Fundamentals of Remote Sensing & Geographic Information System

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Course Name: Overview of Geoprocessing using Python & Machine Learning

Content

About Geodata
Geo-Spatial Analysis - Raster and Vector

1. Geospatial Technology: Users and Applications
2. Definition of Remote Sensing and GIS
3. Data sources for Geo-processing
4. Overview of Spatial Data Analysis

Course Name: Overview of Geoprocessing using Python & Machine Learning

Objective of the Session

To make you aware about the data types and processing involved in

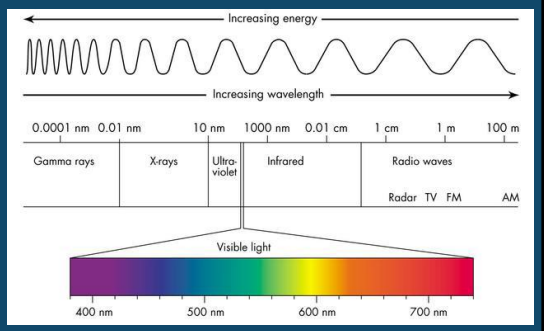
Geo-Processing and Geo-Visualization

Course Name: Overview of Geoprocessing using Python & Machine Learning

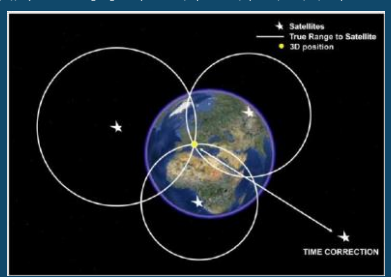
Geospatial Technology

Geospatial technology enables us to acquire location-specific data about Earth and use them for analysis, modeling, simulations and visualization.

- **Remote Sensing** – Sensors operating in different parts of EM region at various SPATIAL, TEMPORAL, SPECTRAL resolutions
- **GIS** (Geographic Information System) – SPATIAL DATA CREATION, UPDATION, VISUALISATION & ANALYSIS
- **Satellite Navigation** – Positioning, Time (GPS, NavIC, etc.)



Source: https://myremotesensingblog.wordpress.com/wp-content/uploads/2014/10/emspectrumcolor.jpg



Source: Brčić, David. (2012). Ensuring sustainability through utilisation of satellite navigation technology.

Users and Usage of Geospatial Spatial Analysis

- An *urban planner* might want to assess the extent of urban fringe growth in her/his city, and quantify the population growth that some suburbs are witnessing. S/he might also like to understand why *these* particular suburbs are growing and others are not;
- A *biologist* might be interested in the impact of slash-and-burn practices on the populations of amphibian species in the forests of a mountain range to obtain a better understanding of long-term threats to those populations;
- A *natural hazard analyst* might like to identify the high-risk areas of annual monsoon-related flooding by investigating rainfall patterns and terrain characteristics;

Users and Usage of Geospatial Spatial Analysis

- A *geological engineer* might want to identify the best localities for constructing buildings in an earthquake-prone area by looking at rock formation characteristics;
- A *mining engineer* could be interested in determining which prospective copper mines should be selected for future exploration, taking into account parameters such as extent, depth and quality of the ore body, amongst others;
- A *geoinformatics engineer* hired by a telecommunications company may want to determine the best sites for the company's relay stations, taking into account various cost factors such as land prices, undulation of the terrain *et cetera*;

Users and Usage of Geospatial Spatial Analysis

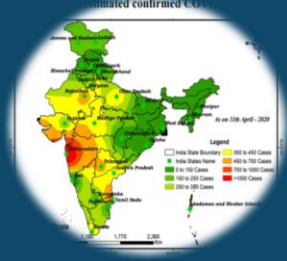
- A *forest manager* might want to optimize timber production using data on soil and current tree stand distributions, in the presence of a number of operational constraints, such as the need to preserve species diversity in the area;
- A *hydrological engineer* might want to study a number of water quality parameters of different sites in a freshwater lake to improve understanding of the current distribution of *Typha* reed beds, and why it differs from that of a decade ago.

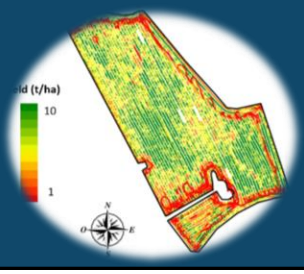
Users and Usage of Geospatial Spatial Analysis

Urban planning & development
- Develop resilient urban cities
- Monitor the urban heat island (UHI) effect in cities
- Determine the quality of life
- Traffic flow analysis

Public health management
- Map disease spread
- Analysis of sanitation & health Facilities
- Map vaccination stats

Agriculture & farming
- Crop monitoring
- Predict crop yield
- Monitor farm animals
- Soil nutrient analysis





What is GIS

A GIS is a computer-based system that provides the following four sets of capabilities to handle georeferenced data:

1. **Data capture and preparation**
   - Gathering spatial data from various sources such as satellite imagery, GPS, surveys, and remote sensing.
2. **Data management, including storage and maintenance**
   - Organizing and maintaining data to ensure its accuracy, consistency, and accessibility.
3. **Data Analysis**
   - Performing spatial analysis to uncover patterns, relationships, and trends. This can include overlay analysis, proximity analysis, network analysis, and more.
4. **Data Visualization & Presentation**
   - Creating maps, 3D models, and other visual representations to communicate findings effectively.

(Aronoff, 1989)

5. **Data Integration**
   - Combining GIS with other technologies such as IoT (Internet of Things), AI (Artificial Intelligence), and big data analytics for enhanced capabilities.

Fundamental Principle of Geospatial technology

The fundamental problem that we face in many uses of **geospatial technology** is that of understanding phenomena that have a spatial or geographical dimension as well as temporal dimension.

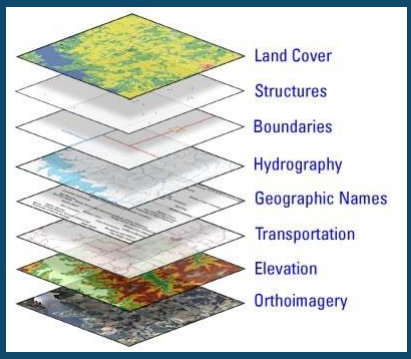
Spatio-temporal problems

This means that our object of study has different characteristics for different locations (the geographical dimension) and also that these characteristics changes over time (the temporal dimension)

Geospatial Data

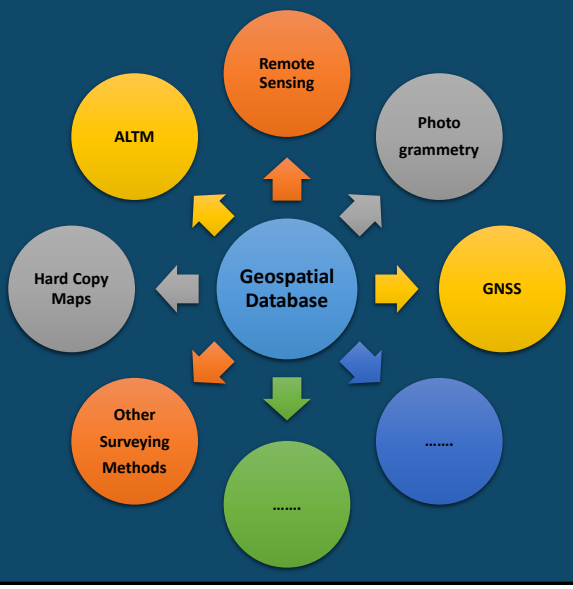
- "Geographically referenced data that describe both the location (geometry) and the characteristics of spatial features."

(Chang, 2009)



(*Image source*: Wikimedia Commons, via USGS)

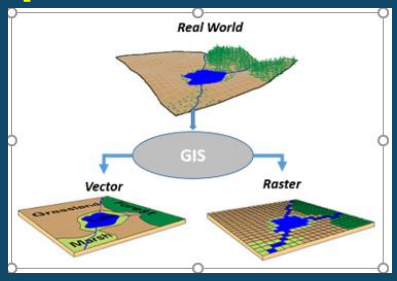
Sources of Input Data for Geoprocessing



Computer Representation of Geospatial Phenomena

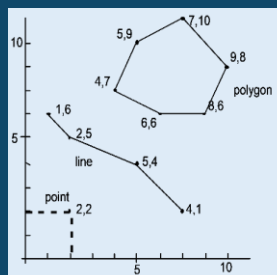
Raster Data Model

- Grid based data structure
- Smallest element: pixel
- Examples: Satellite Images, Aerial Photo, Maps etc.

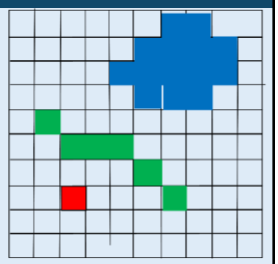


Vector Data Model

- Geometry based data structure
- Element: point, line and polygon
- Examples:
  - Roads represented as line,
  - Boundaries like city, country etc., building footprints



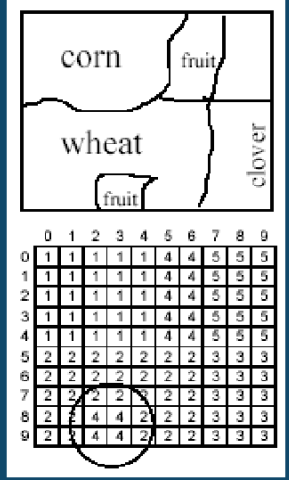
Vector data model


Raster data model

Spatial Data Models - Raster

Raster model

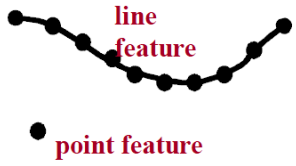
- Area is covered by grid with (usually) equal-sized cells
- Cells often called *pixels* (picture elements); raster data often called *image* data
- Attributes are recorded by assigning each cell a single value based on the majority feature (attribute) in the cell, such as land use type

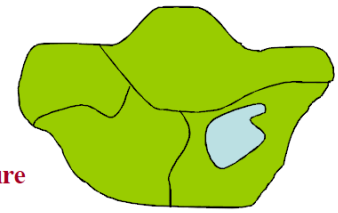


Spatial Data Models: Vector

Vector model

- In a vector-based GIS data are handled as:
  - **Points X,Y coordinate pair + label**
  - **Lines series of points**
  - **Areas line(s) forming their boundary (series of polygons)**





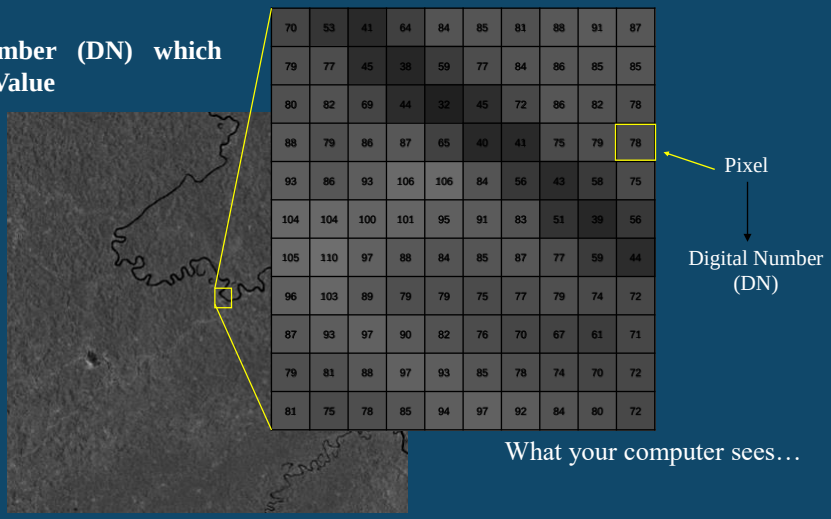
Attribute Table: An Example

Uttarakhand_Districts — Features Total: 13, Filtered: 13, Selected: 0

	ID	DISTRICT	AREA	PERIMETER	Literacy_%	GenderRati	P_Density
1	1	ALMORA	310000000.000	356590.060	80.47	1139	198
2	2	BAGHESHWAR	228000000.000	307638.560	80.01	1090	116
3	3	CHAMOLI	794000000.000	495065.530	82.65	1019	49
4	4	CHAMPAWAT	253000000.000	354482.370	79.83	980	147
5	5	DEHRADUN	307000000.000	415457.370	84.25	902	549
6	6	HARIDWAR	239000000.000	264819.150	73.43	880	801
7	7	NAINITAL	334000000.000	361656.370	83.88	934	225
8	8	PAURI GARHWAL	546000000.000	387637.000	82.02	1103	129
9	9	PITHORAGARH	636000000.000	500611.840	82.25	1020	68
10	10	RUDRAPRAYAG	122000000.000	188448.890	81.30	1114	122
11	11	TEHRI GARHWAL	440000000.000	497649.250	76.36	1077	170
12	12	UDHAMSINGHNAGAR	354000000.000	573907.750	73.10	920	649
13	13	UTTARKASHI	807000000.000	661452.680	75.81	958	

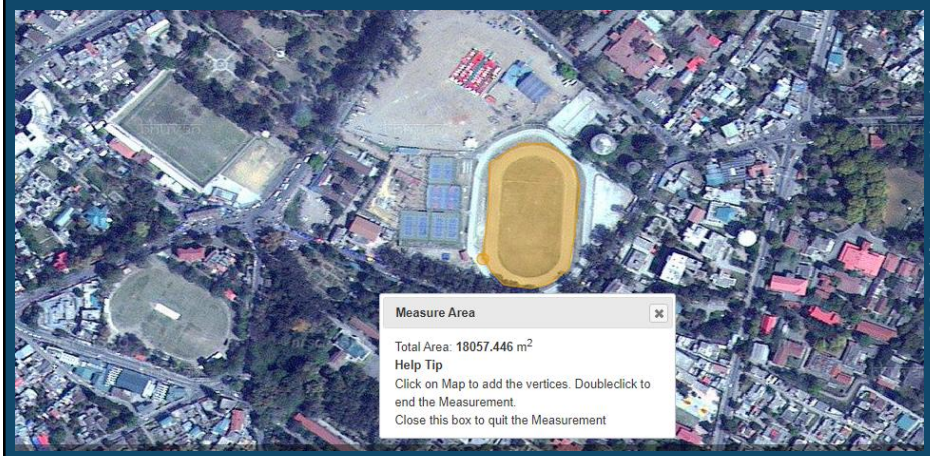
What is a raster image?

- Grid cells or pixels
- Each pixel has a digital number (DN) which represents Spectral Reflectance Value



Characteristics of Image Data

1. Geographically Referenced : The data is in sync with ground coordinates. It helps in making actual measurement on the data



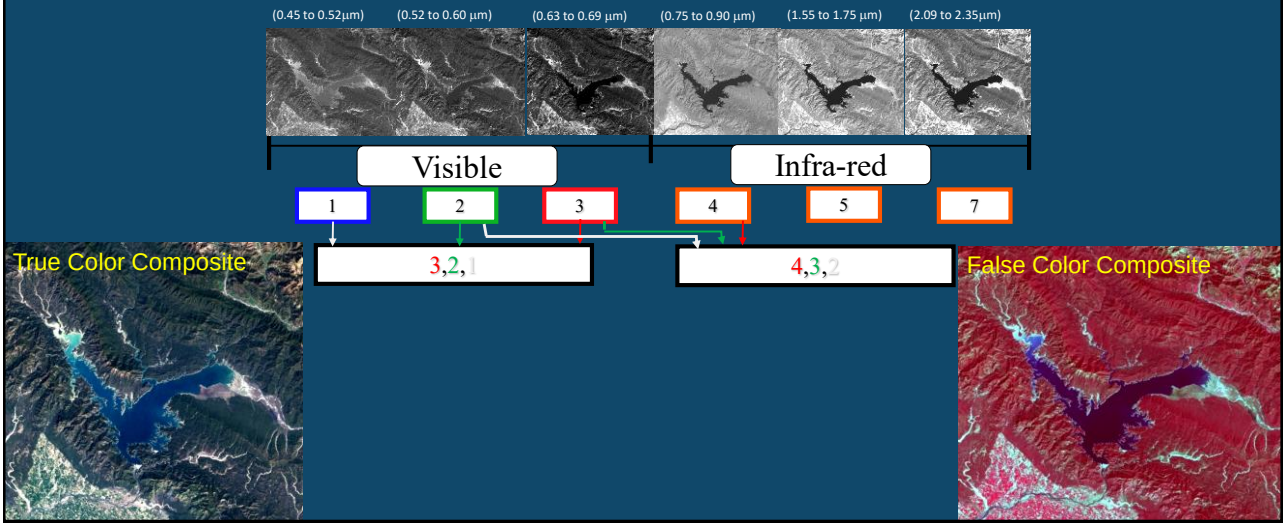
Different Geo-referencing Systems

1. EPSG:3857 :
WGS 84 / Pseudo-Mercator -- Spherical Mercator, Google Maps, OpenStreetMap, Bing, ArcGIS, ESRI
Unit of Measurement: Meter

2. EPSG:4326:
WGS 84 -- WGS84 - World Geodetic System 1984, used in GPS
Unit of Measurement: Degree
More details:
https://epsg.io/4326

Characteristics of Image Data

2. Single/Multiple Spectral bands



Characteristics of Image Data

3. Information content is dependent on Image Pixel Size

A) OCM (360m)
B) 360m (OCM)
C) 188m (WiFS)
D) 72m (LISS-I)
E) 36m (LISS-II)
F) 23m (LISS-III)
G) 5.8m (IRS 1C PAN)

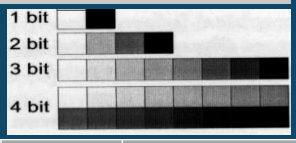
'A' is from a scene from IRS Ocean Colour Monitor (OCM).
The area in the small square marked (≈ 4km x 4km) is shown in various resolutions from B to G..

Characteristics of Image Data

4. Information content is dependent on Image Pixel Depth (Radiometry)

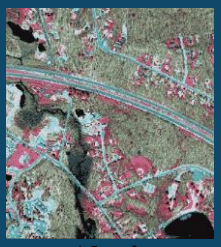
It describes the actual information content in an image.

2 (number of bits) = number of grey levels



bits	Grey Levels	Range (b-w)
1	2	0-1
2	4	0-3
3	8	0-7
4	16	0-15
5	32	0-31
6	64	0-63
7	128	0-127
8	256	0-255
9	512	0-511
10	1024	0-1203

256 colors

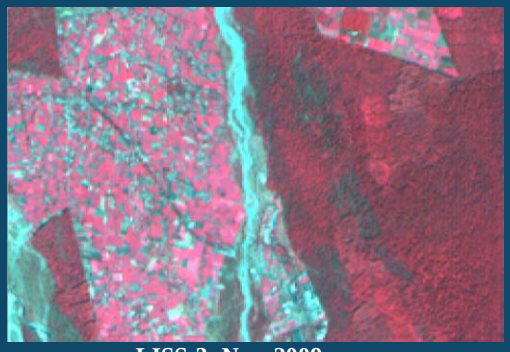


16 colors

2 colors

Characteristics of Image Data

4. Pixel values varies with respect to time (temporal change)



LISS-3: Nov. 2009

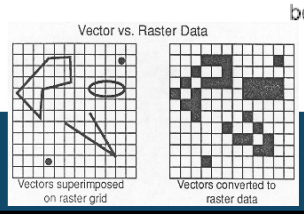
LISS-3: Feb. 2009

Spatial Data Models (3)

Raster Model Vs. Vector model

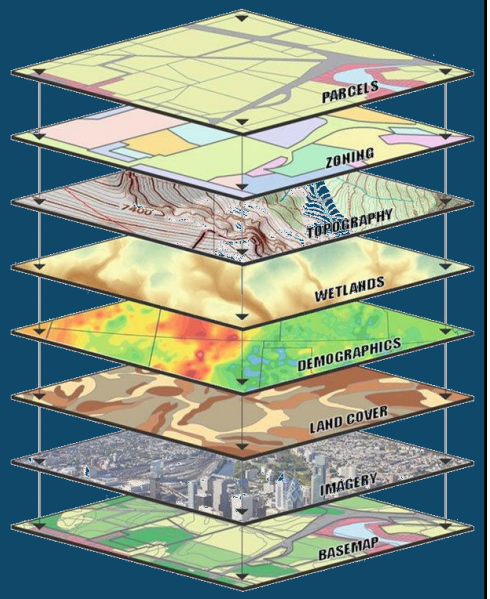
- **Raster data model**
  - location is referenced by a grid cell in a rectangular array (matrix)
  - attribute is represented as a single value for that cell
  - much data comes in this form
    - images from remote sensing (LANDSAT, SPOT)
    - scanned maps
    - elevation data from USGS
  - best for continuous features:
    - elevation
    - temperature

- **Vector data model**
  - location referenced by x,y coordinates, which can be linked to form lines and polygons
  - attributes referenced through unique ID number to tables
  - much data comes in this form
    - DIME and TIGER files from US Census
    - DLG from USGS for streams, roads, etc
    - census data (tabular)
  - best for features with discrete boundaries
    - property lines
    - political boundaries
    - transportation



Definition of Spatial Analysis

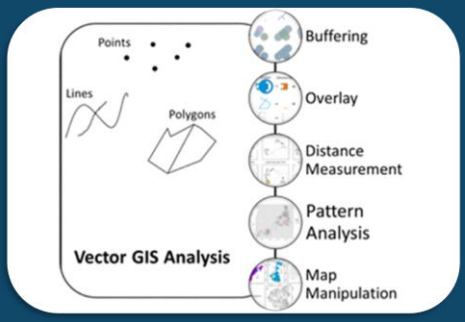
Spatial analysis is the process of studying entities by examining, assessing, evaluating, and modeling spatial data features such as locations, attributes, and relationships that reveal the geometric or geographic properties of data.

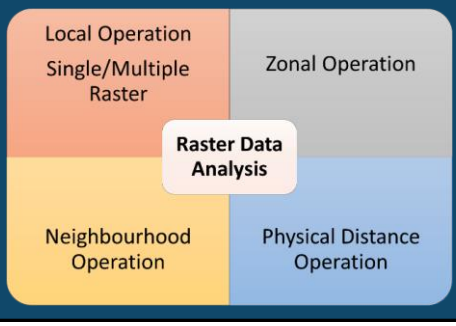


Source of image: https://www.researchgate.net/figure/Different-layers-of-data

Spatial Analysis:

- Spatial analysis involves examining and understanding the patterns, relationships, and trends in geodata.
- It is the process of applying analytical techniques to geospatial data to gain insights, make informed decisions, and solve problems related to geography and location.
- Analysis differ based on data type: raster or vector





Spatial Analysis : Vector & Raster Based

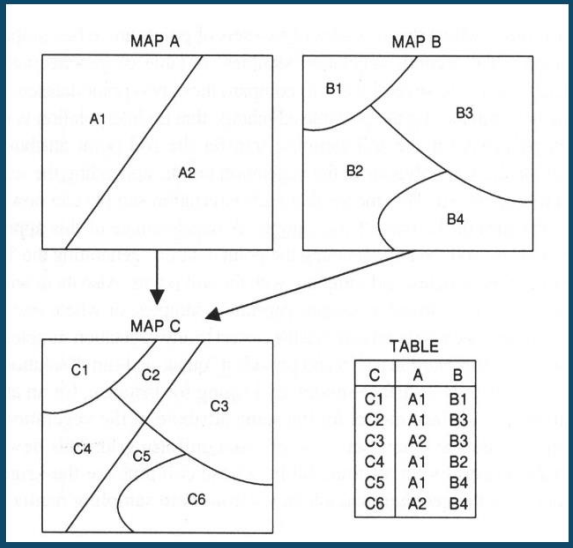
VECTOR BASED ANALYSIS

- **Map Overlay**
  - Union, Intersect
  - Point in Polygon, Line in Polygon, Polygon in Polygon
- **Map manipulation**
  - Dissolve, Clip, Append, Eliminate, Update, Erase, Split
- **Proximity Analysis**
  - Buffer, Multiple Ring Buffer, Point Distance
- **Pattern Analysis**
  - Nearest Neighbour Analysis, Spatial Autocorrelation
- **Network Analysis**
  - Shortest route

RASTER BASED ANALYSIS

- **Functions**
  - Local, Focal , Zonal , Global
- **Map Algebra**
  - Operators: Boolean, Relational and Arithmetic
  - Functions: Mathematical, Logarithmic, Arithmetic, Trigonometric, Power
- **Terrain Analysis**
  - Derivatives: Contour, Slope, Aspect, Hillshade, Viewshed
- **Hydrology Analysis**
  - Flow Directions, Flow Accumulation, Stream Order, Watershed etc.
- **Reclassification**

Overlay Operation: Vector (polygon) Layers



TABLE

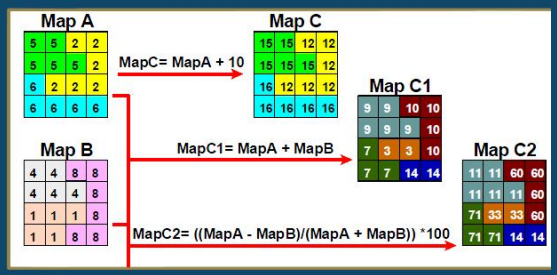
C	A	B
C1	A1	B1
C2	A1	B3
C3	A2	B3
C4	A1	B2
C5	A1	B4
C6	A2	B4

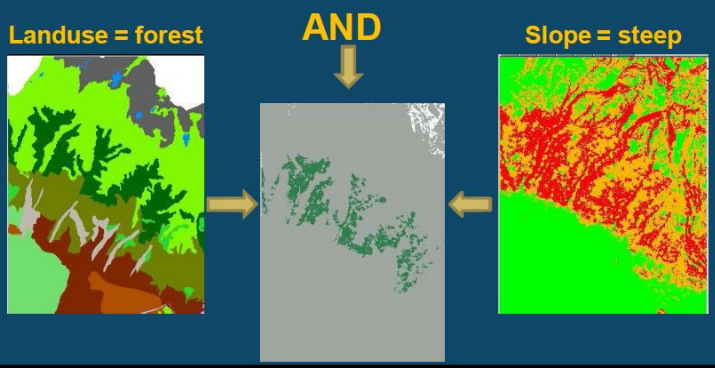
Result : new set of polygons common to both maps

After Bonham-Carter

Overlay Operation: Raster Layers

- Arithmatic Operations
- Relational and Logical Operators
- Conditional Statements
- Any Combination





Raster Overlay Operation : Relational Function

Map A

5	5	2	2
5	5	5	2
6	2	2	2
6	6	6	6

Map B

4	4	8	8
4	4	4	8
1	1	1	8
1	1	8	8

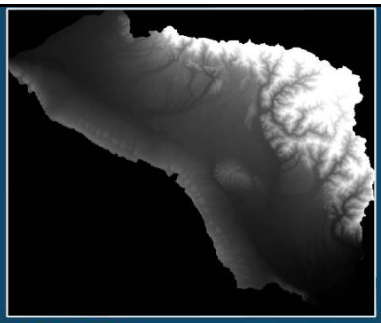
Output = Map A > Map B

Output

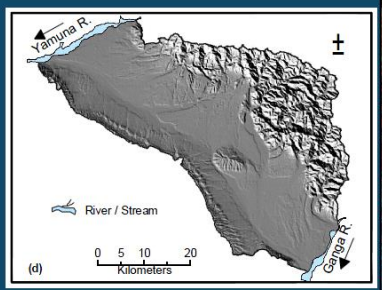
1	1	0	0
1	1	1	0
1	1	1	0
1	1	0	0

0 = FALSE
1 = TRUE

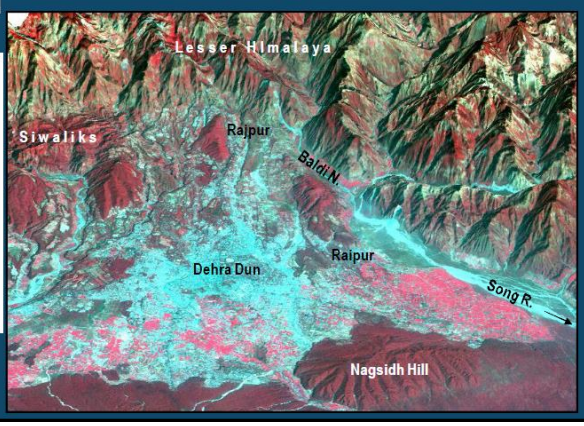
Terrain Visualisation



DEM (SRTM)

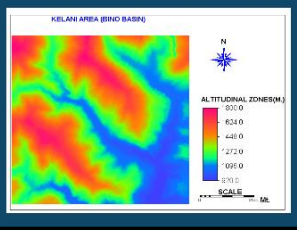


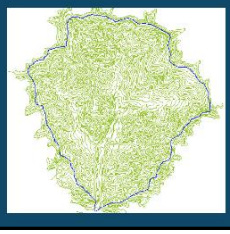
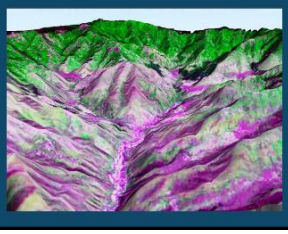
Shaded Relief Images prepared from SRTM DEM (*solar azimuth–225º, Solar elevation–45º*)



Terrain Analysis

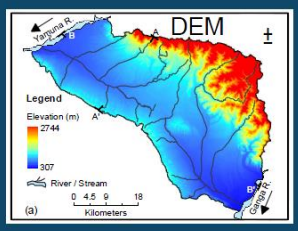
- Slope (Amount) measures the rate of change of elevation at a given surface location.
- Aspect (Slope Aspect) is the directional measure of the slope: the maximum slope direction.
- Surface curvature (Slope shape): convex, concave, or straight .
- Break-in-slope analysis.
- Watershed (or Catchment)/ Hydrological analysis: (i) Flow direction, (ii) Flow accumulation, (3) Stream Order, (4) Watershed boundary

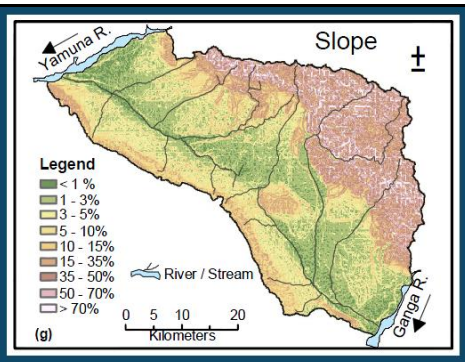


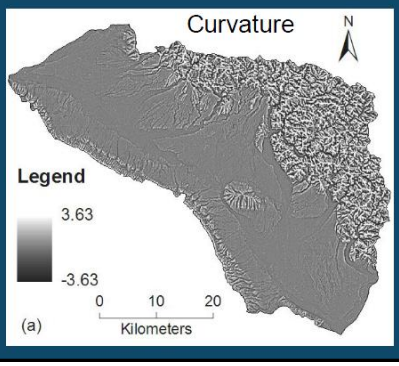



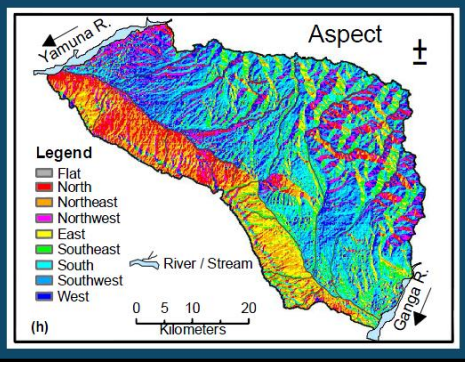
Terrain Analysis (4)

Estimating slopes

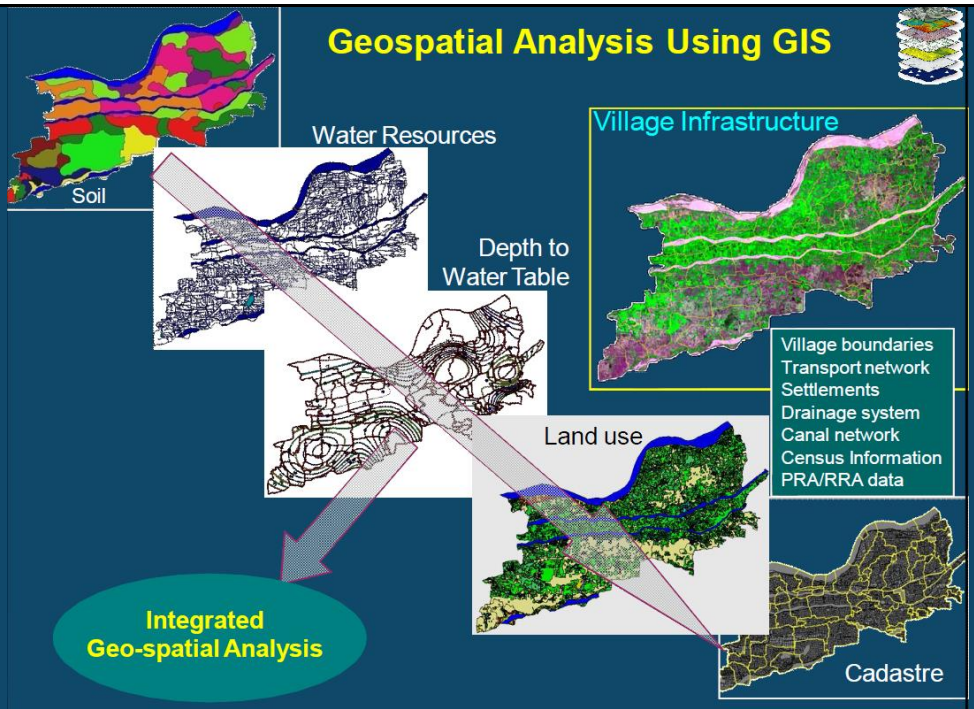




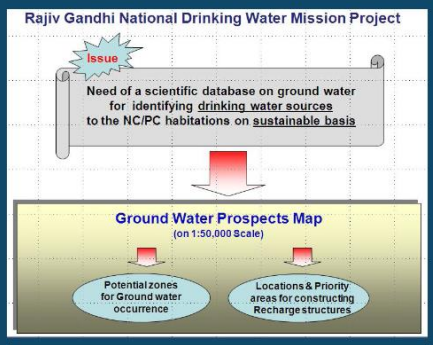


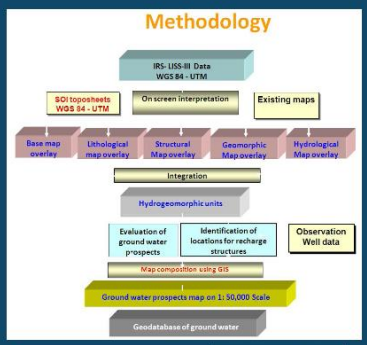


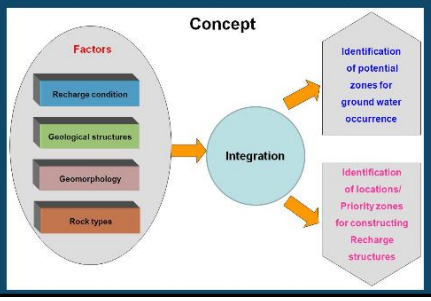
Geospatial Analysis Using GIS

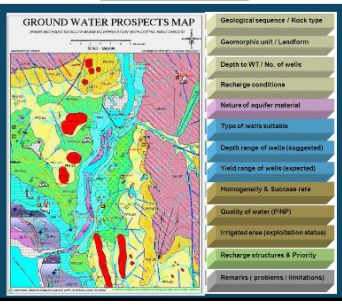


Spatial Modeling for Ground Water Prospects Zoning cond.





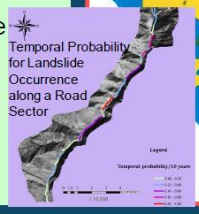




Modelling Landslide Hazard and Risks

Causative Elements

1. Base map
2. Lithological map
3. Geomorphological map
4. Slope aspect
5. Slope Degree
6. Slope Morphology
7. Soil Texture
8. Soil Depth
9. Drainage
10. Lineament & Structure
11. Anthropogenic Factor
12. Landuse
13. Landslide
14. Slope-Dip relation
15. Rock weathering



LHZ Map

Integration Method: Simple Additive Weighting of Causative Elements Layers

$$S = \Sigma^{n}_{i} S_{ij} W_i / \Sigma^{n}_{i} W_i$$

Weights (W_i): Derived from Multi-Criteria Decision Analysis approach, OR Information Value method, expert decision, etc.

POPULAR DATA FORMATS IN GEOSPATIAL DOMAIN

Raster Data Formats

- GeoTiff
- NetCDF
- HDF
- IMG
- ....

Vector Data Formats

- Shape Files
- WKT
- KML
- GeoJSON
- ....

Useful Online Geodata Repositories for ML

- **Bhoondhi**
  - Historical Satellite Data from Indian Satellites (pixel size of 5.8 m)
  - https://bhoonidhi.nrsc.gov.in/
- **ISRO Bhuvan**
  - Web Services for various thematic geospatial data
  - https://bhuvan.nrsc.gov.in
- **MOSDAC**
  - Satellite-based meteorological and oceanographic data
  - https://www.mosdac.gov.in/
- **Era 5 Land**
  - ERA5-Land hourly data from 1950 to present
  - ERA5-Land is a global land-surface dataset at 9 km resolution, consistent with atmospheric data from the ERA5 reanalysis from 1950 onward
  - Temperature, Precipitation, Wind, evaporation etc.
  - https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land?tab=overview
- **Google Earth Engine**
  - Multi-petabyte catalog of satellite imagery and geospatial datasets
- **Open Street Map**
  - Wealth of vector data related to infrastructure like road, rail, building footprints etc.
- **Data.gov.in**
  - Data from various ministries of GOI e.g. historical crop yield etc.

References

ITC (2009). Principles of Geographic Information Systems: An introductory textbook. Otto Huisman, Rolf A. de By (eds.), ITC Educational Textbook Series, Fourth Edition.

Chang, K.T. (2008). Introduction to Geographic Information Systems. The McGraw-Hill Companies, Inc..

Thank You