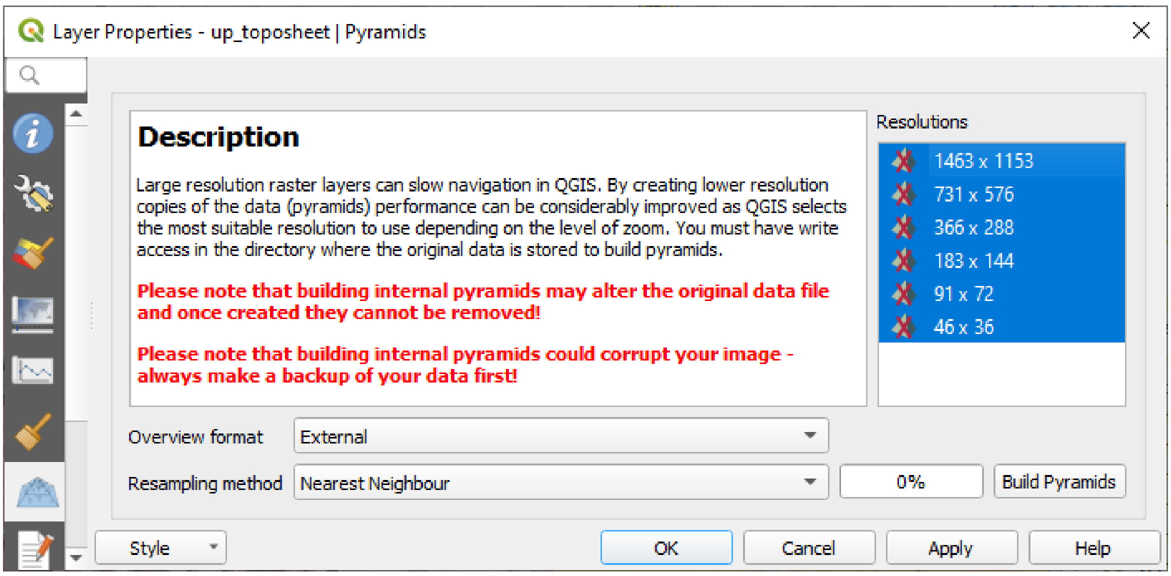


Figure 3

Part 1

Tasks

Create point shapefile

Task 1: Create a point layer of location of interest

Create line shapefile

Task 2: Create a shapefile of linear features like road, river with attribute fields like Name, Type, and Length etc.

Create polygon shapefile

Task 3: Create a shapefile of polygon features representing land use/ land cover classes with attribute fields like Type, Perimeter, Area etc.

Note: Data can be stored in any existing shapefile (with matching geometry) or new shapefile can be used.

Steps to Perform Task 1: Creating new shapefile.

- From the main menu, choose ***Layer → Create Layer → New Shapefile Layer.*** Clicking on New Shapefile Layer will open a new dialogue (Figure 4, Figure 5); choose the desired Geometry type (point, line and polygon).
- Choose the suitable coordinate reference system (CRS) using button, preferably EPSG: 4326, WGS 84.
- Additionally, while creating a GIS layer, you may decide on the attributes that each feature will have.

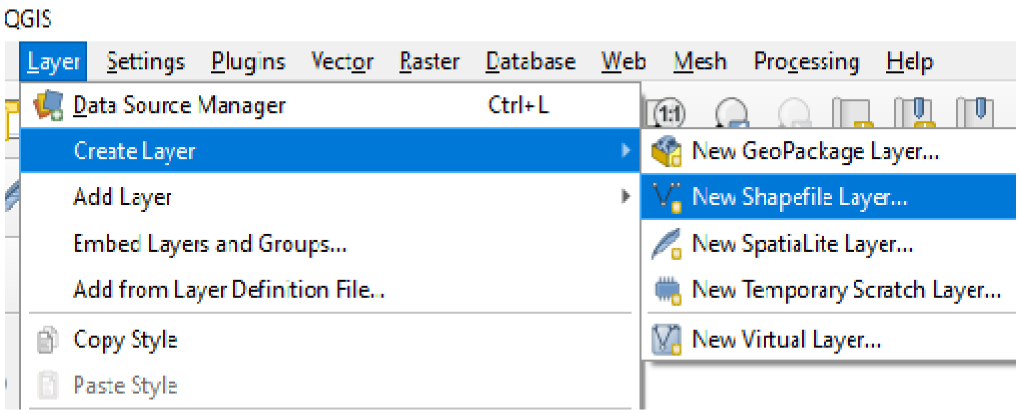


Figure 4

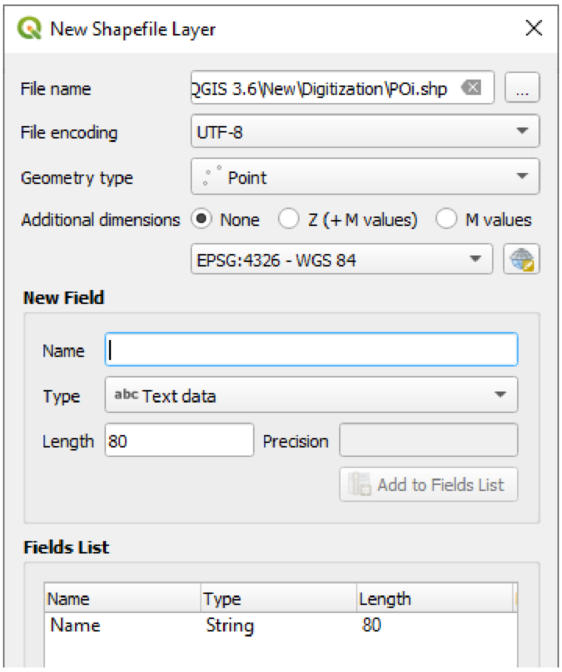


Figure 5

To add attribute fields:

- Enter **Name** of the field and select the data **type (Text data, Decimal number, Whole number, Date).** Also enter the desired **Length** and **Precision** of the field.
- Click on **Add to Fields List.**
- Once all the fields are added, click **OK** to make new shapefile. The empty layer will be automatically loaded in canvas and listed under **layers** panel.

- **To add attribute fields in existing shapefile:**
- Open **attribute table** of the shapefile and start **editing.**
- Click on  to add new field, enter desired details and click **OK** to add field to attribute table and save edits.

Adding New Features:

- Once the layer is loaded, click on  icon to enable editing mode. (Alternate: Right click over the 'layer name' under layer panel and click on **Toggle Editing**.)
- To add some feature, click  on button, this will change the cursor type. In addition, click over the location of interest to add point; this will open a dialogue to enter attribute values (
-). Fill the attribute values and click **OK.**

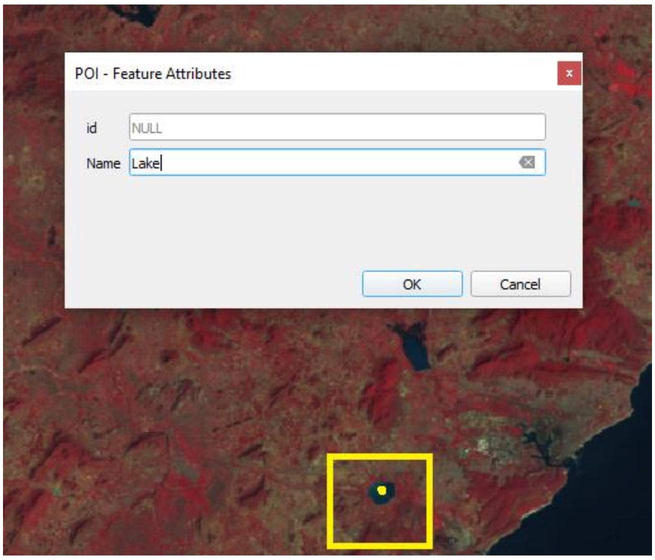


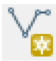
Figure 6

Note: If feature is not properly visible on the map, change symbol type, colour, size.

Repeat the above step until all the desired points are created. once finished do not forget to **stop editing** for the layer. Editing can be stopped by clicking  icon. (Alternate: Right click over the 'layer name' under layer panel and click on **Toggle Editing**.)

Tip: Keep saving the edited layer frequently.

Steps to Perform Task 2: Create Line Shapefile

- Create a new shapefile named **"linear"** as described in task 2. (Steps are similar as of Task 1)
- **Adding New Features**
- Once the layer is loaded, click on  icon to enable editing mode. (Alternate: Right click over the 'layer name' under layer panel and click on **Toggle Editing**.)
- To add some feature, click on  button, this will change the cursor type. Start tracing the feature via mouse click in the map and ***'right click'*** where you want to end. This will open a dialogue to enter attribute values (Figure 7). Fill the attribute values except length and click **OK.**

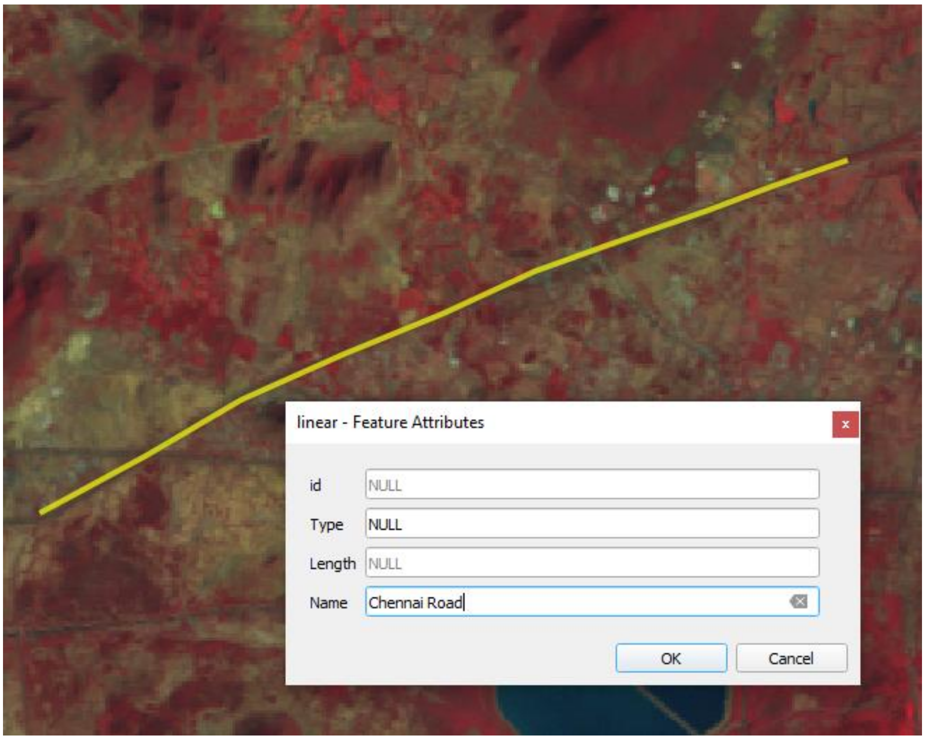


Figure 7

Note: If feature is not properly visible on the map, change symbol type, color, size.

Question: How did you change the symbol?

Repeat the above step until all the desired features are created, once finished do not forget to **stop editing** for the layer. Editing can be stopped by clicking icon. (Alternate: Right click over the 'layer name' under layer panel and click on **Toggle Editing**.)

Steps to Perform Task 3: Create Polygon Shapefile

Create a new shapefile named **"lulc"** as described in task 3. (Steps are similar as of Task 1)

Adding New Features

- Once the layer is loaded, click on icon to enable editing mode. (Alternate: Right click over the 'layer name' under layer panel and click on **Toggle Editing**)
- To add some feature, click on button, this will change the cursor type. Start tracing the feature via mouse click in the map and ***'right click'*** where you want to end. This will open a dialogue to enter attribute values (Figure 8). Fill the attribute values except Perimeter & Area and click **OK.**

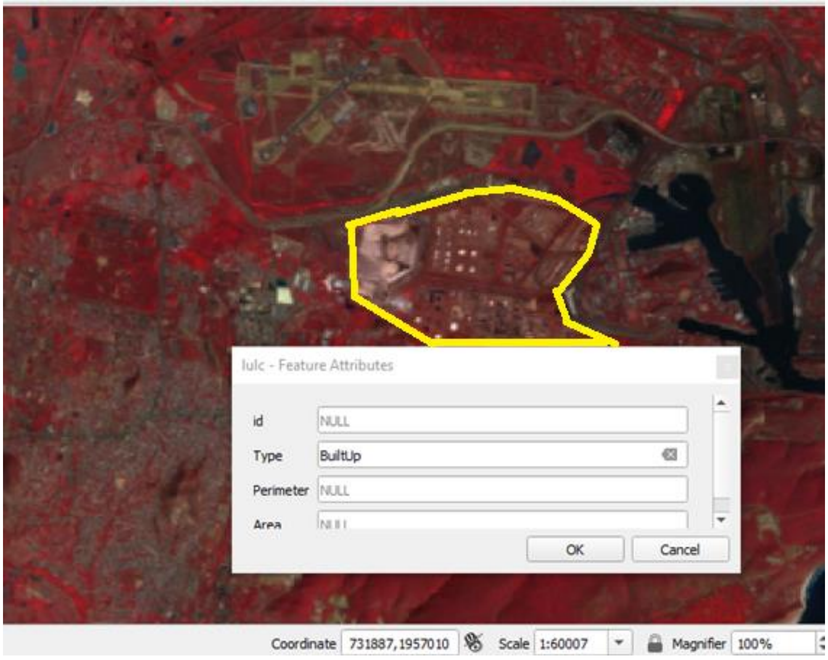


Figure 8

2.2.3 Part 2: Adding existing data

1. Download and install the "Latest release standalone installer" QGIS from www.qgis.org

2. Download the District boundaries of India from https://raw.githubusercontent.com/datameet/shapefiles/master/india/district/india_district.json (These are not the authentic district boundaries of India. This is a **toy dataset**)

3. Open QGIS and drag and drop the india_district.json file that you downloaded in step 2. We have added our first vector data in QGIS! Make sure you know where the file was downloaded.

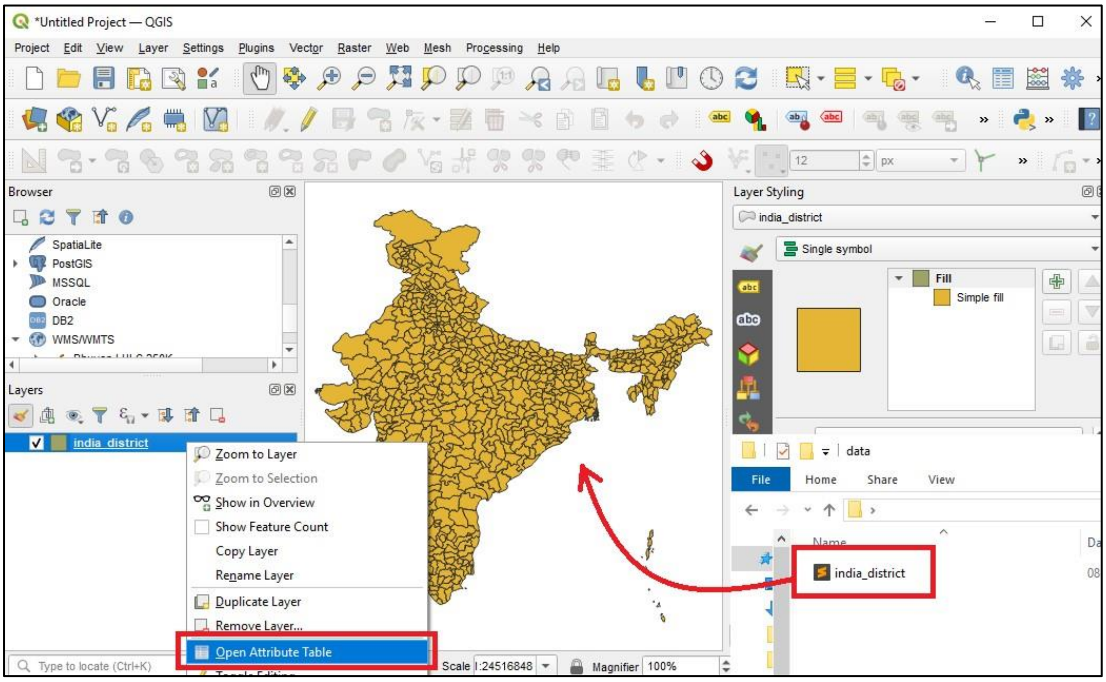


Figure 9

i Querying data

1. Right click on the “india_district” layer name and click on “Open Attribute Table”. You can see the attributes for each district of India.

2. Click on the icon, which looks like the summation sign. When you hover your mouse over it, it says, “Select features using an expression”. It will pop up another box, which is titled “india_district - Select by Expression”.

3. Type this query (in red color) in the Expression box: "district" = 'Tehri Garhwal' . You may see the name of your own district and search for that instead for e.g., "district" = 'Dehradun'. Click on the “Select features” button. (In case you see more than 1 district selected, open the attribute table, Show selected features, press Ctrl and click on the unwanted rows. This will unselect the unwanted rows, and you will be left with the selection of the required district)

4. Close the “Select by Expression” window, and click on the button, which looks like the magnifying glass. When you hover your mouse over it, it says, “Zoom map to the selected rows”. You will see that QGIS will zoom in to your district.

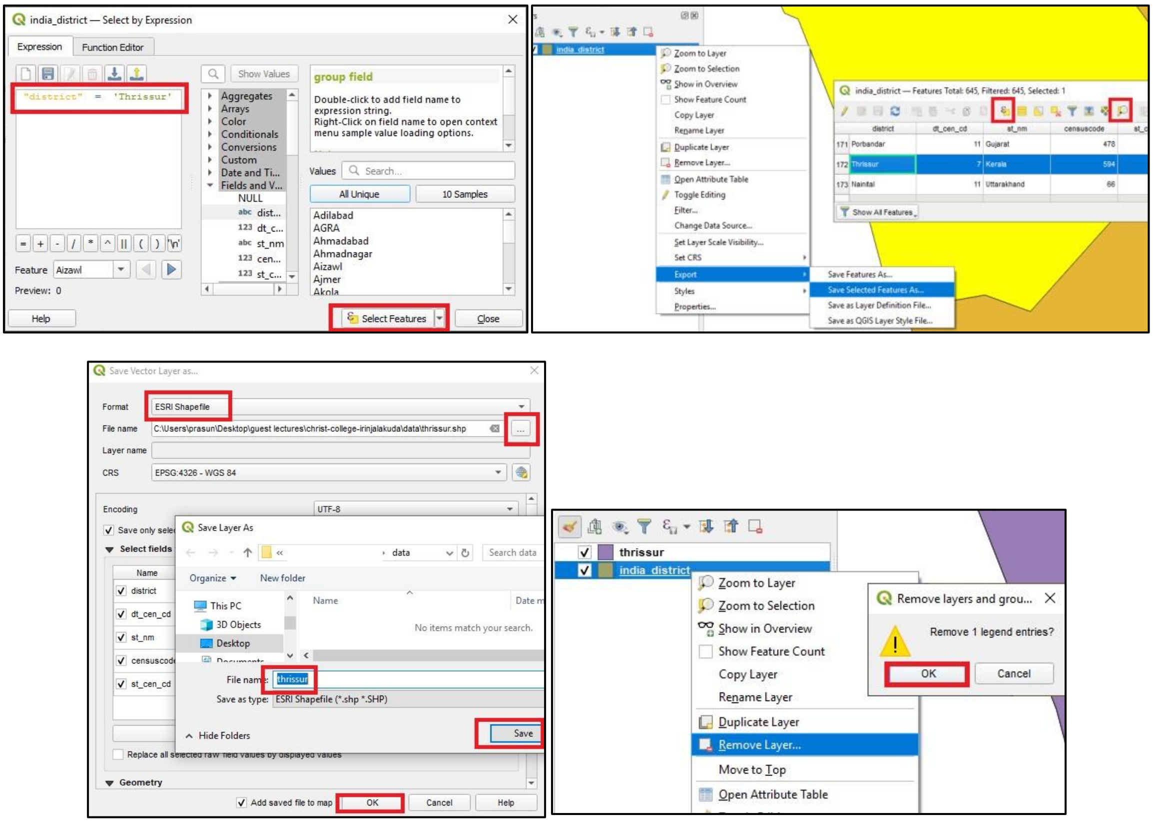


Figure 10

5. Let us save your district as a separate file. Close the attribute table. Right click on the layer name, goto Export - Save selected features as ... Set the following options:

    a. Format: ESRI Shapefile

    b. File name: Click on the browse button (button with 3 dots) and give a name to the output file, let's say "bilaspur". Click on Save.

    c. Click on OK button.

6. You have created your first GIS vector data! Remove the india_district file. Right click on the layer name india_district and click on "Remove layer". Click OK on the confirmation box.

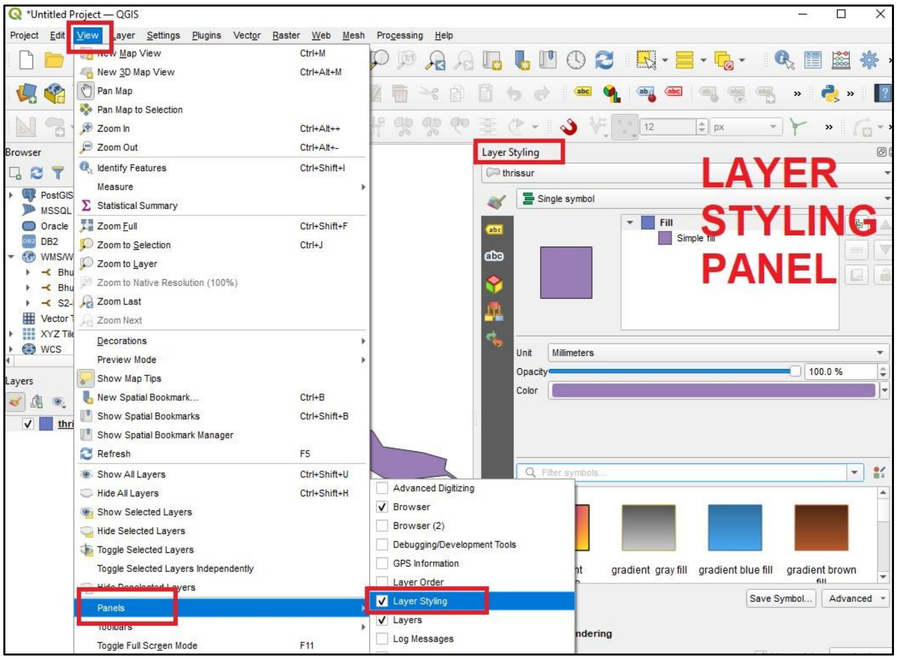


Figure 11

ii. Changing the visualization.

10. Ensure that you are seeing the layer styling panel. If not, the go to View - Panels - Layer Styling. Let us show the district as an inverted fill (you will see in next section why we chose this symbology).

11. Click on the dropdown, which says “Single symbol”. Select the option “Inverted polygons” and change the color to white.

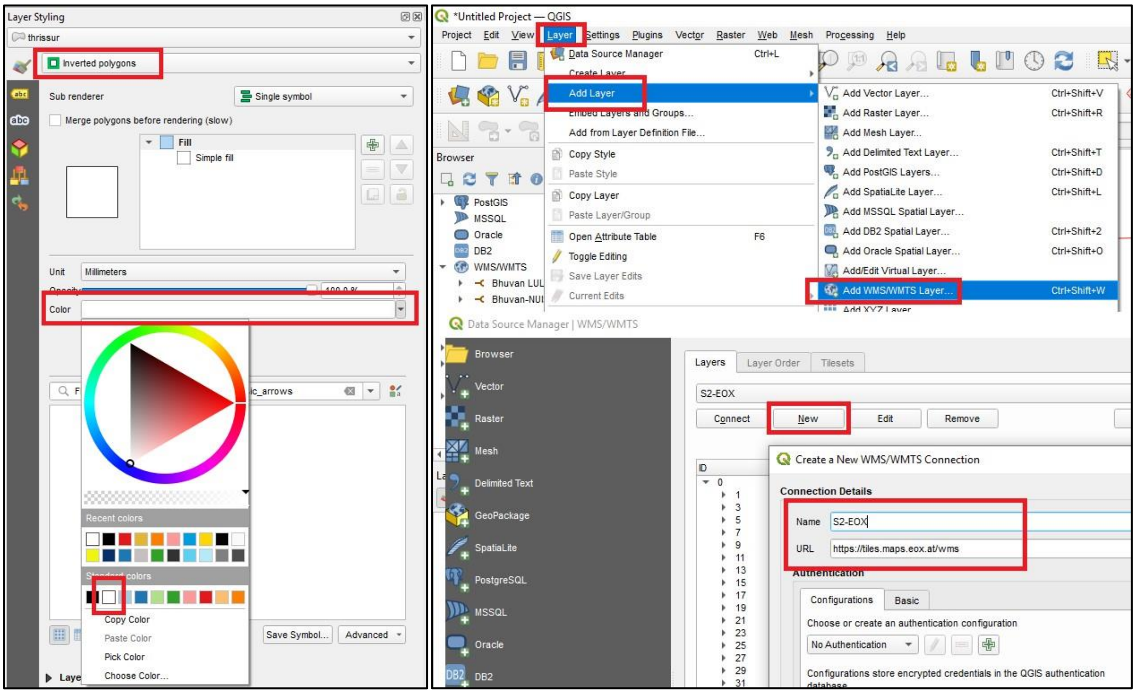


Figure 12

iii. Add Raster Data

12. Next, let us add some land use land cover data. Usually, we can download such files from ISRO's Bhuvan portal. However, this time let us explore something very new - a WMS layer! WMS layers are image, which are streamed on the internet. Make sure you have a good internet connection to do this part.

13. Click on Layer - Add WMS/WMTS layer. Click on New. Type the following details:

    a. Name: Bhuvan LULC

    b. URL: https://bhuvan-vec2.nrsc.gov.in/bhuvan/wms

14. Click on OK and then click on Connect. In the search box, type "UK_LULC" (for Uttarakhand LULC) and select the latest one "lulc:LULC50K_1516_NEW" (as on March 2023). Click on Add and close the box.

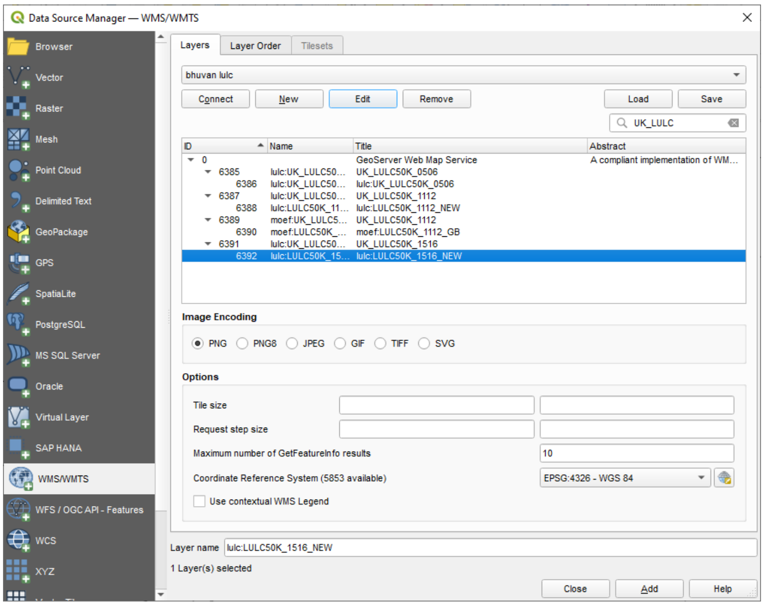


Figure 13

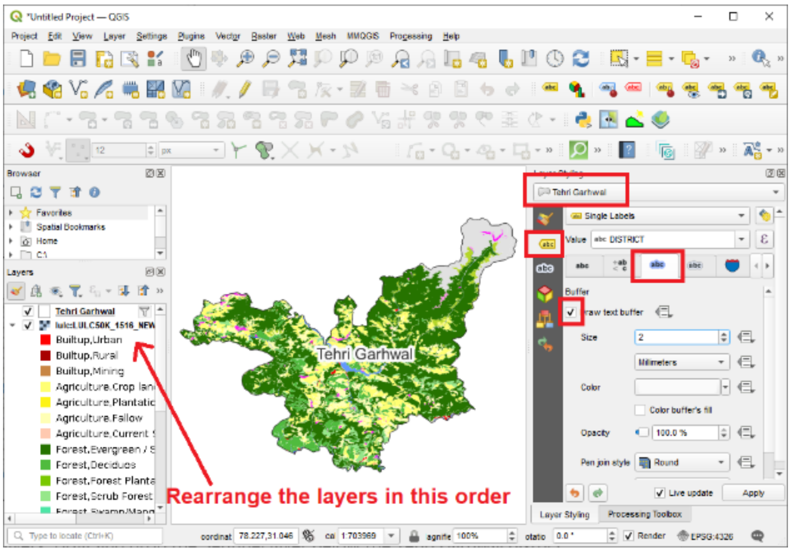


Figure 14

15. You have added a WMS rater layer! This is from the ISRO's LULC programme. You may need to rearrange the layers. Drag and drop the Sentinel layer below the Tehri Garhwal district boundary layer. You see just the satellite image of your district!
16. Let us show the name of the district. Left click on the layer name, in the layer styling panel, click the icon which says "abc", when you hover you mouse over it, it says "Labels". In the value dropdown, ensure "district" is selected. Click on the tab (hover says) "Buffer" and put tick on the checkbox for "Draw text buffer".

iv. Input data from a text file

17. Save the coordinates of your college in a text file as shown below.

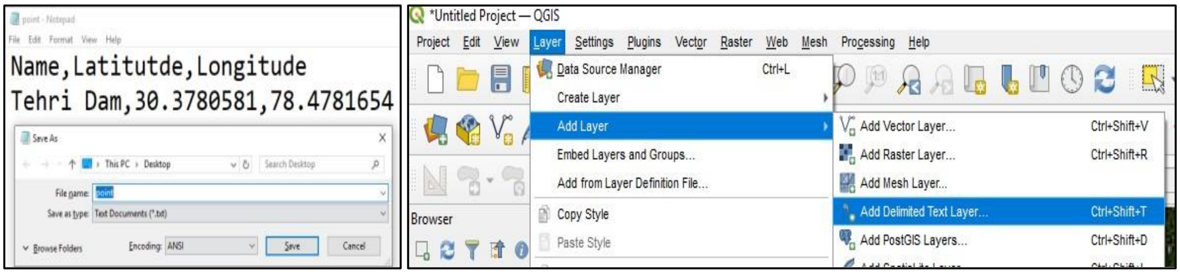


Figure 15

18. In QGIS, click on Layer - Add layer - Add delimited text layer.
19. Click on the browse button, select the text file (point), and set the following options:
    a. Custom delimiter: Comma
    b. First record has field names.
    c. Point coordinates (X field = Longitude; Y filed = Latitude) 20. Click on Add and close.

20. Customize the labels to look like shown below.

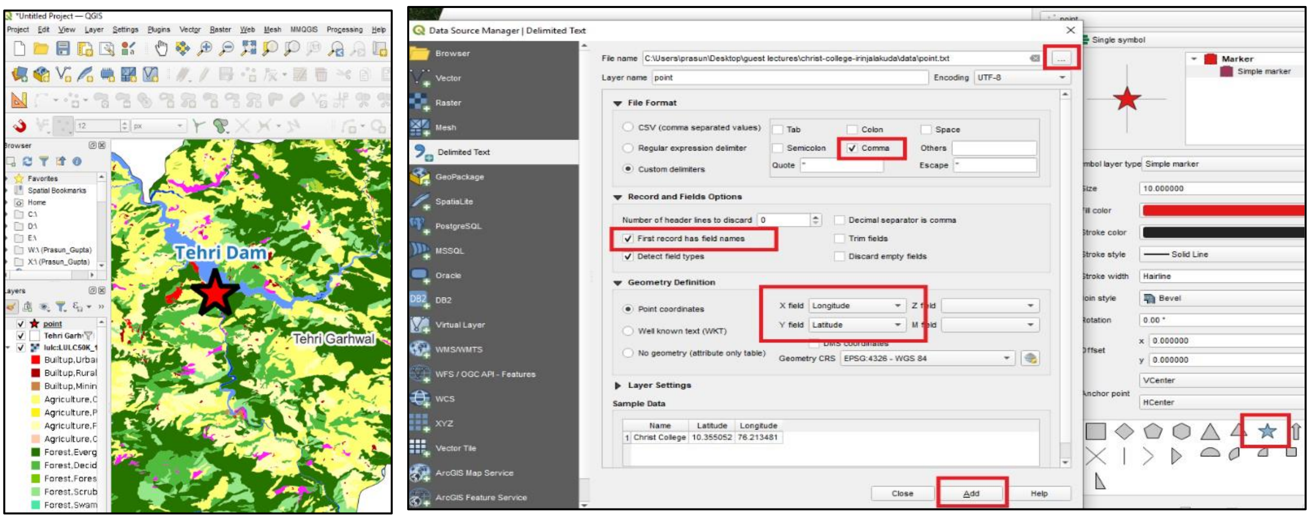


Figure 16

v. Making the map

22. Click on Project - New Print Layout. Click ok on confirmation box.
23. Click on Add item and add map. Drag the area where you want the map to be.
24. Add other map elements such as title, legend, scale, grids etc.
25. Export the map to pdf or jpeg.

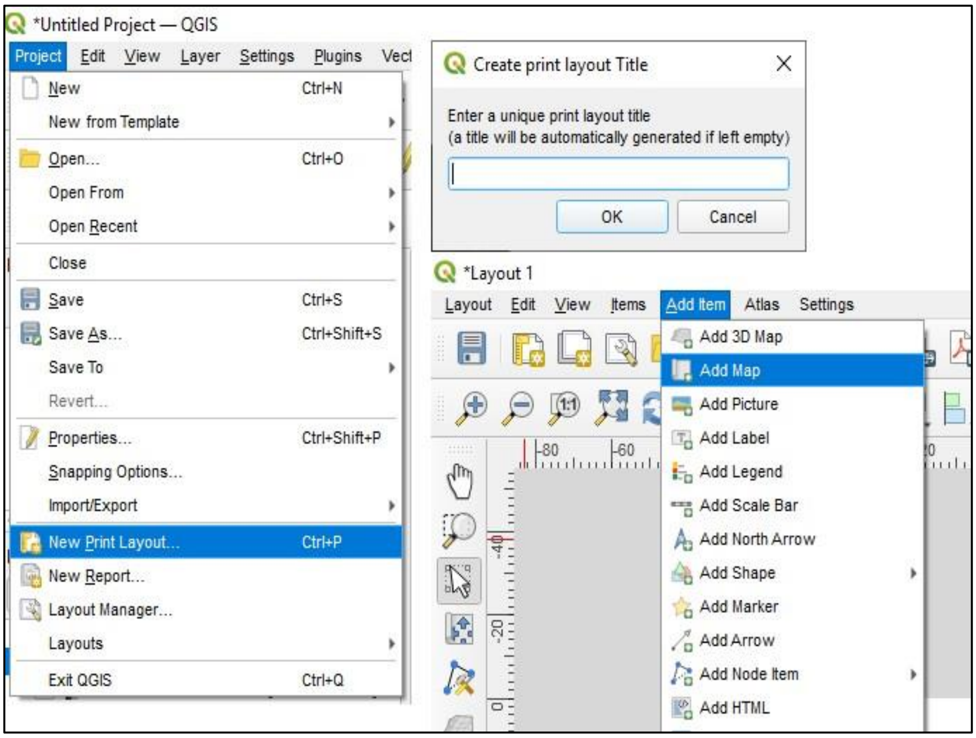


Figure 17

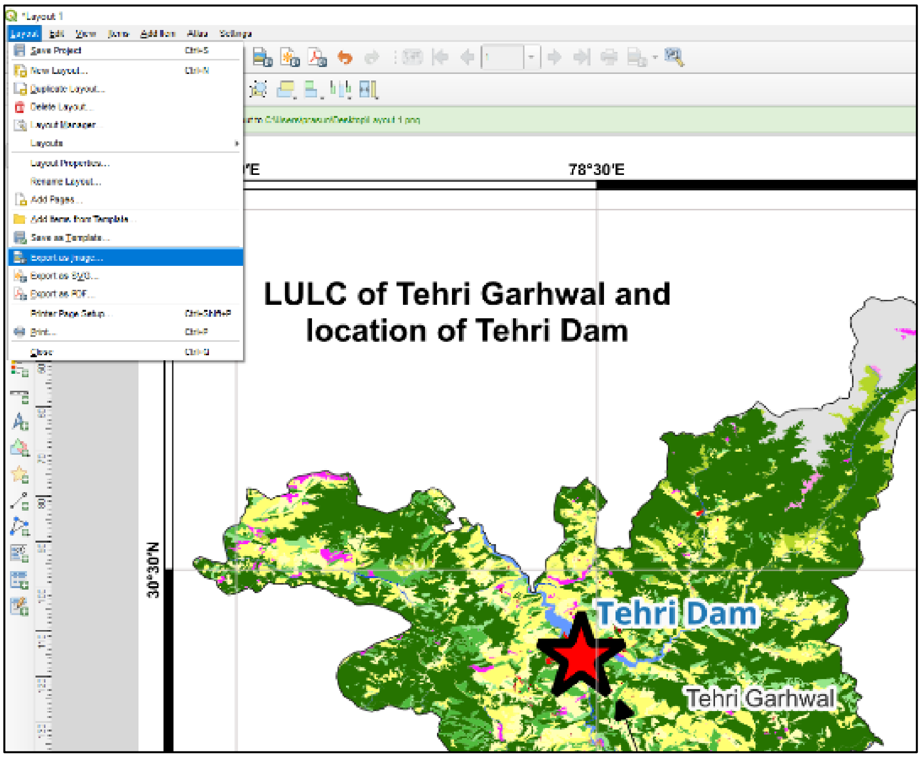


Figure 18

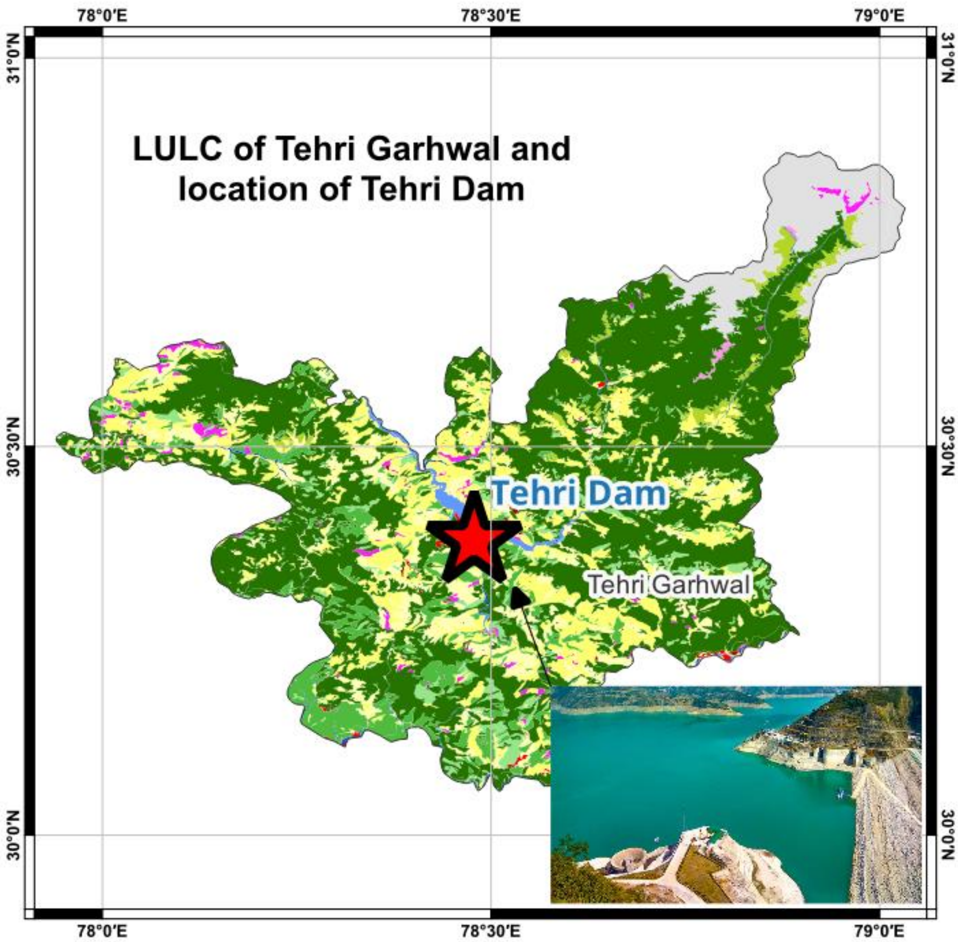


Figure 19

On completion of this exercise, the learners will be able to:

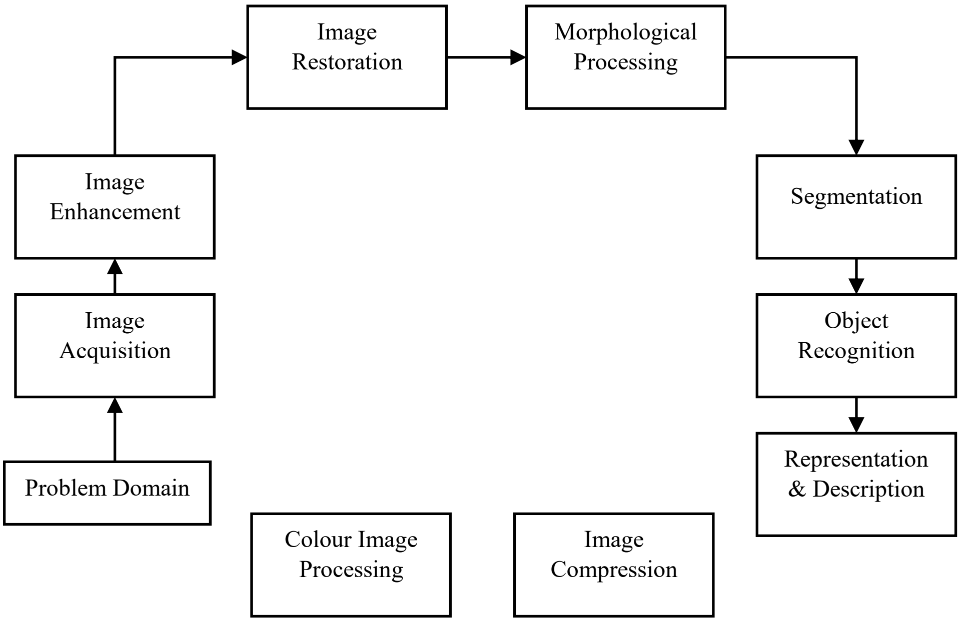
- Know the basic functionalities of QGIS operations like Adding new data to QGIS canvas,
- Digitisation and creating vector data,
- Performing queries,
- Create a map in GIS environment for visualisation.

Having knowledge of such operations is essential for anyone working/ planning to work in the direction of satellite data processing.

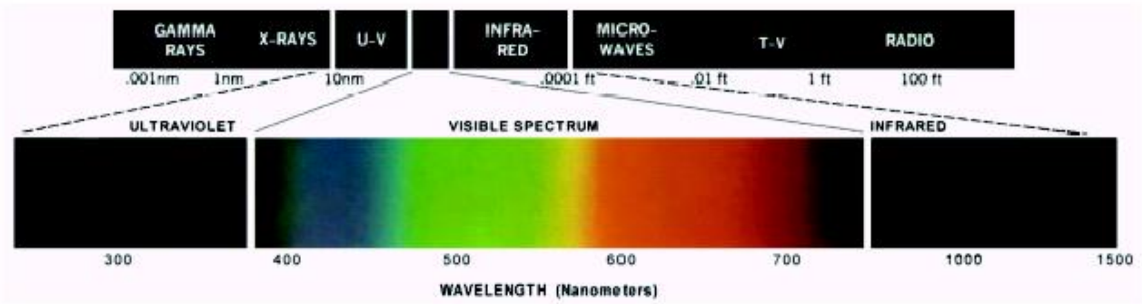
Exercise 3

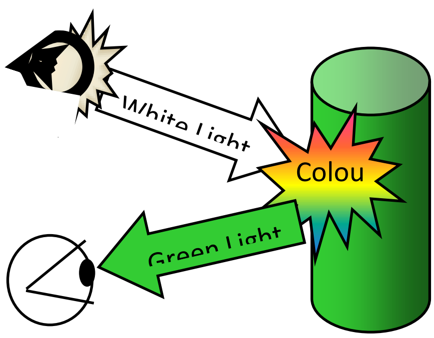
DIGITAL IMAGE PROCESSING

3.1 Key Stages in Digital Image Processing



3.2 Light and the Electromagnetic Spectrum





3.3 Image Acquisition

Images are typically generated by *illuminating* a *scene* and absorbing the energy reflected by the objects in that scene.

Typical notions of illumination and scene can be way off:

- X-rays of a skeleton
- Remote sensing images
- Electro-microscopic images of molecules

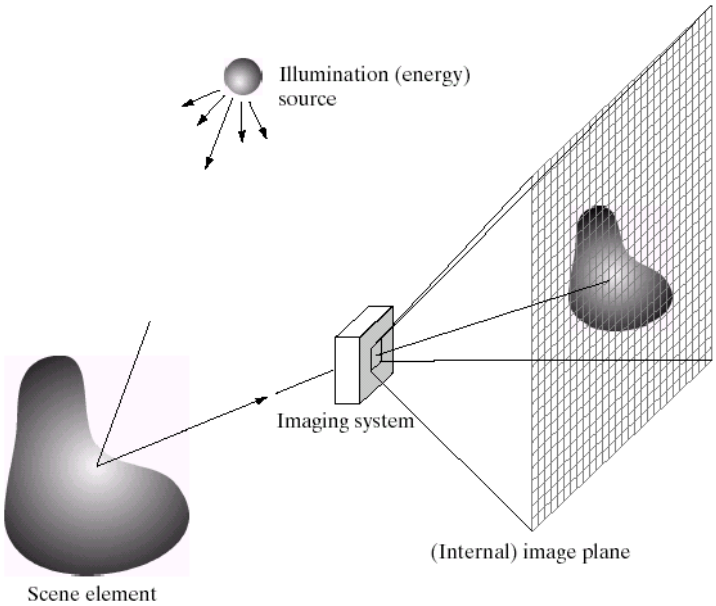
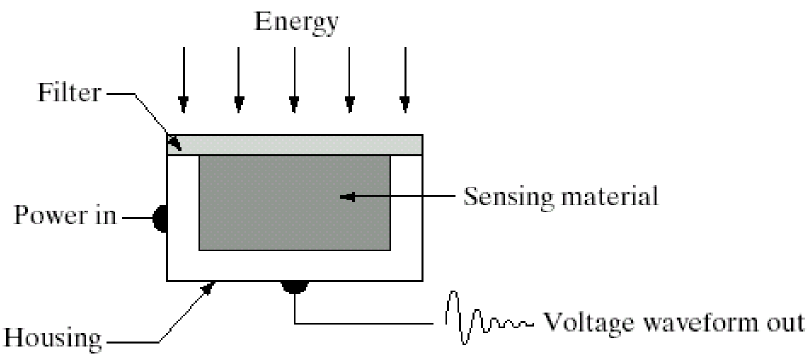


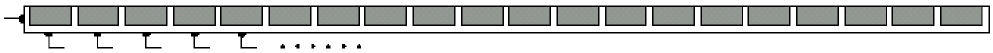
Image Sensing:

- Incoming energy lands on a sensor material responsive to that type of energy and this generates a voltage.
- Collections of sensors are arranged to capture images.



Imaging Sensor:

Line of Image Sensor



Array of Image Sensor

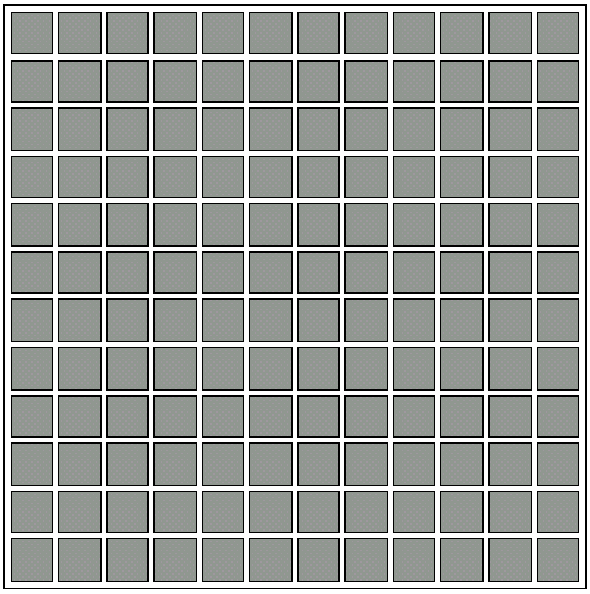
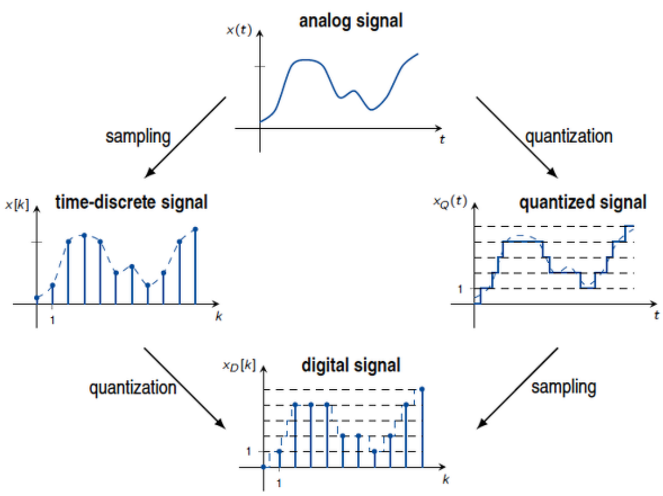
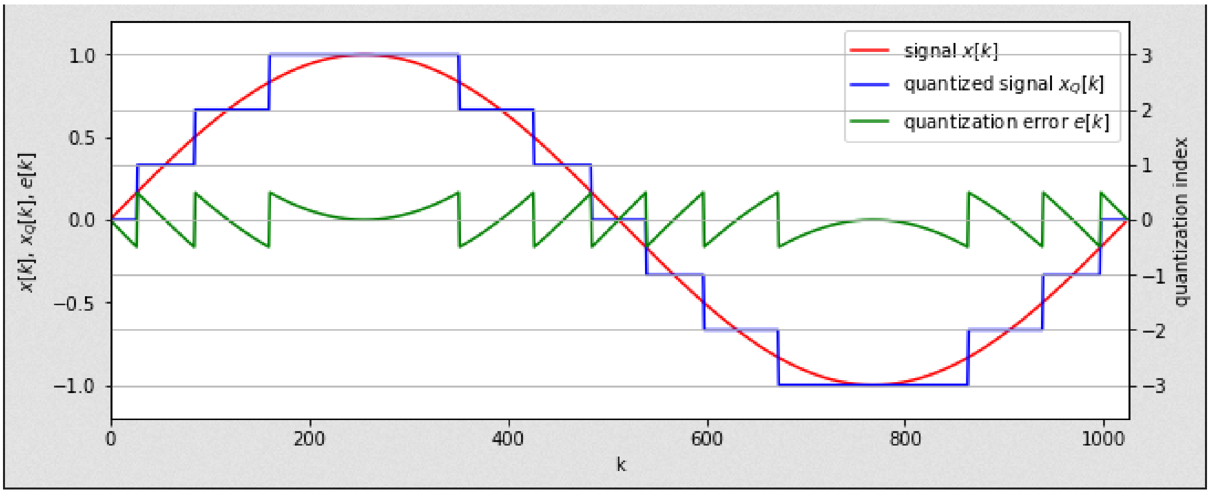


Image Sampling and Quantisation

- A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels
- *Quantisation* is the process of converting a continuous **analogue** signal into a digital representation of this signal.





Resampling Problem:

Knowing image intensities at discrete *(x,y),*

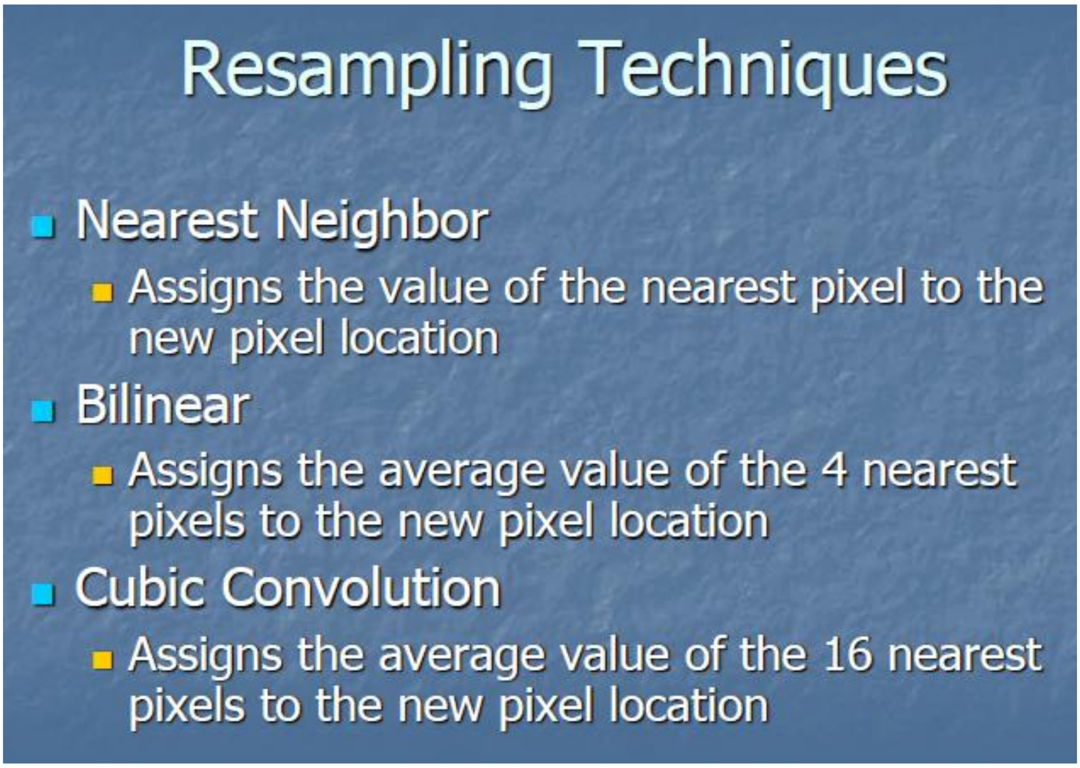
determine the intensity at an arbitrary *(X,Y).*

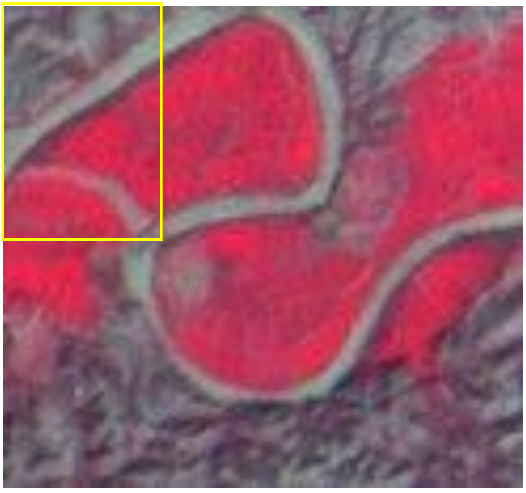
Approach:

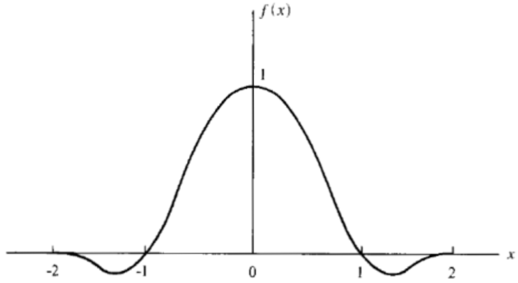
Fit a surface to the discrete

points and estimate the

surface value at *(X,Y).*

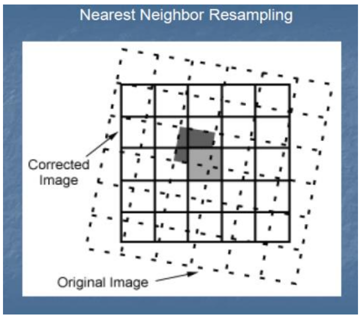




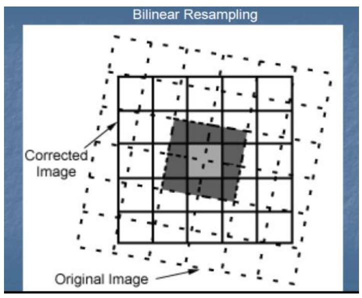


$$I(x_j) = \sum_k I(x_k) f(x_j - x_k)$$

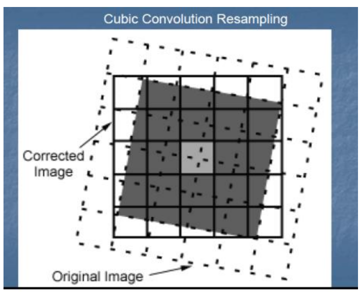
N



BILINE



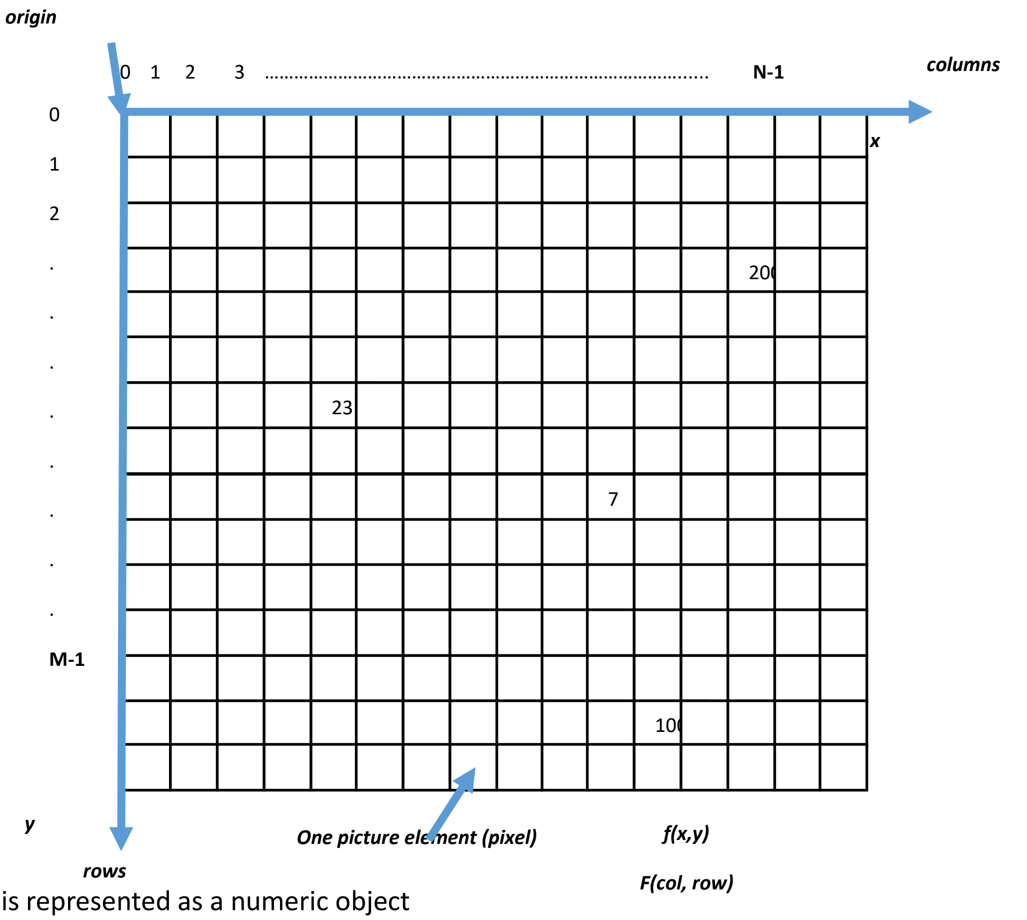
CUBI



Sync function = sin(x)/x

$$f(x) = \begin{cases} f_1(x) = 1 - 2|x|^2 + |x|^2 + |x|^3, \; 0 \leq |x| < 1; \\ f_2(x) = 4 - 8|x| + 5|x|^2 - |x|^3, \; 1 \leq |x| < 2; \\ f_3(x) = 0, \; 2 \leq |x|. \end{cases}$$

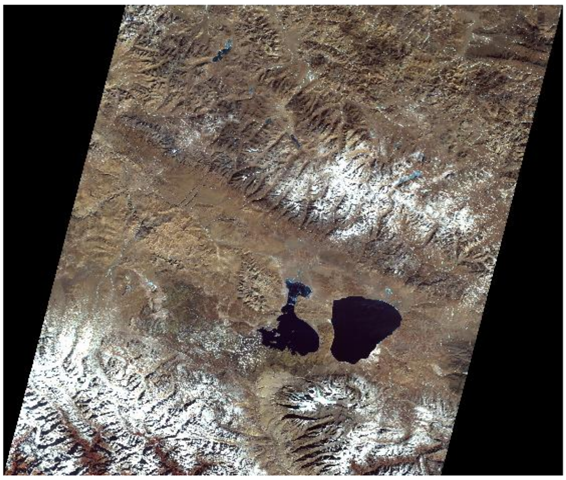
Image Representation

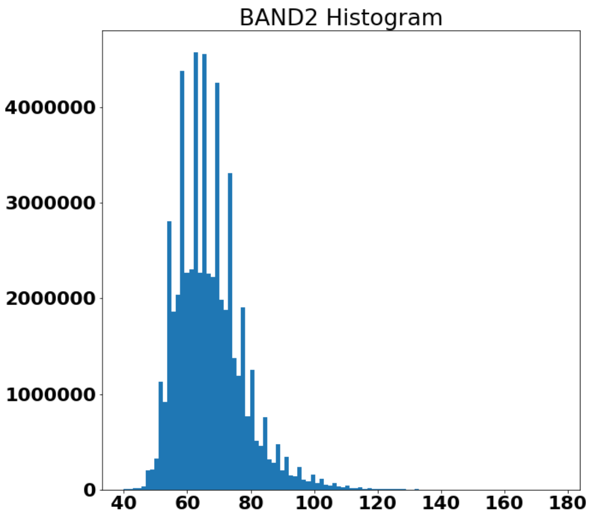


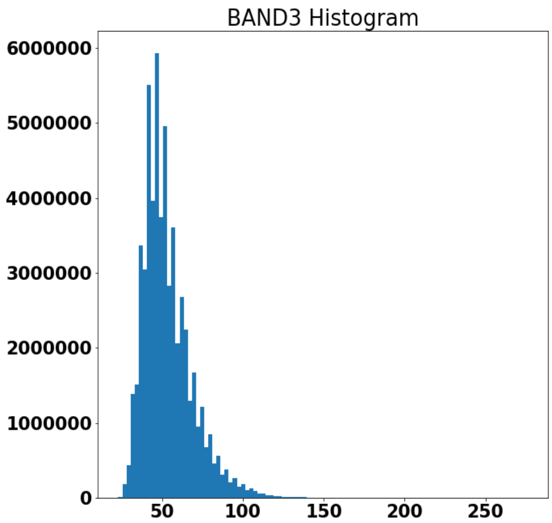
- Image is represented as a numeric object
- A matrix with value range dictated by analogue to digital conversion
- Has a chosen origin of the coordinate system
- Value of the cell is represented by a function of position in 2D or more dimensions.

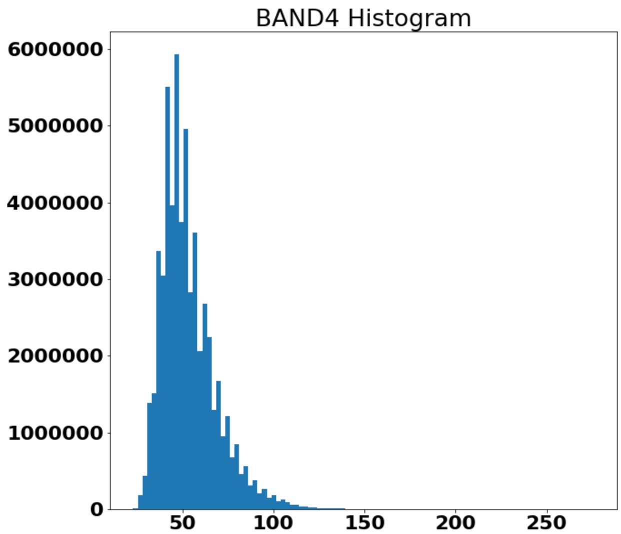
IMAGE HISTOGRAM

Study the range, peaks and shape of the envelope of the individual Band data histograms





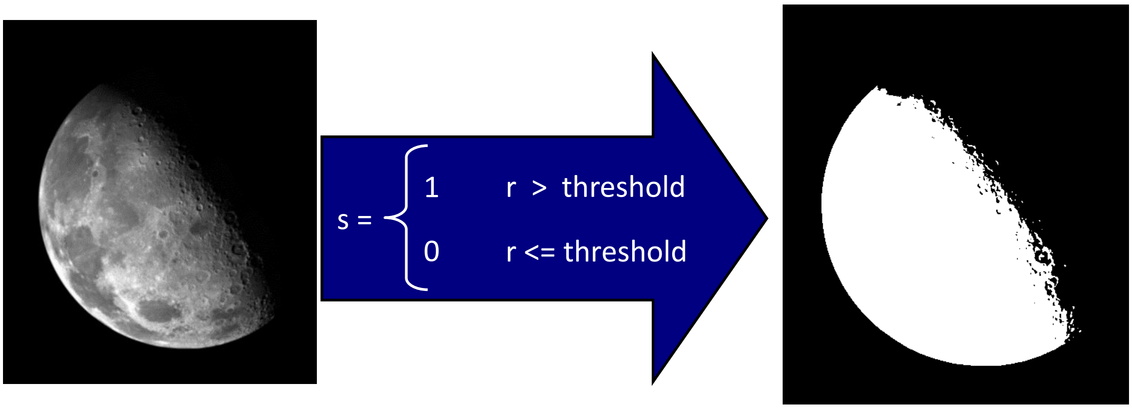




We can manipulate histograms for enhancing the visual quality of the image.

Point Processing: Thresholding

Thresholding transformations are particularly useful for segmentation in which we want to isolate an object of interest from a background.



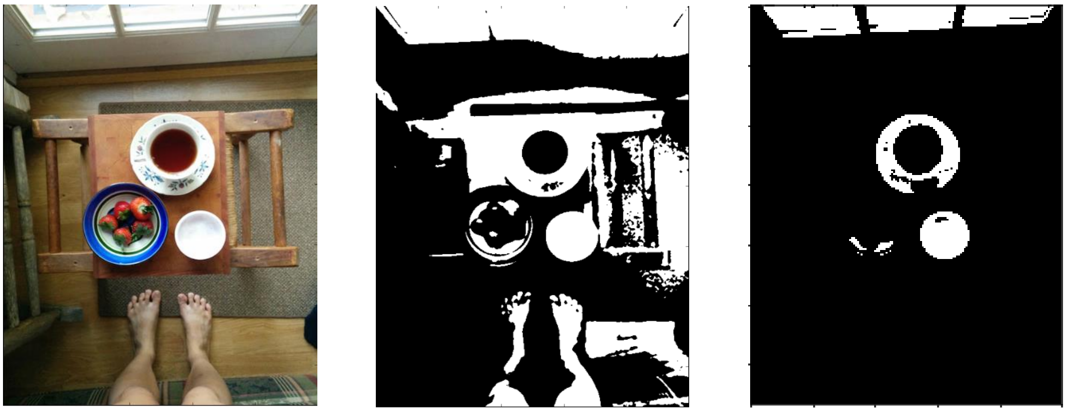
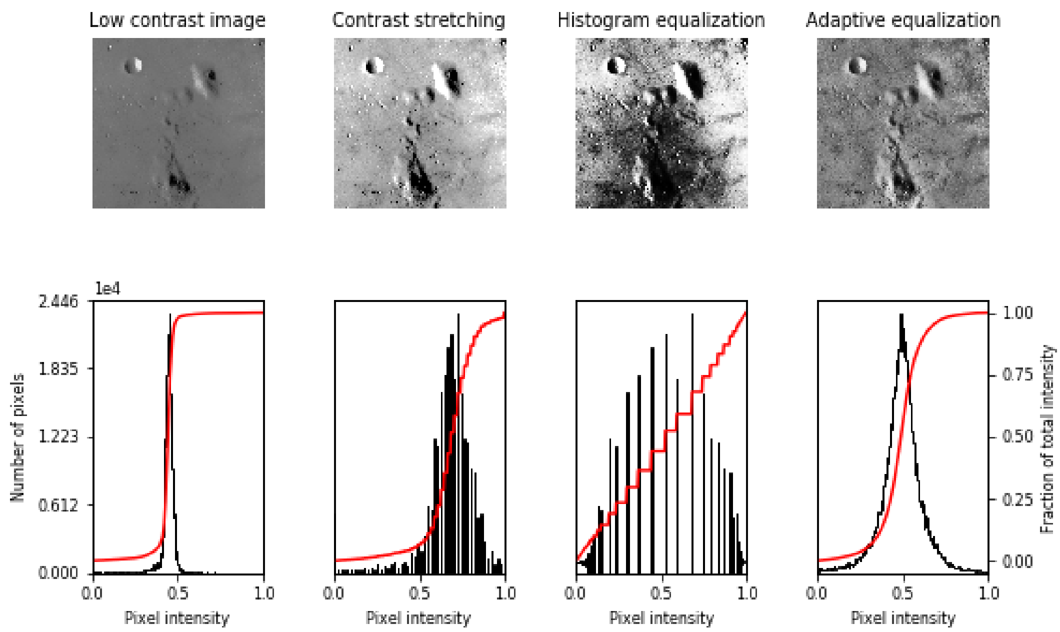


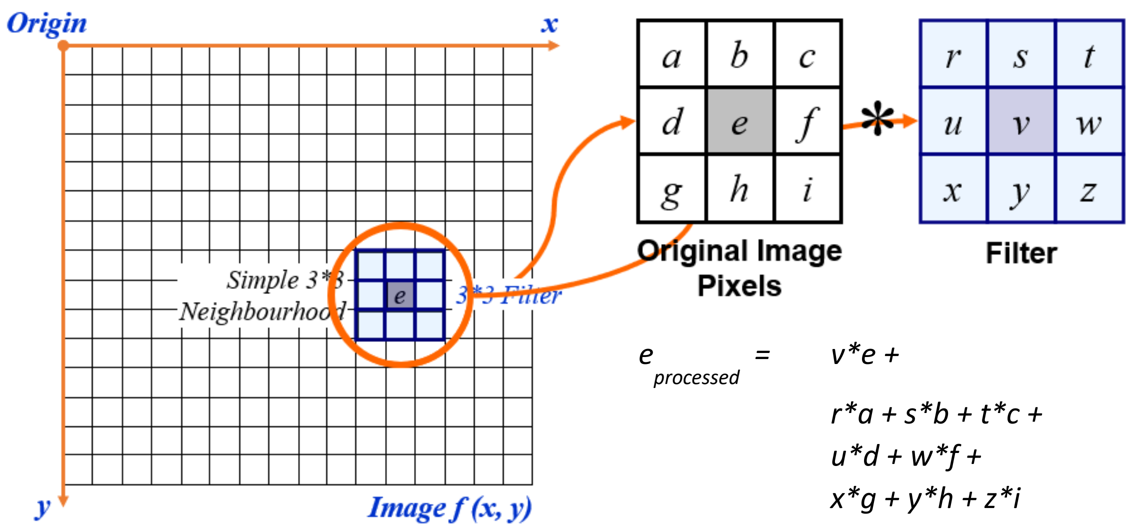
Image Low threshold High threshold

Image Enhancement

Original images could occupy a narrow dynamic range, we have to enhance for better viewing. Use histogram, its range, cumulative histogram, desired range, and a mapping function.



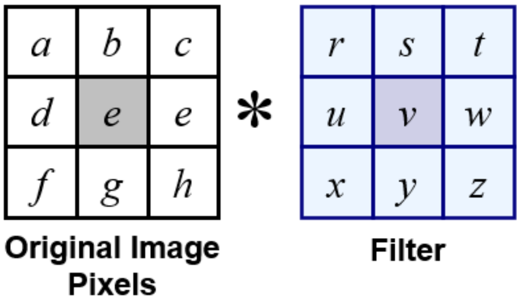
The Spatial Filtering Process



The above is repeated for every pixel in the original image to generate the filtered image.

Correlation & Convolution

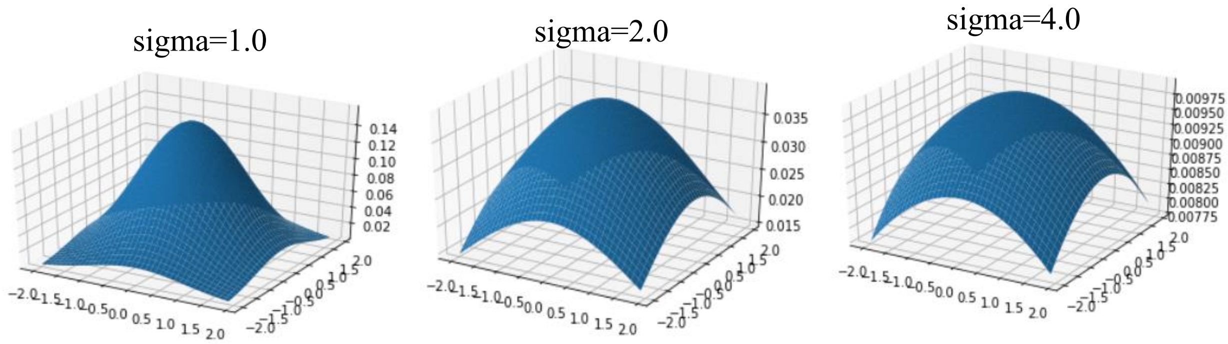
- The filtering is referred to as *correlation.*
- *Convolution* is a similar operation, with just one subtle difference



$$e_{processed} = v*e + z*a + y*b + x*c + w*d + u*e + t*f + s*g + r*h$$

- For symmetric filters it makes no difference (180-degree flip)

Smoothing Gaussian filter



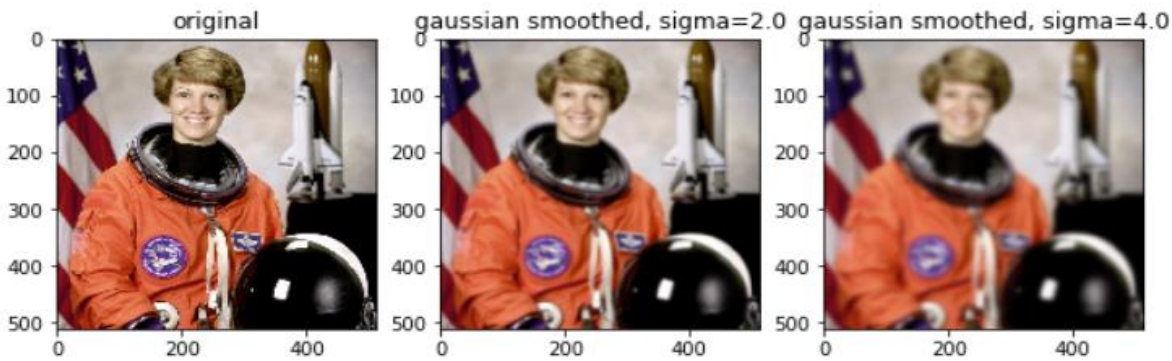
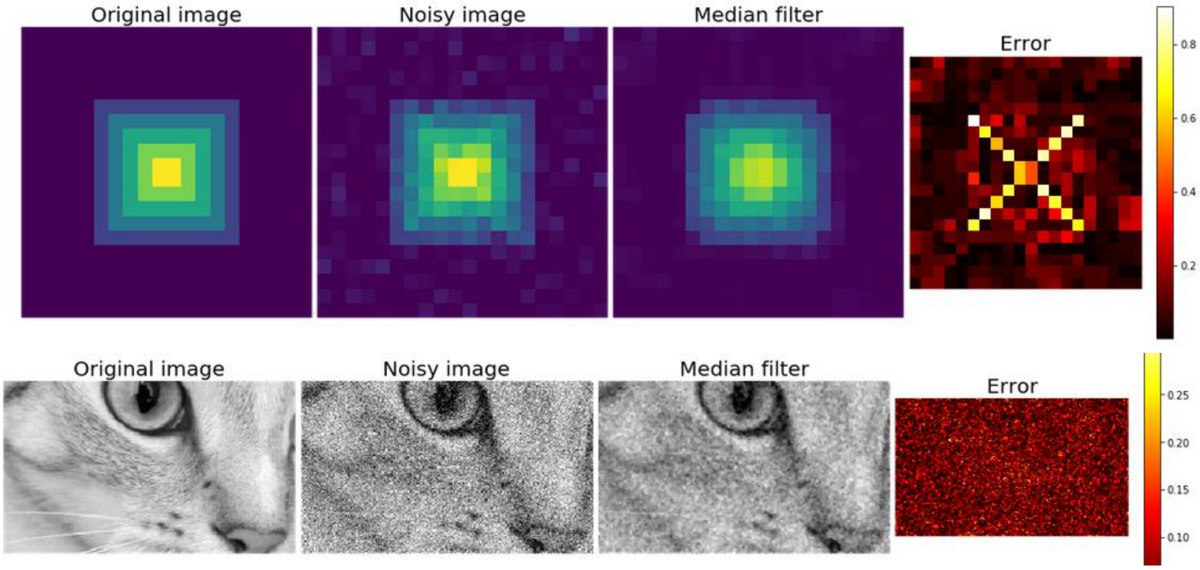


Image Denoising using Median Filter



Different Image Filters

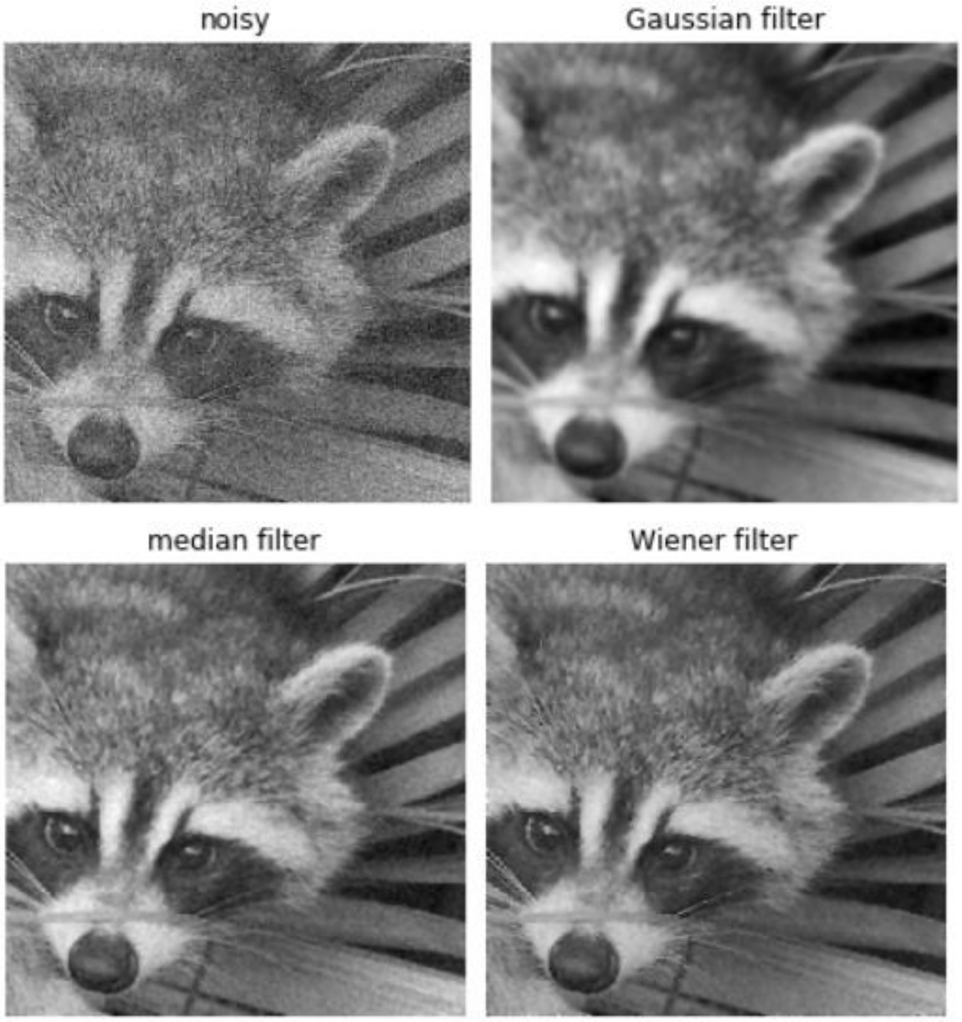
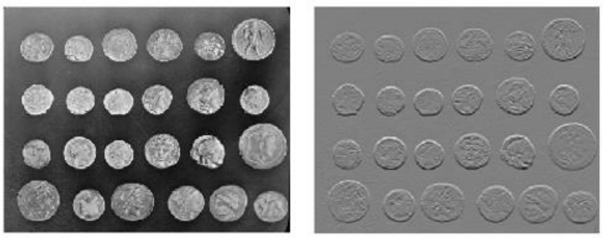


Image Gradients: Sobel Operators

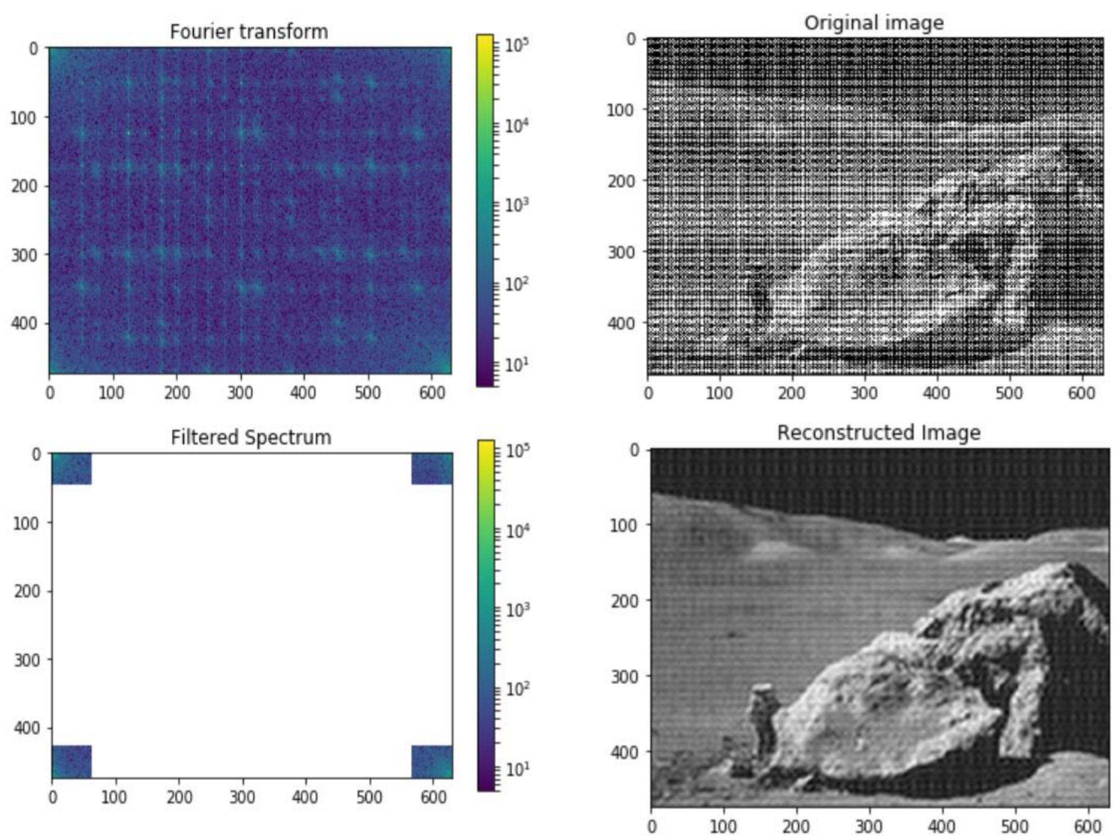
-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

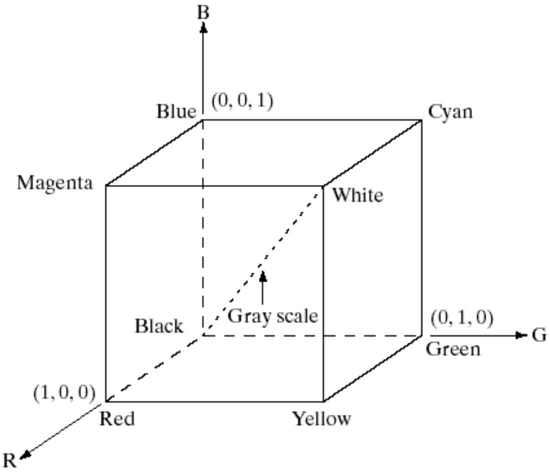


To filter an image, it is filtered using both operators the results of which are added together.

(a) Magnitude Only Reconstruction, (b) Phase Only Reconstruction and (c) Magnitude and Phase Reconstruction

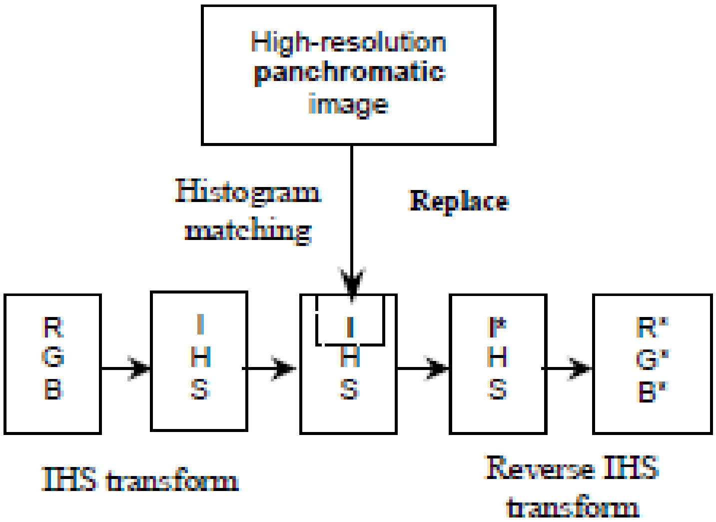


Color Transformations - RGB and HIS



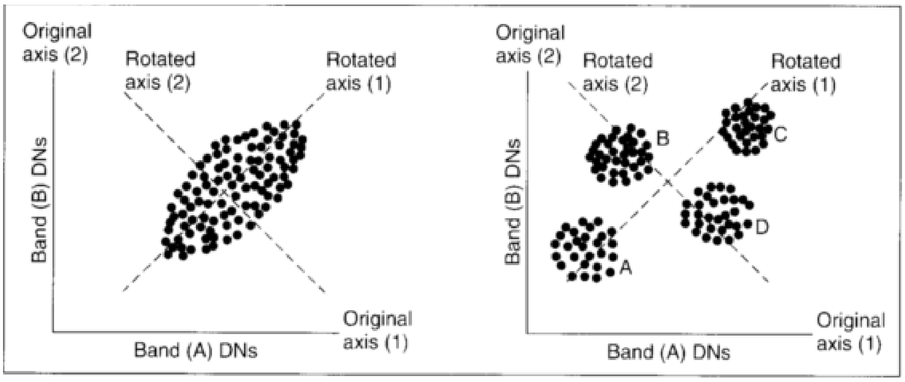
$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & 0 \end{bmatrix} \begin{bmatrix} XS_3^R \\ XS_2^R \\ XS_1^R \end{bmatrix}, \quad \begin{aligned} H &= \tan^{-1}\left[\frac{V_2}{V_1}\right] \\ S &= \sqrt{(V_1)^2 + (V_2)^2} \end{aligned}$$

Used for Image Fusion



Principal Components Analysis

- Compute a set of new, transformed variables (components), with each component largely independent of the others (uncorrelated).
- The components represent a set of mutually orthogonal and independent axes in a n-dimensional space.
- The first new axis contains the highest percentage of the total variance or scatter in the data set.
- Each succeeding (lower order) axis containing less variance.



Principal Component Analysis

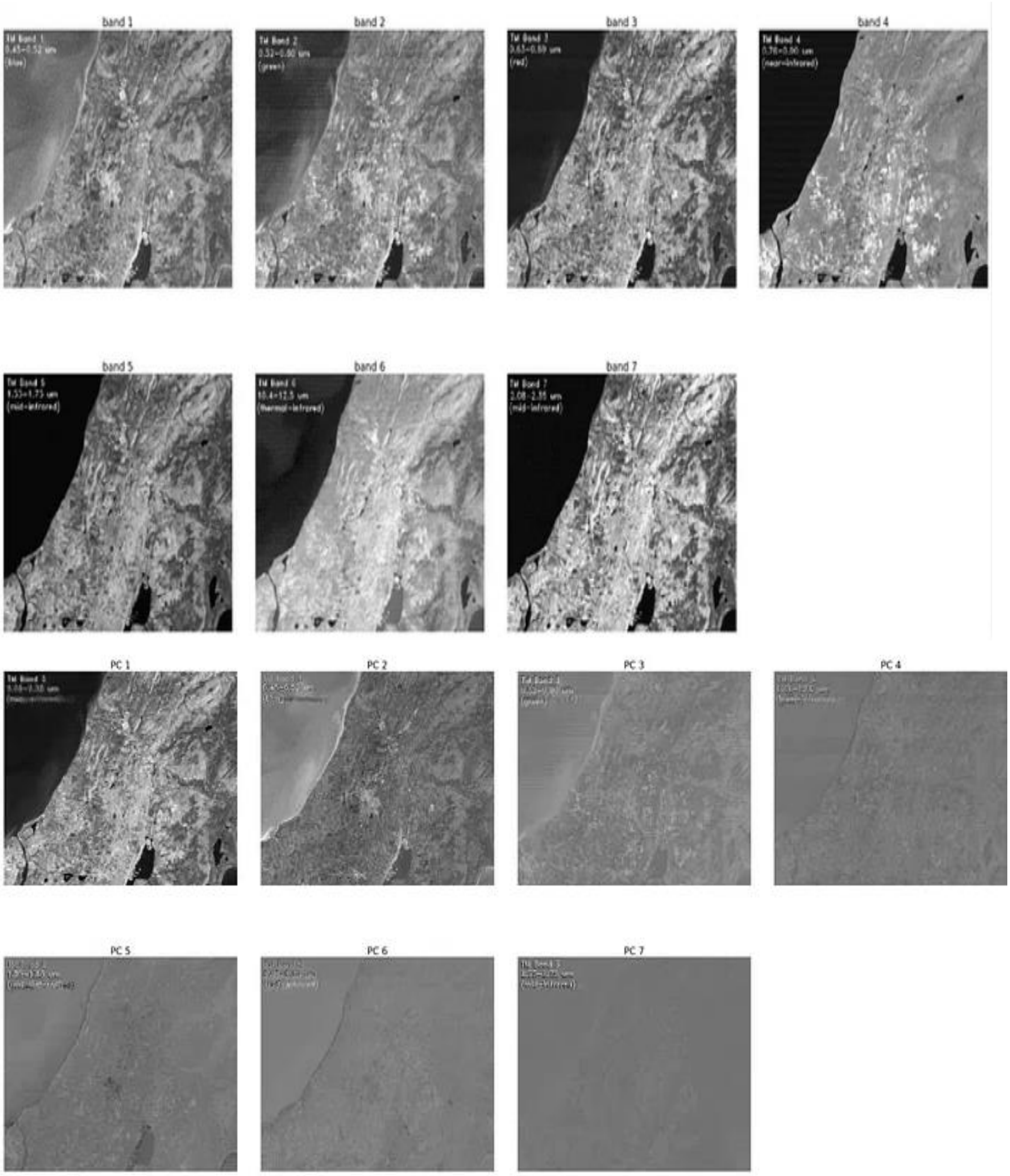
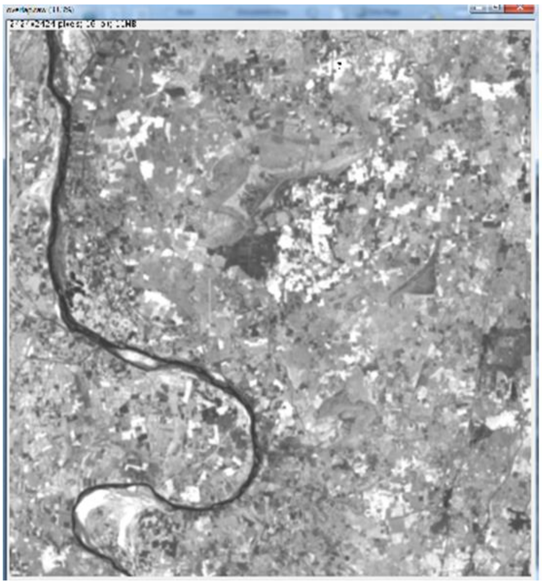
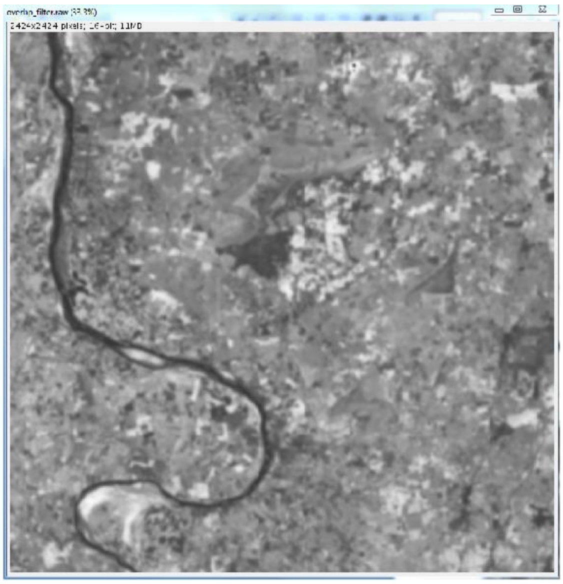


Image segmentation

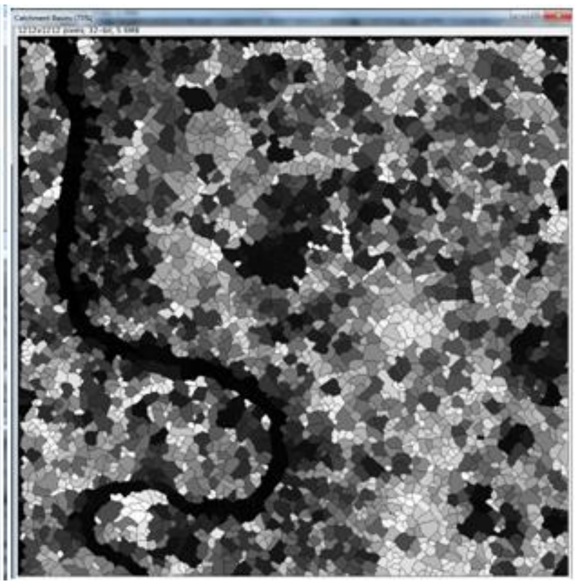


Image



Filtered Image

Segmentation by threshold

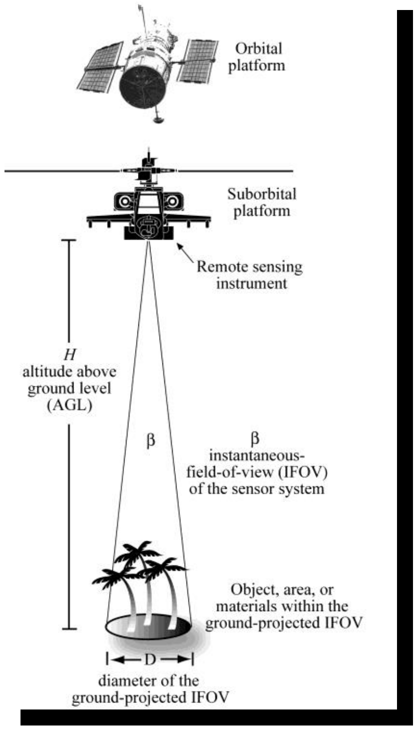


Segmentation by watershed

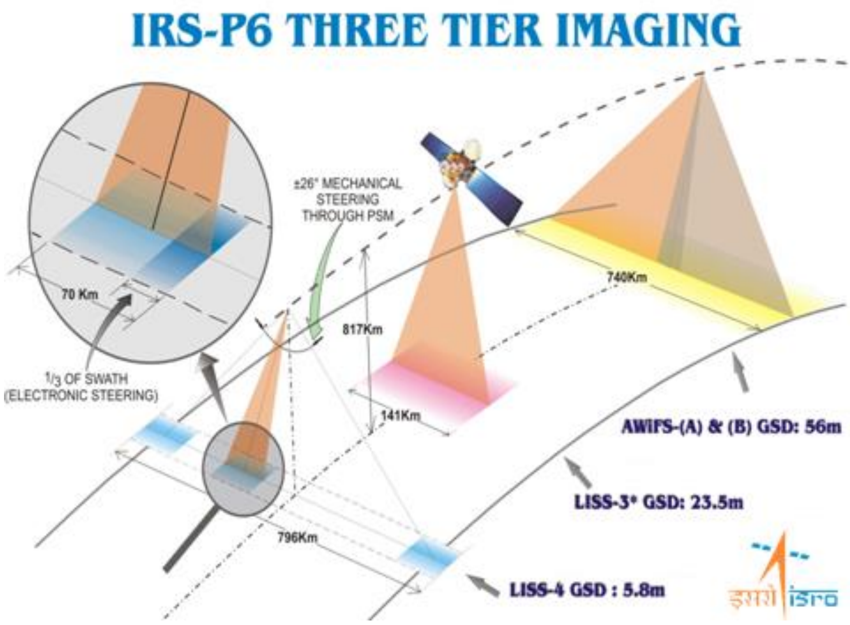
Remote sensing Images

Optical remote sensing

A remote sensing instrument collects information about an object or phenomenon within the instantaneous-field-of-view (IFOV) of the sensor system without being in direct physical suborbital on tact with it. The sensor is located on a suborbital or satellite platform.



Applications dictate performance requirements.



Spatial Resolution: Determined by its pixel size -- pixel is the smallest unit measured by a sensor.

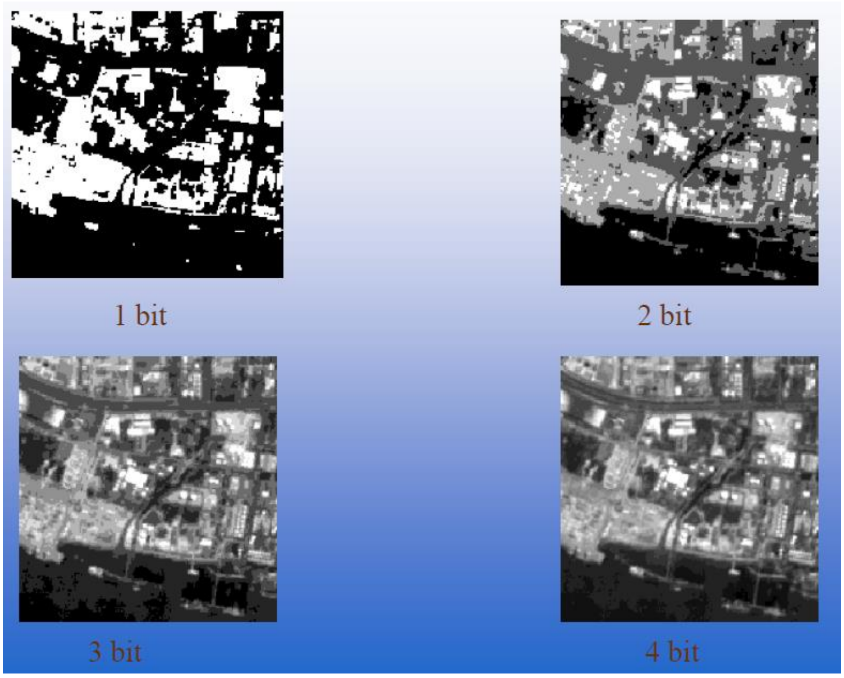
Spatial Coverage: The geographical area covered by a satellite.

Radiometric Coverage: brightness levels

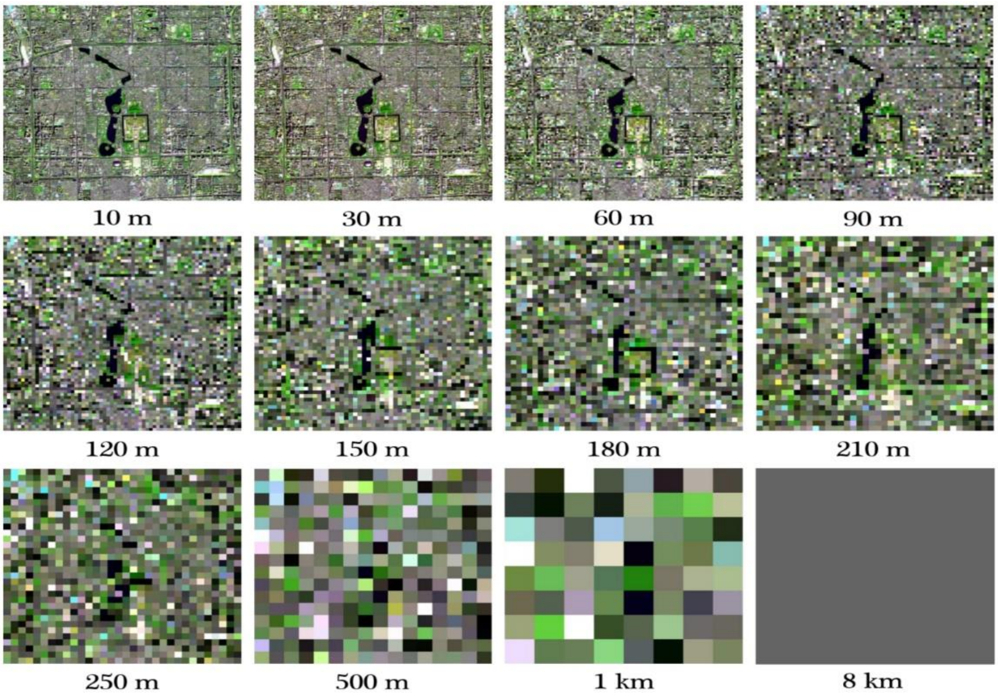
Spectral Coverage: observation wavelength, bandwidth, no of bands

Temporal resolution: How frequently a satellite observes the same area of the earth

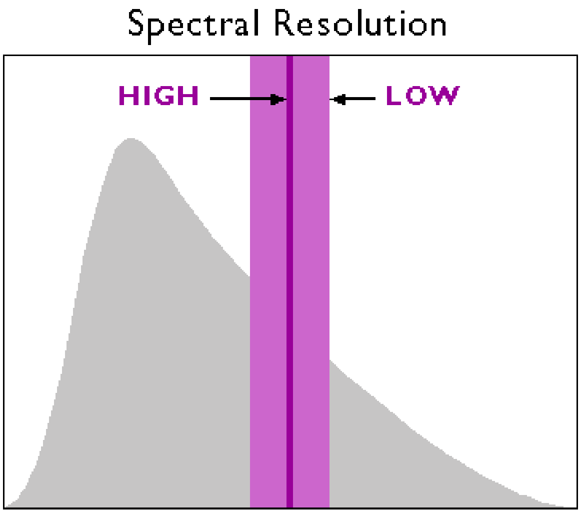
Temporal Coverage: Time span or life-time of a satellite for which measurements are available.



Spatial Resolution

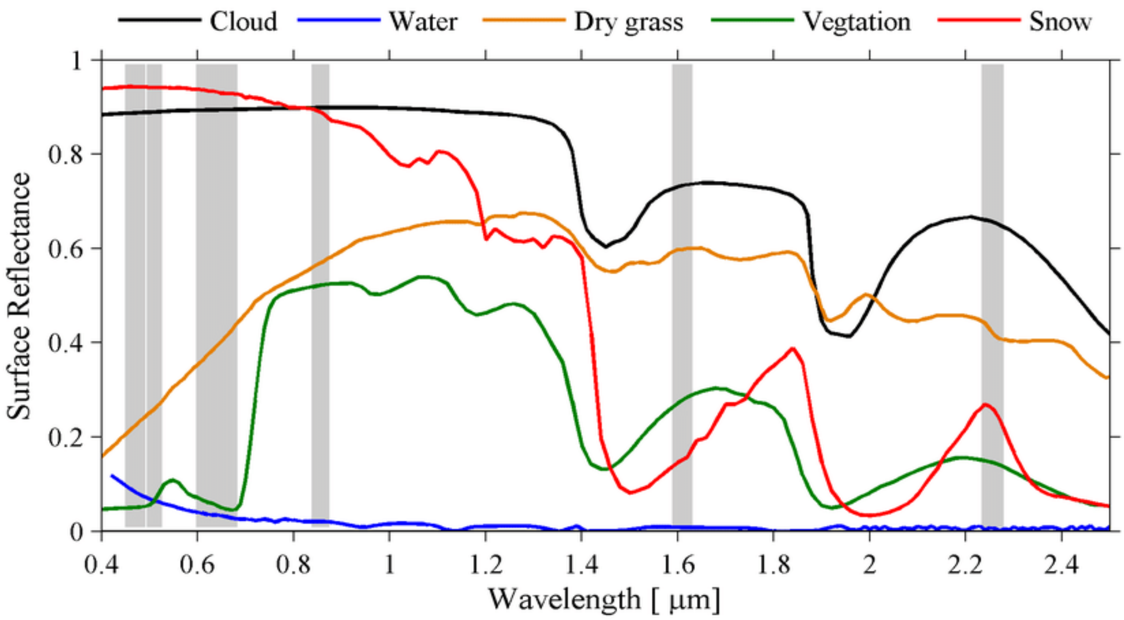


EM Spectrum: Spectral Resolution

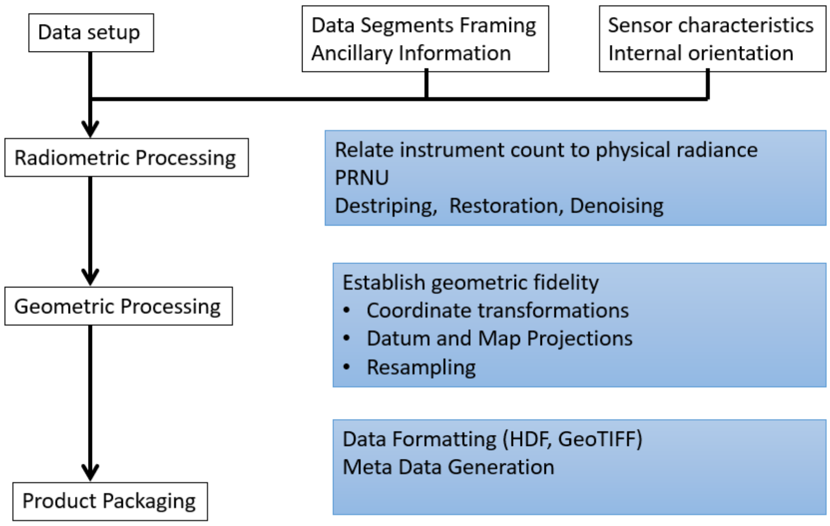


Spectral Signature

- Reflectance profile over a range of wavelength so-called signature of the target.
- Every earthly feature/study target depicts an unique pattern curve shown (wavelength versus reflectance).
- Depending upon the surface category (water, vegetation, or soil) and selected spectral bands varying high and low reflectance happen.



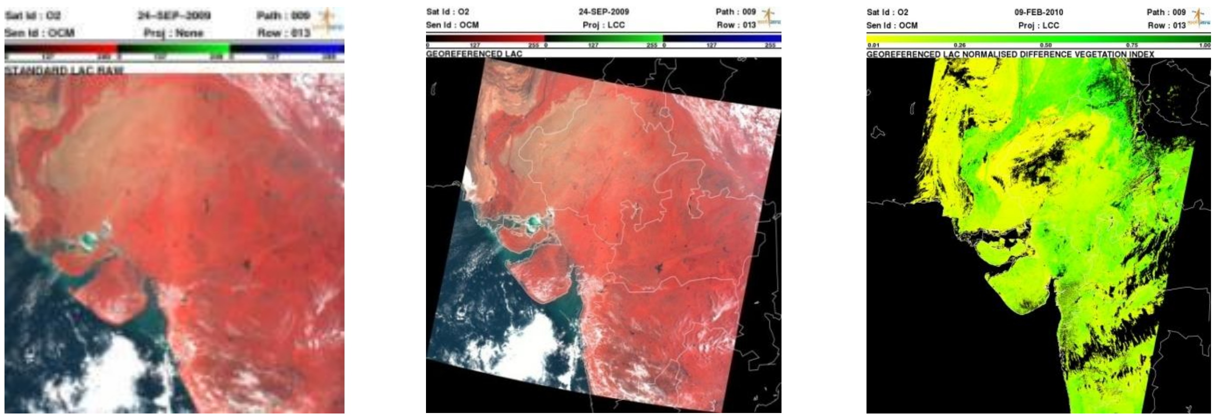
Optical Data Processing: workflow



Data Products: Levels of Processing

- Level-0: RAW Data Products.
- Level-1: Geometrically corrected/tagged.
- Level-2: Geophysical Parameter Products.
- Level-3: Time composited parameter-based products.

Raw Georeferenced NDVI



Radiometric Correction

- Photo Response non uniformity (PRNU)
- Striping
- Restoration
- Noise
- Atmospheric Correction

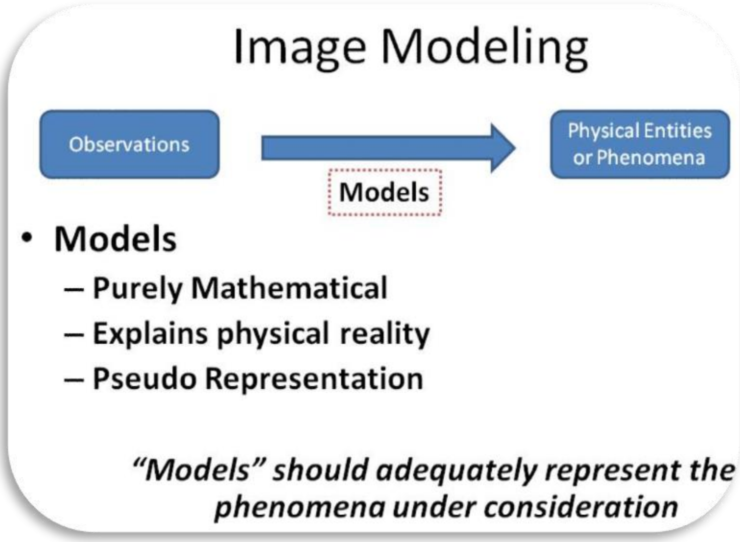
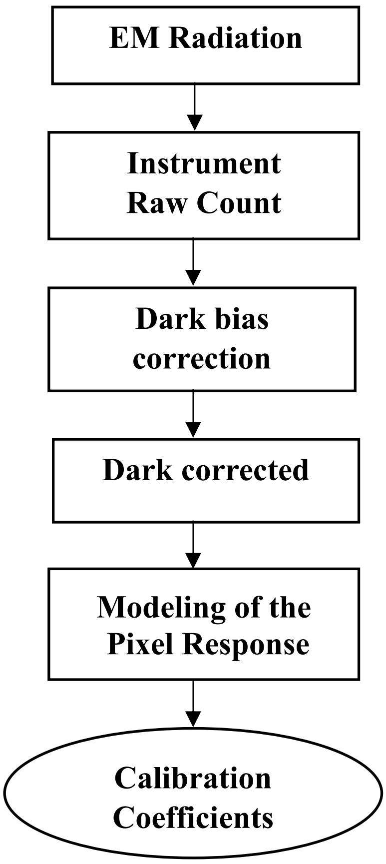
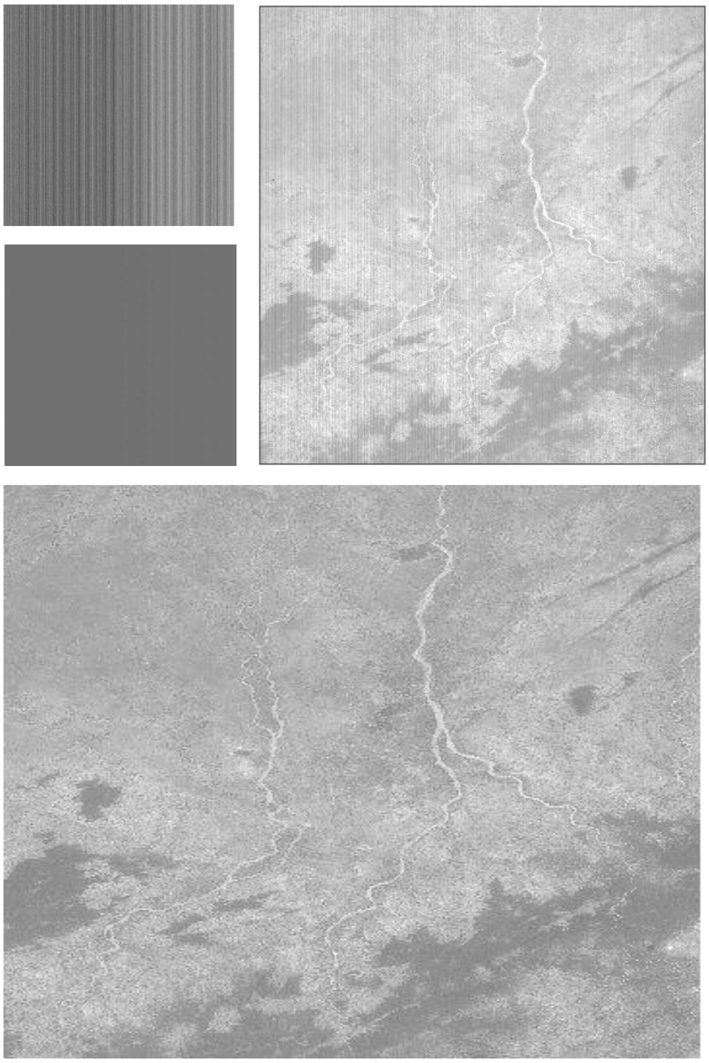


Photo Response Non-Uniformity Correction (PRNU)



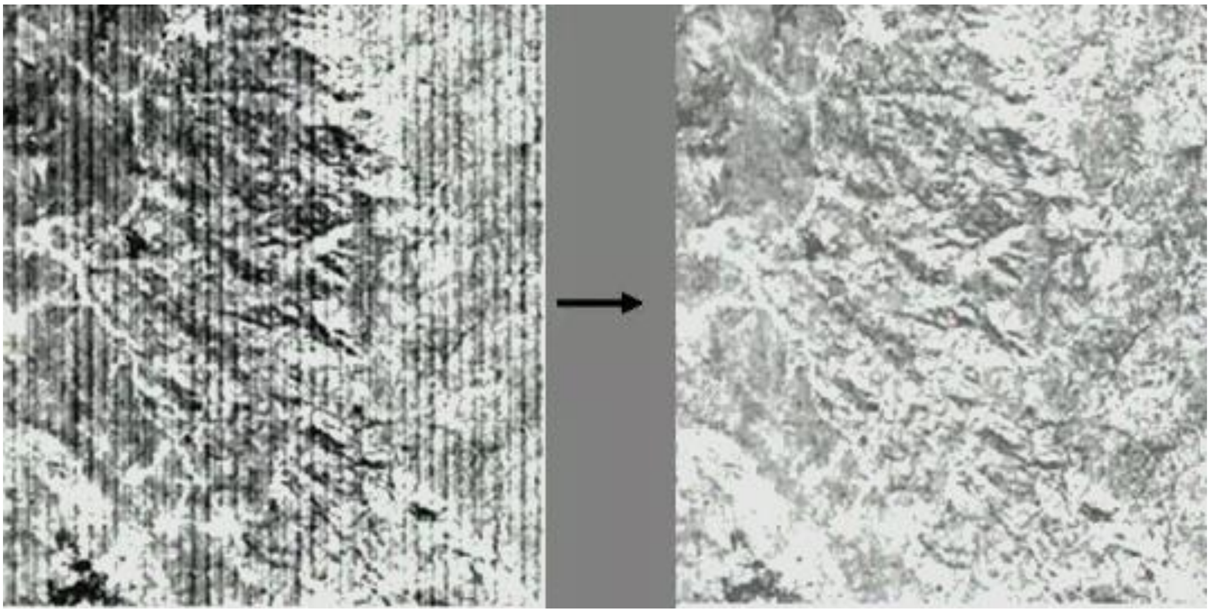


Gray Value = a * Signal + b

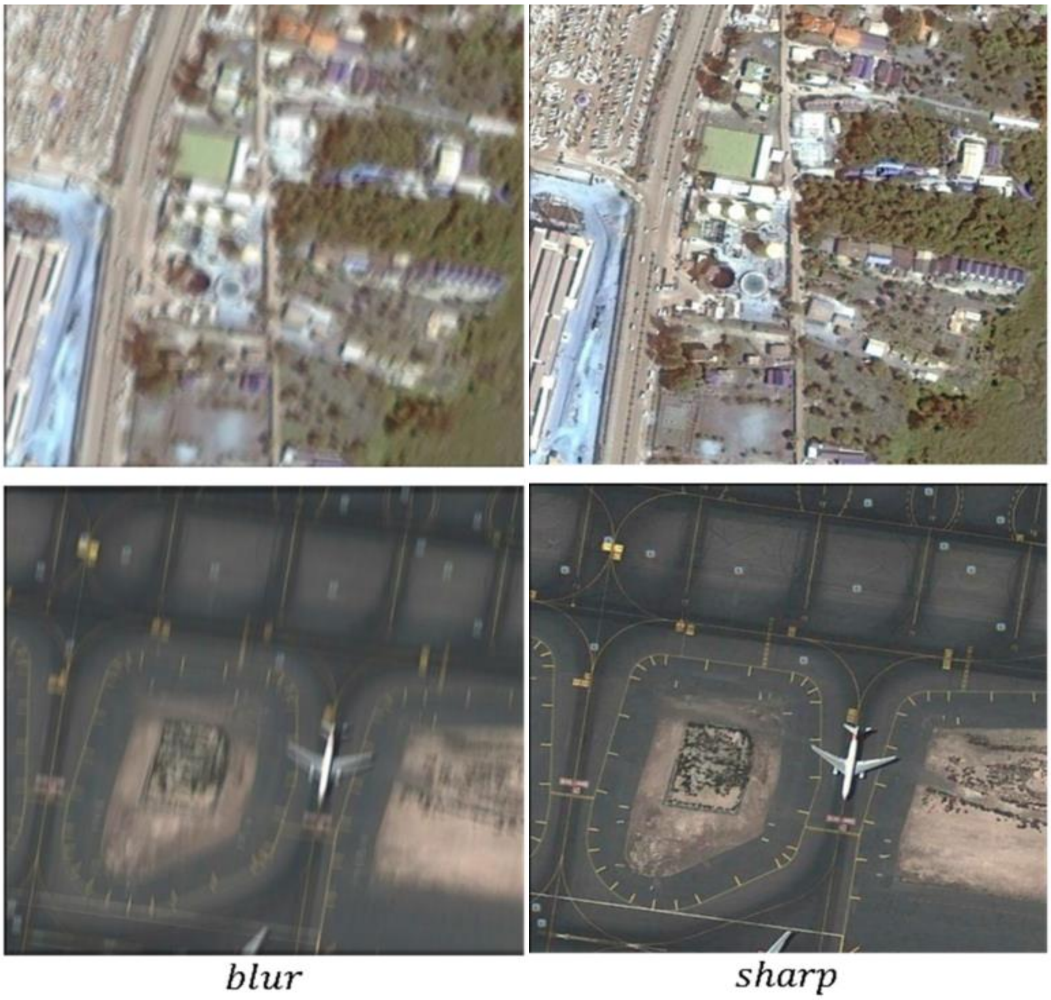
$$SNR = \frac{Mean_{Signal}}{\sigma_{Signal}}$$

High SNR data is always preferred.

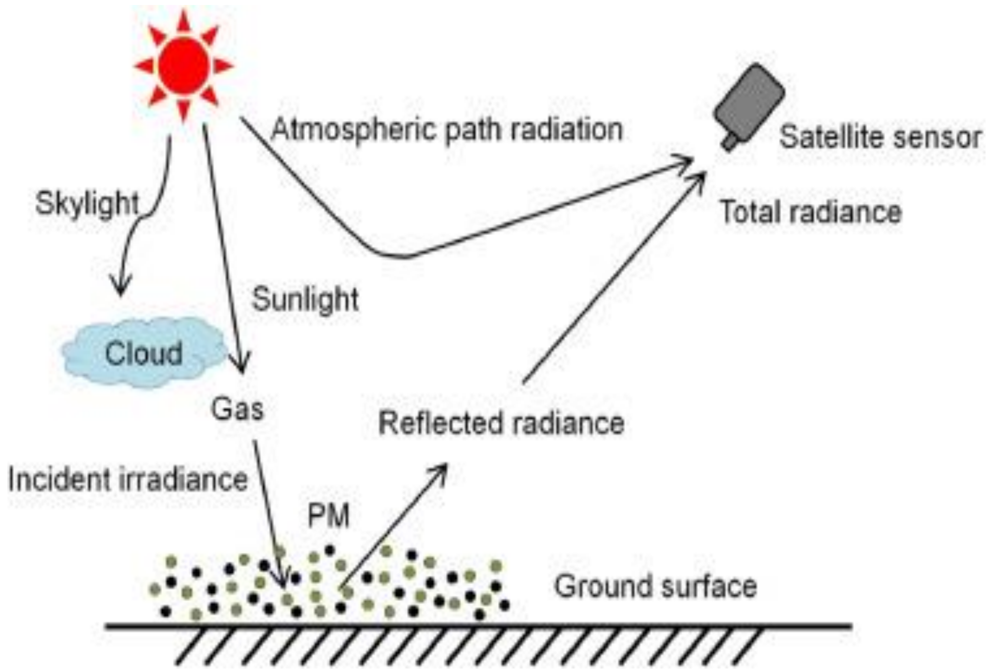
PRNU correction removes artifacts.

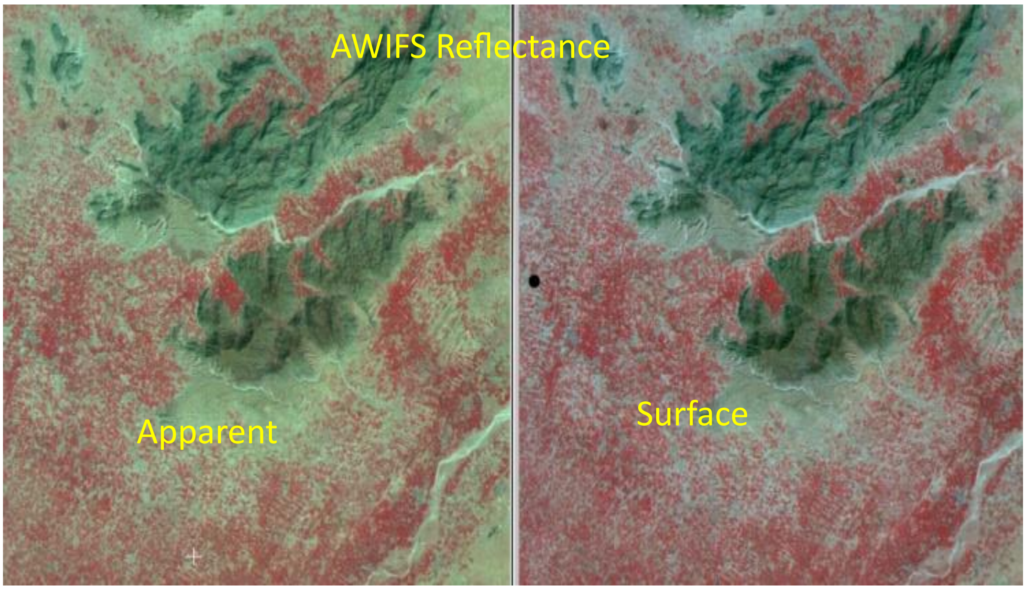


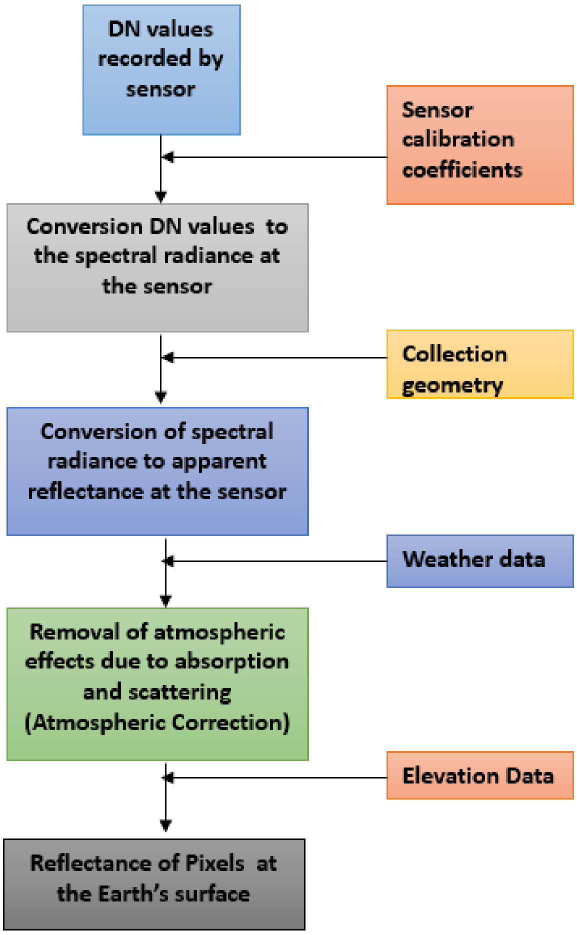
RESTORATION - DEBLURRING



Atmospheric Correction:







Geometric Corrections

The raw data acquired from satellite suffers degradations geometrically due to various factors related to

- **platform**
- **sensor and**
- **earth geometry**

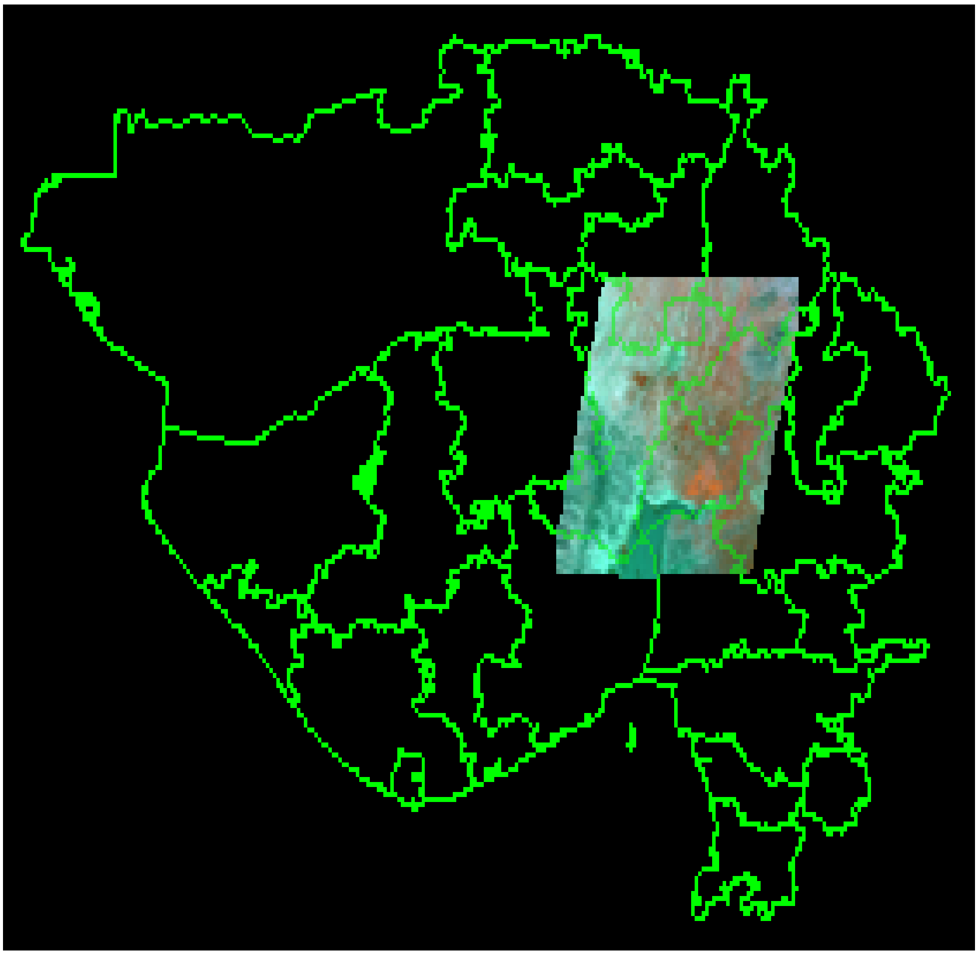
We need to rectify all of them one at a time or together.

- Scan Skew
- Mirror-Scan Velocity
- Panoramic Distortion
- Platform Velocity
- Earth Rotation
- Perspective
- Altitude

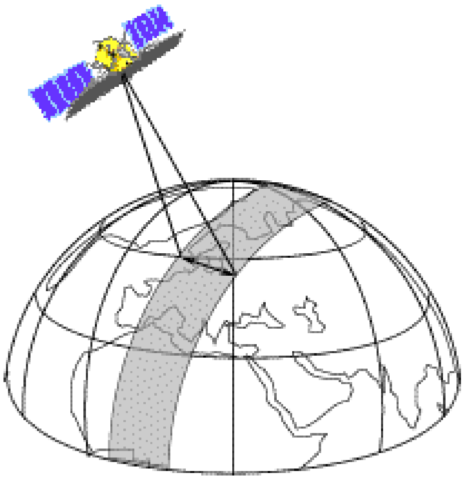
Geometric Correction:

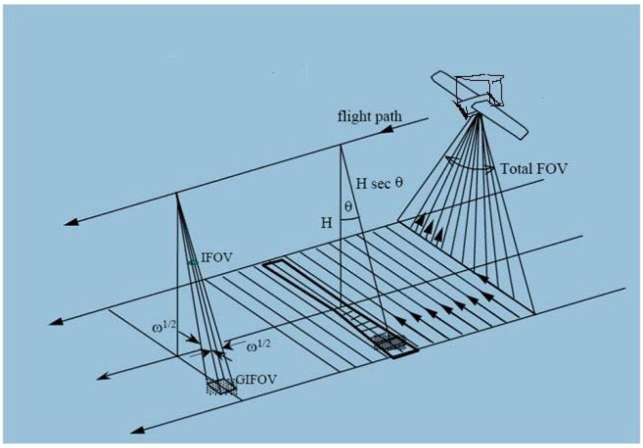
Georeferencing

- Relate the **image pixels with geographic** coordinates by using **geometric models**
- Improve location knowledge by using **reference data sets.**
- Transform (**Resample**) the acquired and radiometrically data to the required geometry.
- which can be consumed readily by Remote Sensing **Users** in various **image processing environments including GIS platforms.**
- Facilitates multi data **overlay, fusion etc.**



FOV, IFOV, GSD & SWATH





IFOV = D/F   radians

GSD = HD/F   meters

AT Resol = Vg X IT   meters

SWATH = GSD X NDet

D – Detector Size

F – Focal Length

AT – Along Track

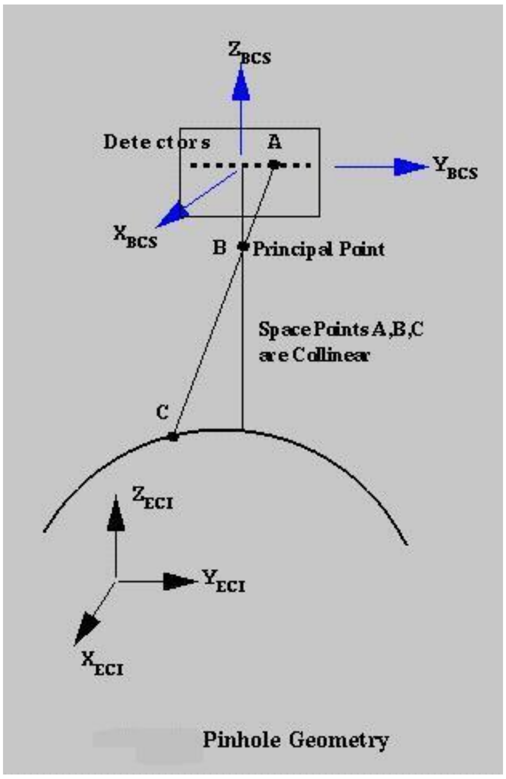
H – S/C Altitude

Vg - Ground Trace Velocity

IT – Integration Time

GSD – Ground Sample Distance

NDet – No of Detectors

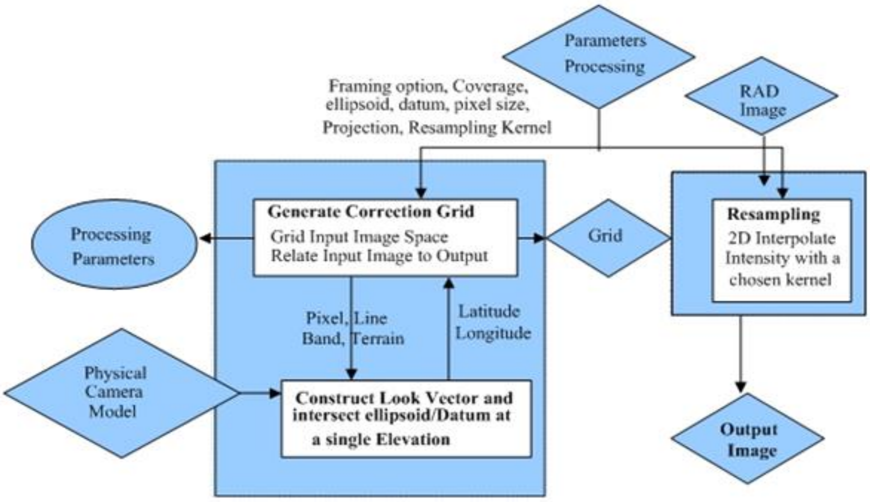


Physical Sensor Model: pinhole geometry, Series of coordinate transformations.

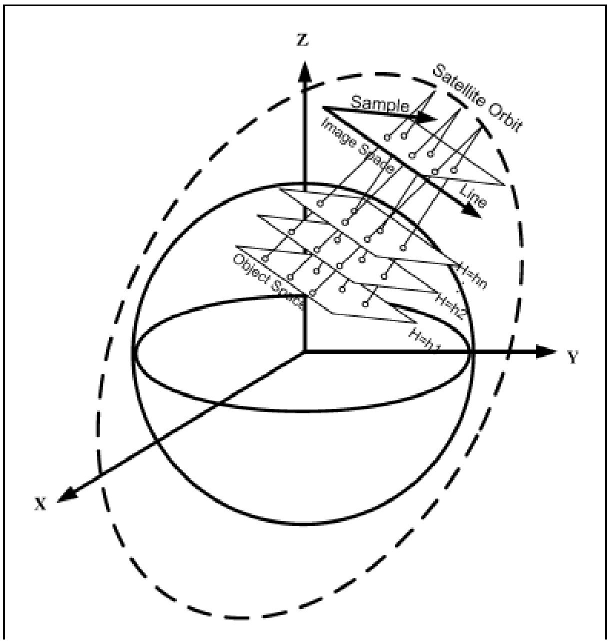
Modelling the whole imaging process consuming camera geometry model, payload to s/c master cube reference, orbit and attitude data.

- Establish Coordinate systems & transformations.
- Detector to Earth Object Coordinates (Pts A,B,C)
- Solving look point equation with an ellipsoid.
- Conversion of (x,y,z) to geographic coordinates
- Conversion to map projection coordinates.

Georeferencing radiometrically corrected data



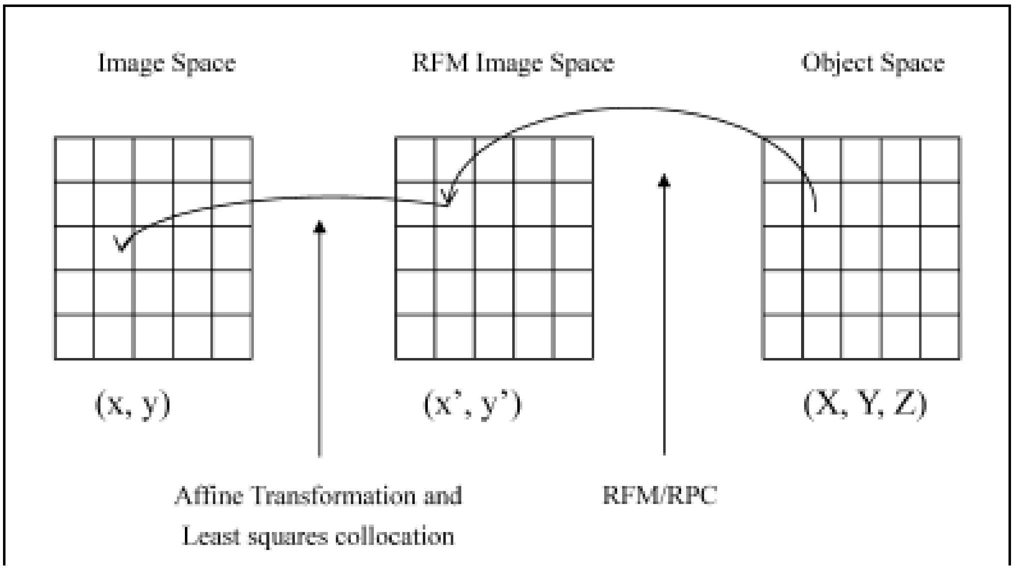
Rational Function Model: Image – Object Relationship Alternate Representation using a dense grid of points generated by physical model.



$$x = \frac{p_a(X,Y,Z)}{p_b(X,Y,Z)} = \frac{\sum_{i=0}^{m1}\sum_{j=0}^{m2}\sum_{k=0}^{m3} a_{ijk}\, X^i Y^j Z^K}{\sum_{i=0}^{n1}\sum_{j=0}^{n2}\sum_{k=0}^{n3} b_{ijk}\, X^i Y^j Z^K}$$

$$y = \frac{p_c(X,Y,Z)}{p_d(X,Y,Z)} = \frac{\sum_{i=0}^{m1}\sum_{j=0}^{m2}\sum_{k=0}^{m3} c_{ijk}\, X^i Y^j Z^K}{\sum_{i=0}^{n1}\sum_{j=0}^{n2}\sum_{k=0}^{n3} d_{ijk}\, X^i Y^j Z^K}$$

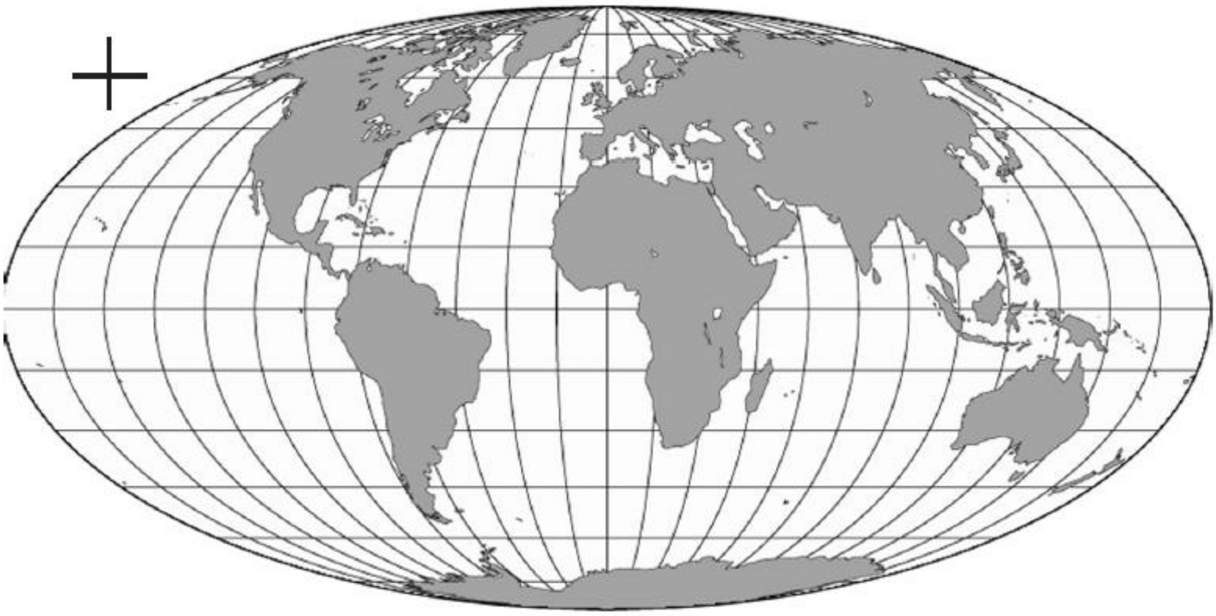
where, X^n , Y^n and Z^n is the homogeneous coordinate of a 3D point, x and y is the corresponding image point, and p_a, p_b, p_c and p_d are homogeneous polynomials of degree m.



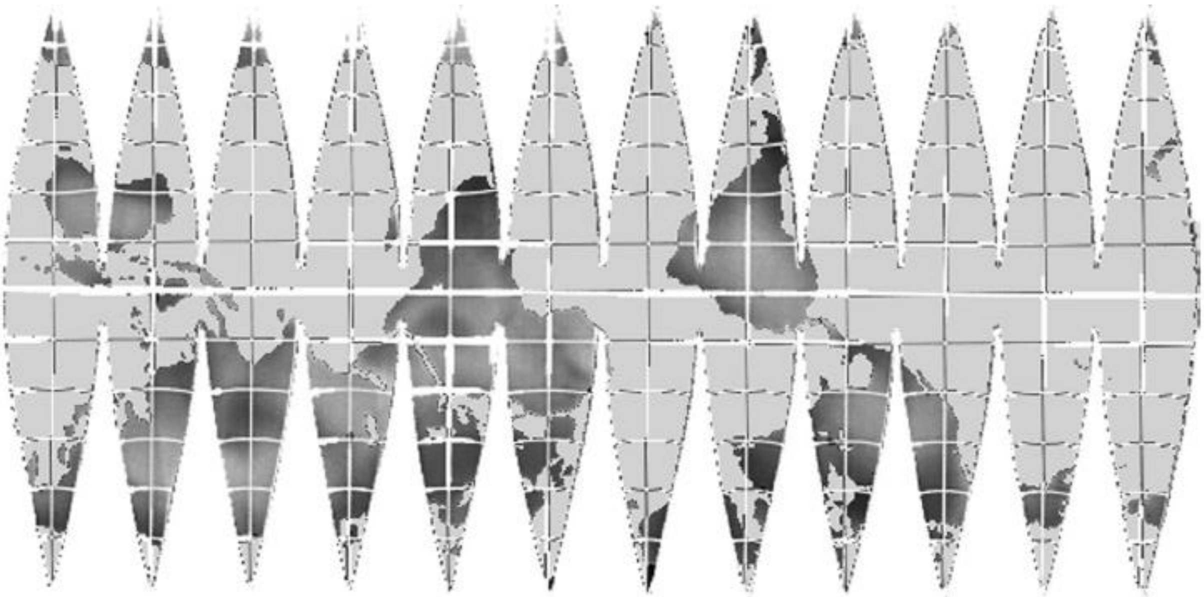
MAP PROJECTION

3D earth portions are portrayed in 2D using. Map is a Standard Reference

3D GLOBE MODEL



2D MAP OBTAINED BY CUTTING & STRIGHTENING ABOVE



Map Projection Parameters

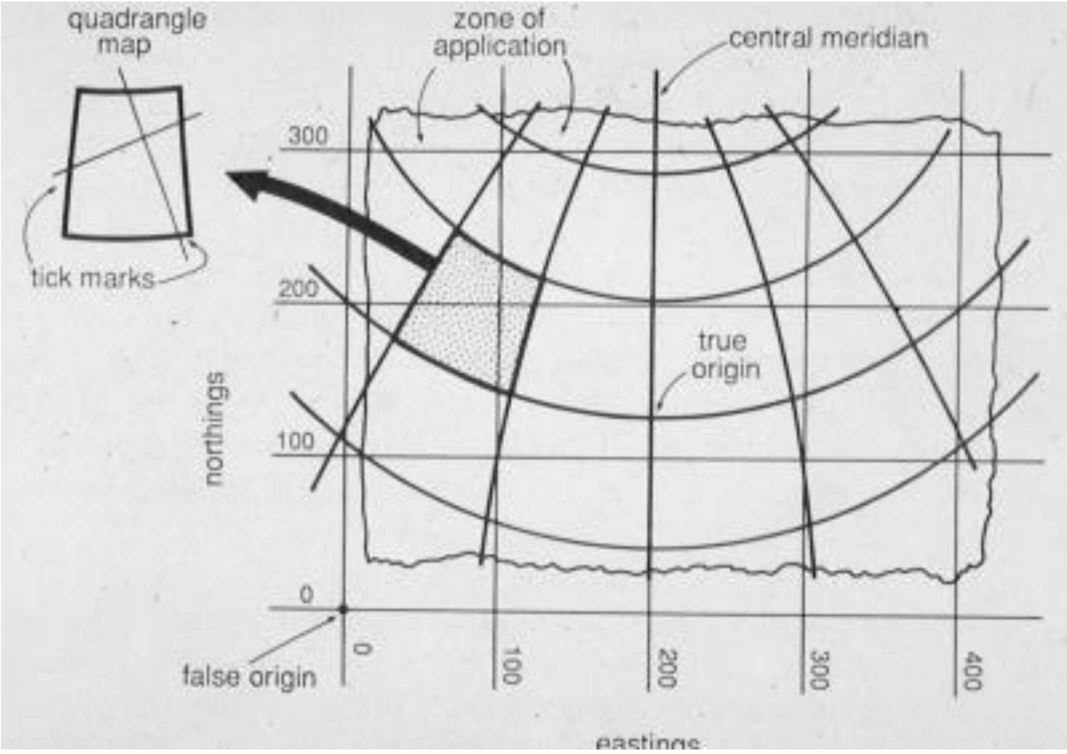


Image Registration

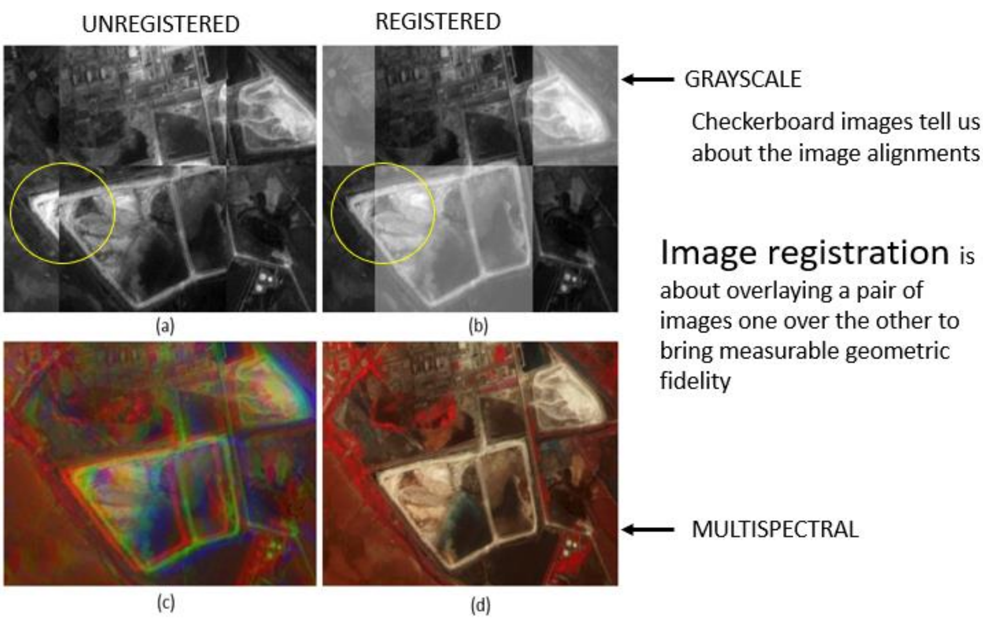


Image registration is the process of overlaying two or more images that represent the same geographical area such that the corresponding pixels in all the set of images that are registered belong to the same parcel on the ground.

The **feature space** extracts the **information** in the images that will be used for **matching**.

The **search space** is the **class of transformations** that is capable of aligning the images.

The **search strategy** decides how to choose the next transformation from this space, to be tested in the search for the **optimal transformation**.

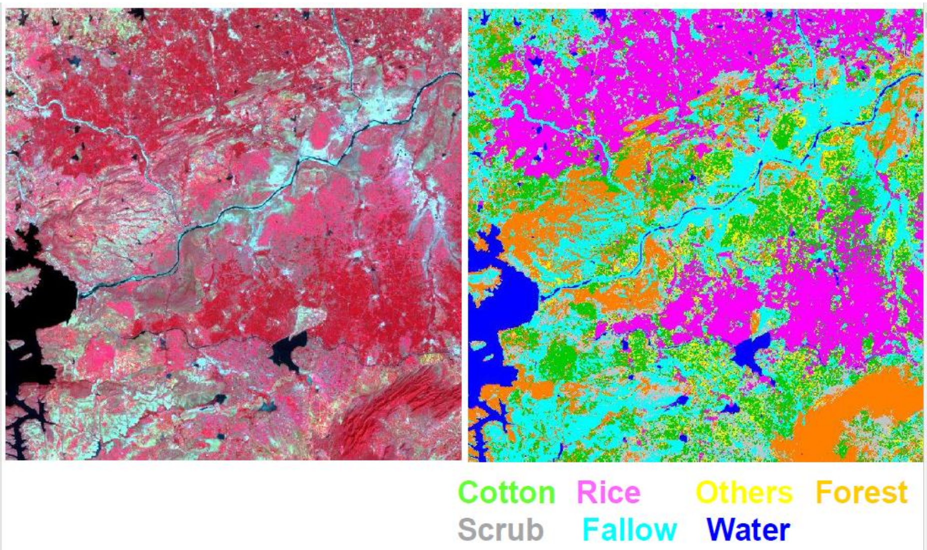
The **similarity metric** determines the **relative merit** for each test. Search continues according to the search strategy until a transformation is found whose similarity measure is satisfactory.

Registration methods can be viewed as different combinations of choices for the following four components:

1. a feature space,
2. a search space,
3. a search strategy, and
4. a similarity metric.

Image Classification

- Compute statistics of known pixels and predict for other pixels.
- Generally, if you do not have training sets, you can't label the classes.
- Experienced user may be able to label using other information available or derived.



What is image classification or pattern recognition.

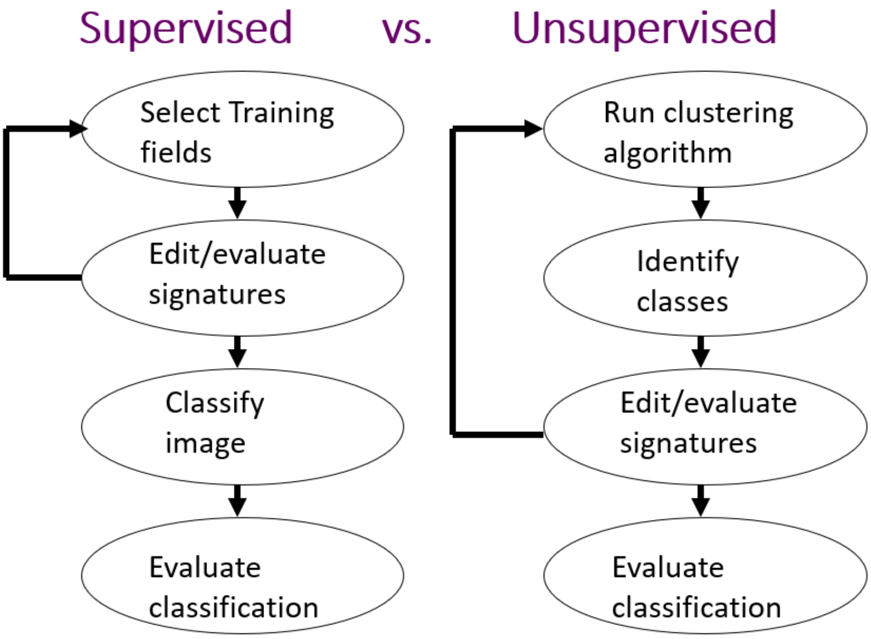
Is a process of classifying multispectral (hyperspectral) images into **patterns of varying gray or assigned colors** that represent either

- **Clusters** of statistically different set of multiband data, some of which can be correlated with separable classes/features/materials. This is the result of **unsupervised classification** or

- **Numerical discriminators** composed of these sets of data that has been grouped and specified by associating each with a particular **class**, etc. whose identity is known independently and which has representative areas (training sites) within the image where that class is located. This is the result of **Supervised classification**.

Spectral Classes are those that are inherent in the remote sensing data and must be identified and labeled by the analyst.

Information classes are those users define,



Supervised vs. Unsupervised Approaches

a. Unsupervised - statistical "clustering" algorithms used to select spectral classes inherent to the data, more computer-automated **Posterior Decision**

b. Supervised - image analyst "supervises" the selection of spectral classes that represent patterns or land cover features that the analyst can recognize Prior **Decision**

Training Sets

- # of pixels - want to statistically characterize the spectral properties of an informational class
- (i.e. forest, crop, water), should have >= 100 pixels total for an informational class
- location - geographically dispersed, boundaries away from edge/mixed pixels number of areas - depends on number of information categories, 10 at a minimum, enough for accuracy assessment and incorporation of spectral subclasses uniformity - unimodal distributions, use training areas to characterize **mean, variance,**

covariances - sometimes not easy due to spectral variation present

Statistical classifier methods

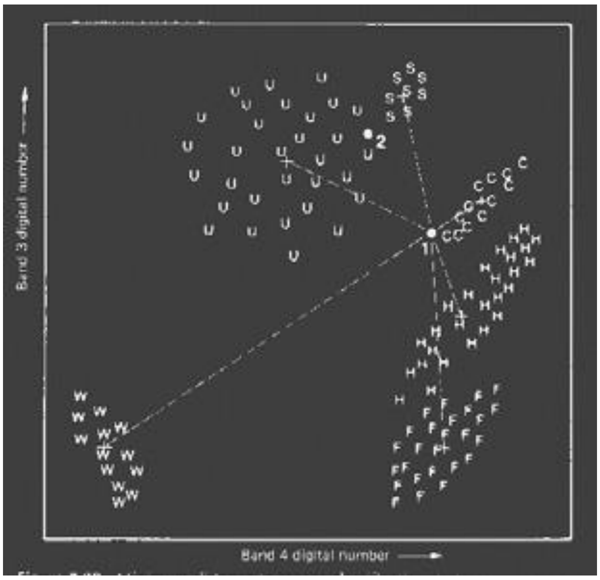
- Minimum distance to means algorithm: uses the central values (means) of the spectral data clusters (defined by training data) to assign pixels to information categories.

- Parallelepiped algorithm: uses ranges of pixel values within the training data to define classification regions in multivariate space; one of the earliest classification algorithms developed.
- Maximum likelihood algorithm estimates the means and variances of information classes defined by training data to estimate probabilities for each pixel in an image, most commonly used method takes into account the shape of the cluster distribution, as well as overlapping regions, requires normal distributions.

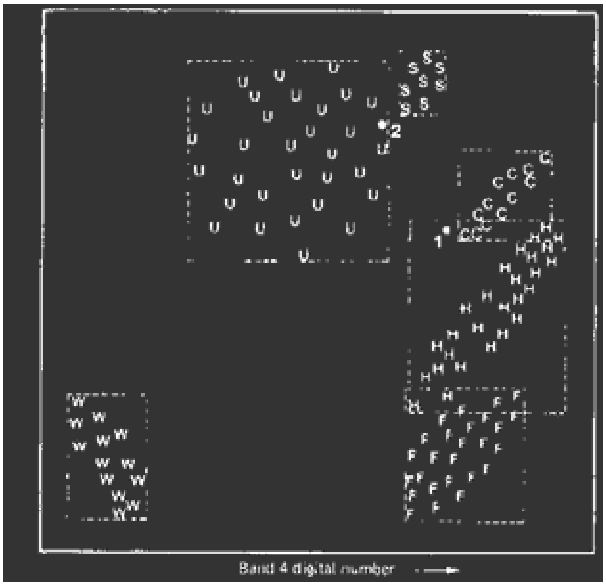
There are several other methods such as rule based, ISO/K-Means clustering, Random Forest,

Deep Learning based to explore and compare.

Minimum distance to means algorithm.



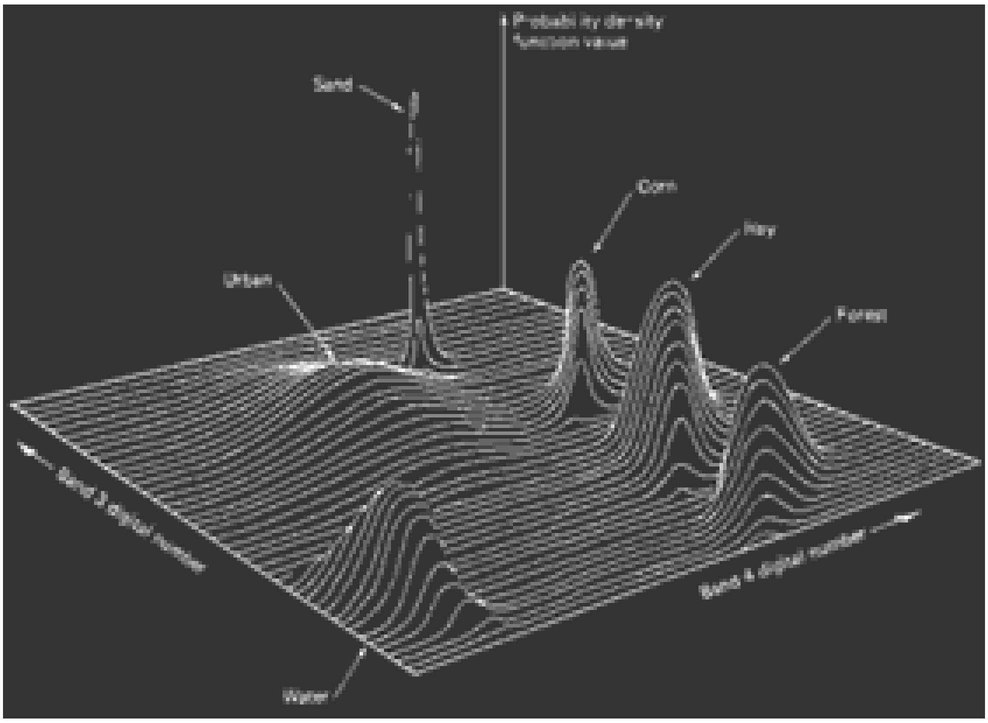
Parallelepiped algorithm

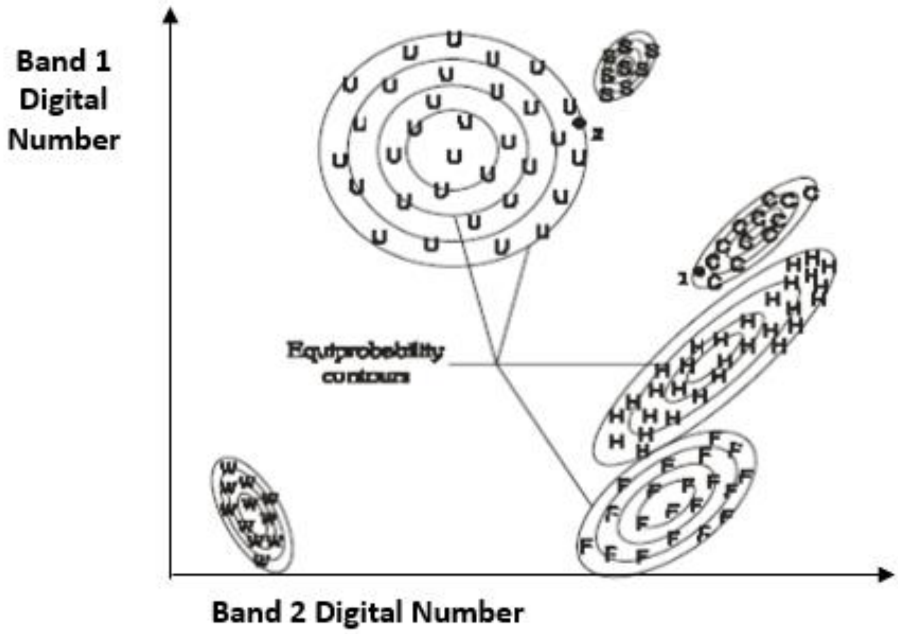


Maximum Likelihood Classifier

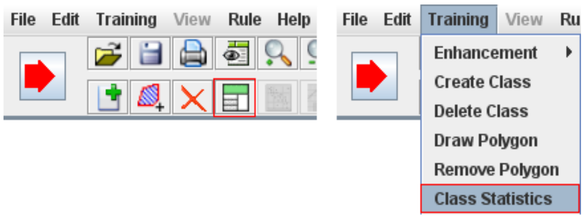
Based on a normalized (Gaussian) estimate of the probability density function of each class.

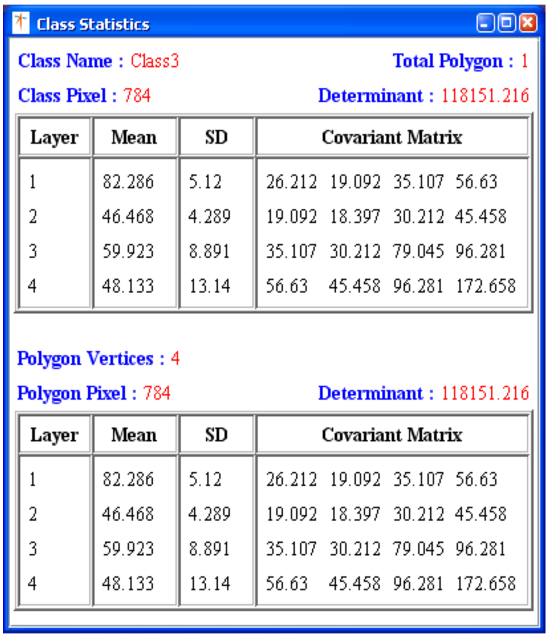
Quantitatively evaluates both variance and covariance of the category spectral response patterns while classifying an unknown pixel.

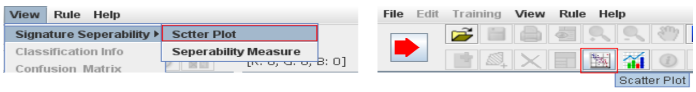


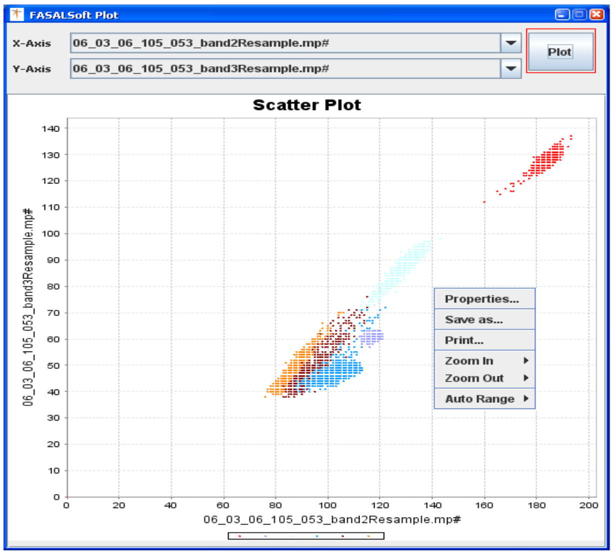


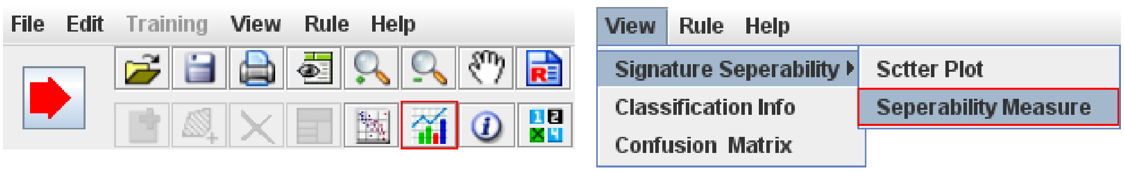
Class statistics/separable measures











Classification accuracy

Confusion Matrix

Class	Wheat	Water	Marshy	Sand	Row Count
Wheat	2193	0	9	0	2202
Water	0	1995	0	0	1995
Marshy	0	0	2238	13	2251
Sand	0	0	3	2025	2028
Column Count	2193	1995	2250	2038	**8476**

Classification Accuracy

Class	User Accuracy	Producer Accuracy	Mapping Accuracy	Over ALL Accuracy	Kappa Coefficient
Wheat	0.996	1.000	0.996	0.997	0.996
Water	1.000	1.000	1.000		
Marshy	0.994	0.995	0.989		
Sand	0.999	0.994	0.992		

Producer's Accuracy of class i:

Xii/X+i = (1 – error of omission)

User's Accuracy of class i

Xii/Xi+ = (1 – error of commission)

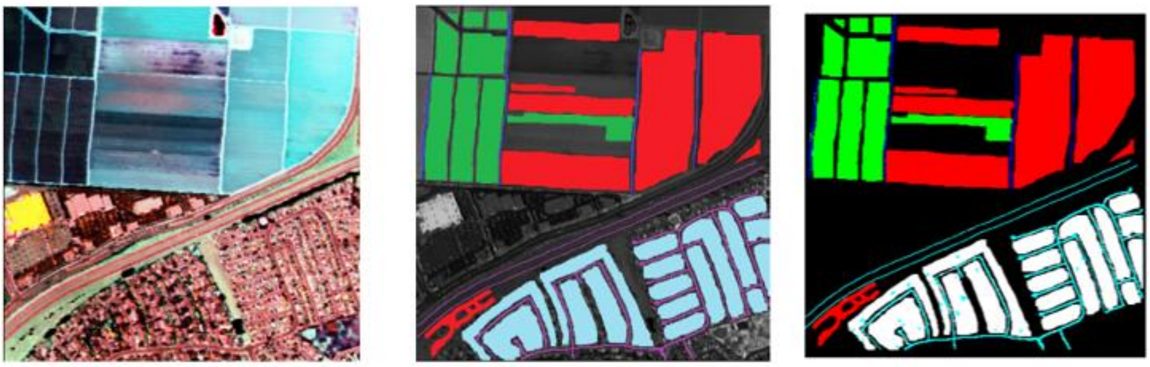
Mapping Accuracy of class i = xii / (Xi+ + x+i – Xii)

=(1 – error of commission – error of omission)

Overall Accuracy: It is a measure of joint accuracy of all the classes taken together.

Kappa coefficient: It is a measure of joint accuracy of all the classes taken together. It is similar to overall accuracy after deducting the effects of chance agreement.

Deep Learning Based Classification



(a) FCC (b) Ground Truth (c) Classified Map

Accuracy (Spectral + Spatial): 98.85 %

Class	Total	Training	Test
Dry Veg	30205	21192	9013
Healthy Veg	14881	10491	4390
Dirt Path	1320	905	415
Urban	23566	16432	7134
Pavement	5254	3674	1580

Exercise 4

GEOPORTALS AND DATA DISSEMINATIONS

4.1 Introduction

In the modern era of data-driven decision-making and technological advancements, geospatial information has become increasingly vital for citizen services, planning and governance activities. Geoportals and online geodata repositories have emerged as powerful tools that facilitate the discovery, access, and utilization of geospatial data. These platforms provide centralized access to a vast array of geospatial datasets, enabling users to explore, analyze, and leverage geospatial information for a wide range of applications. Geoportals serve as gateways to geospatial data and related services. They act as online platforms or web portals that aggregate, organize, and present geospatial data from multiple sources in a user-friendly and accessible manner. Geoportals may be developed by governmental bodies, research institutions, private organizations, or a combination thereof. They serve as a hub for geospatial data and typically offer a range of functionalities such as data searching, visualization, and data download services etc. One of the primary benefits of geoportals is their ability to provide users with a single point of access to diverse geospatial datasets and services. These datasets can include satellite imagery, aerial photography, digital elevation models, land cover maps, weather data, demographic information, and much more. By offering a centralized repository of geospatial data, geoportals simplify the process of data discovery and retrieval, saving valuable time and effort for individuals and organizations working with geospatial information.

Online geodata repositories, on the other hand, are specialized platforms that focus on hosting and managing geospatial datasets. These repositories serve as online storage facilities, where users can upload, store, and share their geospatial data with others. They provide a scalable infrastructure to accommodate large volumes of geospatial data, ensuring its availability and accessibility to a wide range of users. The key advantage of online geodata repositories is their ability to promote data sharing and collaboration within the geospatial community. Researchers, scientists, government agencies, and businesses can upload their datasets to these repositories, making them openly available for others to access and utilize. This fosters innovation, encourages interdisciplinary collaborations, and allows for the integration of different datasets to derive meaningful insights. Geoportals and online geodata repositories play a crucial role in supporting various sectors, including urban planning, environmental management, agriculture, natural resource exploration, disaster response, and many others. These platforms enable users to leverage geospatial data for informed decision-making, policy development, research, and development of applications and services.

In this hand-on exercise, we will learn about popular geoportals and online geo-data repositories with special emphasis on ISRO Geoportals. The Graphical User Interface (GUI) and URLs of the presented geo-portals are expected to change over the time due to advancements in computer systems, technologies and services offered by the host organizations. The learners are advised to keep on checking the latest version & URL of these geoportal for better understanding and knowledge.

Following popular geoportal expected to be explored by the learners:

1. Google Map
2. Open street Maps
3. NASA Earth Observing System Data and Information System (EOSDIS)
4. Bing Map

5. USGS EarthExplorer
6. ISRO Bhuvan
7. ISRO MOSDAC
8. ISRO VEDAS
9. NIC Bharat Maps
10. India WRIS
11. ArcGIS online

4.2 Google Maps

Google Maps is a widely recognized and extensively used mapping and navigation platform developed by Google. It offers a comprehensive set of features that allow users to explore the world, plan routes, and find local businesses and points of interest. With its accurate and up-to-date mapping data, real-time traffic information, street-level imagery, and integration with various transportation options, Google Maps provides users with a versatile tool for navigating and getting around in different modes of transportation. Moreover, Google Maps Application Programming Interface (API)allows developers to incorporate mapping and geolocation capabilities into their own applications. The Google Maps API provides developers with a robust set of tools and resources to integrate mapping and geolocation capabilities into their own applications, ranging from navigation apps to on-demand services and asset tracking systems. This versatility has contributed to the widespread adoption and integration of Google Maps into countless digital products and services.

4.2.1 Exercise

Step 1- Visit URL- https://maps.google.com

Step 2- Explore Different Geo-visualization tools and applications (Figure 1)

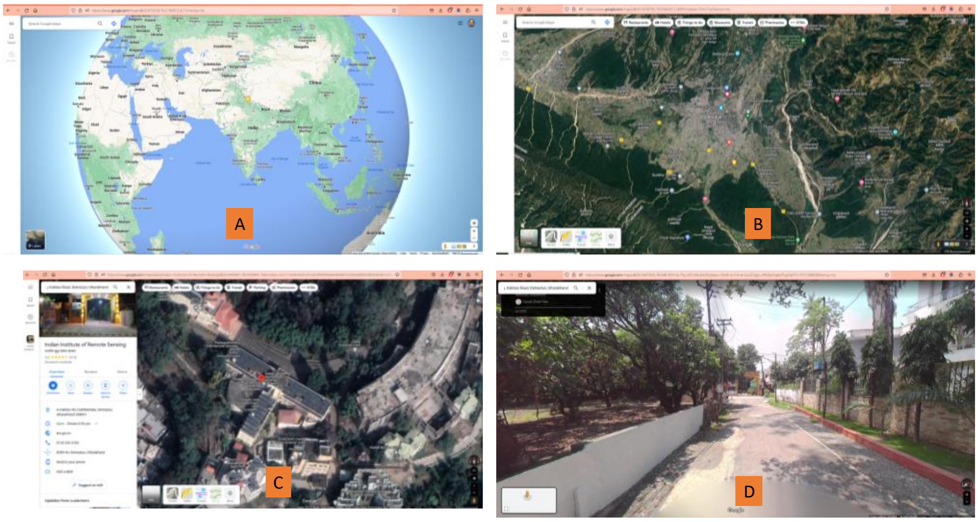


Figure 1- Geo-visualization tools and applications in google maps

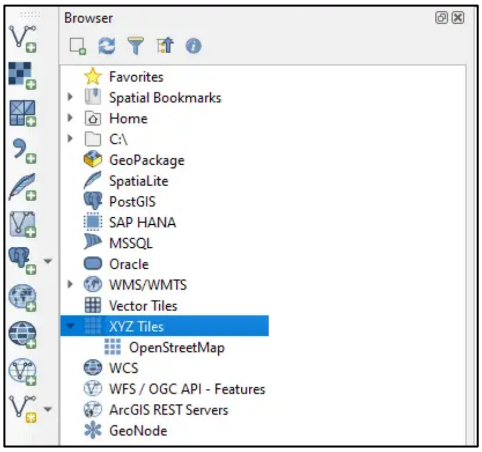
A- Map visualization at Global, Regional, National, State, City & Street
B- Switch of Satellite view and explore services and amenities around the city.
C- Zoom up to building/street level.
D- Further zoom to street level and explore the street view.

Search the place of interest and also explore the feature "Direction" for routing purpose. You can see the route with various option. Explore live traffic status and also understand the calculation of time to reach from one place to another.

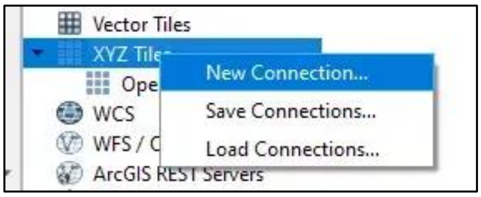
Step 3- Accessing google maps in QGIS. First open QGIS and add XYZ Tiles to QGIS

Now that we have the links to the tiled maps sources we need to add them to QGIS as XYZ tiles. This is easy to do and is explained by the directions below.

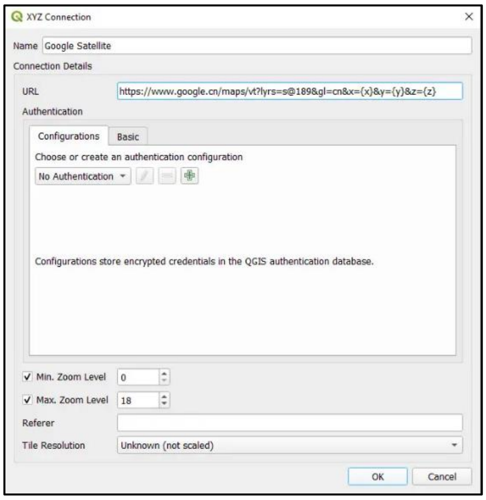
1. Navigate to the QGIS Browser panel and find the XYZ tiles section. OpenSteetMap is the only default entry.



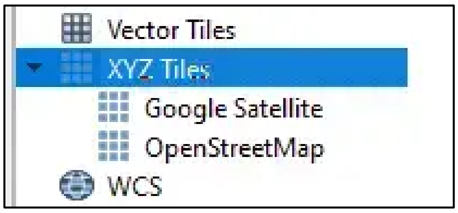
2. Right-click on 'XYZ Tiles' and select 'New Connection'. This will open a new window to enter the connection details.



3. In the new window enter a name for the new connection and provide the URL to the tiled map service (from the table below), then click OK. In this example I've added the URL for Google Satellite.



4. You will now see that the new connection has been added under XYZ tiles.



5. Add the basemap to your project by dragging it from the Browser Panel into the map area or adding it from the QGIS Data Source Manager.

6. Now you can pan, zoom, and navigate the map like any other layer.

Table 1- URLS for accessing google map services in QGIS

Product	URL
Google Maps	https://mt1.google.com/vt/lyrs=r&x={x}&y={y}&z={z}
Google Satellite	https://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}
Google Satellite Hybrid	https://mt1.google.com/vt/lyrs=y&x={x}&y={y}&z={z}
Google Terrain	https://mt1.google.com/vt/lyrs=t&x={x}&y={y}&z={z}
Google Roads	https://mt1.google.com/vt/lyrs=h&x={x}&y={y}&z={z}

Step 4- Accessing google map APIs. If you are software develop, you can also explore google map APIs for your software applications by accessing following URL- https://developers.google.com/maps/documentation

4.3 Open street Maps (OSM)

OpenStreetMap (OSM) is a crowd-sourced and open-source mapping project that has gained global recognition and popularity. With a collaborative community of contributors worldwide, OSM provides free and editable geospatial data that can be accessed, used, and enhanced by anyone. The platform allows users to view, edit, and contribute to the mapping of roads, buildings, landmarks, and various points of interest. OSM has become a valuable resource for individuals, businesses, and organizations seeking accurate and up-to-date mapping information, promoting open data principles and fostering a spirit of community-driven mapping around the world.

4.3.1 Exercise

Step 1- Visit URL- https://maps.google.com

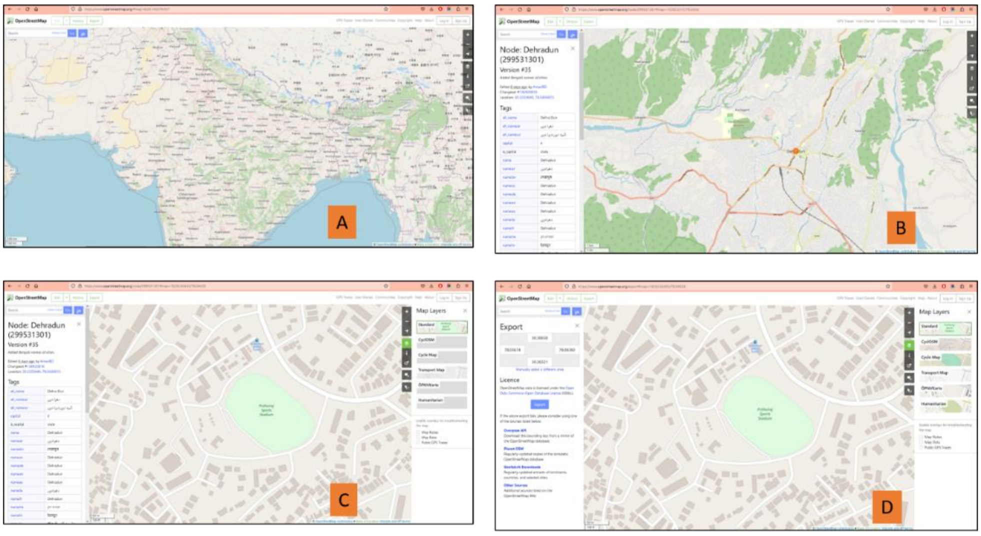


Figure 2- Geo-visualization tools and applications in Openstreet maps

Step 2- Explore Different Geo-visualization tools and applications (Figure 2)

a. Map visualization at Global, Regional, National, State, City & Street
b. Zoom to area of interest or search for a place e.g. Dehradun.
c. Zoom to best map scale and explore the locality.
d. Expand map layer (right side) and export the data at map extents level as .osm. The .osm file is axml document which can exported as GIS layer (.shp file) using GIS software such as QGIS.

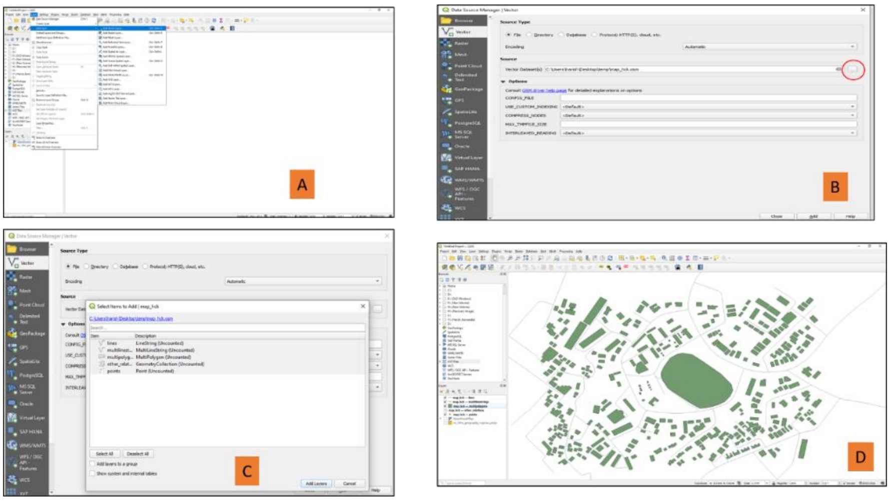


Figure 3- Accessing. OSM file in QGIS

A. Open QGIS and Click on “Add Layer” -> “Vector Layer”.
B. Browse for. osm file.

C. Load file and select the option “Select All”. Point, Line and Polygon Layers will be loaded in QGIS.
D. Right click on Layer name and select “Zoom to Layer”.

Explore different options by right click on Layer name. You can see all the attribute, edit it and further save as .shp file.

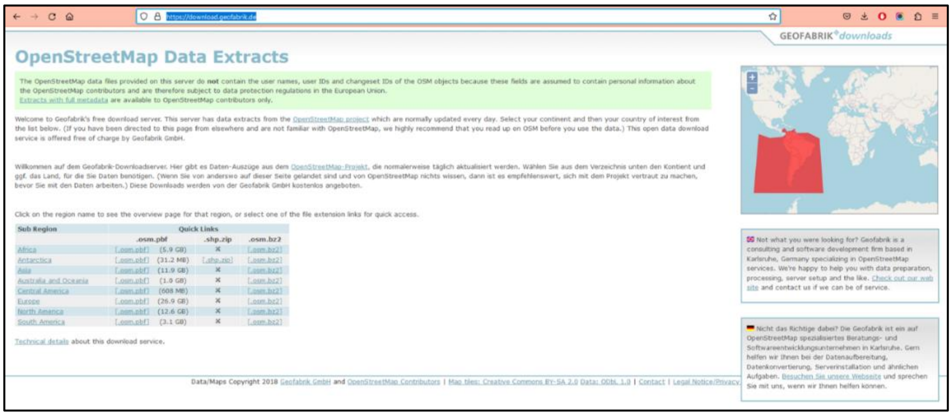
Step 3- Understanding Openstreet Map editing feature.

Create your account in the website and login. Now click on “Edit” button shown on upper left to your web browser screen.

Explore different Map editing feature for existing object. Also explore creating new point, line and polygon with its attribute editing.

Step 4- Downloading Openstreet Map data from Cloud.

You can download OSM data as GIS shape file from following website- https://download.geofabrik.de/

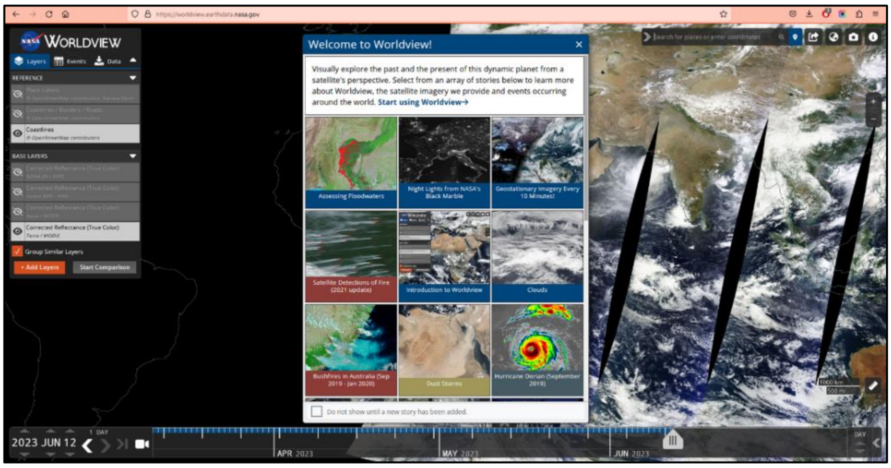


4.4 NASA Earth Observing System Data and Information System (EOSDIS)

The Earth Observing System Data and Information System (EOSDIS) is a comprehensive and cutting-edge geoportal operated by NASA. It serves as a centralized repository for a vast collection of Earth science data and information, encompassing a wide range of disciplines such as atmospheric science, oceanography, climate studies, and land cover analysis. EOSDIS enables scientists, researchers, and the public to access, explore, and analyze data from NASA's Earth observation missions, including satellites like Terra, Aqua, and the recently launched Sentinel-6 Michael Freilich. With its user-friendly interface and powerful data processing capabilities, EOSDIS plays a crucial role in advancing our understanding of Earth's processes, supporting climate research, and facilitating informed decision-making for environmental management and policy development.

4.4.1 Exercise

Visit website- https://worldview.earthdata.nasa.gov/ and all the maps available under different themes as shown below.



4.5 Bing Map

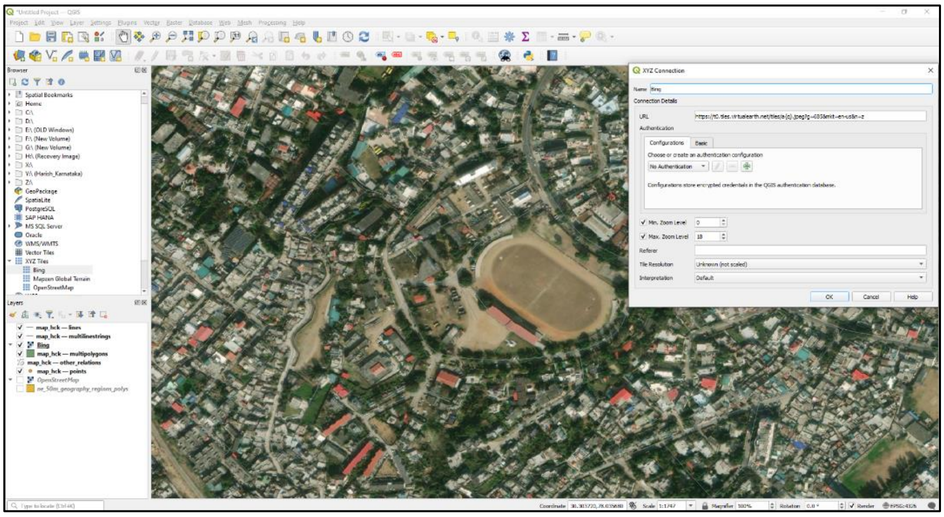
Bing Maps is a widely used mapping and geolocation platform developed by Microsoft. Offering a range of features and services, Bing Maps allows users to explore and navigate the world with ease. The platform provides detailed maps, satellite imagery, and street-level views, enabling users to visualize locations from different perspectives. Bing Maps also offers robust routing and directions functionality, allowing users to plan and optimize their routes for various modes of transportation. Additionally, Bing Maps integrates with other Microsoft services, such as Bing Search and Microsoft Office, enhancing its versatility and usability across different applications. With its comprehensive mapping data, intuitive interface, and integration with Microsoft's ecosystem, Bing Maps has become a popular choice for individuals, businesses, and developers seeking reliable mapping and geolocation services. Bing APIs are considered as one of powerful APIs for Web GIS applications.

4.5.1 Exercise

Accessing Bing Map in QGIS. Bing Map APIs can be accessed in QGIS for map visualization and other mapping applications.

STEPS-

- In the Browser panel, click on the “XYZ Tiles” button.
- In the XYZ Tiles window, click on the “New Connection” button.
- In the “New XYZ Connection” window, enter the following:
- Name: **Bing Maps Satellite Imagery**
- URL : https://t0.tiles.virtualearth.net/tiles/a{q}.jpeg?g=685&mkt=en-us&n=z
- Click “OK” to save the connection.
- In the XYZ Tiles window, select “**Bing Maps Satellite Imagery**” from the list of connections.
- Click “Add” to add the “**Bing Maps Satellite Imagery**” basemap to your project.



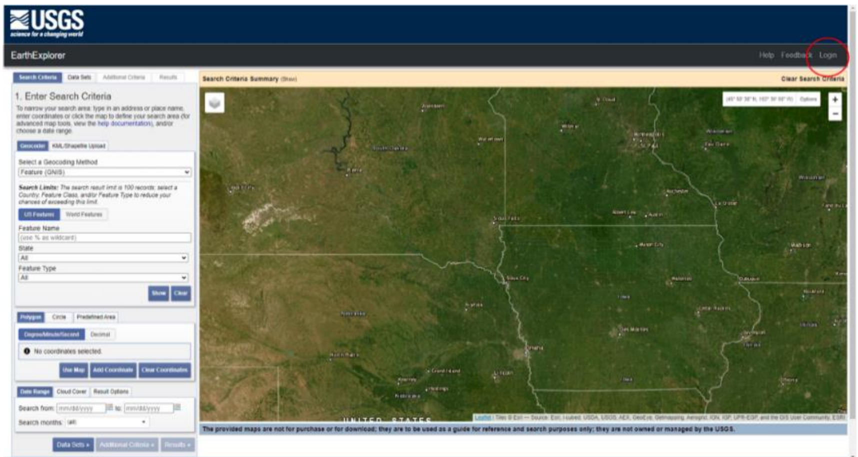
The basemap will appear in the Layers panel. You can adjust the opacity and style of the basemap as needed.

4.6 USGS EarthExplorer

USGS EarthExplorer is a widely used geoportal operated by the United States Geological Survey (USGS). It serves as a valuable resource for accessing and downloading a vast collection of geospatial data and imagery. EarthExplorer offers a wide range of datasets, including satellite imagery, aerial photography, digital elevation models, and land cover data. With its intuitive search interface and advanced filtering options, users can easily discover and retrieve the specific geospatial data they need. EarthExplorer supports various applications, including environmental monitoring, land management, and research. The platform's extensive data archive, user-friendly interface, and powerful search capabilities make it a go-to resource for accessing high-quality geospatial data for entire globe. URL- https://earthexplorer.usgs.gov/

4.6.1 Exercise

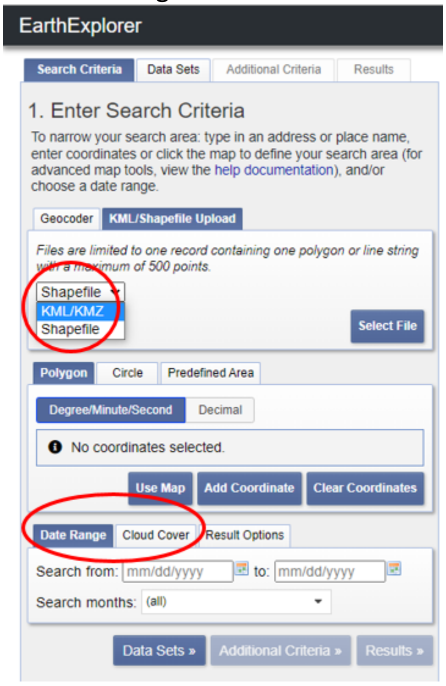
The USGS Earth Explorer interface uses Google Maps. To download satellite imagery from USGS, first an account needs to be created. In the top-right corner, click the Login button and then Create new account and follow the instructions to activate the account.



The satellite data can be downloaded from USGS by following the 4 steps stated below:

Step 1: Define the Study Area and Search Criteria.

- Users can double-click the browser to create regions of interest. Users can follow other alternative methods as well to define the study area such as using an address to search or by importing a shapefile (in a zip file) or KML.
- To define the study area using shapefile, click on shapefile tab in the search criteria and select the zip file having the shapefile and other associated files. Similarly, KML/KMZ file can also be uploaded.
- At the bottom of the search criteria window, select a range of dates for which the satellite data is required.
- The satellite data scenes can also be filtered for the cloud cover by selecting the Cloud Cover option on the right side of the Date Range. This options asks to set the minimum percent of cloud cover required to filter the images.



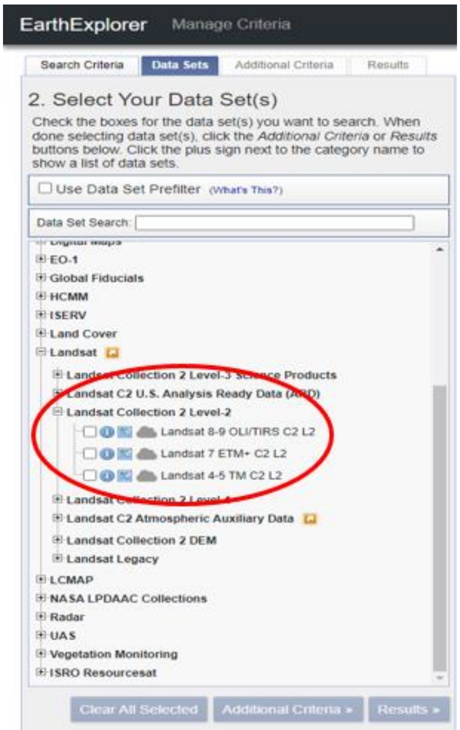
Step 2: Select data to download in the "Data Sets" tab

The USGS Earth Explorer provides various remote sensing datasets such as aerial imagery, AVHRR, commercial imagery, digital elevation models, Landsat, LiDAR, MODIS, Radar, and more. User can search for the required dataset in the **Data Set Search bar** or can click on the drop down of different categories.

For Landsat collection, the data can be found in the Landsat archive drop down. Follow the drop down as:

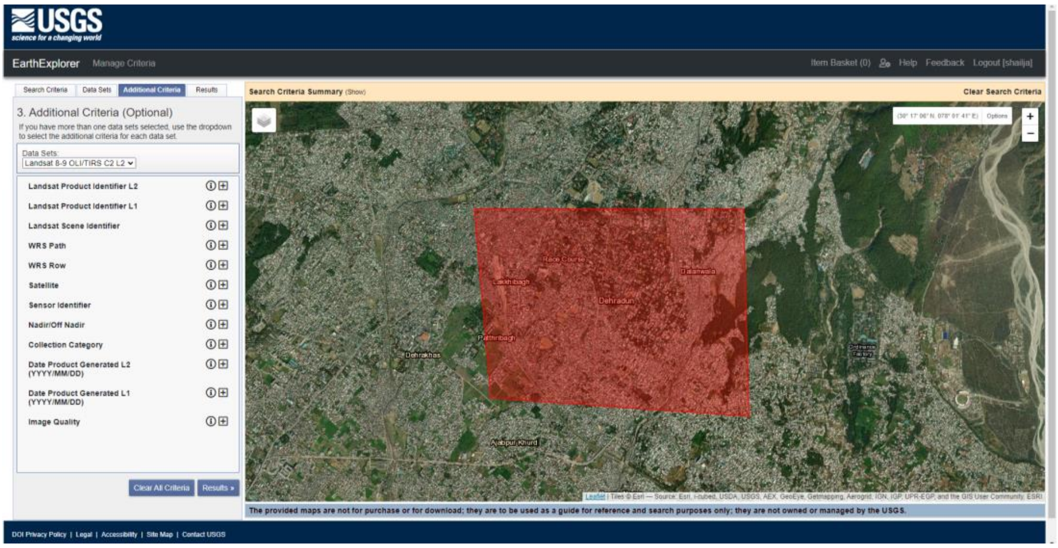
Landsat > Landsat Collection 2 Level-2 > Landsat 8-9 OLI/TIRS C2 L2

Now that the study area has been identified in step 1, the checkbox in the Landsat Archive category, for **Landsat 8-9 OLI/TIRS C2 L2** can be selected to browse the data for Landsat 8 or 9.



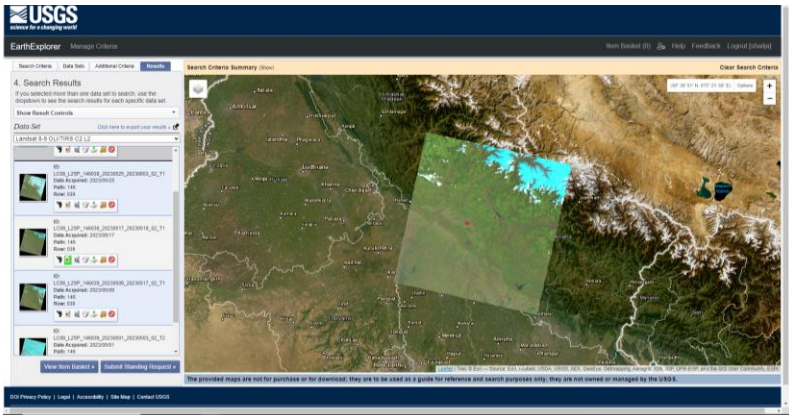
Step 3: Filter the data in the "Additional Criteria" tab

Next select the Additional Criteria tab. Here, the data can be filtered by Satellite Product Identifier, Scene Identifier, WRS Path and row, Image Quality etc. this is an optional step. If no particular criteria are needed to be set, then satellite imagery can be downloaded in the next step.

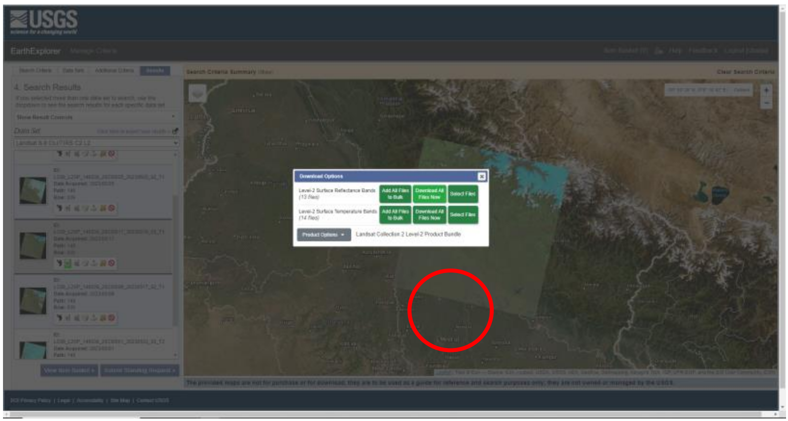


Step 4: View Results & Select Data to Order / Download

Now as study area, date range, type of data, and additional criteria have been defined, the search **Results** tab will populate with data sets that match the query. In the **Results** tab, all of the scenes available for the required parameters from the website will be listed. Here, specific imagery can be selected for downloading. The footprint for the scene can be checked by clicking on the icons below the scene to see exactly where that scene is located.



The data scene can also be previewed to check for the image quality, coverage and where clouds are in the image. The scene can be downloaded by clicking on the "**Download option**" icon.



Then finally, click on **Download all files now** to download the selected scene.

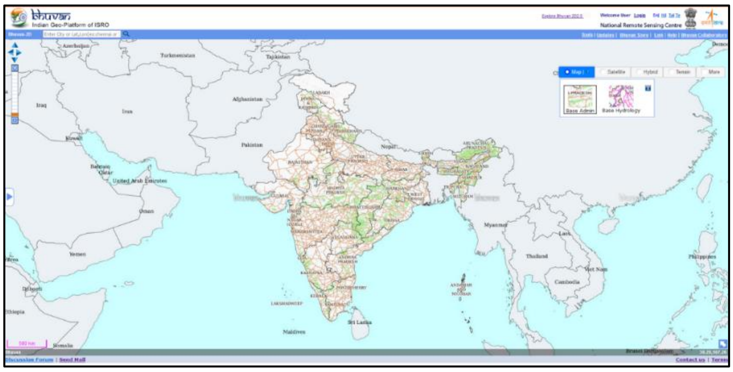
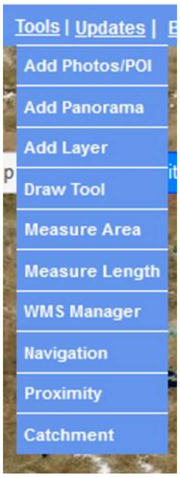
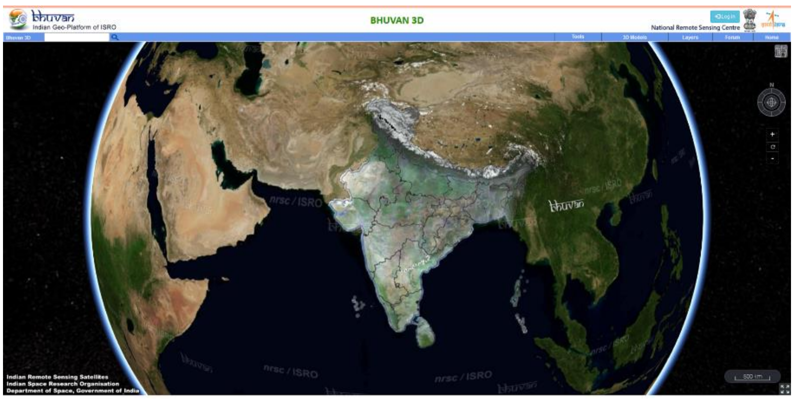
4.7 ISRO Bhuvan

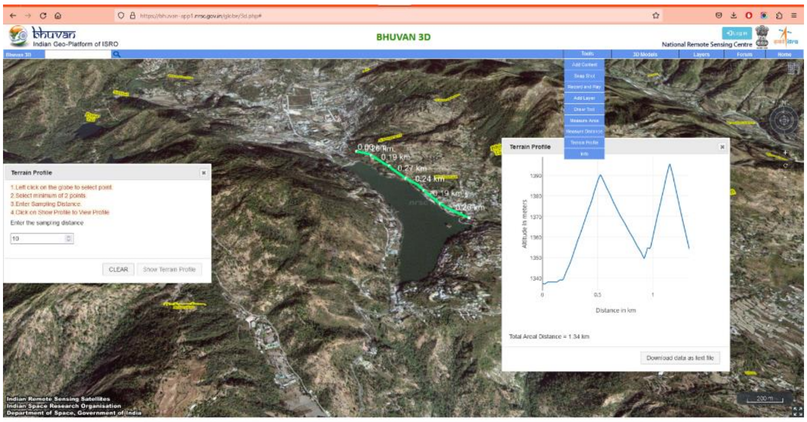
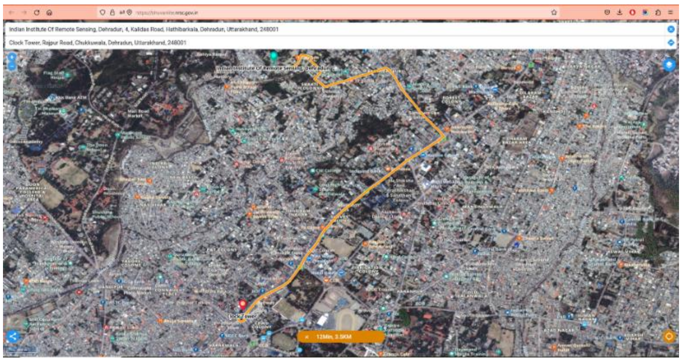
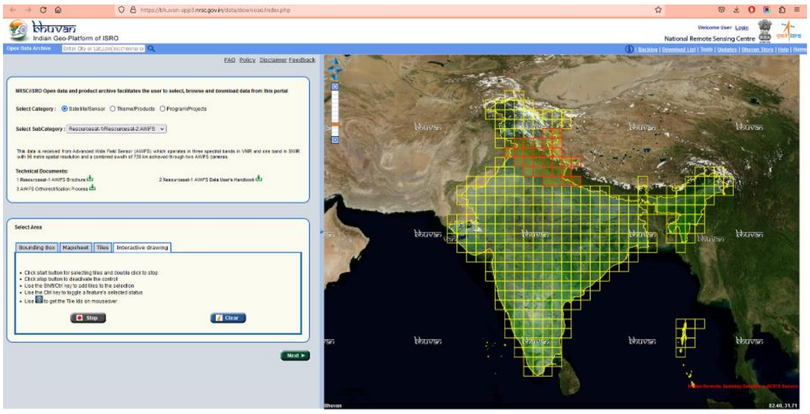
Bhuvan (the name is derived from the Sanskrit word which means Earth), a Geoportal of ISRO and Gateway to Indian Earth Observation Data Products and Services (https://bhuvan.nrsc.gov.in or www.bhuvan.nrsc.gov.in), is an initiative of Indian Space Research Organisation (ISRO), Department of Space, Government of India, to evince the Indian Earth Observation capabilities from the Indian Remote Sensing (IRS) series of satellites. Buvan is hosted at National Remote Sensing Centre (NRSC) Hyderabad India. The satellite images showcased on Bhuvan are from Multi-sensor, Multi-platform and Multi-temporal domains with capabilities to overlay thematic information, derived from such satellite imageries, as vector layers on virtual globe for the benefit of user community. Apart from its unique visualization capabilities, Bhuvan also facilitates the users to download the satellite data and products through its Open EO Data Archive (NOEDA).

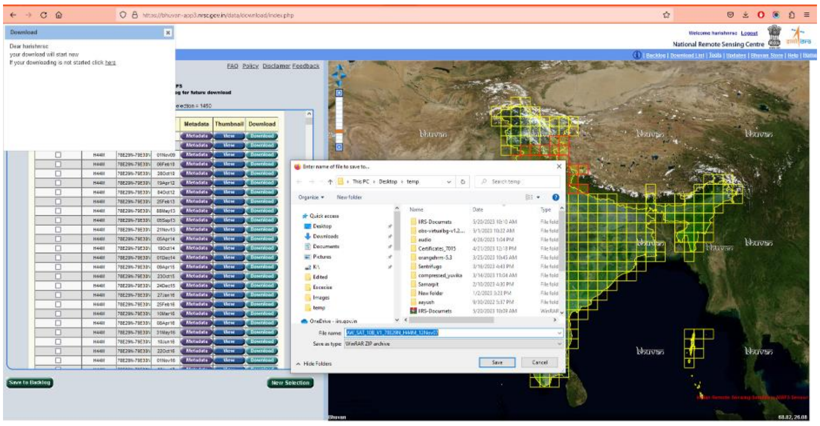
4.7.1 Exercise

Browse and access ISRO Bhuvan web portal using URL- https://bhuvan.nrsc.gov.in . Explore following components.

S. No.	**Component**	**Description & Exercise**

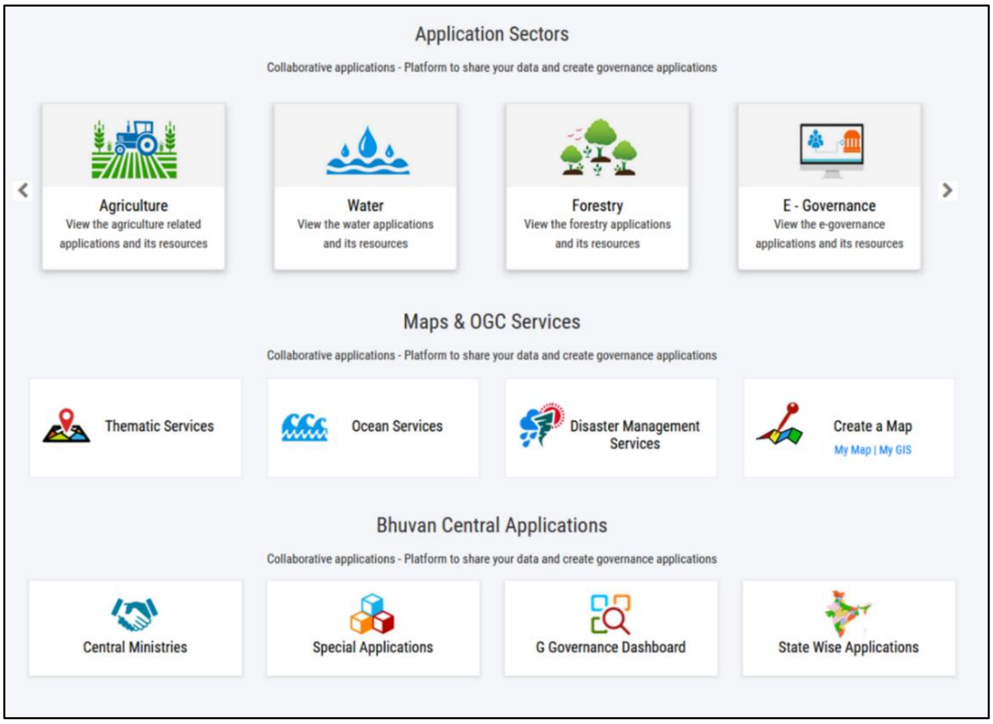
Visualization & Free Download		
1	Bhuvan 2D	Two dimensional Map visualization service. **Step 1**- Explore Maps (Base admin & hydrology), Satellite, Hybrid and terrain options.  **Step 2**- Search the place of interest (top left screen) and zoom to city level. **Step 3**- Click on "Date icon"  (first icon of top right screen) and understand the time stamping on satellite imageries. **Step 4**- Explore "Tool" option and experiment with different features. 
	Bhuvan 3D	Three dimensional Map visualization service **Step 1**- Open and Explore Bhuvan 3D mapping service 

		Step 2- Zoom to area of Interest and use scroll button of your mouse to tilt the map. Explore "Tools" option and understand the feature "terrain profile". 
	Bhuvan Lite	Light weight web application for map visualization and navigation services. **Step 1**- Explore Bhuvan lite for Map visualization and navigation services. For navigation purpose, the MapMyIndia APIs are integrated. 
	Open Data Archive	Allows download of free satellite data and products of specified period and resolution. **Step 1**- Explore the Open data archive and access data download service. Selecting area of Interest using interactive drawing is shown below: 

		Step 2- Create your account in the portal and download the data in .zip file 

Explore following services from ISRO Bhuvan portal:

1. **Application sector**- The governance applications in different thematic domain are available under this component.
2. **Maps & OGC Services**- The thematic maps specially generated under ISRO NR-Census programme are available as map visualization and Web Mapping Services (WMS). The services from ISRO Disaster Management Support programme for natural Disaster is also available.
3. **Bhuvan Central Services**- Explore different special mapping services for central and state governments in India.



More Demonstrations are available in following links:

ISRO Bhuvan in Hindi- https://www.youtube.com/watch?v=kdnVnc7ZfZw

ISRO Bhuvan in English- https://www.youtube.com/live/GjaueiRlEU4?feature=share&t=827

4.8 ISRO MOSDAC

ISRO MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre) is a specialized center operated by the Indian Space Research Organisation (ISRO). It serves as a dedicated facility for the archival and dissemination of meteorological and oceanographic satellite data. MOSDAC provides access to a wide range of satellite data products, including imagery, atmospheric parameters, sea surface temperature, and ocean color data. These datasets are vital for weather forecasting, climate studies, and oceanographic research. MOSDAC plays a crucial role in facilitating data access, analysis, and utilization by scientists, researchers, and operational weather agencies across India, contributing to improved understanding and prediction of weather and oceanographic phenomena in the region.

4.8.1 Exercise

Step 1- Visit URL- https://www.mosdac.gov.in/ and explore different map visualization and data download services available in the website.

Step 2- Watch the video session on ISRO MOSDAC web portal and learn the different features available for the users.

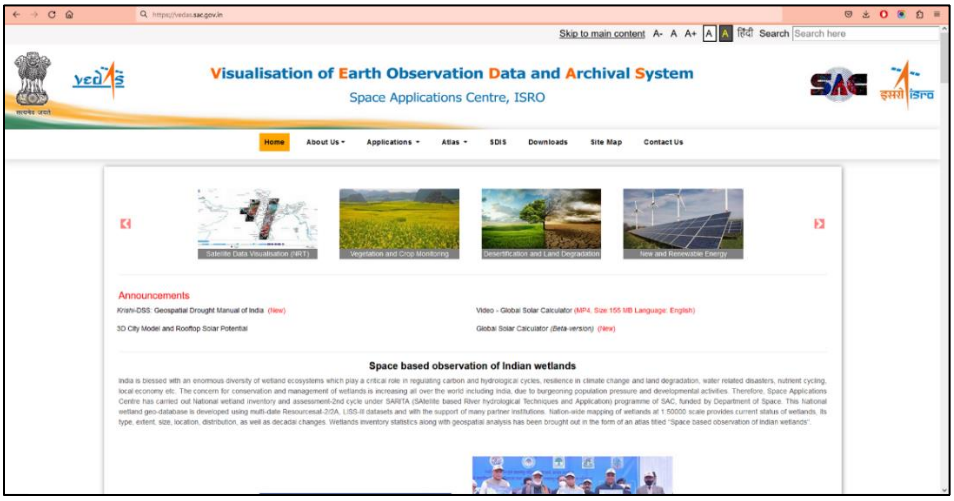
Video link- https://www.youtube.com/live/q33C4PriTL0?feature=share&t=212

4.9 ISRO VEDAS

ISRO VEDAS (Visualization of Earth observation Data and Archival System) is an innovative platform developed by the Indian Space Research Organisation (ISRO) to provide access to Earth observation data and services. VEDAS combines advanced visualization techniques and data analytics to offer users a comprehensive and interactive experience in exploring and analyzing satellite imagery and geospatial data. It enables users to visualize multi-temporal and multi-sensor data, perform change detection analysis, and generate custom thematic maps. VEDAS aims to empower researchers, policymakers, and decision-makers with a user-friendly interface and powerful tools to harness the full potential of Earth observation data for monitoring and managing natural resources, land cover, and environmental changes in India.

4.9.1 Exercise

Step 1- Visit URL- https://vedas.sac.gov.in and explore different map visualization and data download services available in the website.



Step 2- Watch the video session on ISRO VEDAS web portal and learn the different features available for the users.

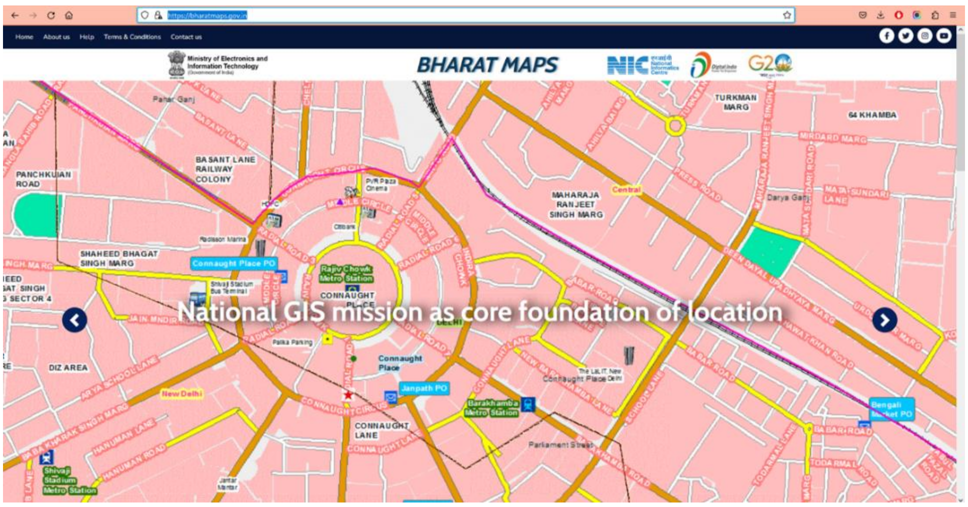
Video link- https://www.youtube.com/live/Qy1hIu8FNQ8?feature=share&t=103

4.10 NIC Bharat Maps

Digital India aims to establish end to end geo-spatial electronics delivery systems as part of Mission Mode Projects in e-Governance domain and envisages "National GIS Mission" as core foundation of location based Electronic Delivery of Services for Planning & Governance. NIC/DeitY has created Multi-Layer GIS Platform named "Bharat Maps" which depicts core foundation data as "NICMAPS", an integrated base map service using 1: 50,000 scale reference data from Survey of India, ISRO, FSI, RGI and so on. This encompass 23 layers containing administrative boundaries, transport layers such as roads & railways, forest layer, settlement locations etc., including terrain map services.

4.10.1 Exercise

Step 1- Visit URL- https://bharatmaps.gov.in/ and explore different map visualization and data download services available in the website.



4.11 ArcGIS Online

ArcGIS Online is a powerful and widely used cloud-based geospatial platform developed by Esri. It provides a comprehensive suite of tools and capabilities for creating, sharing, and analyzing geographic data and maps. ArcGIS Online allows users to access a vast collection of authoritative spatial data, create custom maps and applications, collaborate with others, and publish their work for wider dissemination. With its intuitive interface and robust functionality, ArcGIS Online caters to a broad range of users, including individuals, businesses, and government organizations, enabling them to make informed decisions, solve complex spatial problems, and communicate geospatial information effectively. The platform's scalability, versatility, and extensive integration options make it a leading choice for geospatial professionals seeking a comprehensive solution for their mapping and analysis needs.

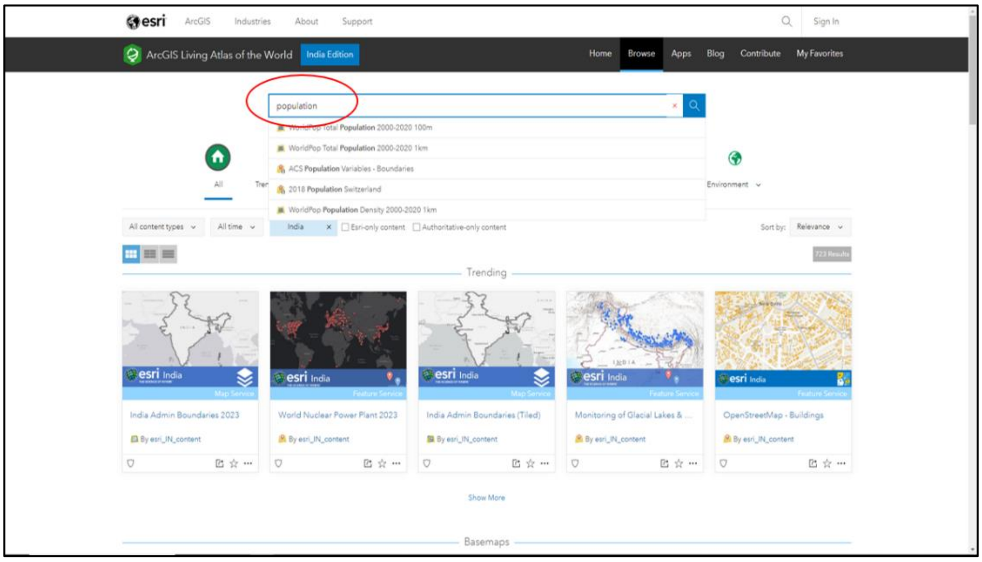
4.11.1 Exercise

ArcGIS online can be accessed using URL: https://www.arcgis.com/home/index.html

The homepage of ArcGIS online contains an option to Sign in on the top right corner. An account will be required to download the data from ArcGIS online.

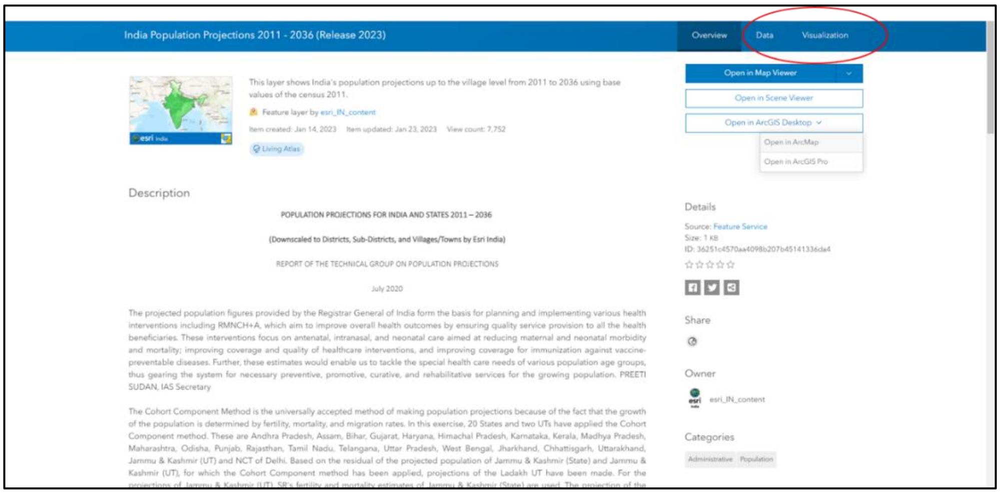
Step 1- To explore the datasets available in the ArcGIS online catalogue, click on Go to **Living Atlas**.

Living atlas will be opened in a different tab and will show the available datasets by default. User can either search for a specific dataset by typing the keywords in the search bar. For example, to see the datasets available for the population in ArcGIS online catalogue, type population in the search bar as shown in the figure below. The drop down will show all the datasets available related to the population.



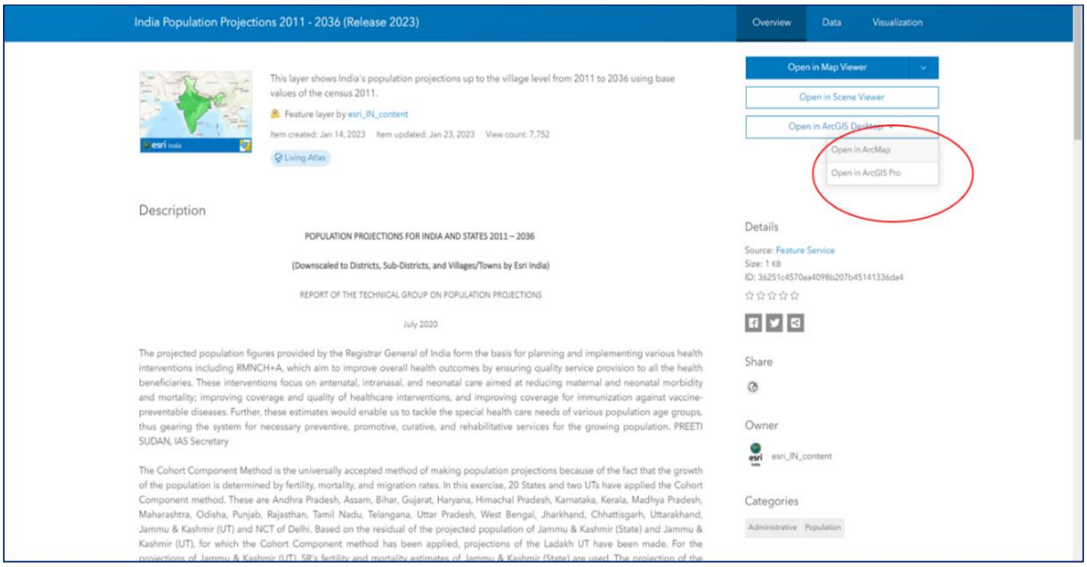
The datasets can also be browsed based on different themes such as boundary, people, infrastructure, environment etc.

Click on the dataset that needs to be downloaded or explored. It will open in different tab and will show the details and properties of the dataset selected. The attribute table of the data and the layer visualization can be done by clicking **Data** and **Visualization** tabs respectively.



Step 2- Download the data.

The data can be downloaded by clicking on **Open in ArcMap** or **Open in ArcGIS Pro** on the right side of the page. It will download the ArcGIS Portal item file.



Once the file is downloaded, it can be imported into ArcGIS Desktop, Pro, or other compatible geospatial software.

Exercise 5

OPEN-SOURCE PLATFORMS FOR GEO-DATA PROCESSING

Google Earth Engine is a geospatial processing service. With Earth Engine, you can perform geospatial processing at scale, powered by Google Cloud Platform. The purpose of Earth Engine is to provide an interactive platform for geospatial algorithm development at scale; enable high-impact, data-driven science; and to make substantive progress on global challenges that involve large geospatial datasets.

Earth Engine can be accessed using JavaScript in the Code Editor and Python locally or using Google Colab. This document helps you learn Earth Engine using the Code Editor available online and can be accessed via https://code.earthengine.google.com/. You will first need to sign-up for Earth Engine using your Google account on the link https://signup.earthengine.google.com.

5.1 Section 0 - JavaScript Syntax

```
// Line comments start with two forward slashes. Like this line.
```

```
/* Multi line comments start with a forward slash and a star, and end with a star and a forward slash.
*/
```

Variables are used to store objects, and are defined using the keyword var.

```
var the_answer = 42;
```

String objects start and end with a single quote.

```
var my_variable = 'I am a string';
```

String objects can also start and end with double quotes.

```
// But don't mix and match them.
var my_other_variable = "I am also a string";
```

Statements should end in a semi-colon, or the editor complains.

```
var test = 'I feel incomplete...'
```

Parentheses are used to pass parameters to functions.

```
print('This string will print in the Console tab.');
```

Square brackets are used for items in a list. The zero index refers to the first item in the list.

```
var my_list = ['eggplant', 'apple', 'wheat']; print(my_list[0]);
```

Curly brackets (or braces) can be used to define dictionaries (key:value pairs).

```
var my_dict = {'food': 'bread', 'color': 'red', 'number': the_answer};
```

Square brackets can be used to access dictionary items by key.

```
print(my_dict['color']);
```

Or you can use the dot notation to get the same result.

```
print(my_dict.color);
```

Functions can be defined as a way to reuse code and make it easier to read.

```
var my_hello_function = function(string) {   return 'Hello ' + string + '!';
};
print(my_hello_function('world'));
```

5.2 Section 1 - Hello, Images

1. Clear the script by selecting "Clear script" from the Reset button dropdown menu.
2. Search for “alos dem” and click on the **ALOS DSM: Global 30m** result to show the dataset description.
3. Click on Import, which moves the variable to the Imports section at the top of your script.
4. Rename the default variable name "image" to be "alos_dem".
5. iAdd the image object to the map with the script:

   print(alos_dem);

6. Browse through the information that was printed. Open the “bands” section to show the one band named “AVE”, which is the “elevation value calculated by average resampling a 5-meter mesh model”. Let us create a variable “elevation” to contain only this band: **var elevation = alos_dem.select("AVE");**
7. Use the Map.addLayer() method to add the image to the interactive map. We will start simple, without using any of the optional parameters.

   Map.addLayer(elevation);

8. The displayed map will look pretty flat grey, because the default visualization parameters map the full 16-bit range of the data onto the black–white range, but the elevation range is much smaller than that in any particular location. We’ll fix it in a moment.
9. Select the Inspector tab. Then click on a few points on the map to get a feel for the elevation in this area. Finally, set visualization parameters:

   Map.addLayer(elevation, {min: 0, max: 5000});

5.3 Section 2 - Apply a Computation to an Image

1. Pan over to the Kedarnath Region, where there are some dramatic elevation differences.
2. Next add a simple computation, for example a threshold on elevation.

   var high = elevation.gt(2000);
   Map.addLayer(high, {}, 'Above 2000m');

3. Do another computation to compute slope from the elevation data and display it on the map as a separate layer. Also add a third parameter to the addLayer() method, which names the layer.

   var slope = ee.Terrain.slope(elevation);
   Map.addLayer(slope, {min: 0, max: 60}, 'Slope');

4. Layers added to the map will have default names like "Layer 1", "Layer 2", etc. To improve the readability, give each layer a human-readable name.

   var slope = ee.Terrain.slope(elevation);
   Map.addLayer(elevation, {min: 0, max: 5000}**, 'DEM'**);
   Map.addLayer(slope, {min: 0, max: 60}**, 'Slope'**);

5.4 Section 3 - Apply a Spatial Reducer

1. Select the polygon geometry tool and draw a triangle (or more complex polygon) on the map.
2. Print the mean value for the region.

   Map.addLayer(geometry, {}, 'AOI'); var dict = srtm.reduceRegion({
   reducer: 'mean', geometry: geometry,
   scale: 30
   });
   print('Mean elevation', dict);

3. Clear the workspace by clicking

   Reset -> Clear script

Challenge: Try uploading the Dehradun shapefile and find the mean, minimum and maximum elevation (in meters) within Dehradun District. (Answer: 1087, 279, 3069 meters)

5.5 Section 4 - Load and Filter an Image Collection

1. Delete the **alos_dem** object from the Import section, by rolling your cursor over the object, then clicking on the trash can icon.

2. Search for "Landsat 8 toa" and add "USGS Landsat 8 Collection 1 Tier 1 TOA Reflectance" to the imports section. Rename the collection "L8".

3. Apply a date filter to the image collection, using the filterDate() method.

   var filtered = L8.filterDate('2018-01-01', '2018-11-01'); Map.addLayer(filtered);

More Info: To understand the Landsat Collection Tiers i.e., the inventory structure for Level-1 data, read https://landsat.usgs.gov/landsat-collections#C1%20Tiers

5.6 Section 5 - Play with Image Bands

1. With the default visualization parameters, the data looks dark and the colors look wrong. Pick better visualization parameters.

   var filtered = L8.filterDate('2018-01-01', '2018-11-01');
   Map.addLayer(filtered, **{min: 0, max: 0.3, bands:['B4', 'B3', 'B2']}**);

2. Copy and paste the second line and modify the bands to create the classic false-color look, with vegetation highlighted in red, and demonstrate giving each layer a human-readable name. var filtered = L8.filterDate('2018-01-01', '2018-11-01');

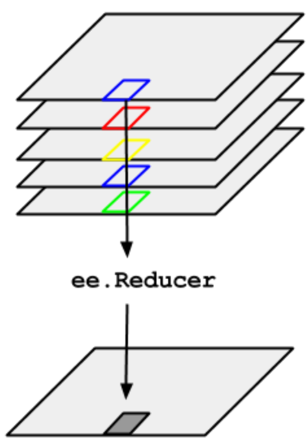
   Map.addLayer(filtered, {min: 0, max :0.3, bands:['B4', 'B3', 'B2']}**, 'RGB'**);
   Map.addLayer(filtered, {min: 0, max: 0.3, bands:['B5', 'B4', 'B3']}, 'False Color');

3. We're going to use these visualization parameters a lot, so pull them out into a variable.

   var rgb_vis = {min: 0, max: 0.3, bands:['B4', 'B3', 'B2']}; var filtered = L8.filterDate('2018-01-01', '2018-11-01'); Map.addLayer(filtered, **rgb_vis**, 'RGB');

More Info: Explore the visualization parameters. Use the layer opacity slider. Click on the settings icon and select a Range Stretch method, and then apply it to the image.

5.7 Section 6 - Reducing Image Collections



1. Expand out the date range. var filtered = l8.filterDate('2018-01-01', '2018-11-01').

   filterMetadata('CLOUD_COVER', 'less_than', 30); var rgb_vis = {min: 0, max: 0.3, bands:['B4', 'B3', 'B2']};
   Map.addLayer(filtered, rgb_vis, 'RGB - CC < 30');

2. Show that you get the same result if you mosaic() the filtered collection var filtered = l8.filterDate('2018-01-01', '2018-11-01');

   Map.addLayer(filtered**.mosaic()**, rgb_vis, 'RGB - mosaic reducer');

3. Show the results of using the median() reducer var filtered = l8.filterDate('2018-01-01', '2018-11-01');

   Map.addLayer(filtered**.median()**, rgb_vis, 'RGB - median reducer');

5.8 Section 7 - Compute NDVI

1. Using the select() method, pick out the NIR and red bands, and do some math the "hard" way by hand.
   var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']}; var filtered = L8.filterDate('2018-01-01', '2018-10-31')

   .filterMetadata('CLOUD_COVER', 'less_than', 10)

   .filterBounds(geometry);

   var image = ee.Image(filtered.first()); **var red = image.select('B4'); var nir = image.select('B5'); var ndvi = nir.subtract(red).divide(nir.add(red));**
   Map.addLayer(image, rgb_vis, 'RGB');
   Map.addLayer(ndvi, {min: 0, max: 1, palette: ['white', 'green']}, 'NDVI');
   Map.centerObject(image, 10);

2. Find the ee.Image.normalizedDifference() method in the docs. Use it to simplify the script.
   var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']}; var filtered = L8.filterDate('2018-01-01', '2018-10-31')

   filterMetadata('CLOUD_COVER', 'less_than', 10)

   .filterBounds(geometry);

   var image = ee.Image(filtered.first());
   var ndvi = image.normalizedDifference(['B5', 'B4']);
   Map.addLayer(image, rgb_vis, 'RGB');
   Map.addLayer(ndvi, {min: 0, max: 1, palette: ['white', 'green']}, 'NDVI');
   Map.centerObject(image, 10);

5.9 Section 8 - Write a Function

Our next goal is to calculate NDVI for a collection of images. To do so, we first need to refactor (rewrite) our code to using a function, which can then be applied to all images in a collection.

1. Start by writing a function that adds a band with NDVI data to an image: var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']};

   ```
   function addNDVI(image) {
     var ndvi = image.normalizedDifference(['B5', 'B4']).rename('ndvi');   return image.addBands(ndvi);
   }
   var filtered = L8.filterDate('2018-01-01', '2018-10-31')
                       .filterMetadata('CLOUD_COVER', 'less_than', 10)
                       .filterBounds(geometry);
   var image = ee.Image(filtered.first());
   var ndvi = addNDVI(image); Map.addLayer(image, rgb_vis, 'RGB');
   Map.addLayer(ndvi, {min: 0, max: 1}, 'NDVI');
   ```

2. Click on the Inspector tab, then on the image. Look in the Inspector tab results to see that the code has added a band called "ndvi".
3. Note that the image has change, because the first band (B1) is being displayed by default, instead of the "ndvi" band. Add a visualization parameter to correct this:

   ```
   var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']};
   function addNDVI(image) {
     var ndvi = image.normalizedDifference(['B5', 'B4']).rename('ndvi');   return image.addBands(ndvi);
   } var filtered = L8.filterDate('2018-01-01', '2018-10-31')
                       .filterMetadata('CLOUD_COVER', 'less_than', 10)
                       .filterBounds(geometry);
   var image = ee.Image(filtered.first()); var ndvi = addNDVI(image);
   Map.addLayer(image, rgb_vis, 'RGB');
   Map.addLayer(ndvi, {bands: 'ndvi', min: 0, max: 1}, 'NDVI');
   ```

5.10 Section 9 - Map a Function over a Collection

1. Now that we have a function, we will 'map' the function across the filtered Landsat 8 collection. var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']};

   ```
   function addNDVI(image) {
     var ndvi = image.normalizedDifference(['B5', 'B4']).rename('ndvi');   return image.addBands(ndvi);
   }
   var filtered = L8.filterDate('2018-01-01', '2018-10-31'); var with_ndvi = filtered.map(addNDVI);
   Map.addLayer(filtered, rgb_vis, 'RGB-Mapped');
   Map.addLayer(with_ndvi, {bands: 'ndvi', min: 0, max: 1}, 'NDVI-Mapped');
   ```

2. Using the inspector tab, click on the map to show that each image now has an 'ndvi' band containing the NDVI.

3. To get rid of some clouds, expand out the time range and/or switch to using a median reducer.

   Map.addLayer(filtered**.median()**, rgb_vis, 'RGB-Median');

   Map.addLayer(with_ndvi**.median()**, {bands: 'ndvi', min: 0, max: 1}, 'NDVI-Median');

5.11 Section 10 - Chart NDVI over Time

1. Click on the ROI point that was added earlier, and then drag it to an agricultural field. Add the following line to make a chart of NDVI over time for your ROI.

```
var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']};
function addNDVI(image) {
 var ndvi = image.normalizedDifference(['B5', 'B4']).rename('ndvi');
 return image.addBands(ndvi);
}
var filtered = L8.filterDate('2017-06-01', '2018-07-31');
var with_ndvi = filtered.map(addNDVI);
var chart = ui.Chart.image.series(with_ndvi.select('ndvi'), geometry); print(chart);
```

2. Try out the interactivity of the chart by hovering, expand it to full screen, and testing out the SVG/PNG/CSV download buttons.

5.12 Section 11 - Visually verify trends with UI elements.

The NDVI time series generated in Section 10 should also be cross-verified by displaying the corresponding Landsat images in 3-band (RGB) True color composites. This section will demonstrate how to add a user interface (UI) element, listing all the Landsat Image IDs and adding them when user selects it.

1. Start by making a chart of NDVI over time for a ROI.

```
var rgb_vis = {min: 0, max: 0.3, bands: ['B4', 'B3', 'B2']}; var filtered = L8.filterDate('2017-06-01', '2018-07-31')            .filterMetadata('CLOUD_COVER', 'less_than', 30)
            .filterBounds(geometry); Map.centerObject(geometry, 15); function addNDVI(image) {
 var ndvi = image.normalizedDifference(['B5', 'B4']).rename('ndvi');   return image.addBands(ndvi);
}
var with_ndvi = filtered.map(addNDVI);
var chart = ui.Chart.image.series(with_ndvi.select('ndvi'), geometry); print(chart);
```

2. Write a function to display the image with the given ID.

```
var display = function(id) {   var image = filtered.filter(ee.Filter.eq("system:index", id))
 Map.layers().reset()
 Map.addLayer(image, rgb_vis, "Image") }
```

3. Get the list of Landsat Image IDs and put them into a select UI element. Call the “display” function when the select element is changed.

```
filtered.aggregate_array("system:index").evaluate(function(ids) {
 Map.add(ui.Select({    items: ids,    onChange: display
 }))
});
```

5.13 Section 12 - Use cases

The research and user community is using Earth Engine Apps to develop several use cases. Earth Engine Apps are dynamic, shareable user interfaces for Earth Engine analyses. With Apps, experts can use simple UI elements to leverage Earth Engine's data catalog and analytical power, for experts and non-experts alike to use. Here are some of the Featured Apps listed on the Earth Engine portal (as on March 2023).

Global **forest** canopy height, 2000 and 2020 (Potapov et al., 2022a)

- The application portrays the reduction of global tree cover extent during the first 20 years of the century. The forest height maps were developed through the integration of the Global Ecosystem Dynamics Investigation (GEDI, https://gedi.umd.edu/) lidar forest structure measurements and 2000-2020 Landsat analysis-ready data time-series (https://glad.umd.edu/ard).
- https://glad.earthengine.app/view/forest-height-2000-2020

- Global **cropland** expansion in the 21st century (Potapov et al., 2022b)
- This application has the 2000-2019 globally consistent cropland extent time-series at 30-m spatial resolution, which was derived from the Landsat satellite data archive. Cropland is defined as land used for annual and perennial herbaceous crops for human consumption, forage (including hay), and biofuel. The crop mapping was performed in four-year intervals.
- https://glad.earthengine.app/view/global-cropland-dynamics

- Seasonal **water and ice** dynamics, 2019 (Pickens et al., 2022)
- The application aims to deliver spatially explicit maps of ice cover phenology and monthly area estimates and associated uncertainties of inland surface water and ice cover extent, which will provide important insights into the current state of the global water system. Such spatio-temporally explicit data may be used to inform projections of ongoing and future transitions under the impact of climate change.
- https://glad.earthengine.app/view/global-water-ice

Use cases in diverse areas such as public health management have also been developed using Earth Engine. Some examples are listed below.

SMOKE Policy Tool (Marlier et al., 2019)

- The tool models and projects the impact of Indonesian fires on public health in Equatorial Asia for 2005-2029 based on land use/ land cover classification, GFEDv4s fire emissions, and meteorology.
- https://smokepolicytool.users.earthengine.app/view/smoke-policy-tool

- **Malaria** Atlas Project (Hay & Snow, 2006).
- This platform provides different tools to learn about, explore, and work with malaria data. It also provides malaria data at varying levels of detail to suit different needs. This suite of tools aims to support the needs of diverse audiences, including the general public, the media, policy analysts, engineers, as well as researchers.
- https://data.malariaatlas.org/maps

5.14 References

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क्षमता निर्माण एवं जन बाह्य-पहुँच

Capacity Building and Public Outreach

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