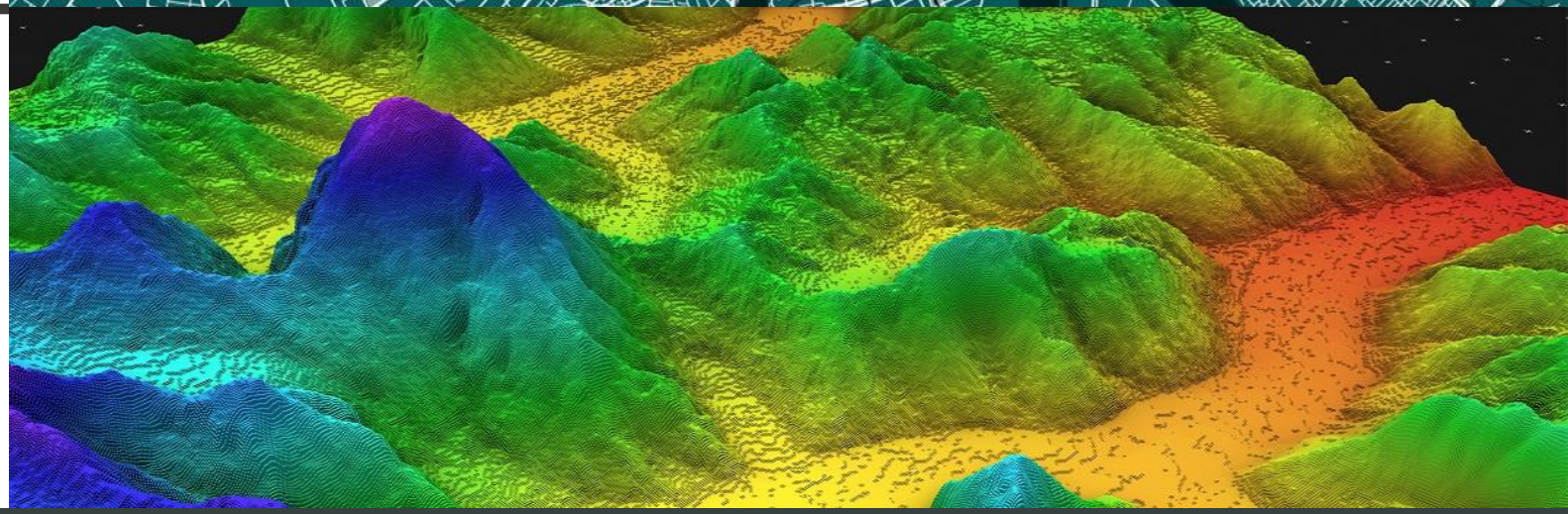
Geographical Information System



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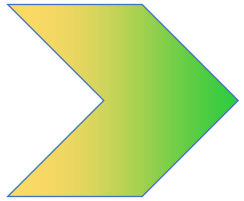
School of Technology, PDEU.
ankit.Deshmukh@sot.pdpu.ac.in

Integration of Drone Photogrammetry and GIS

Drone Photogrammetry

- UAV image acquisition
- High-resolution imagery
- Orthomosaic generation
- DSM/DTM creation
- Point cloud extraction



GIS Integration

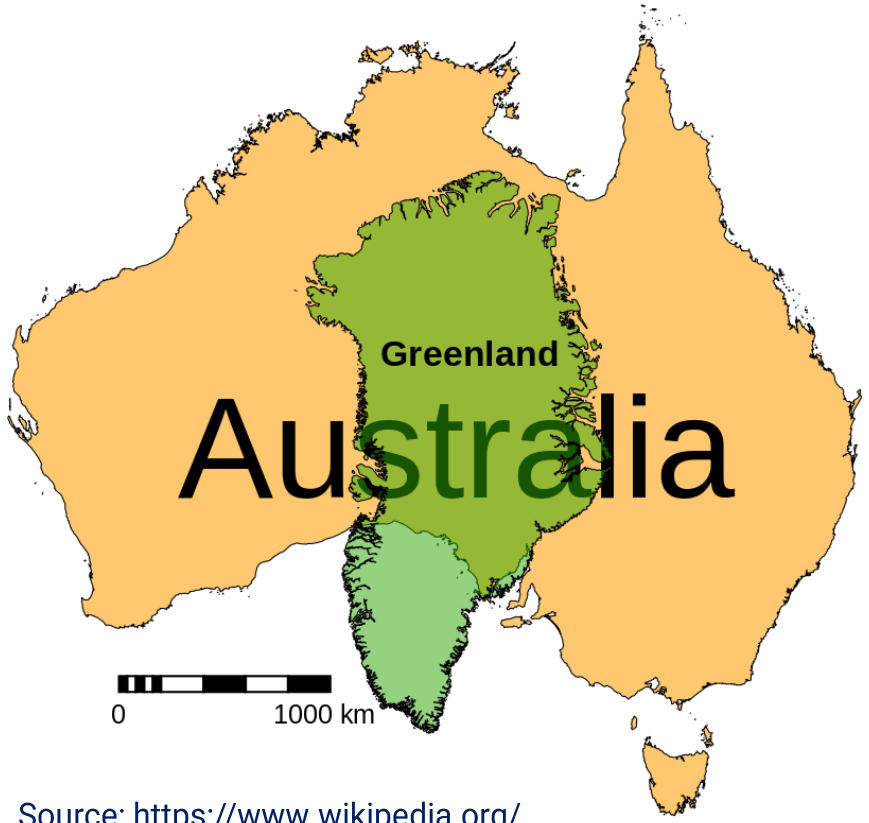
- Spatial analysis
- Terrain modeling
- Land-use mapping
- Hydrological analysis
- Decision support systems

UAV Survey → Image Processing → Orthomosaic/DEM → GIS Analysis → Spatial Decision Making

Why Are Map Projections Required?

Is Greenland Larger Than Australia?

Source: http://getwallpapers.com/



Source: https://www.wikipedia.org/

According to size, Australia's land is approximated to be **7,741,220** square kilometers dwarfing Greenland's cover of merely **2,166,086** square kilometers. Considering the land area, Australia is almost four times bigger than Greenland.

The Shape of the Earth

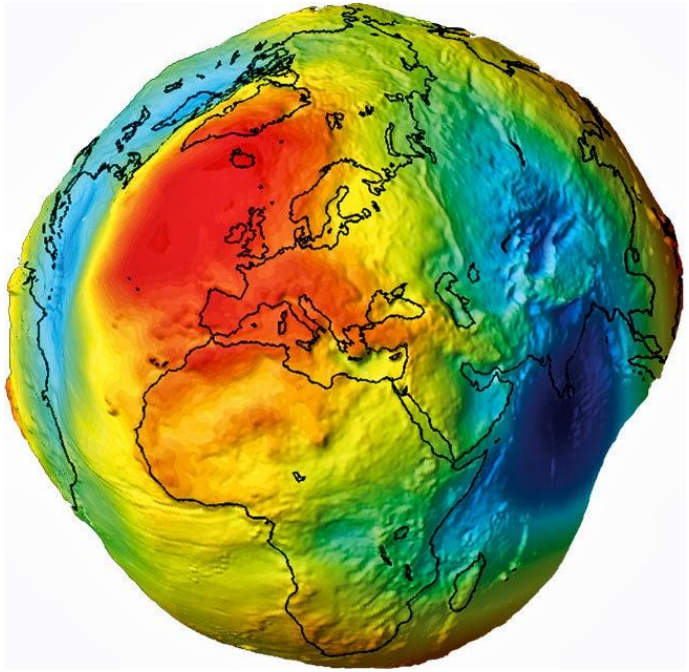
Although it is commonly thought of as a sphere, Earth is not perfectly spherical.

Its actual shape is what we refer to as a "**geoid.**"

Geoid: The hypothetical shape of the Earth, coinciding with mean sea level and its imagined extension under (or over) land areas.

It is an irregular, gravity-based reference surface used as the vertical datum for measuring elevations.

The geoid approximates the "*true physical shape*" of Earth based on gravity.



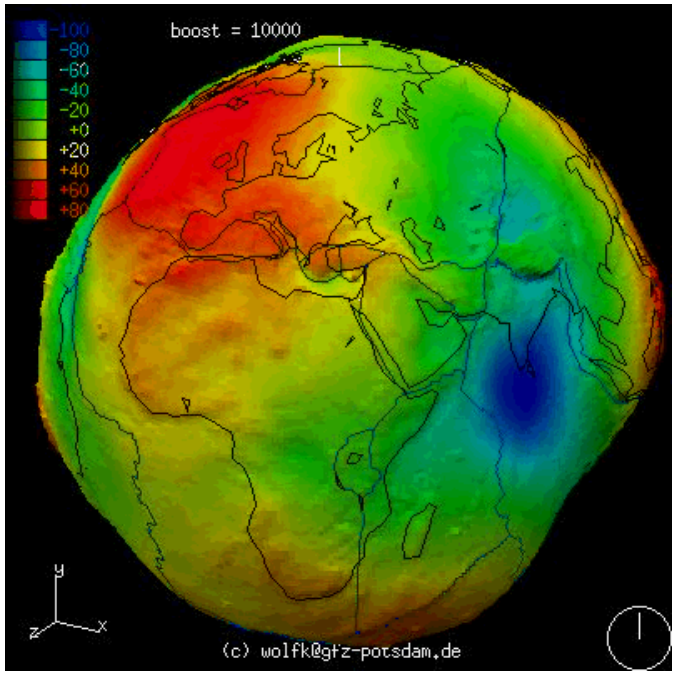


Image Credit: *NASA's Applied Remote Sensing Training Program*

The Shape of the Earth

For spatial data to be displayed in a spatially consistent way, we use an elliptical spheroid to approximate the surface of the Earth.

No spheroid is a perfect fit, so many different approximations are used.

Each approximation will fit one part of the Earth's surface better than others.

Each of these spheroids is calculated using a specific datum as a reference point.

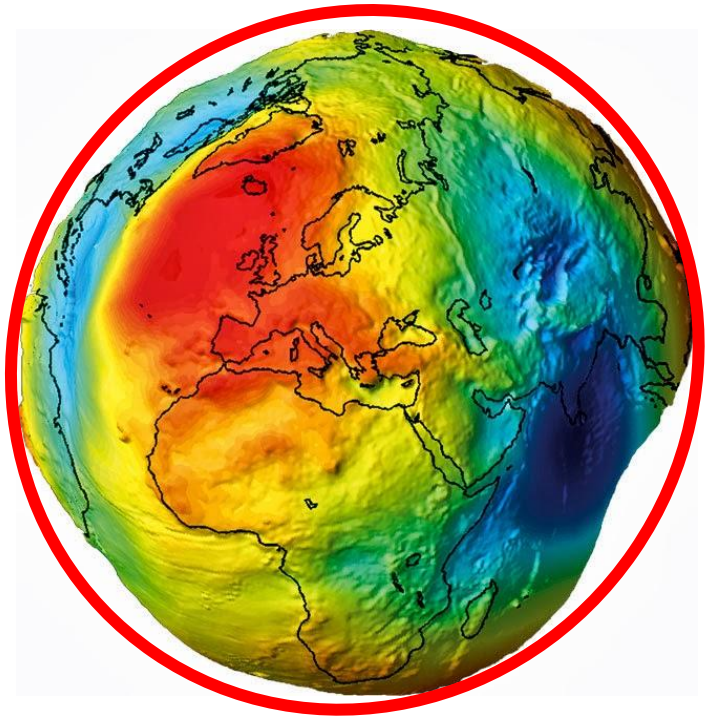


Image Credit: *NASA's Applied Remote Sensing Training Program*

Datum and Spheroid

A datum is a known point on Earth's surface or within its geometry that we can use as a reference point for all other locations.

Because of the irregular shape of the planet, the use of datums is necessary to portray spatial data as accurately as possible.

Example:

- **Local Datum** is NAD 83 (North American Datum 1983)

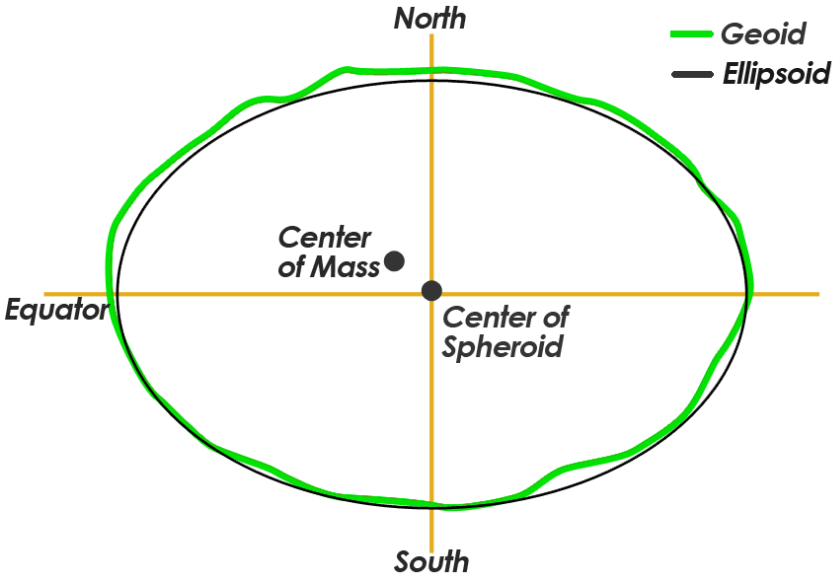
- World Geodetic System 1984 (WGS84) is a **global datum**.

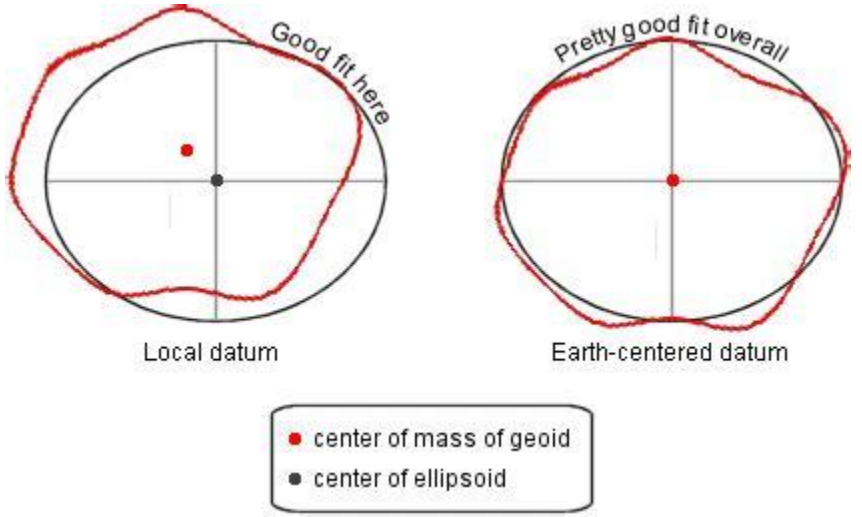
Geoid
A lumpy potato
(real Earth)

Spheroid
A smooth plastic ball.
(mathematical Earth)

Datum
Instructions for:

- how to place the ball over the potato,
- where to center it,
- how to align it.



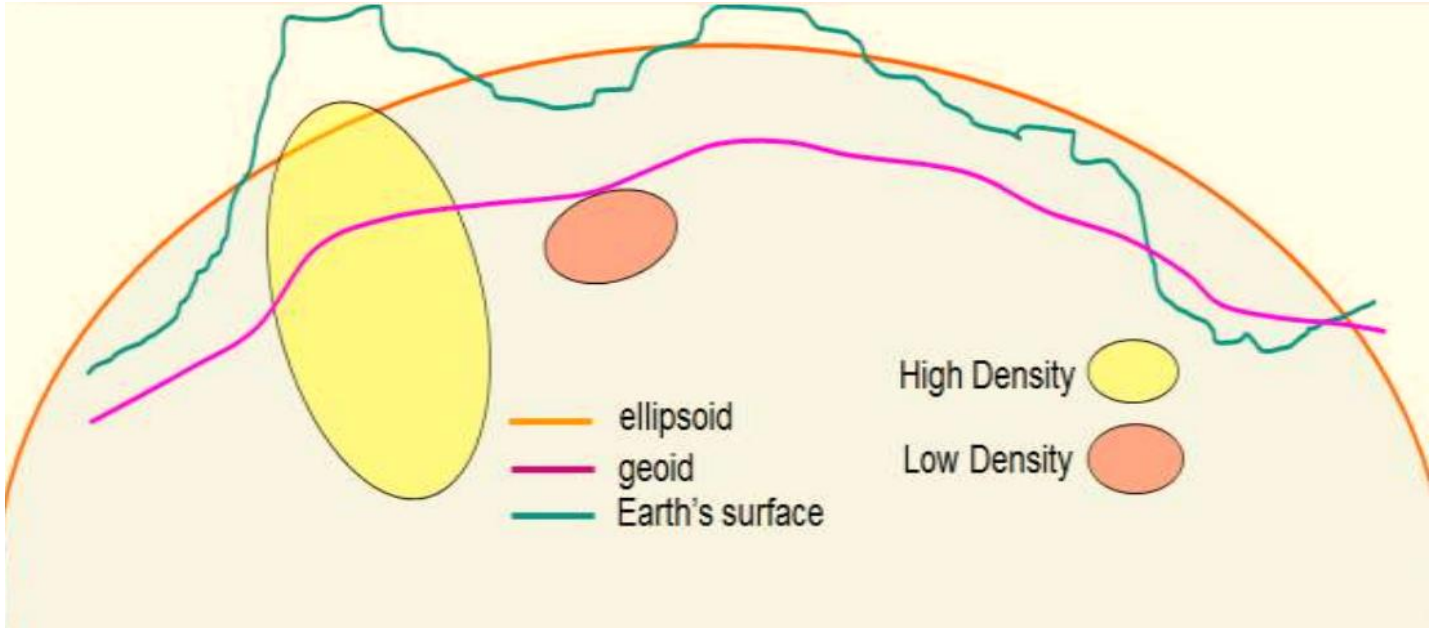


Geodetic Systems (Earth, Ellipsoid)

Reference Ellipsoids:

A Reference Ellipsoid is a mathematically-defined surface that approximates the geoid, the truer figure of the Earth. The semi-major axis, semi-minor axis of the ellipse and flattening completely specify the shape of the ellipsoid.

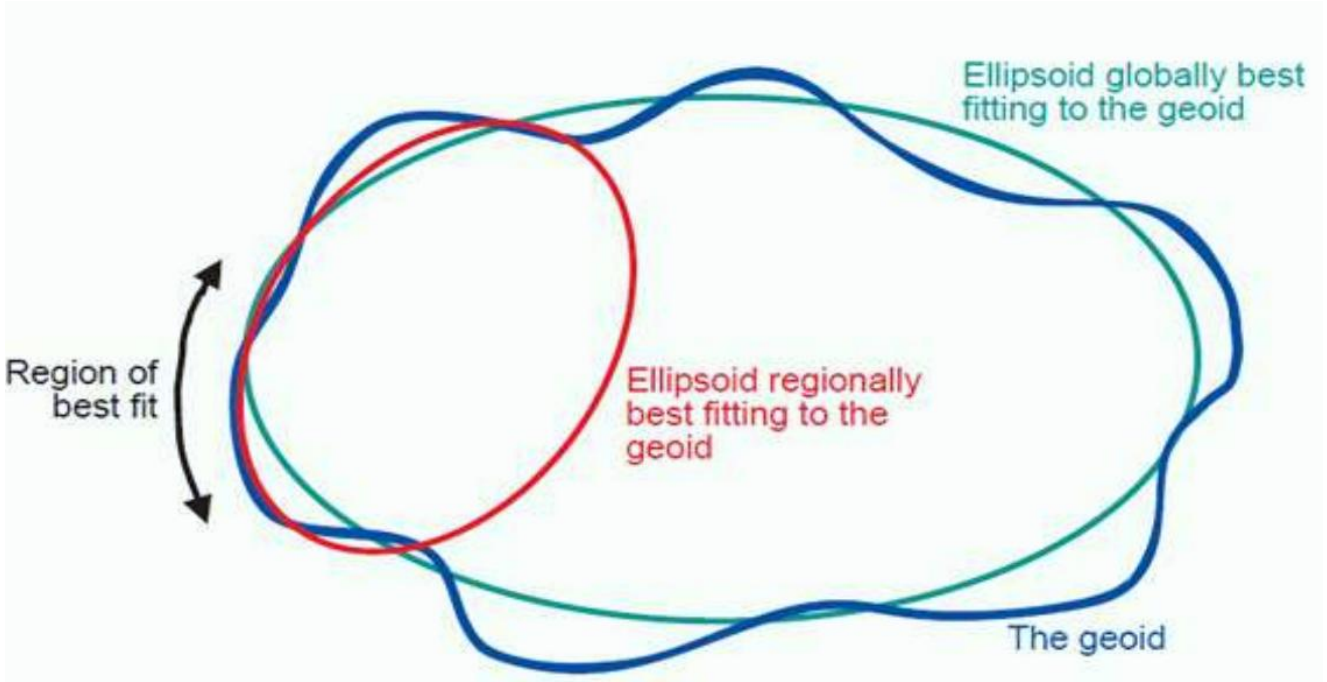
Some of the most popular reference Ellipsoids are: Clarke 1866, International 1924, and WGS 1984. Currently the most common reference ellipsoid used, and that used in the context of the Global Positioning System, is WGS 84.



Local and Global Ellipsoids

Many ellipsoids have been defined in the world. Local ellipsoids have been established to fit the Geoid (mean sea level) well over an area of local interest, which in the past was never larger than a continent.

The International Union for Geodesy and Geophysics (IUGG) plays a central role in establishing these reference figures.



Geographic referencing concepts

A GIS is to be created from available maps of different thematic layers (soils, land use, temperature, etc).

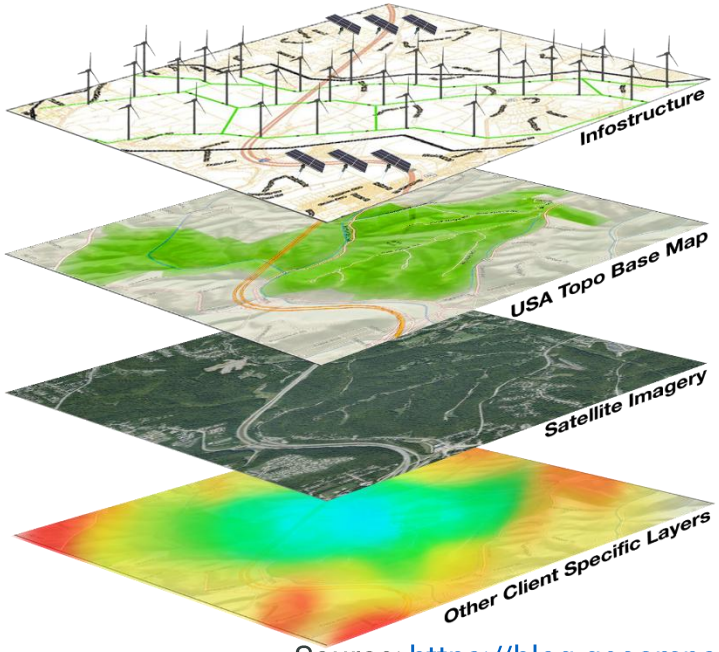
The maps are in two-dimensions whereas the earth's surface is a 3- dimensional ellipsoid. Every map has a projection and scale.

To understand how maps are created by projecting the 3-d earth's surface into a 2-d plane of an analogue map, we need to understand **the georeferencing concepts.**

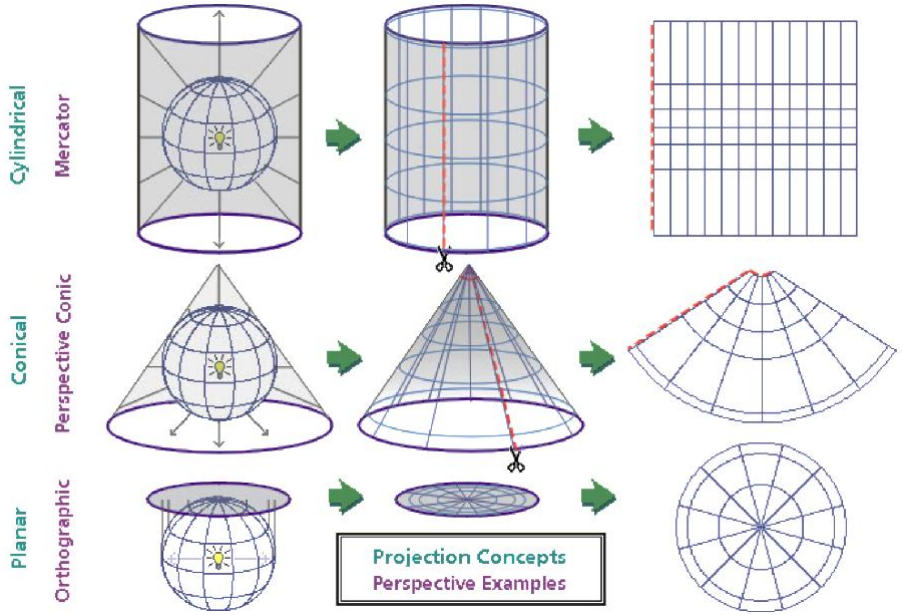
Geo-refencing involves 2 stages: specifying the 3-dimensional coordinate system that is used for locating points on the earth's surface that is,

1. the Geographic Coordinate System (GCS), and
2. the Projected Coordinate System,

that is used for projecting into two dimensions for creating analogue maps.



Source: https://blog.geoamps.com/



https://docs.qgis.org/

Coordinate Reference Systems

All spatial data, including satellite imagery, needs to be tied to a specific location on the Earth's surface through georeferencing.

To link each pixel or data point to its real-world position, we use a coordinate reference system (CRS).

A **Coordinate Reference System (CRS)** is a framework used to define the exact location of features on the Earth using coordinates, datums, and map projections.

- World Geodetic System 1984 (WGS84 – GPS and Google Maps)
- Universal Transverse Mercator (UTM – mapping and GIS analysis).

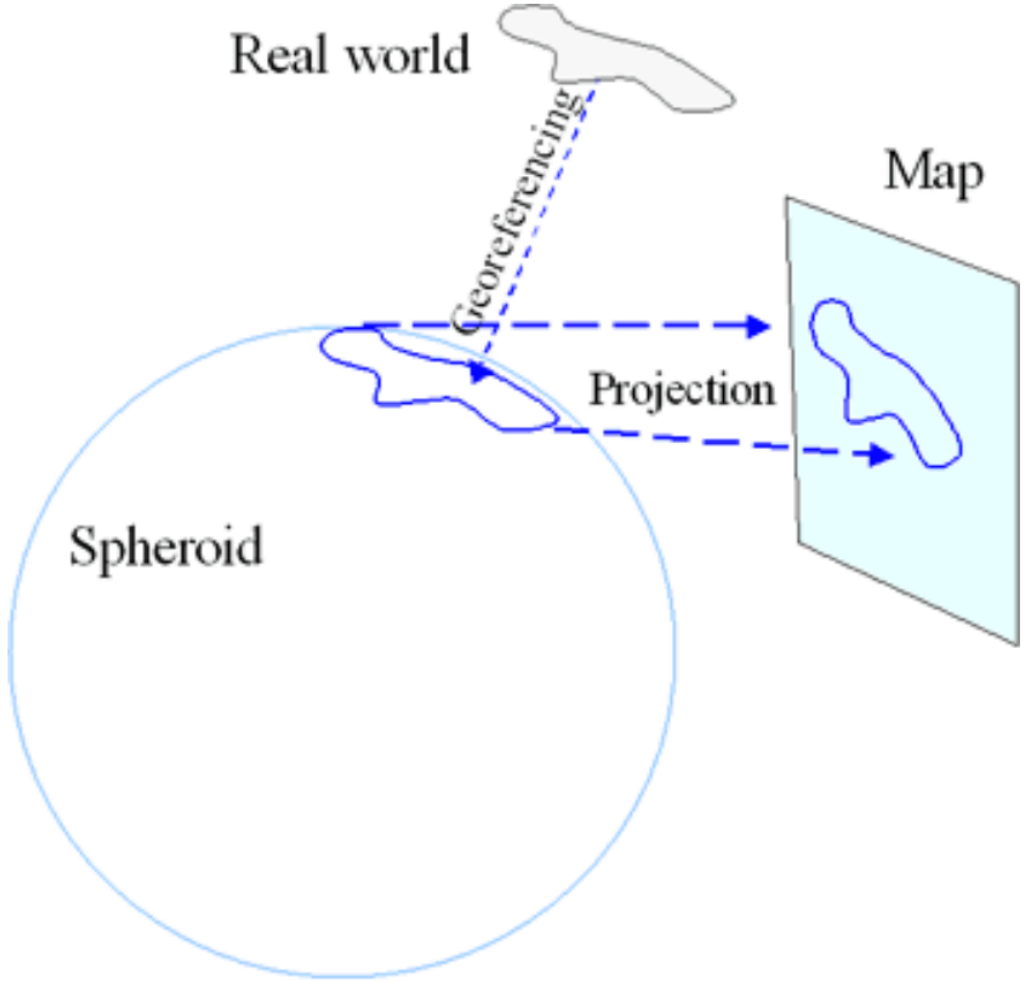
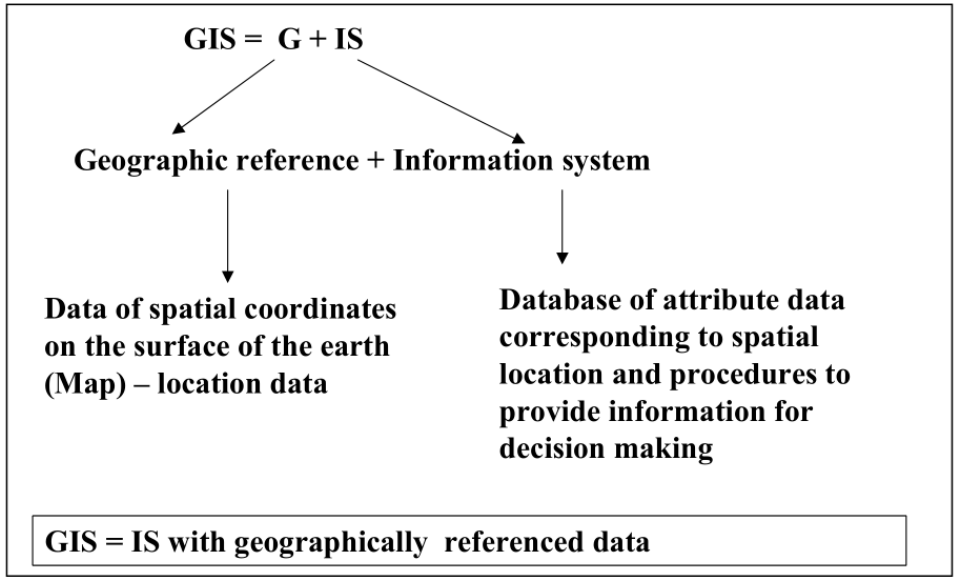


Image Credit: GIS Stack Exchange

What is GIS

A GIS is basically a computerized information system like any other database, but with an important difference: all information in GIS must be linked to a geographic (spatial) reference (latitude/longitude, or other spatial coordinates).



The United States Geological Survey (USGS) defined provided A GIS as a computer hardware and software system designed to collect, manage, analyze and display geographically (spatially) referenced data. This definition is a fairly comprehensive and is suitable for agricultural applications of GIS

World Geodetic System 1984 (WGS 84)

Datum Details	
DATUM NAME:	World Geodetic System 1984
CODE:	6326
AREA OF USE:	World
SCOPE:	Satellite navigation.
TYPE:	geodetic
REALIZATION EPOCH:	
ORIGIN:	Defined through a consistent set of station coordinates. These have changed with time: by 0.7m on 1994-06-29 (G730), a further 0.2m on 1997-01-29 (G873), 0.06m on 2002-01-20 (G1150), 0.2m on 2012-02-08 (G1674) and 0.02m on 2013-10-16 (G1762).
ELLIPSOID:	WGS 84
PRIME MERIDIAN:	Greenwich
APPLICABLE CRS-S:	The following CRS are based on this datum: [WGS 84] [WGS 84] [WGS 84]

- WGS 84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, gravity and geomagnetic fields.
- WGS 84 is the standard U.S. Department of Defence definition of a global reference system for geospatial information.

Common datum used in the GIS analysis

North American Datum 1927 (NAD27)

>> Uses the Clarke 1866 spheroid

>> Reference point is located at Meades Ranch, Kansas

>> Based on ground survey information in the 1800's

North American Datum 1983 (NAD83)

>> Uses GRS80 (Geodetic Reference System) spheroid

>> using the Earth's center as a reference point rather than the surface.

>> Based on ground surveys and satellite information

WGS 1984

>> Most recently developed datum

>> framework for measurements worldwide

>> Earth centered, or geocentric, perspective

>> US military & the GPS system uses WGS84

Types of CRS: 1. Geographic Coordinate Systems

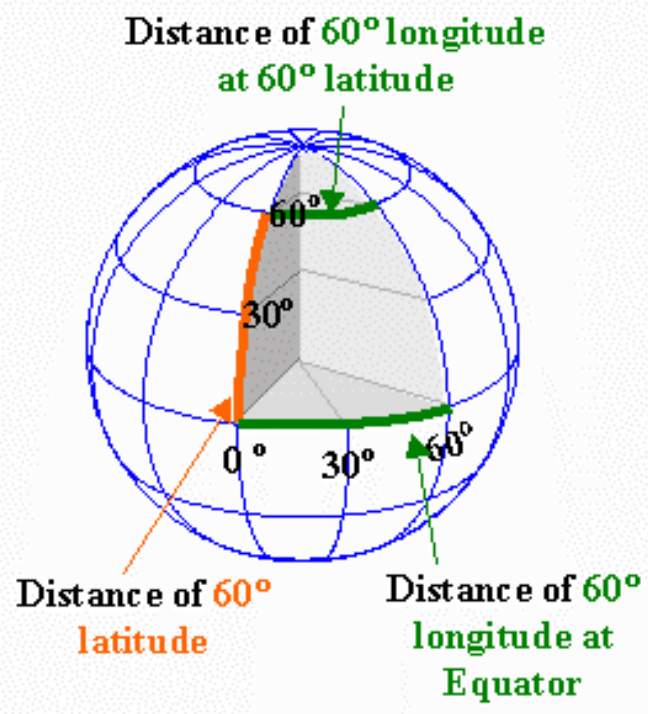
A geographic coordinate system is a coordinate system that enables every location on the Earth to be specified by a set of numbers or letters. The Prime Meridian and the Equator are the reference planes used to define latitude and longitude.

Pros:

- Suitable for global-scale analyses and Earth-wide representations.
- Appropriate for datasets with large spatial extents.

Cons:

- Lower spatial accuracy at local or regional scales.
- Not well suited for analyses involving small geographic extents.

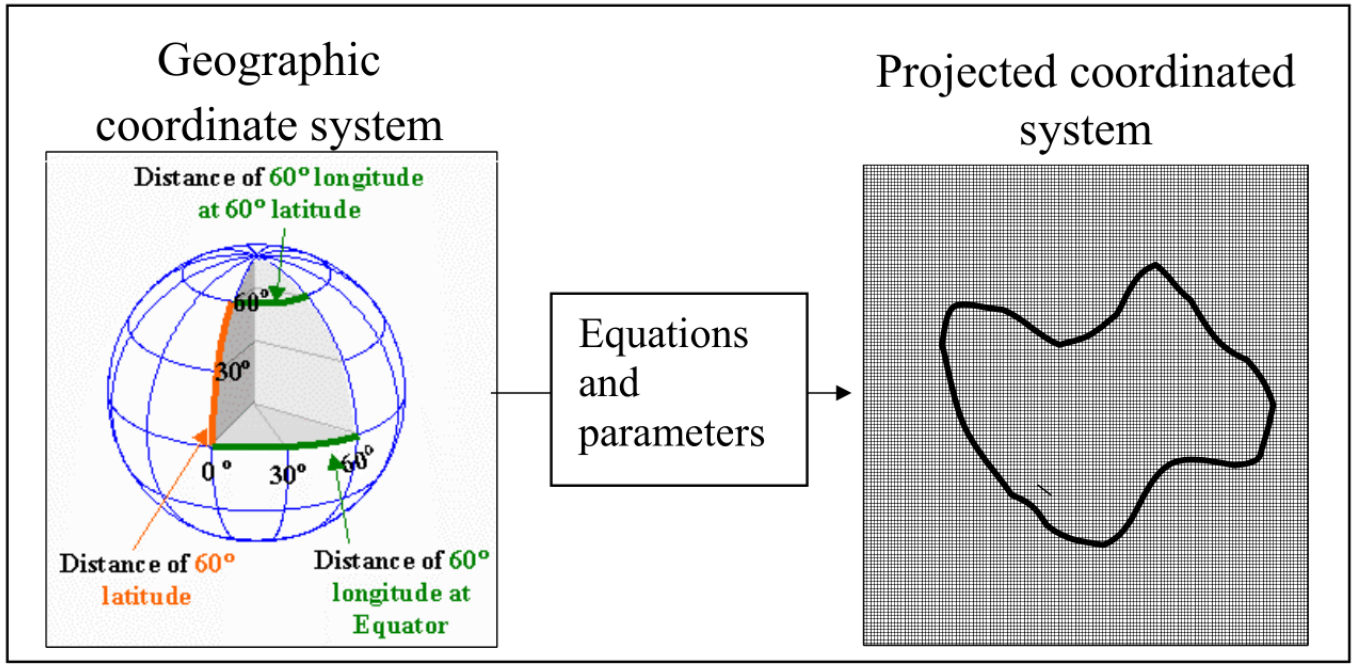


Example of a commonly-used Geographic Coordinate System: **WGS84**

Types of CRS: 2. Projected Coordinate System

GIS often begins with a paper map (an analogue map).

This map is a flat, 2D representation of the Earth's curved surface, created using a projected coordinate system.



Adopted from ESRI

Example of a commonly used Projected Coordinate System: UTM (Universal Transverse Mercator)

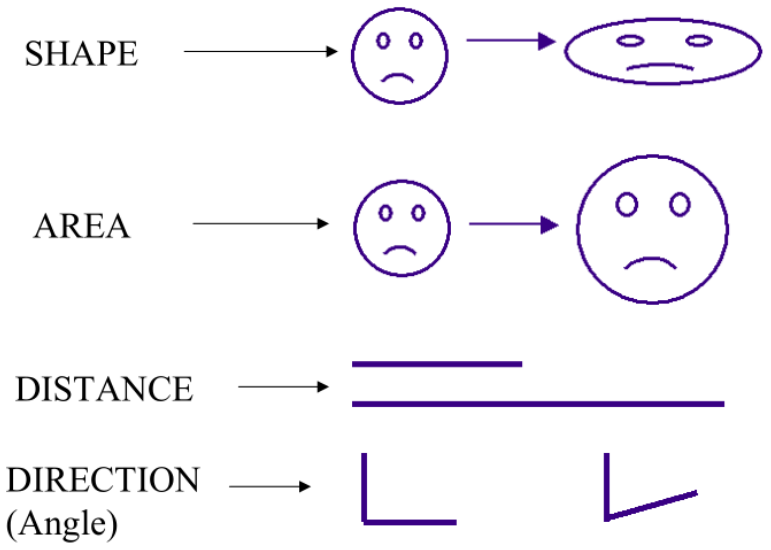
Distortions of map

Source: https://knowwhereconsulting.co.uk/

Depending on the scale and the agreeable tradeoffs with respect to distortions, a specific projection form is chosen.

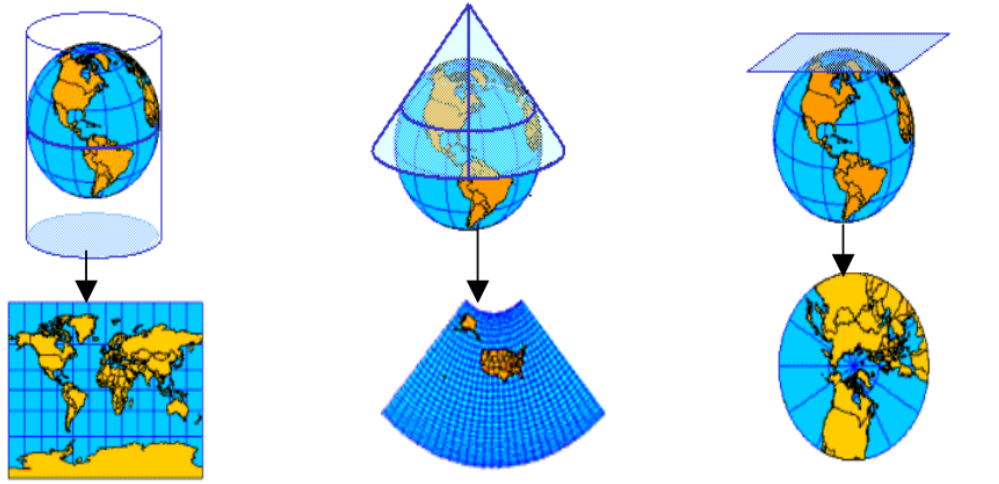
MAP PROJECTIONS LEAD TO DISTORTIONS … ..

Choice of Projections depends on allowable distortions in:



Adopted from ESRI

Types of Projections



Adopted from ESRI

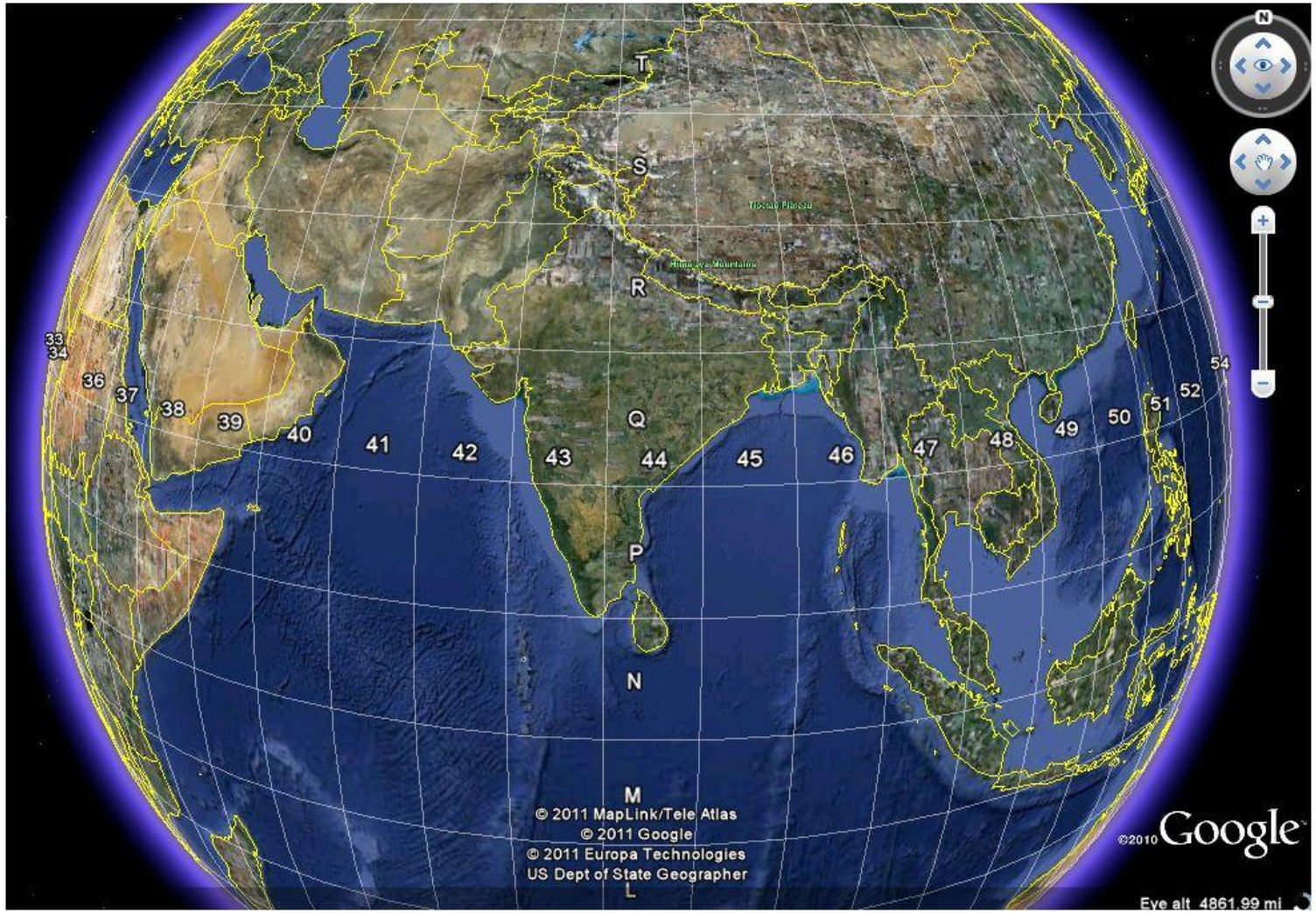
- Different countries have adopted different standard projections at different map scales.
- In India, the polyconic projection is commonly used by Survey of India (SOI).

UTM Zones for Projected CRS

UTM zones are divisions of the Earth into 60 vertical sections, each 6 degrees of longitude wide, used in the

Universal Transverse Mercator (UTM) coordinate system for mapping and navigation.

These zones help **minimize distortion in map projections**, making them useful for accurate positioning.



directionaldrilling.blogspot.com

CRS in Q-GIS

WGS 84

WKT

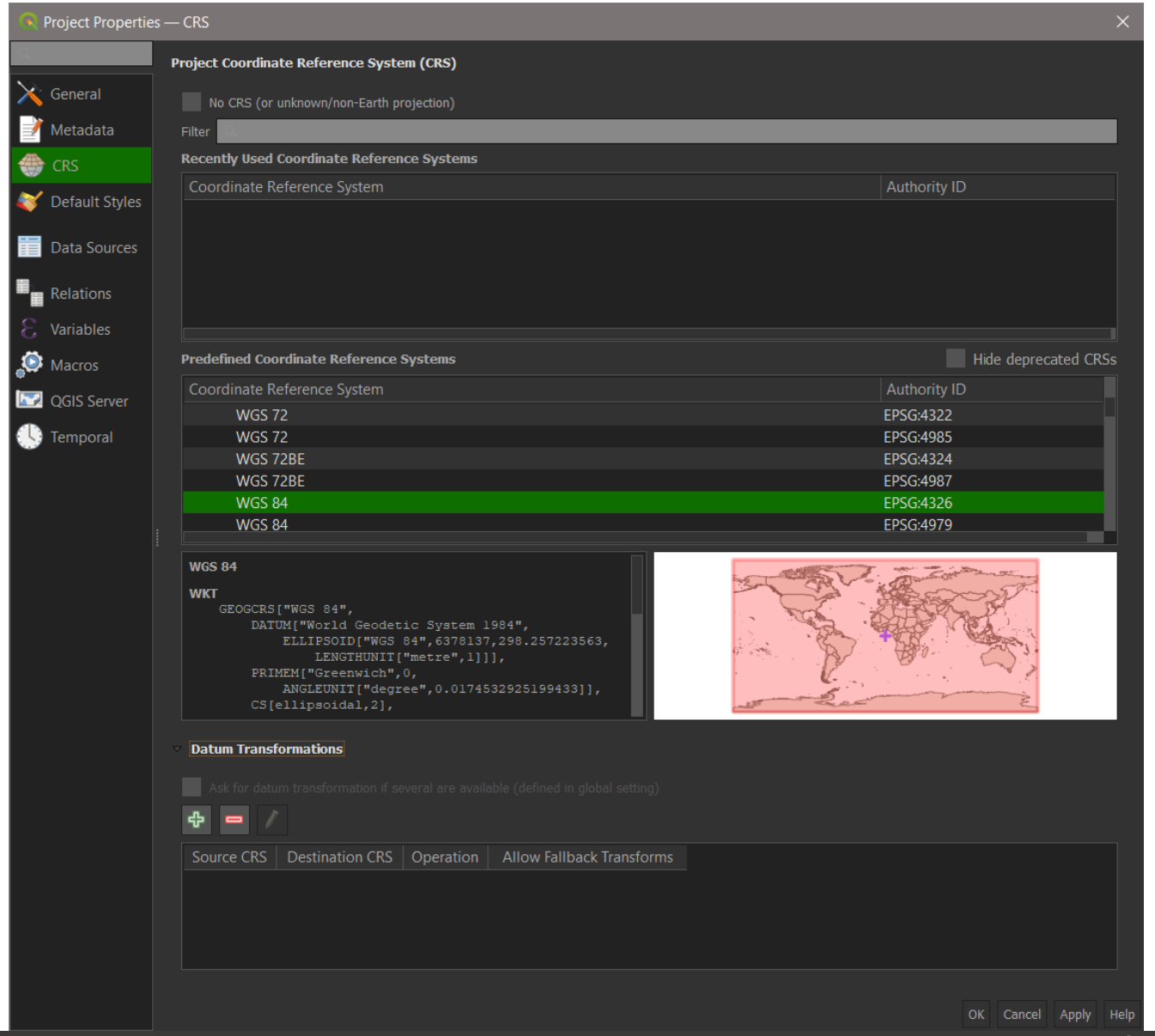
```
GEOGCRS["WGS 84",
    DATUM["World Geodetic System 1984",
        ELLIPSOID["WGS 84",6378137,298.257223563,
            LENGTHUNIT["metre",1]]],
    PRIMEM["Greenwich",0,
        ANGLEUNIT["degree",0.0174532925199433]],
    CS[ellipsoidal,2],
        AXIS["geodetic latitude (Lat)",north,
            ORDER[1],
            ANGLEUNIT["degree",0.0174532925199433]],
        AXIS["geodetic longitude (Lon)",east,
            ORDER[2],
            ANGLEUNIT["degree",0.0174532925199433]],
    USAGE[
        SCOPE["unknown"],
        AREA["World"],
        BBOX[-90,-180,90,180]],
    ID["EPSG",4326]]
```

Proj4

```
+proj=longlat +datum=WGS84 +no_defs
```

Extent

```
-180.00, -90.00, 180.00, 90.00
```



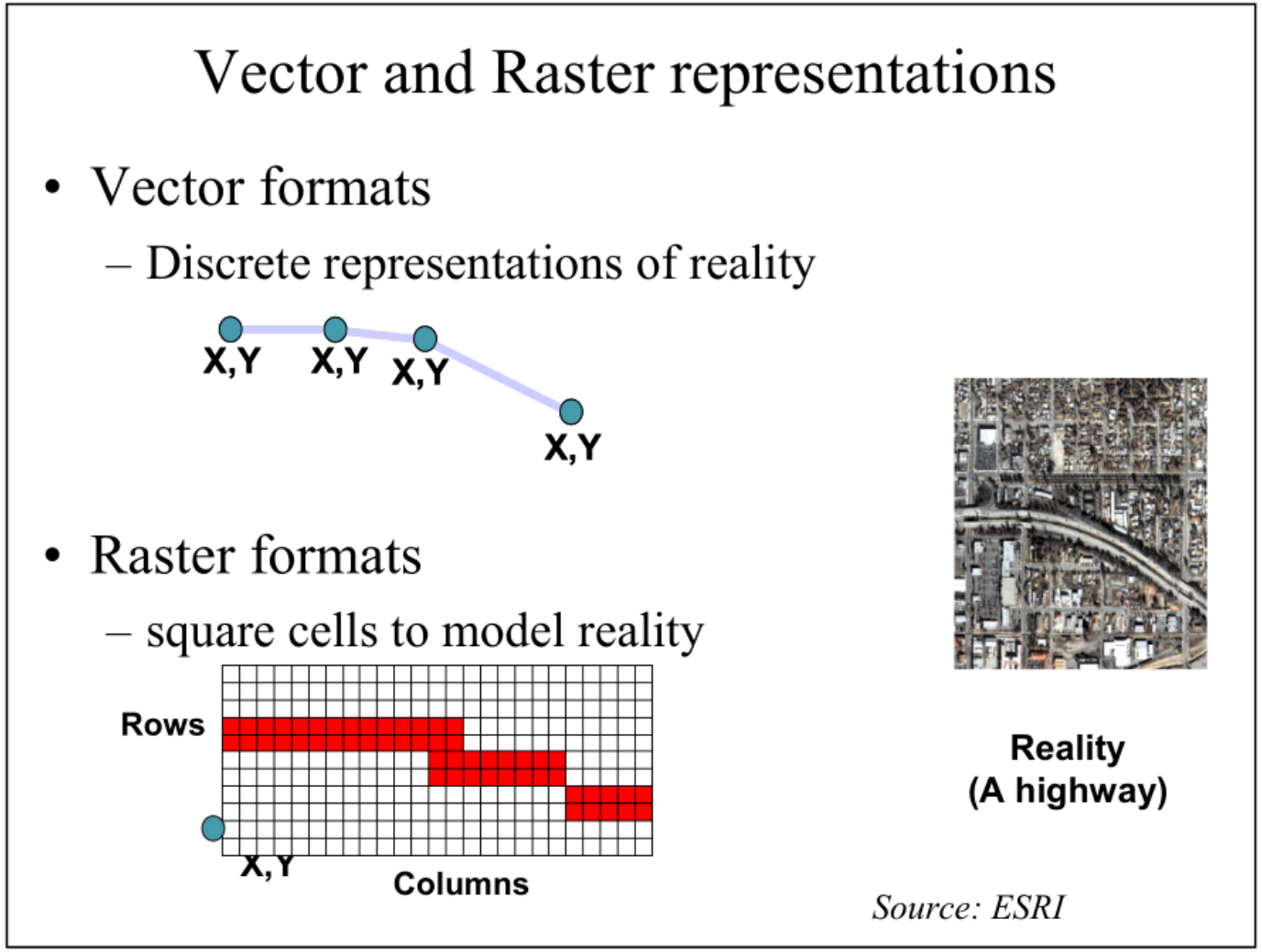
GIS Data Input

Spatial Data capture (representing locations in a database) can be in two basic formats:

(i) Vector format: the reality is represented as points lines and areas

(ii) Raster format: the reality is represented as grid of cells/pixels.

The Vector format is based on discrete objects view of reality (analogue maps) and the raster format is based on continuous fields view of reality (photographs, imageries, etc. In principle, any real world situation can be represented in digital form in both raster and vector formats.



Vector data

This is generally used for capturing data for analogue maps. It is based on the observation that any map consists of 3 basic kinds of features:

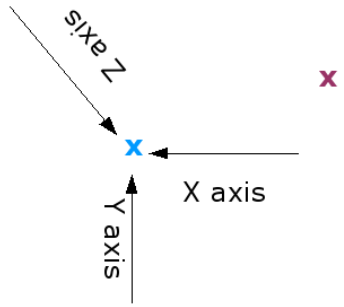
i. **point features,**

ii. **line features and**

iii. **polygon or area features.**

Vector Point Feature

Point Geometry (indicates the x,y and z position of the feature)

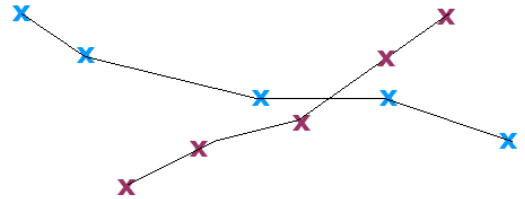


Point attributes (describe the feature)

Id, Name, Description
1, Tree, Outside our classroom 2, Light post, At the school entrance

Vector Polyline Feature

Polyline Geometry (a series of connected vertices that do not form an enclosed shape)

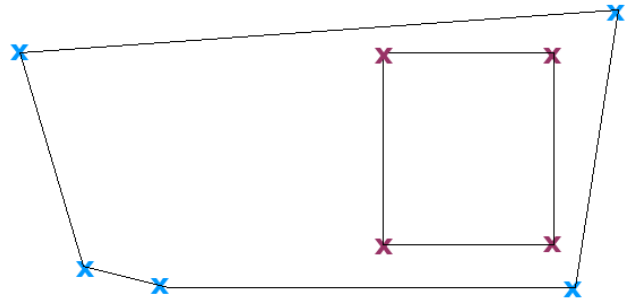


Polyline attributes (describe the feature)

Id, Name, Description
1, Footpath 1, From class to the playground 2, Footpath 2, From the school gate to the hall

Vector Polygon Feature

Polygon Geometry (a series of connected vertices that do form an enclosed shape)



Polygon attributes (describe the feature)

Id, Name, Description
1, School Boundary, Fenceline for the school 2, Sports Field, We play soccer here

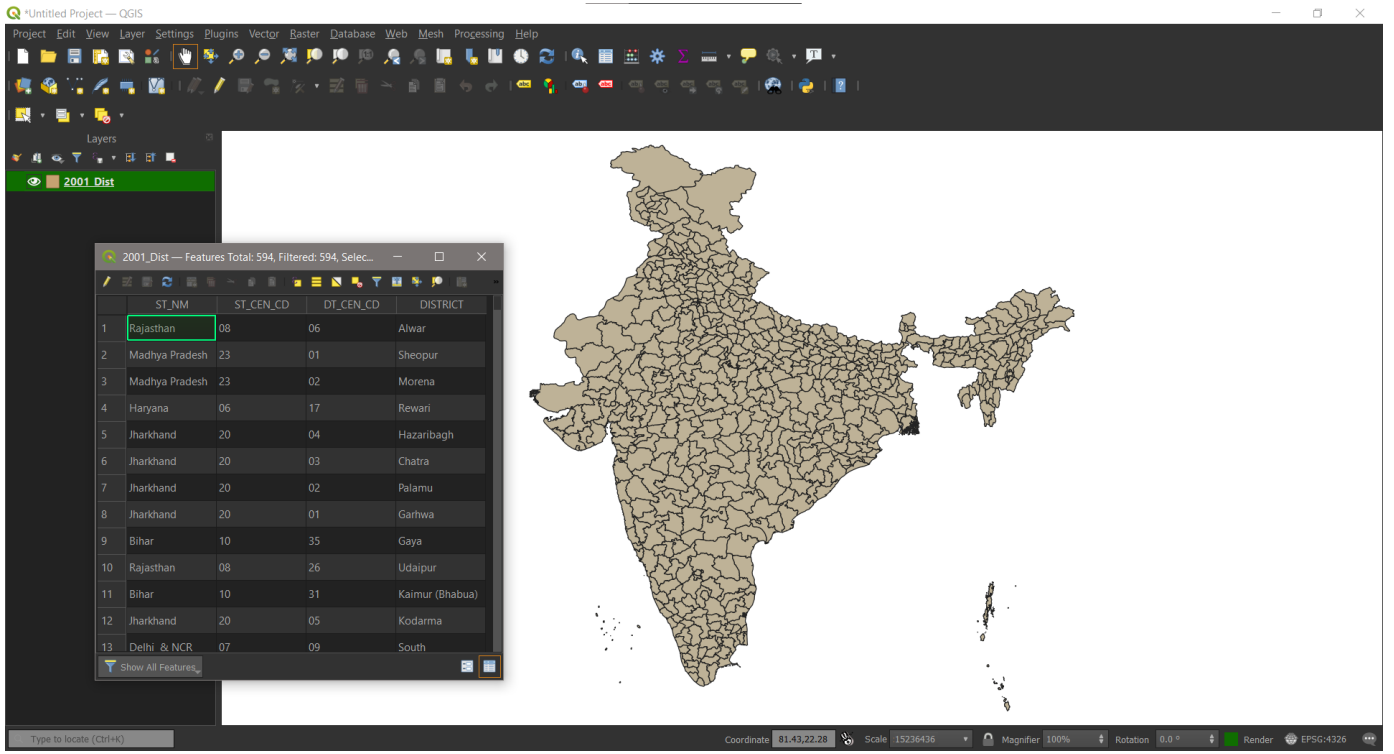
What are the shapefile files?

Main File (.SHP): is a *mandatory* Esri file that gives features their geometry.

Index File (.SHX): are *mandatory* Esri and AutoCAD shape index position.

dBASE File (.DBF): is a standard database file used to store attribute data and object IDs. A .dbf file is *mandatory* for shape files. You can open .dbf files in Microsoft Access or Excel.

Projection File (.PRJ): is an *optional* file that contains the metadata associated with the shapefiles coordinate and projection system.



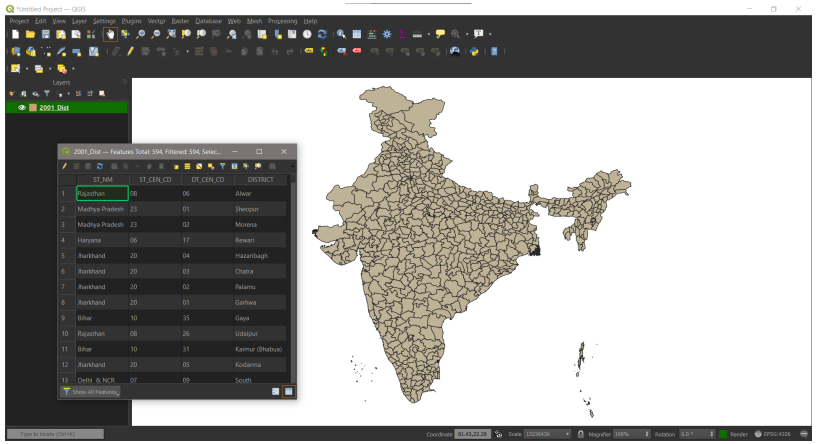
Name	Date modified	Type	Size
IndiaBoundary.cpg	01-10-2020 12:08	CPG File	1 KB
IndiaBoundary.dbf	01-10-2020 12:08	DBF File	13 KB
IndiaBoundary.prj	01-10-2020 12:08	PRJ File	1 KB
IndiaBoundary.sbn	01-10-2020 12:08	SBN File	3 KB
IndiaBoundary.sbx	01-10-2020 12:08	SBX File	1 KB
IndiaBoundary.shp	01-10-2020 12:08	SHP File	6,810 KB
IndiaBoundary.shp.xml	01-10-2020 12:08	XML Document	1 KB
IndiaBoundary.shx	01-10-2020 12:08	SHX File	3 KB

Source: https://gisgeography.com/arcgis-shapefile-files-types-extensions/

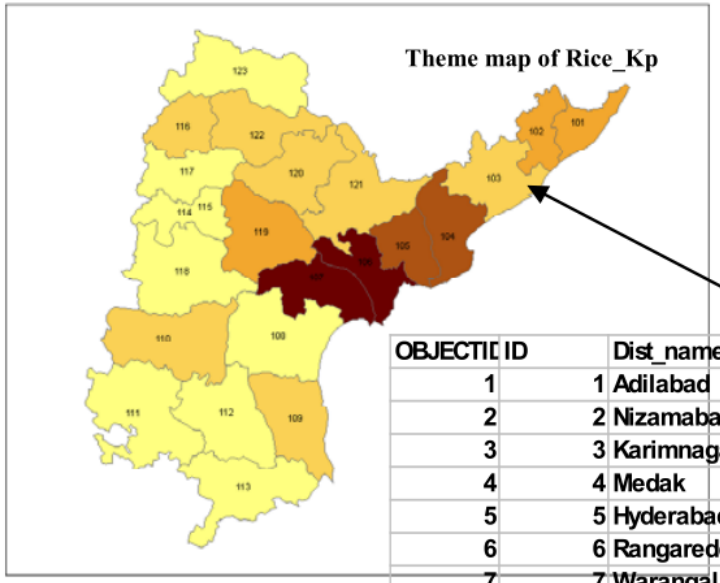
Attribute data – attribute table

Attribute data are descriptive data of point, line and area features.

For points, this may be the name of the location, its elevation, etc. For lines attribute data could be the name of a road etc.



LINKING SPATIAL AND ATTRIBUTE DATA



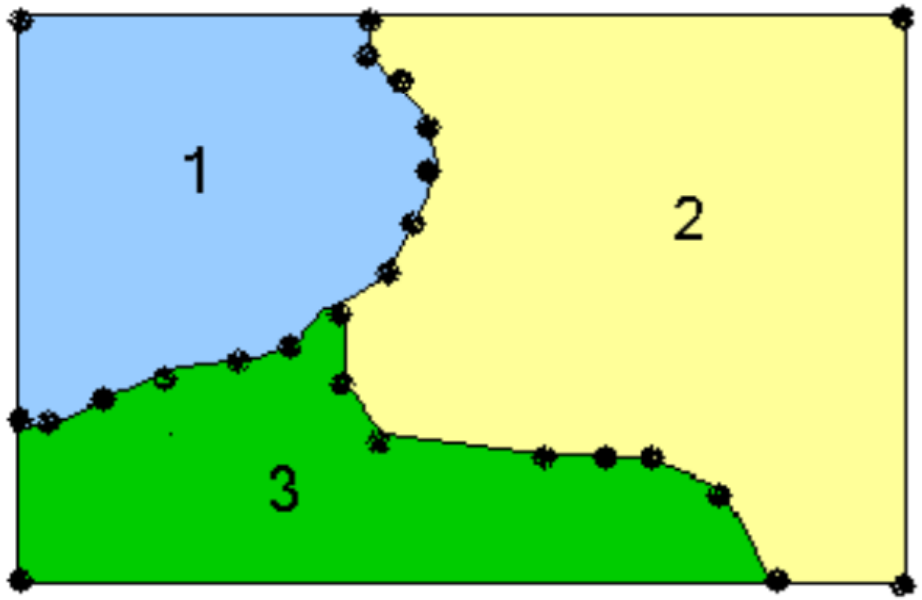
Attribute table of Dist

OBJECTID	ID	Dist_name	Dist_ID	Geometry	Shape_Len	Shape_Area
1	1	Adilabad	123	1Bo	753337	16838673859.80
2	2	Nizamabad	116	1BoG(	430537	7655003826.81
3	3	Karimnagar	122	1BoG	662231	11771979304.40
4	4	Medak	117	1BoG(	573986	9510748717.53
5	5	Hyderabad	115	1BoG\	53851	203218046.01
6	6	Rangareddy	114	1BoG(	587854	7813591915.82
7	7	Warangal	120	1BoG	674389	12701135906.20

Rice_1995 table

OBJECTID	DISTID	DISTNAME	NO_	YEAR_1995	RICEKA	RICEKP	RICERA	RICERP
23	123	Adilabad	113	1995	63	64	7	19
16	116	Nizamabad	78	1995	102	206	34	84
22	122	Karimnagar	108	1995	104	260	88	252
17	117	Medak	83	1995	64	111	41	78
15	115	Hyderabad	73	1995	1	1	1	1
14	114	Rangareddi	68	1995	22	47	18	35

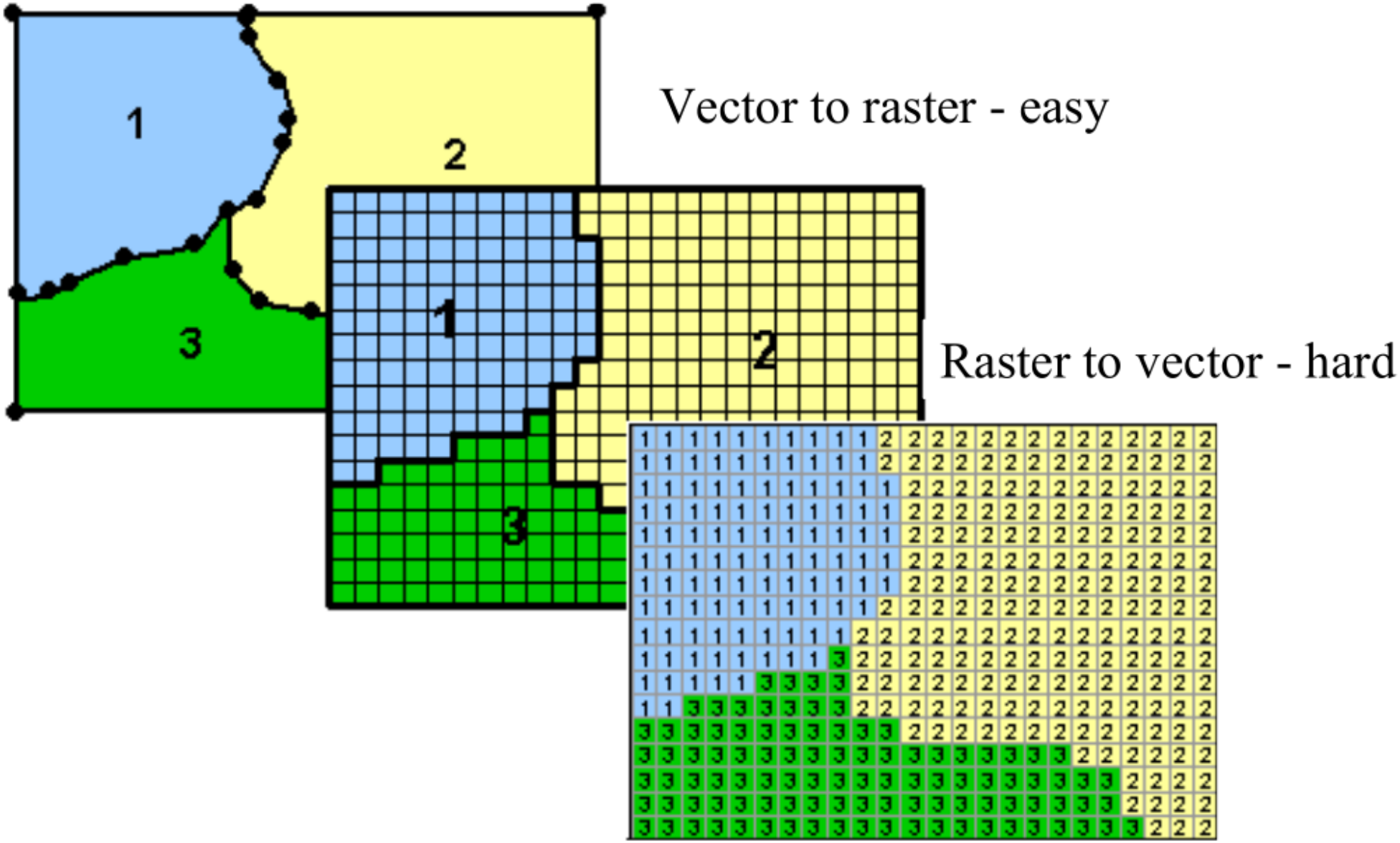
Spatial data Generation in Vector Format



Adopted from FAO

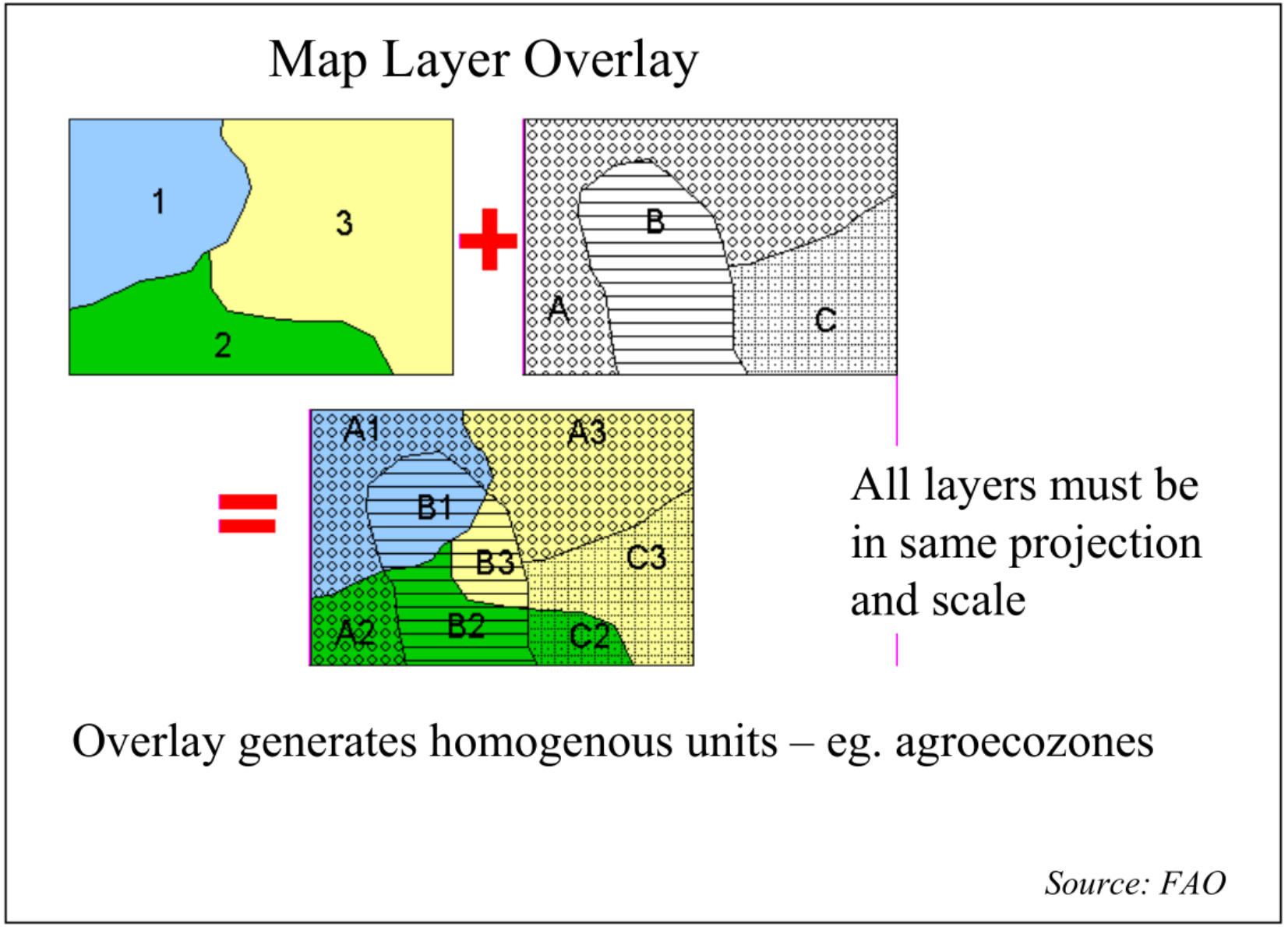
- Discretize lines into points (nodes) and digitize as straight-line segments called vectors or arcs.
- Data of X,Y coordinates of points and vectors and their connections (topology) are generated and stored in a database for areas, geometry (area, perimeter) data are generated
- points, lines and areas have independent database tables
- add attribute data to database

Most GIS software permit Raster-Vector format conversions:

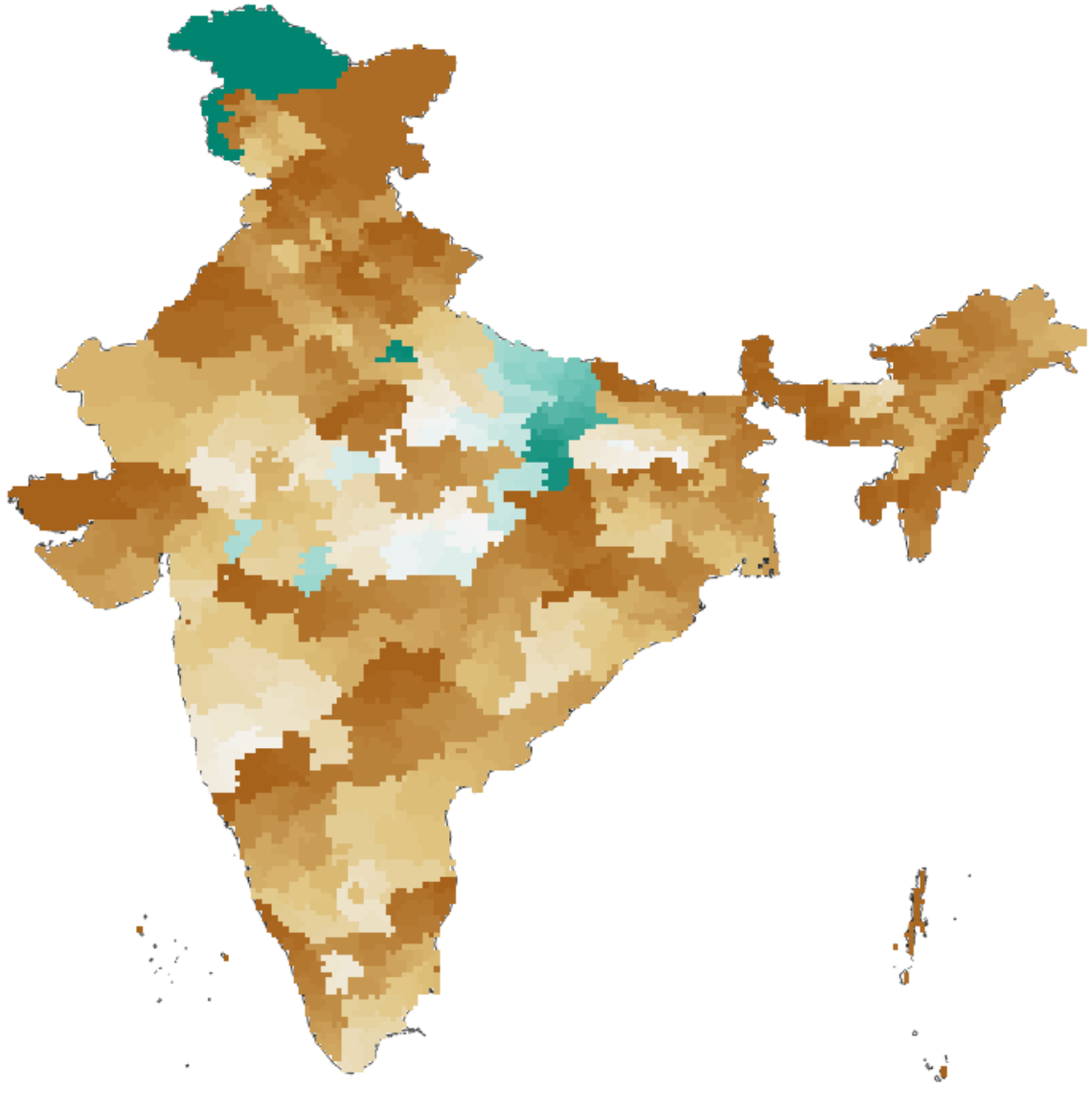


Geographic Analysis

Overlays of thematic maps,
Creation of buffers,
Calculations of lengths and areas.



Geographic Analysis

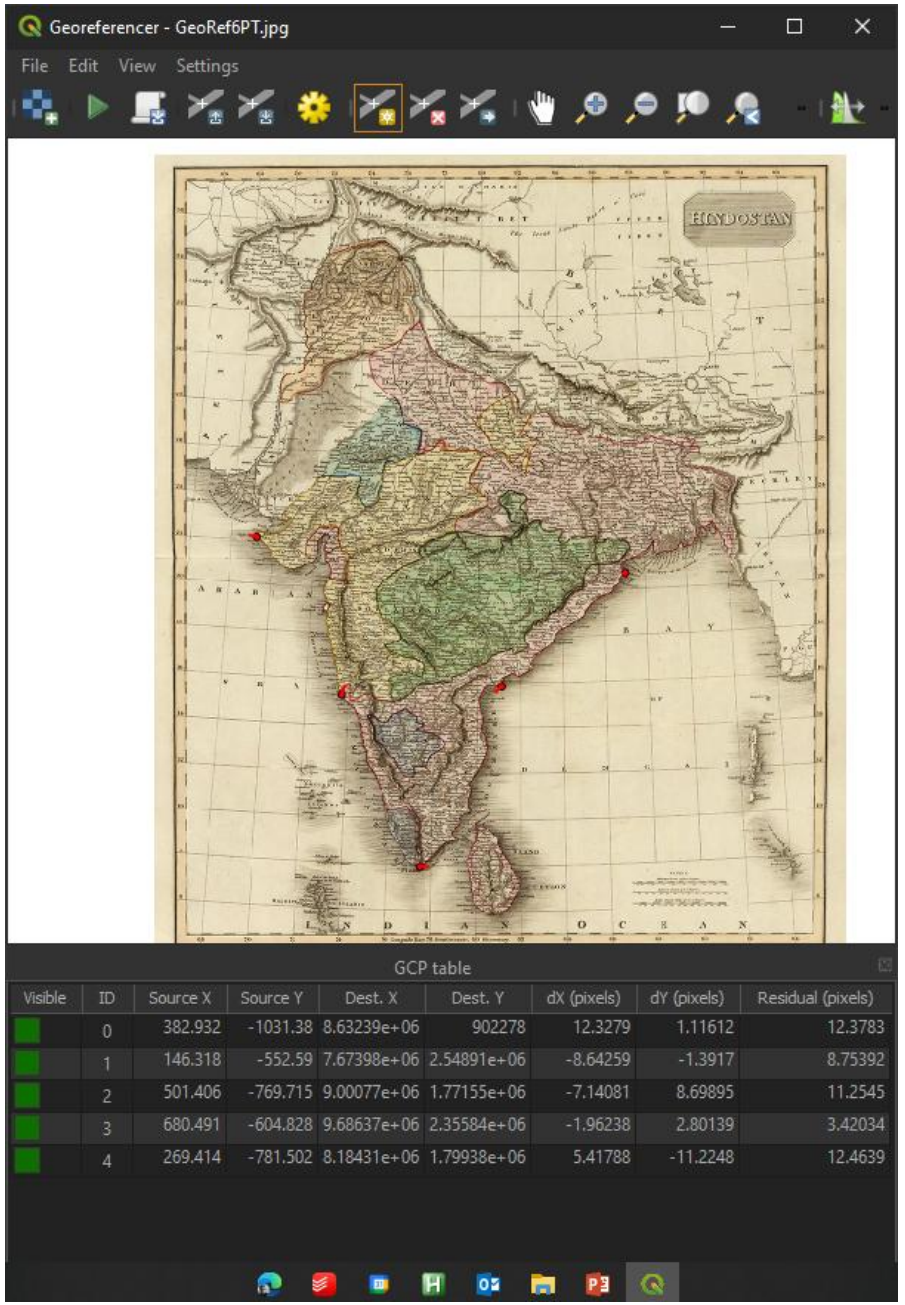


Georeferencing

- Georeferencing means that the internal coordinate system of a map or aerial photo image can be related to a geographic coordinate system.

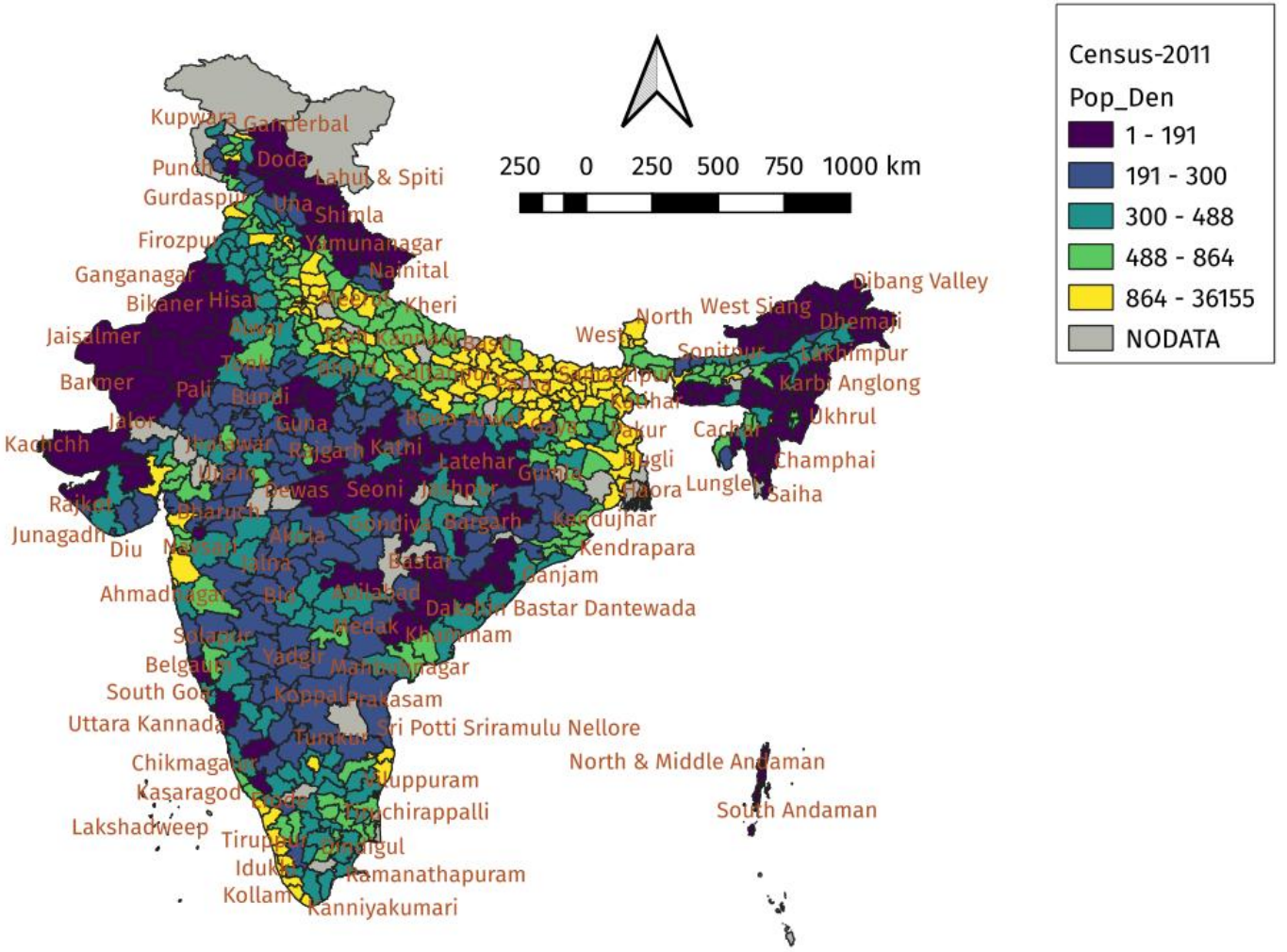
- Georeferencing means to associate a digital image file with locations in physical space.

- The relevant coordinate transforms are typically stored within the image file (GeoPDF and GeoTIFF are examples)

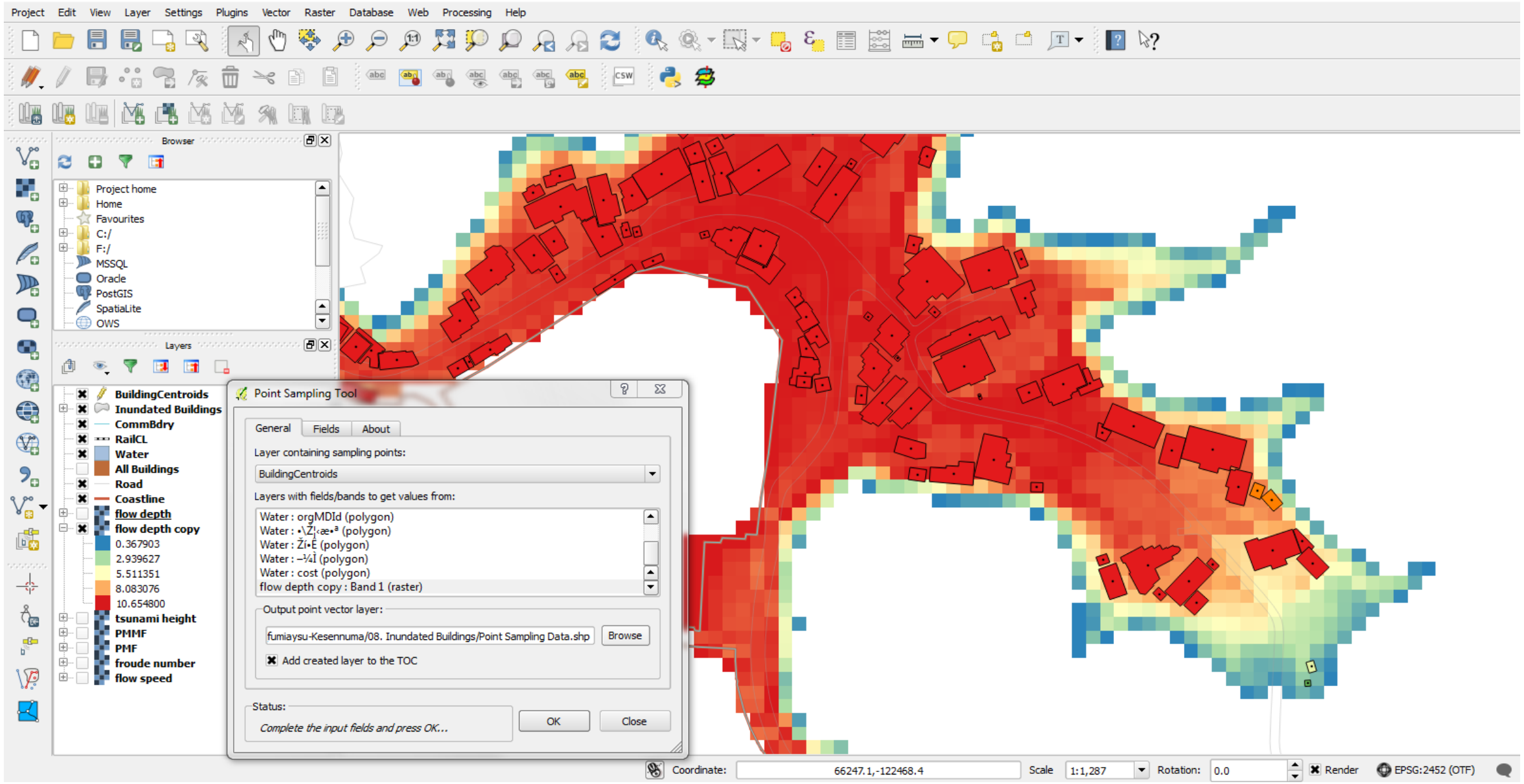


Visible	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)	Residual (pixels)
	0	382.932	-1031.38	8.63239e+06	902278	12.3279	1.11612	12.3783
	1	146.318	-552.59	7.67398e+06	2.54891e+06	-8.64259	-1.3917	8.75392
	2	501.406	-769.715	9.00077e+06	1.77155e+06	-7.14081	8.69895	11.2545
	3	680.491	-604.828	9.68637e+06	2.35584e+06	-1.96238	2.80139	3.42034
	4	269.414	-781.502	8.18431e+06	1.79938e+06	5.41788	-11.2248	12.4639

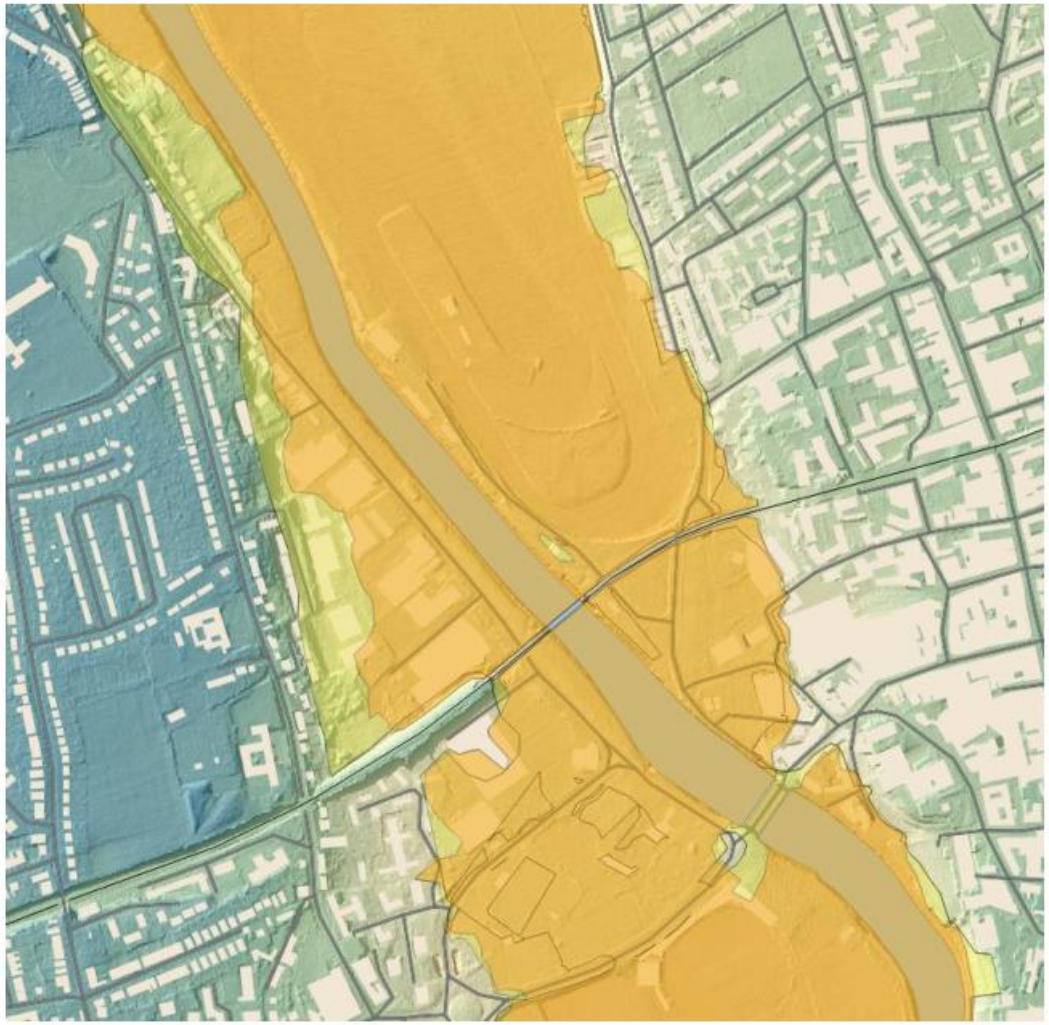
Field calculator and Map making



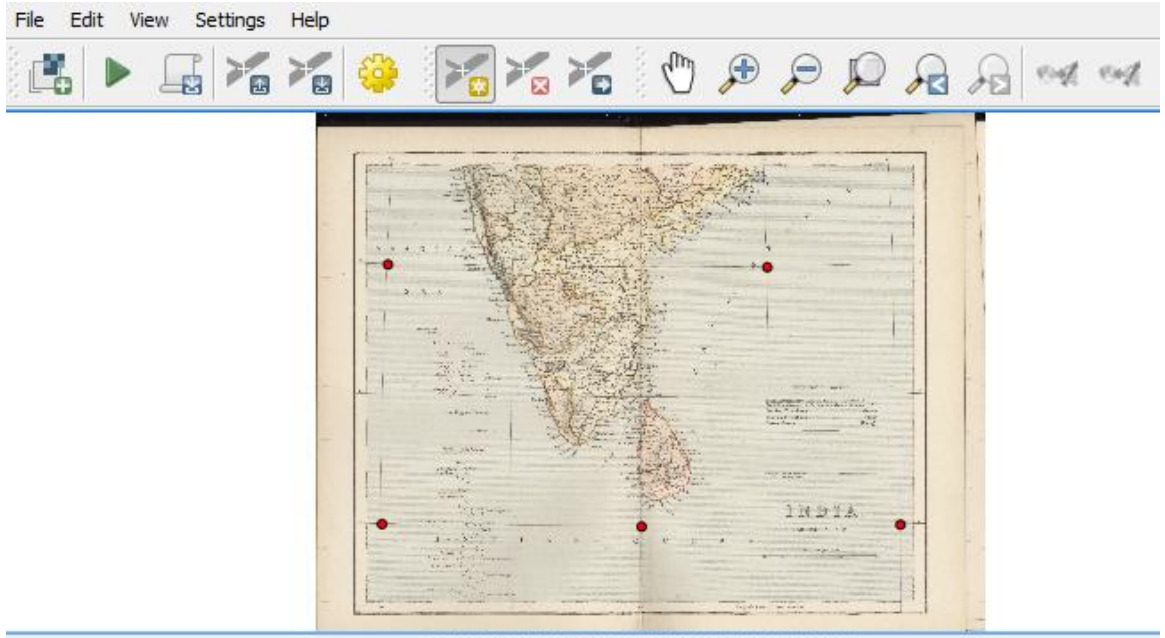
Flood evacuation zone analysis



QGIS Flood Risk Mapping Walkthrough

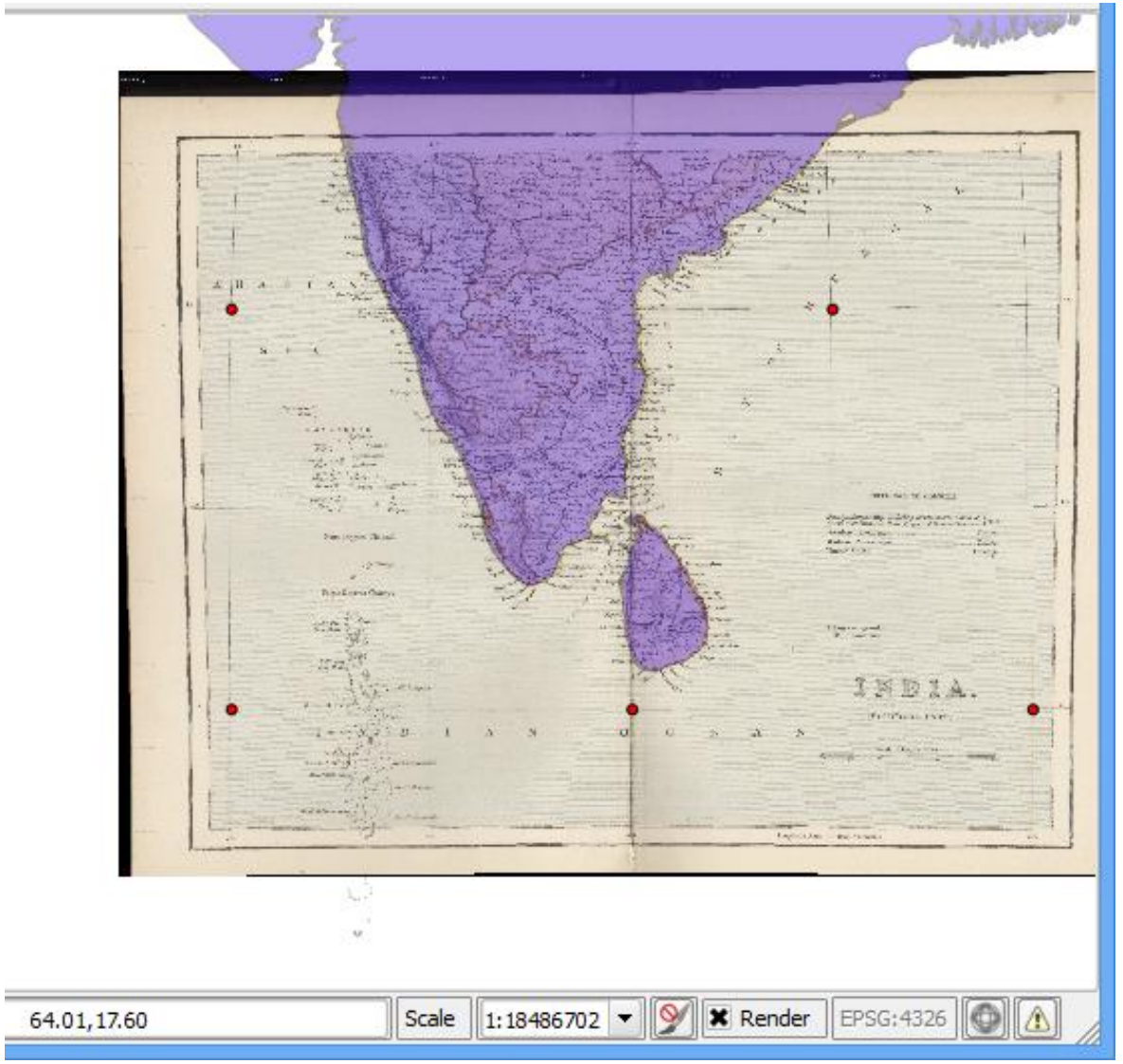


Georeferencing raster in QGIS



GCP table

on/off	id	srcX	srcY	dstX	dstY	dX[pixels]	dY[pixels]	residual[pixels]
✖	0	416.76	-895.21	70.00	15.00	0.00	0.00	0.00
✖	1	2664.84	-910.74	85.00	15.00	0.00	0.00	0.00
✖	2	381.64	-2431.93	70.00	5.00	0.00	0.00	0.00
✖	3	3454.12	-2435.80	90.00	5.00	0.00	0.00	0.00
✖	4	1919.70	-2446.69	80.00	5.00	0.00	0.00	0.00



QGIS: A Free and Open-Source Geographic Information System

QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, printing, and analysis of geospatial data.

- Hydrological Modeling
- Spatial Analysis of Water Features
- Water Quality Monitoring
- Drought Analysis

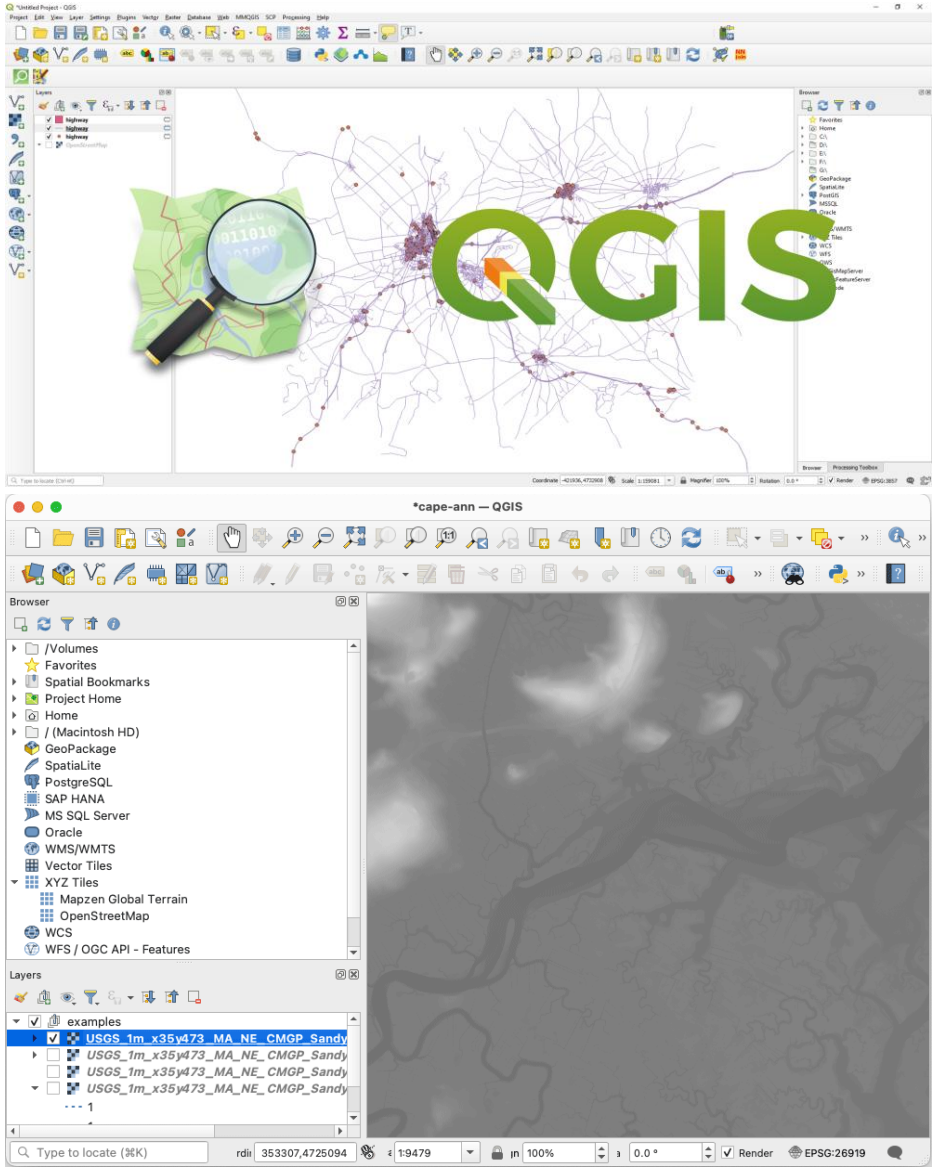
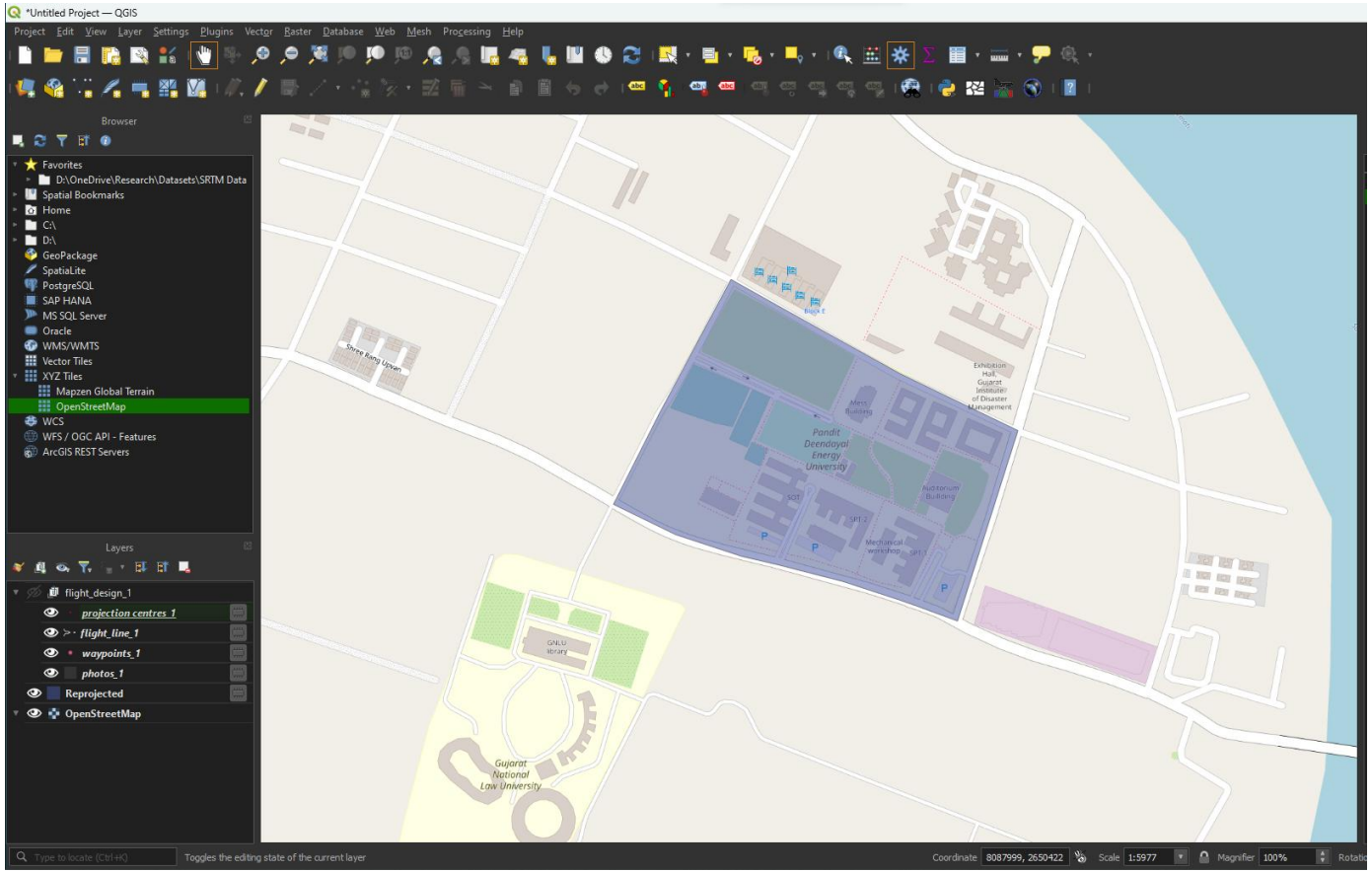


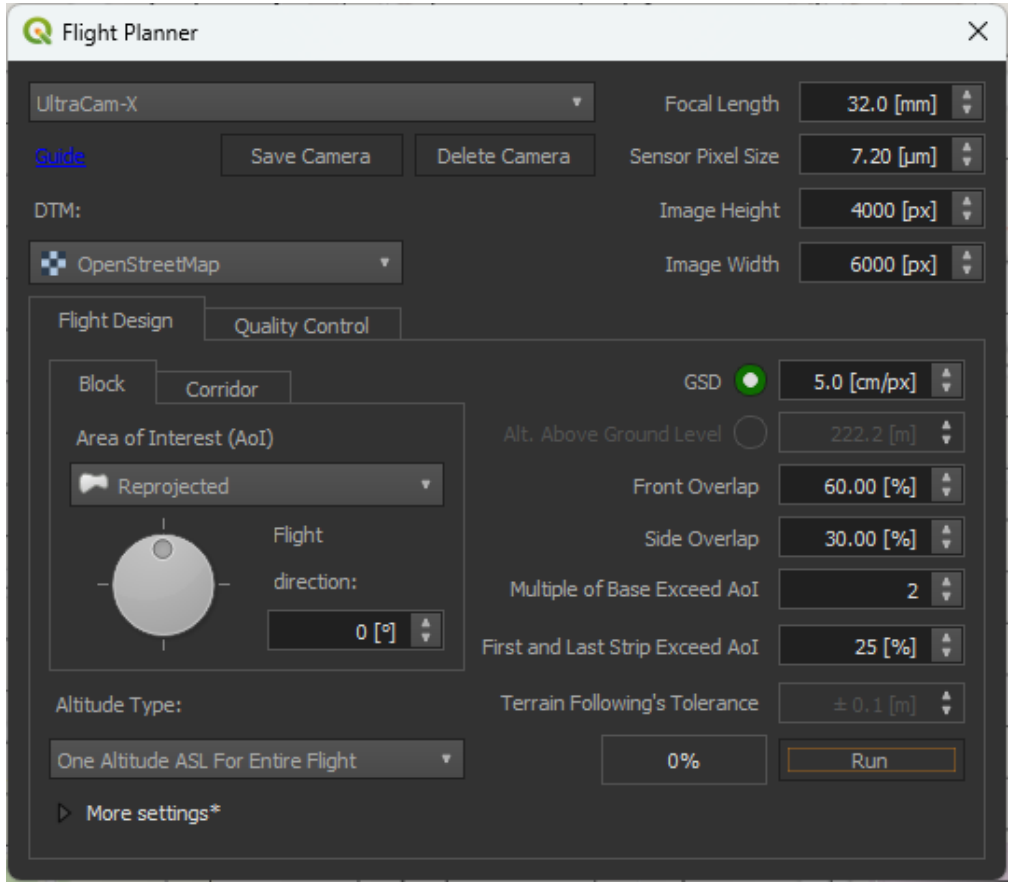
Image Source: https://www.osgeo.org/

QGIS for flight planning

[v3.3 (Detailed) · QGroundControl User Guide]

[Guide · JMG30/flight_planner Wiki · GitHub]





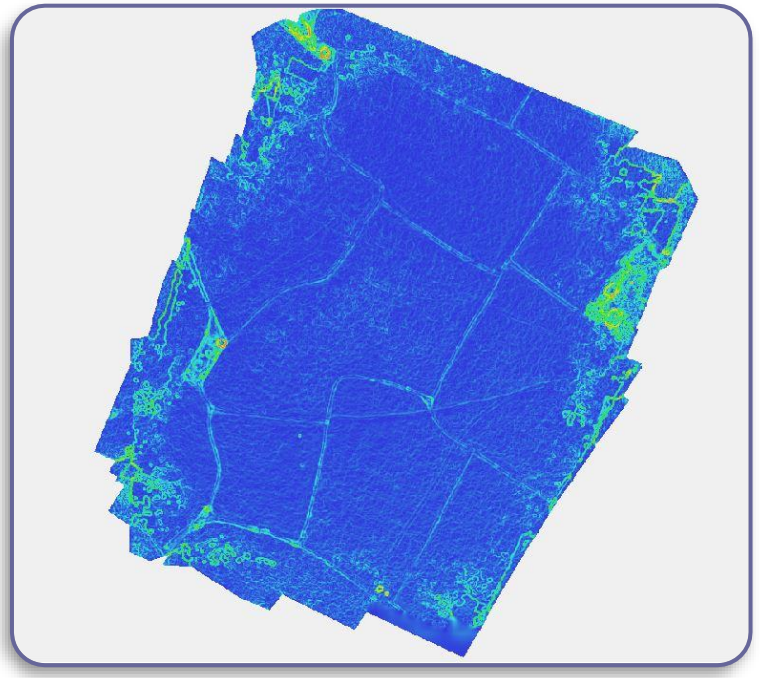
Post processed data with Emlid Studio, Agisoft Metashape, and Pix4D

Emlid Studio is a cross-platform desktop application designed specifically for Georeferencing[1] the images (from Main sensor)[2]

Pix4D to generates 3D spatial data, Ortho-mosaic, and DEM.

Ortho-mosaic

Digital elevation model



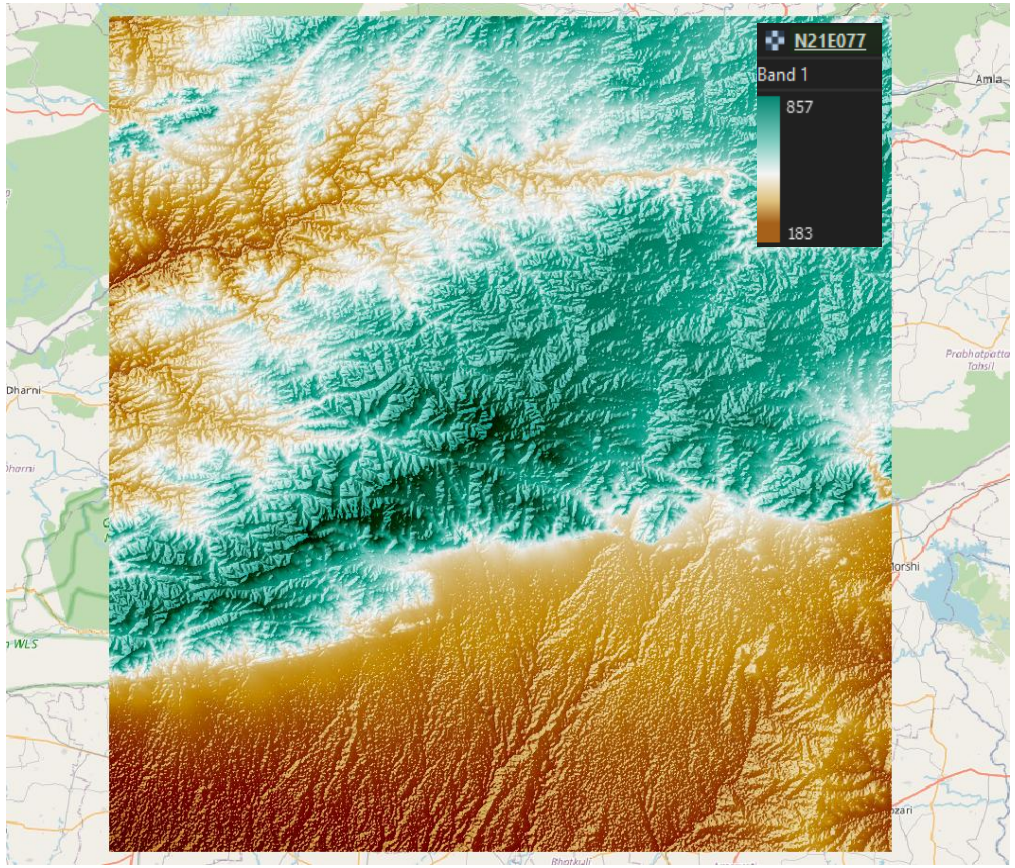
1: Georeferencing or georegistration is a type of coordinate transformation that binds a digital raster image or vector database that represents a geographic space to a spatial reference system
2: https://docs.emlid.com/emlid-studio/

A Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) is a representation of **the bare ground (bare earth) topographic surface** of the earth

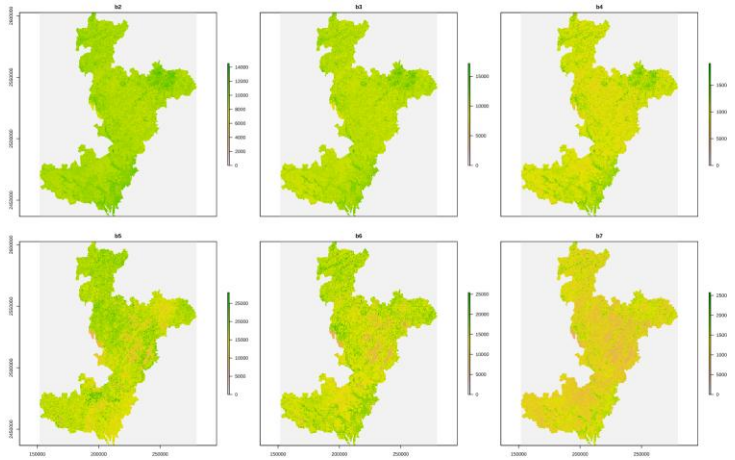
The built (power lines, buildings, and towers) and natural (trees and other types of vegetation) aren't included in a DEM.

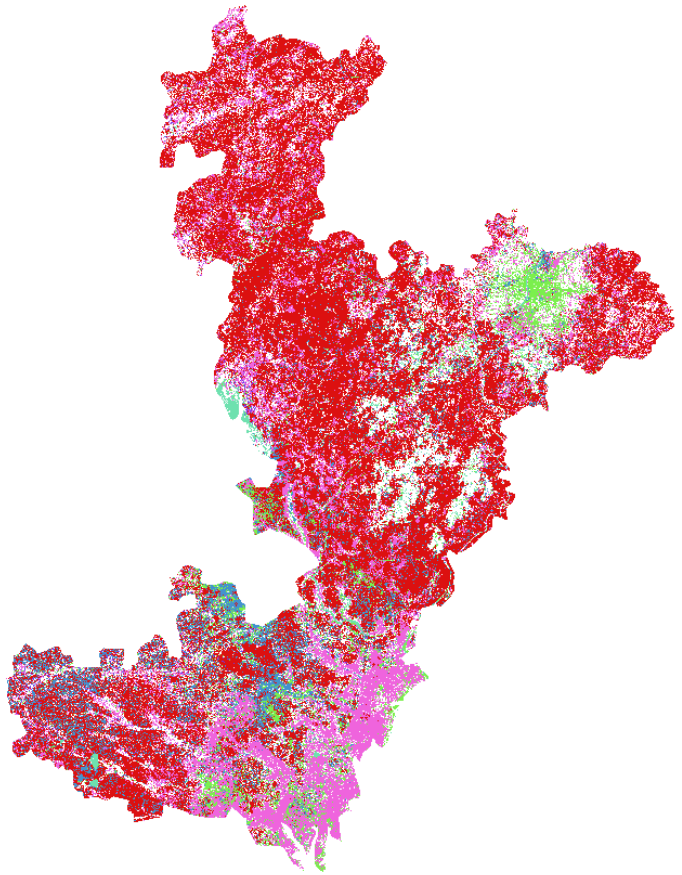
- Hydrologic Modeling
- Terrain Stability
- Soil Mapping
- Land use and Land cover

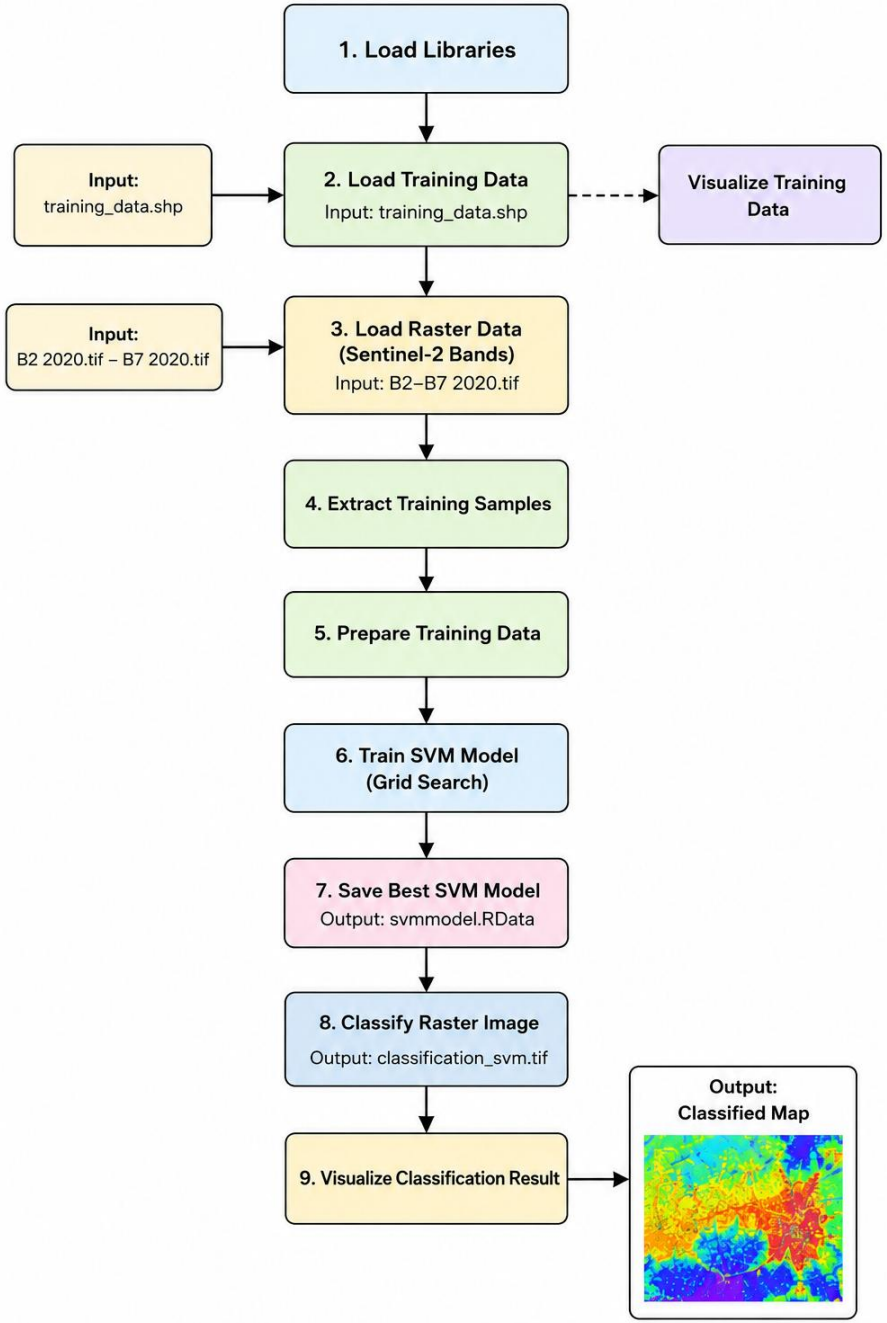


Source: [DEM, DSM & DTM: Elevation Models in GIS]

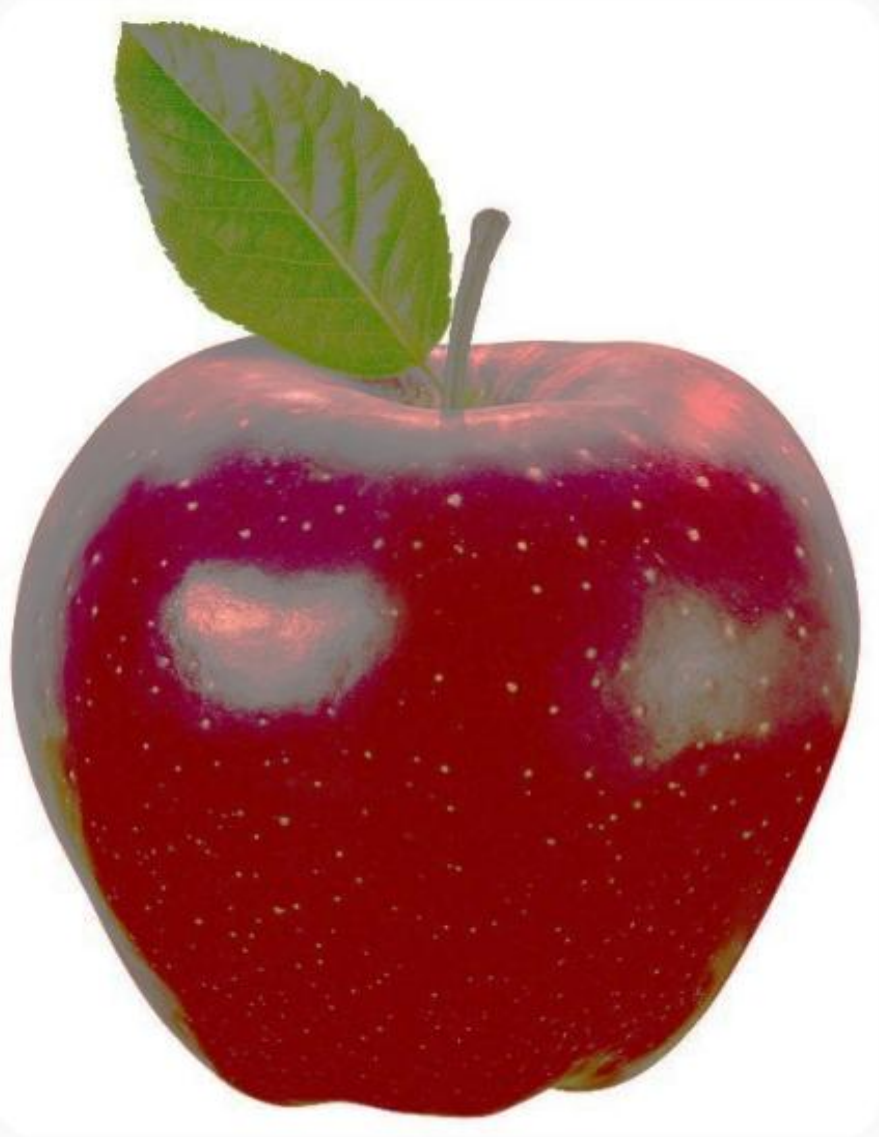
Image classification



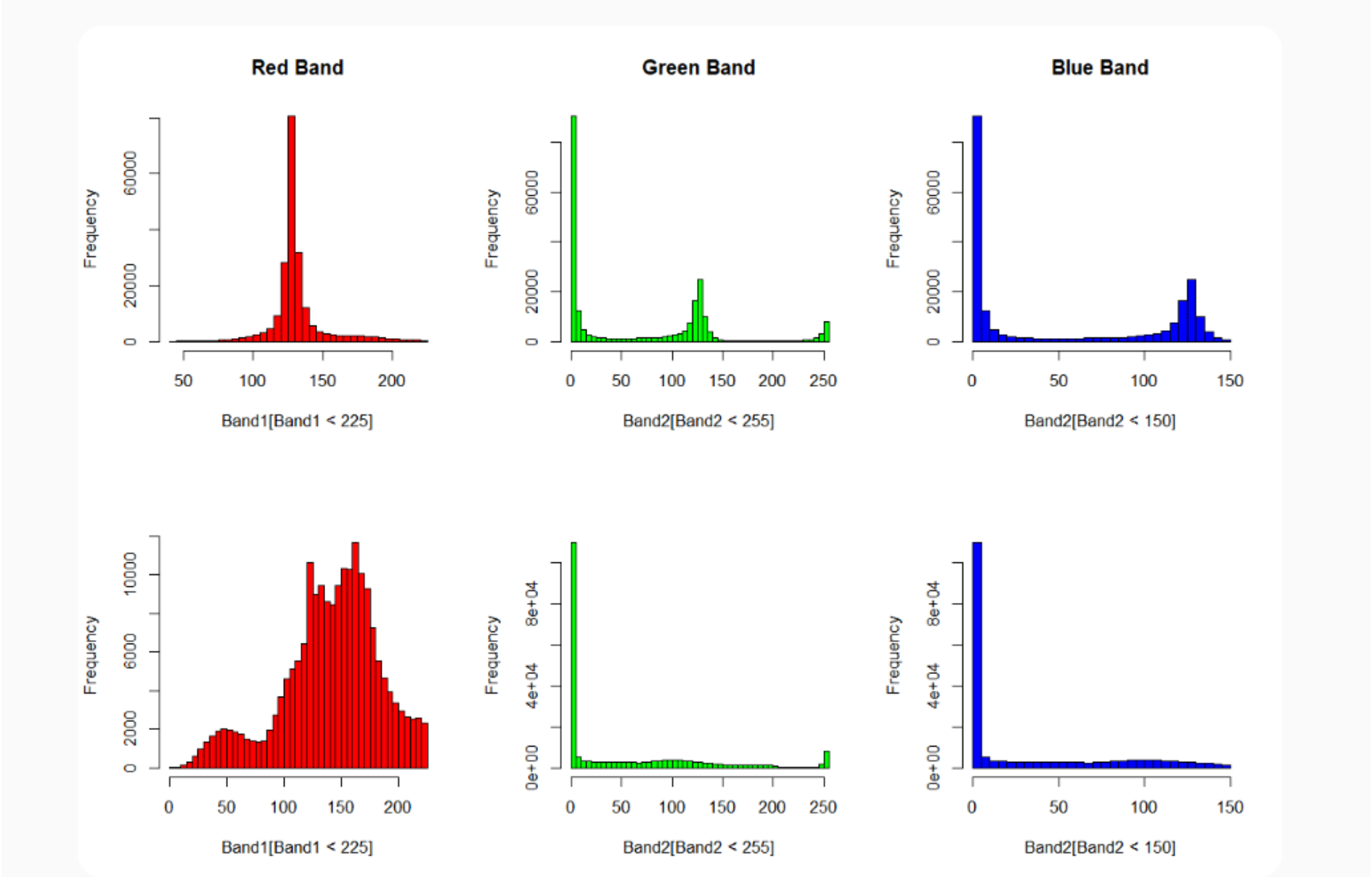




Sampe image: An apple



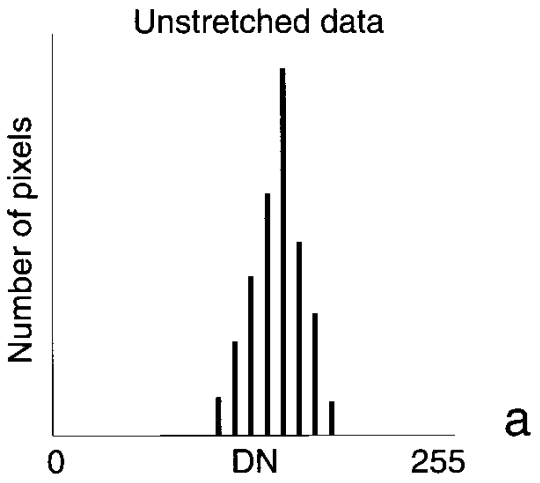
Linear Contrast Enhancement

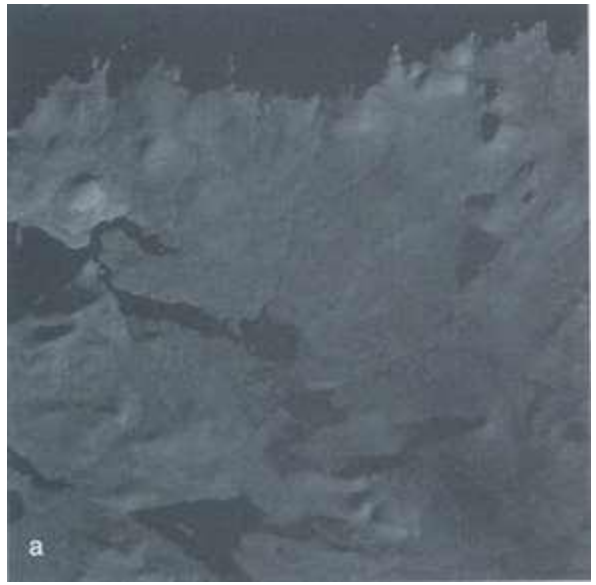


Contrast Enhancement

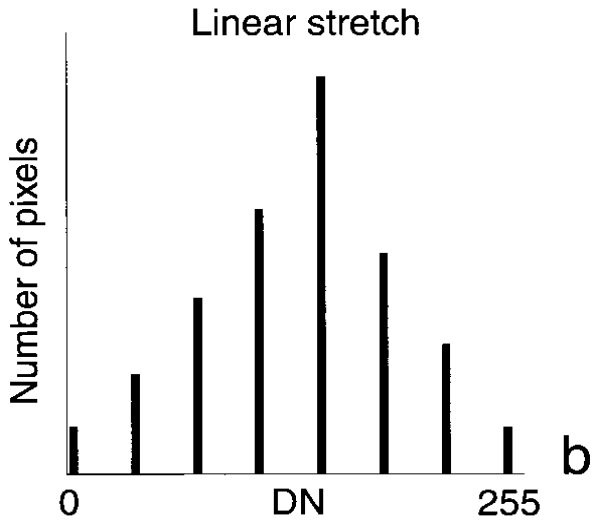
1. Linear Contrast Enhancement
2. Non-Linear Contrast Enhancement

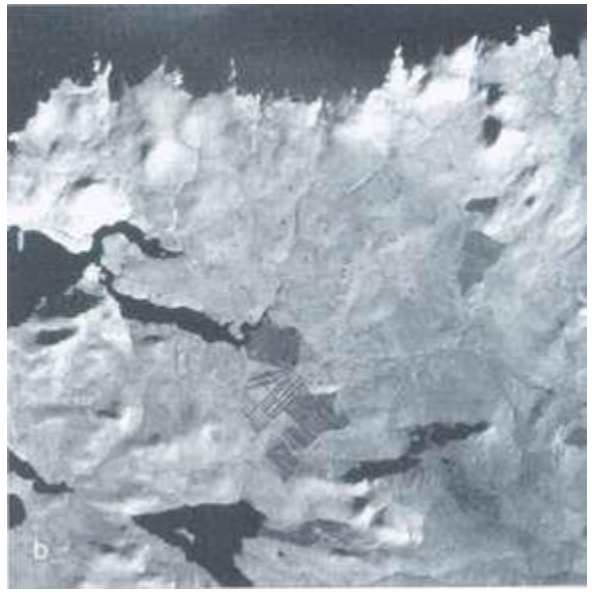
Displayed in an 8-bit system
Image is vague
DN values range from 60-158
0-59 and 159-255 are not utilized





DN values are stretched to 0-255
Contrast is improved
Light tones appear lighter
Dark tones appear darker



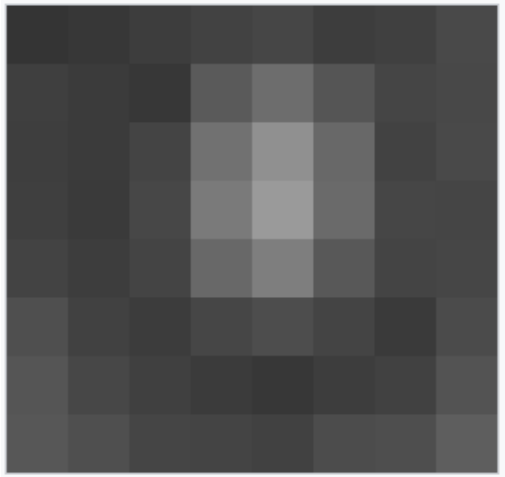


Landsat TM Band-5

Histogram-Equalized Stretch

Resource: Histogram Equalization

- DN values are enhanced based on their frequency in the original image.
- The 8-bit grayscale image shown has the following values:



52	55	61	59	79	61	76	61
62	59	55	104	94	85	59	71
63	65	66	113	144	104	63	72
64	70	70	126	154	109	71	69
67	73	68	106	122	88	68	68
68	79	60	70	77	66	58	75
69	85	64	58	55	61	65	83
70	87	69	68	65	73	78	90

The histogram for this image is shown in the following table. Pixel values that have a zero count are excluded for the sake of brevity.

0	12	53	32	190	53	174	53
57	32	12	227	219	202	32	154
65	85	93	239	251	227	65	158
73	146	146	247	255	235	154	130
97	166	117	231	243	210	117	117
117	190	36	146	178	93	20	170
130	202	73	20	12	53	85	194
146	206	130	117	85	166	182	215

This *cdf* shows that the minimum value in the sub image is 52 and the maximum value is 154. The cdf of 64 for value 154 coincides with the number of pixels in the image. The cdf must be normalized to [0,255]. The general histogram equalization formula is:

$$h(v) = \text{round}\left(\frac{\text{cdf}(v) - \text{cdf}_{\text{min}}}{(M \times N) - \text{cdf}_{\text{min}}} \times (L-1)\right)$$

M × N gives the image's number of pixels (for the example above 64, where M is width and N the height) and L is the number of grey levels used (in most cases, like this one, 256).

Sample calculation

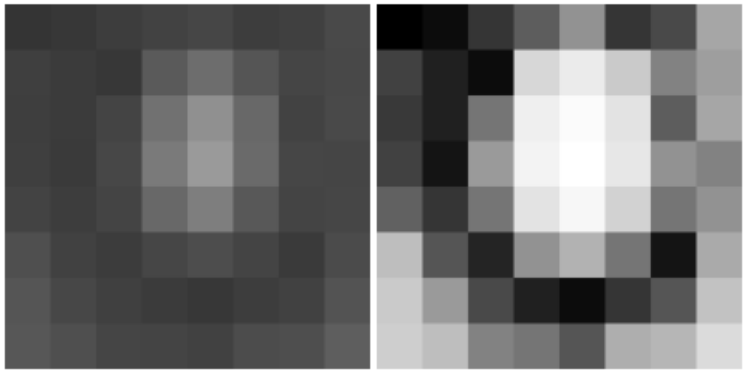
Microsoft Excel Worksheet

The equalization formula for the example scaling data from 0 to 255, inclusive, is:

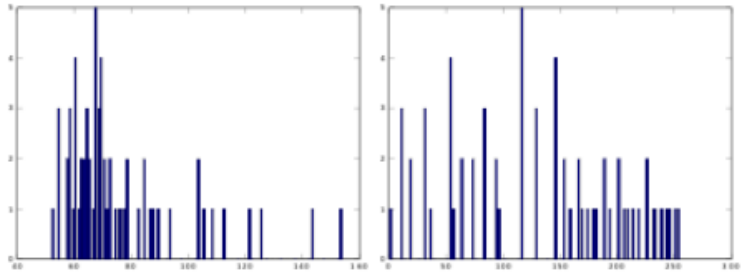
$$h(v) = \text{round}\left(\frac{\text{cdf}(v) - 1}{63} \times 255\right)$$

For example, the cdf of 78 is 46. (The value of 78 is used in the bottom row of the 7th column.) The normalized value becomes

$$h(78) = \text{round}\left(\frac{46 - 1}{63} \times 255\right) = \text{round}\,(0.714286 \times 255) = 182$$



Original Equalized



Histogram of Original image Histogram of Equalized image

v, Pixel Intensity	Count	cdf(v)	h(v), Equalized v
52	1	1	0
55	3	4	12
58	2	6	20
59	3	9	32
60	1	10	36
61	4	14	53
62	1	15	57
63	2	17	65
64	2	19	73
65	3	22	85
66	2	24	93
67	1	25	97
68	5	30	117
69	3	33	130
70	4	37	146
71	2	39	154
72	1	40	158

Hands on QGIS

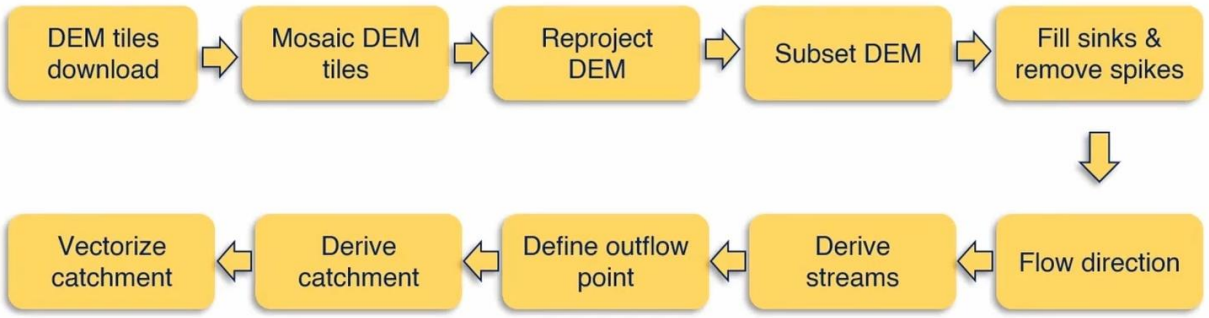
Basic operation in QGIS

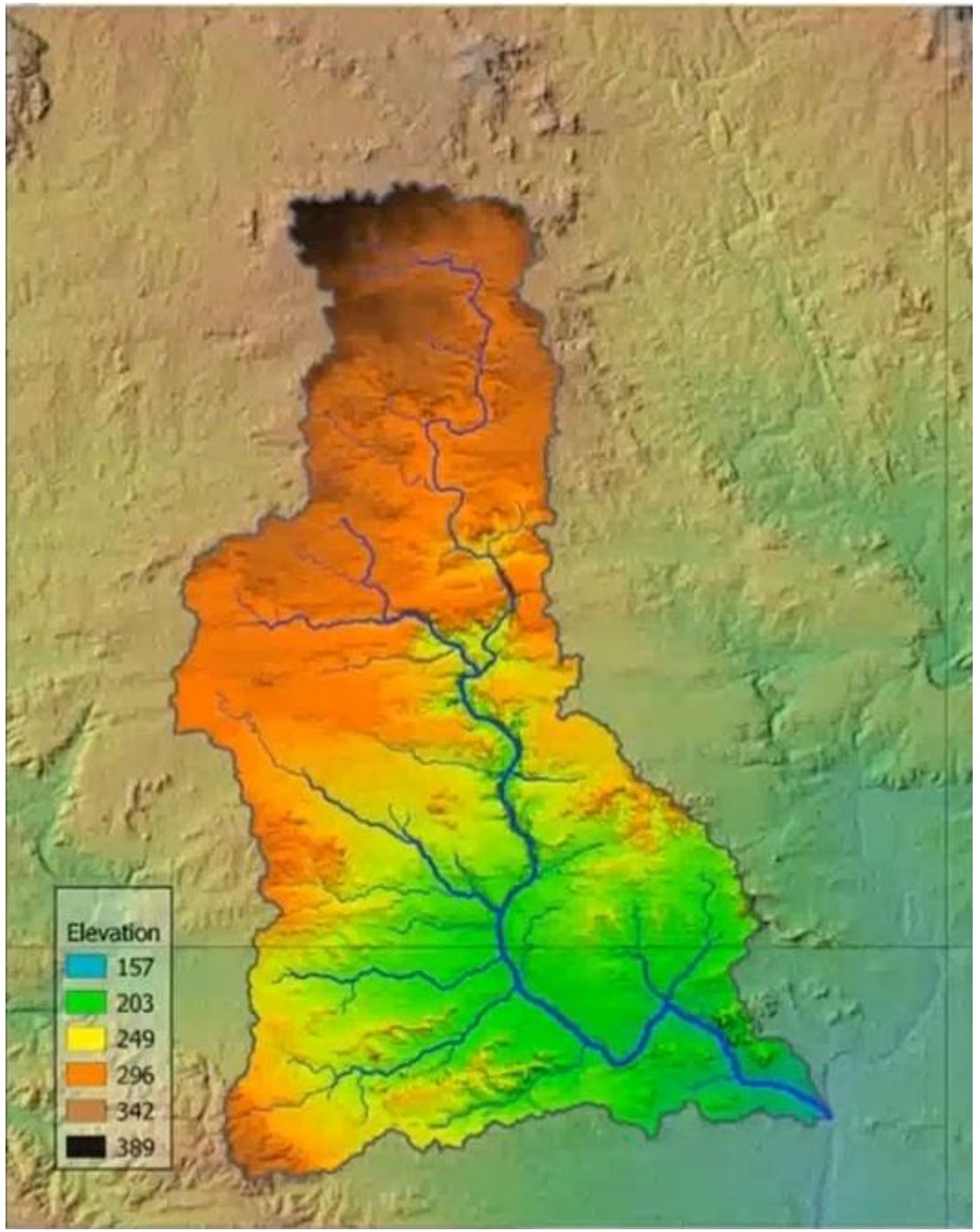
1. Fight Plan in QGIS
2. Raster manipulation – TCC, FCC, Crop, Reproject, Mask, DEM, Contour
    1. DEM derivatives:
        1. Slope
        2. Aspect
        3. Hillshade
        4. Orthomosaic visualization
3. Vector manipulation
    1. Point, line, polygon,
    2. Attribute table editing
4. Point Cloud Visualization
5. Area/perimeter calculation
6. GPS point import
7. Print layout

Hydrological Analysis

Catchment and stream network delineation with QGIS

https://www.youtube.com/watch?v=pp6NX5lyx54



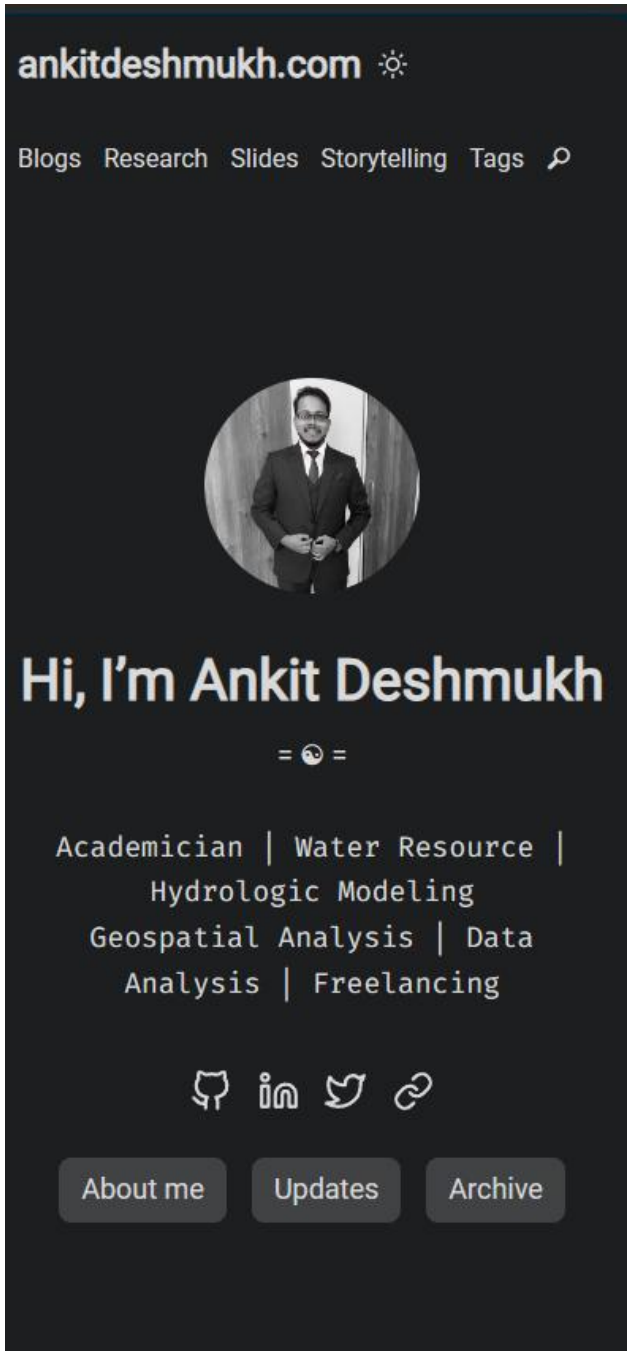


Reference

[1] There are lots of useful tutorials and guides available on the QGIS tutorial website, but the Flood Risk Mapping Practical on this site gives a good introduction to some of the basic features and functions.

[2] Tomaszewski, Brian. *Geographic Information Systems (GIS) for Disaster Management*, n.d.

[3] Shi, P., Kasperson, R. (Eds.), 2015. World Atlas of Natural Disaster Risk, IHDP/Future Earth-Integrated Risk Governance Project Series. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-45430-5



About my research

- My fields of interest are:
- Computational Hydrology,
- Water resource management
- Understating the catchment response under anthropogenic changes.

My specialization is on: "The approaches to identify the catchment vulnerability to environmental changes."

My current research focuses on the development of a Physio-climatic catchment characteristics dataset for the Indian subcontinent that can be utilized for prediction in the ungauged basins. I possess a strong understanding of GIS processing and am efficient in Geo-spatial analysis.
I am highly motivated in the field of data analysis (finding meaningful insights in data and ML), skilled in programming with R, MATLAB, and Python scripting.

Reach out to me:

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