



ICIMOD

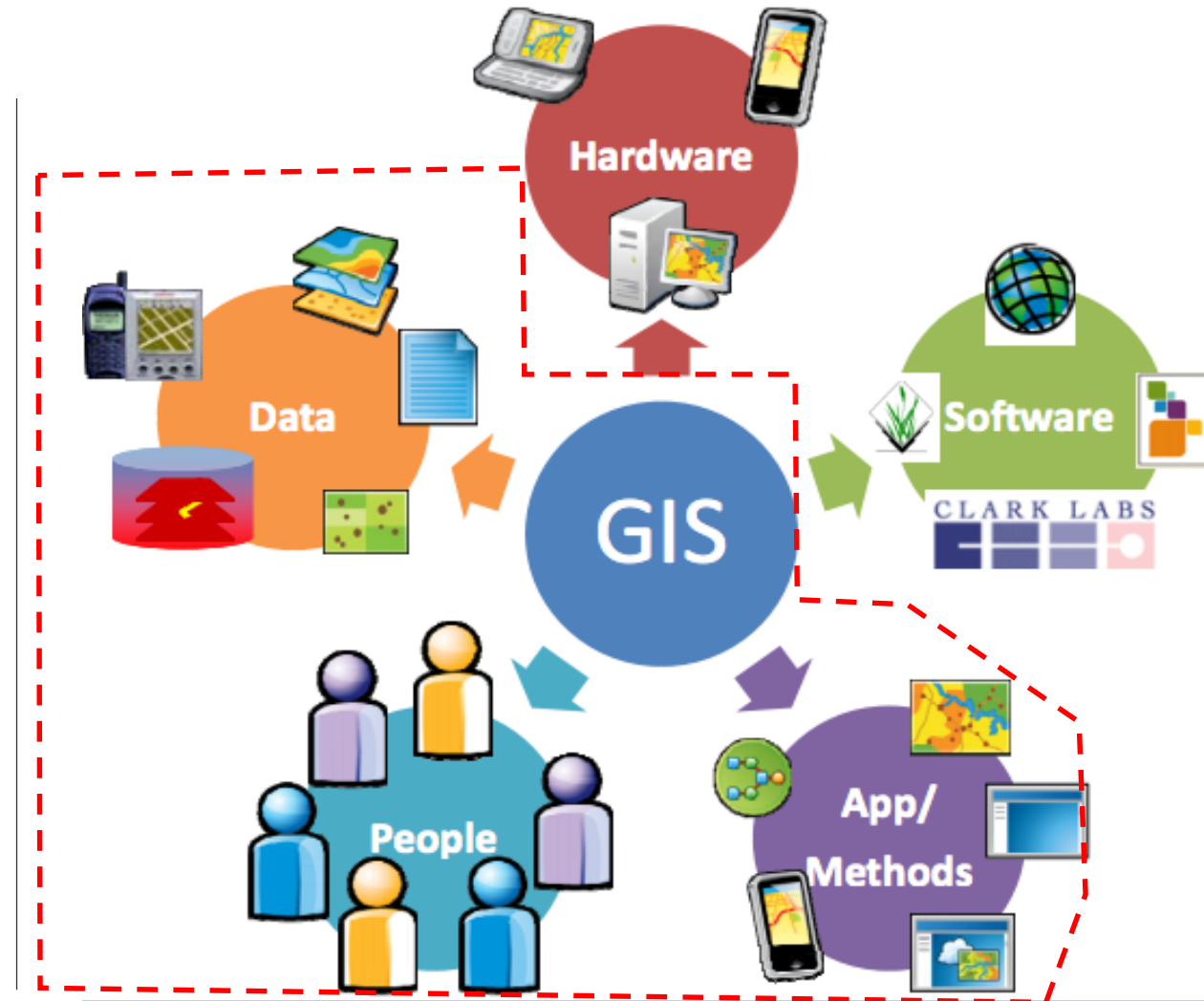
Poonam Tripathi, PhD
Geospatial Training Analyst
Poonam.Tripathi@icimod.org

GIS concepts and applications

INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS

What is GIS?

- An organized integration of
- Hardware
- Software and
- Geographic system



▼ Search

Lahore, Pakistan

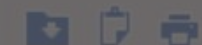
Search

ex: Computer repair near Boston

[Get Directions](#) [History](#)

Lahore

GEOGRAPHIC- Location



▼ Places

☐ My Places☐ [Sightseeing Tour](#)

Majority of data and information are associated with some location in space or referenced to the locations on the earth



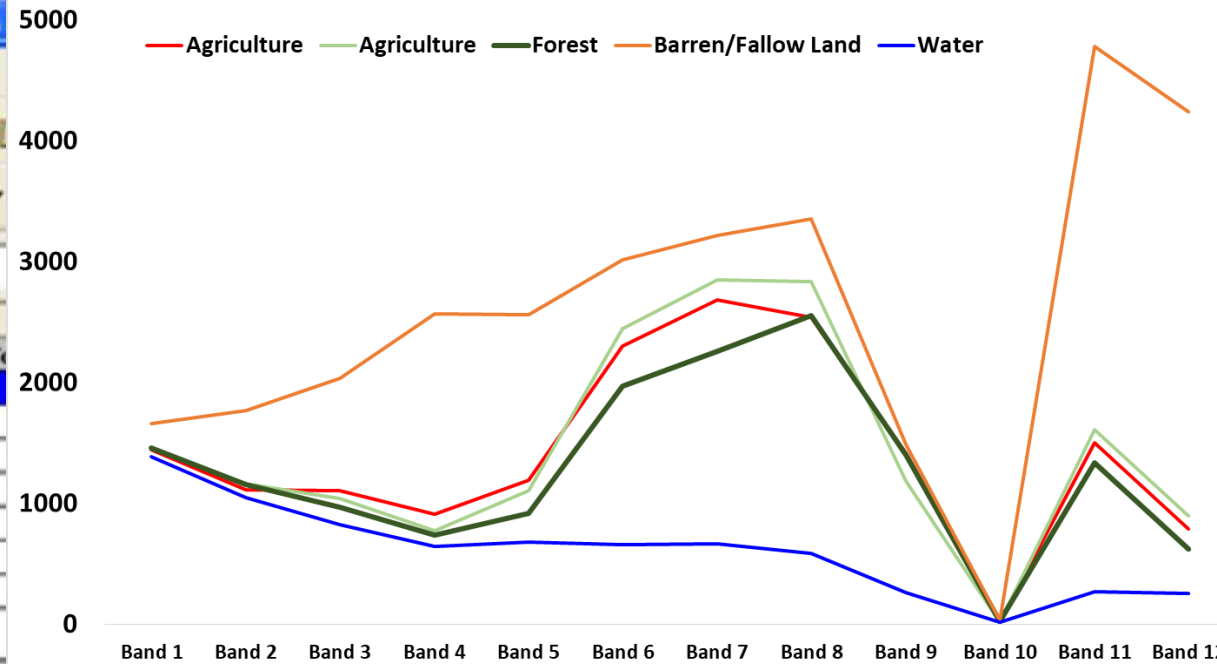
Web Site Stats - OpenOffice.org Calc

File Edit View Insert Format Tools Data Window Help

Bitstream Vera Sans 10 B I U

G14

	C	D	E	F	G	H	I	J	K
3	Month	Daily Avg				Monthly Tot			
4		Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages
6	Mar 05	82	62	68	18	332	22436	499	1703
7	Feb 05	76	67	65	15	303	21443	467	1687
8	Jan 05	72	64	53	13	293	19452	432	1661
9	Dec 04	58	50	44	11	214	14704	364	1380
10	Nov 04	77	64	58	10	222	17149	319	1743
11	Oct 04	61	48	45	7	162	13296	231	1397



INFORMATION-Attributes

Top 20 of 20 Total Countries - J

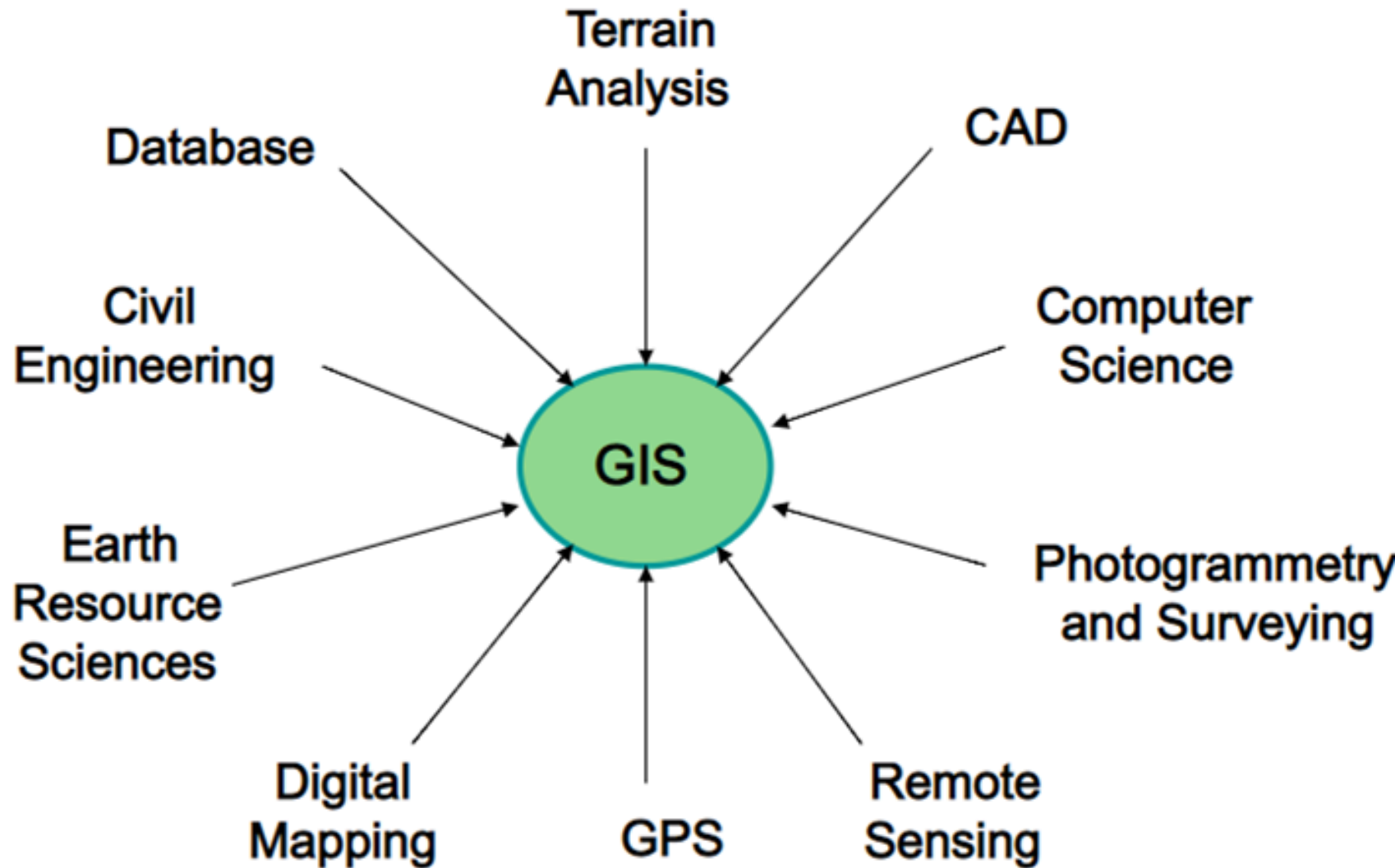
#	Hits		Files		
1	865	38.43%	774	38.64%	7
2	592	26.30%	512	25.56%	4
3	439	19.50%	402	20.07%	3
4	197	8.75%	175	8.74%	1
5	49	2.18%	45	2.25%	
6	21	0.93%	17	0.85%	
7	13	0.58%	13	0.65%	
8	12	0.53%	12	0.60%	

STD * Sum=0

Attributes, or the characteristics (data), can be used to symbolize and provide further insight into a given location



SYSTEM- Manipulation

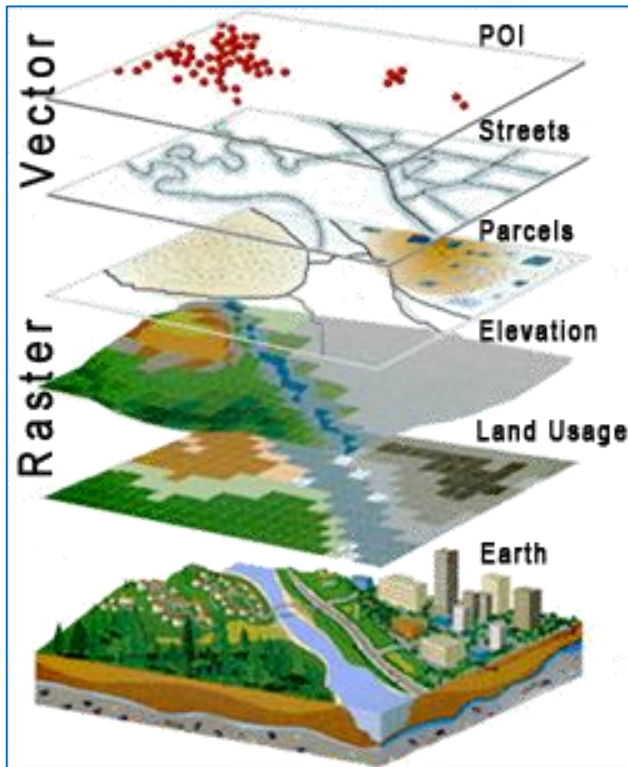


A seamless operation linking the information to the geography – which requires hardware, networks, software, data, and operational procedures



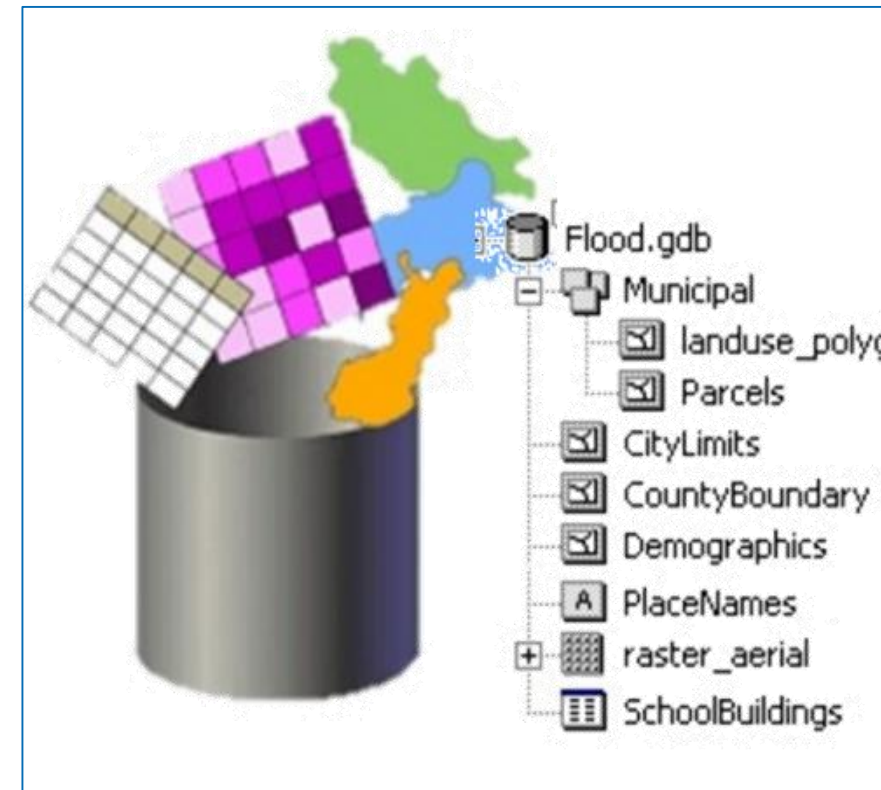
Functions of GIS

Data Acquisition and Preprocessing



Digitization, editing, topology, projection, format conversion

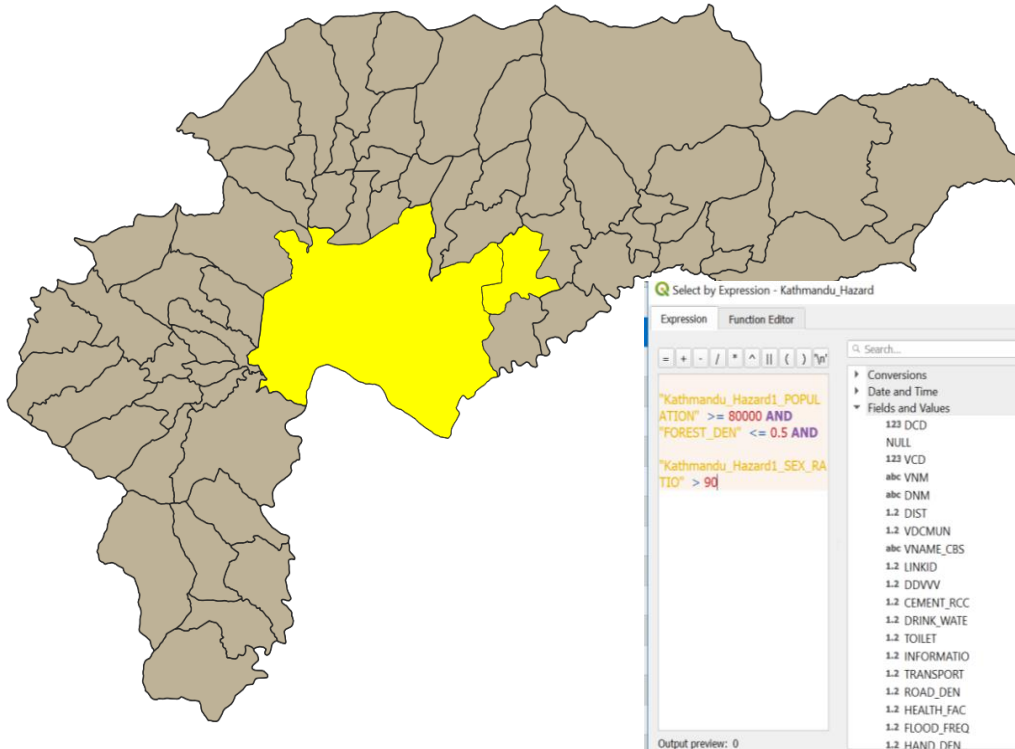
Database Management, Update and Retrieval



Data retrieval, Updation, Maintenance, Security and, Integration

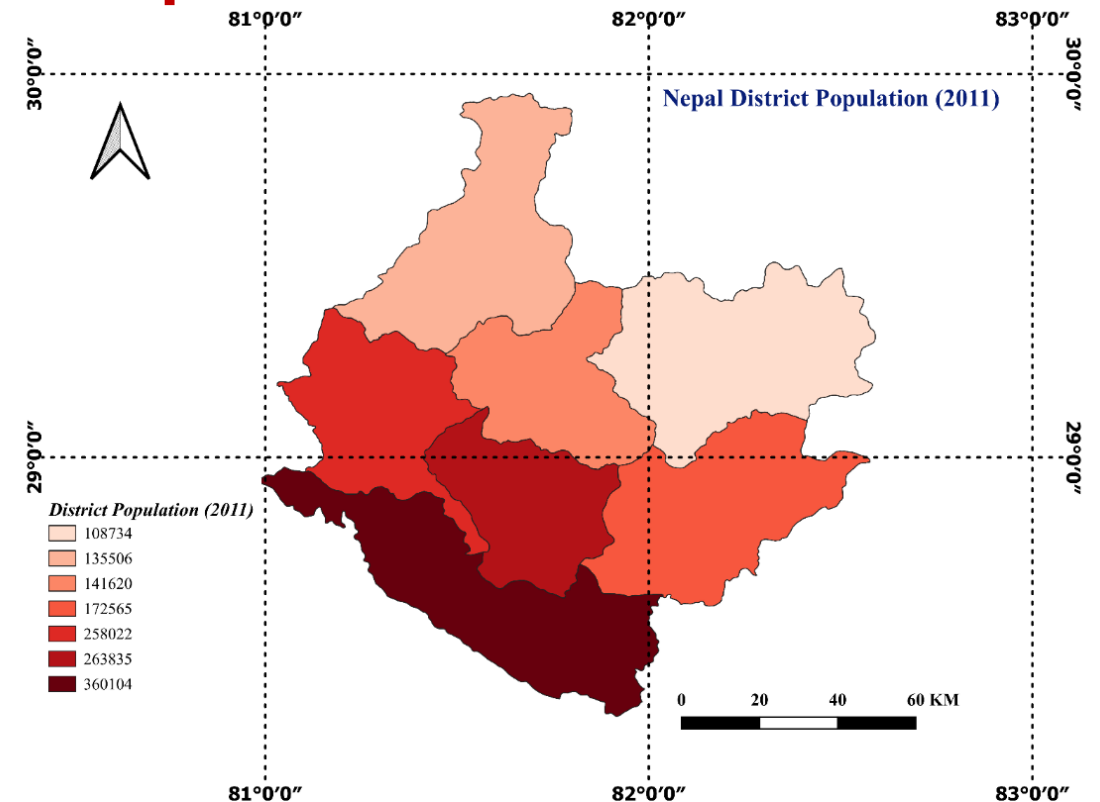
Functions of GIS

Spatial Modeling, Measurement and Analysis



Hierarchical, Network, Relational modelling, Attribute query etc.

Presenting Results – Graphical output and Visualization



Scale transformation, Generalization, Map, Statistical representation etc.



Fundamental Data types

1) Spatial Data: Objects or elements that are present in a geographical space or horizon

- Map
- Image

2) Non-Spatial Data: Not involving Space - Describes the quantitative or qualitative characteristic of spatial features

- Area
- Length
- Population

Spatial data can be mapped and usually stored as coordinate and topology



Fundamental Data types

Spatial Information

Non-Spatial Information

universities of bangladesh

Rating Hours More filters

Bangladesh University
4.5 ★★★★★ (53)
Private university · 5/B, Beribandh, Main Rd
Closed · Closed · Opens 10AM Thu · +880 1744-291258

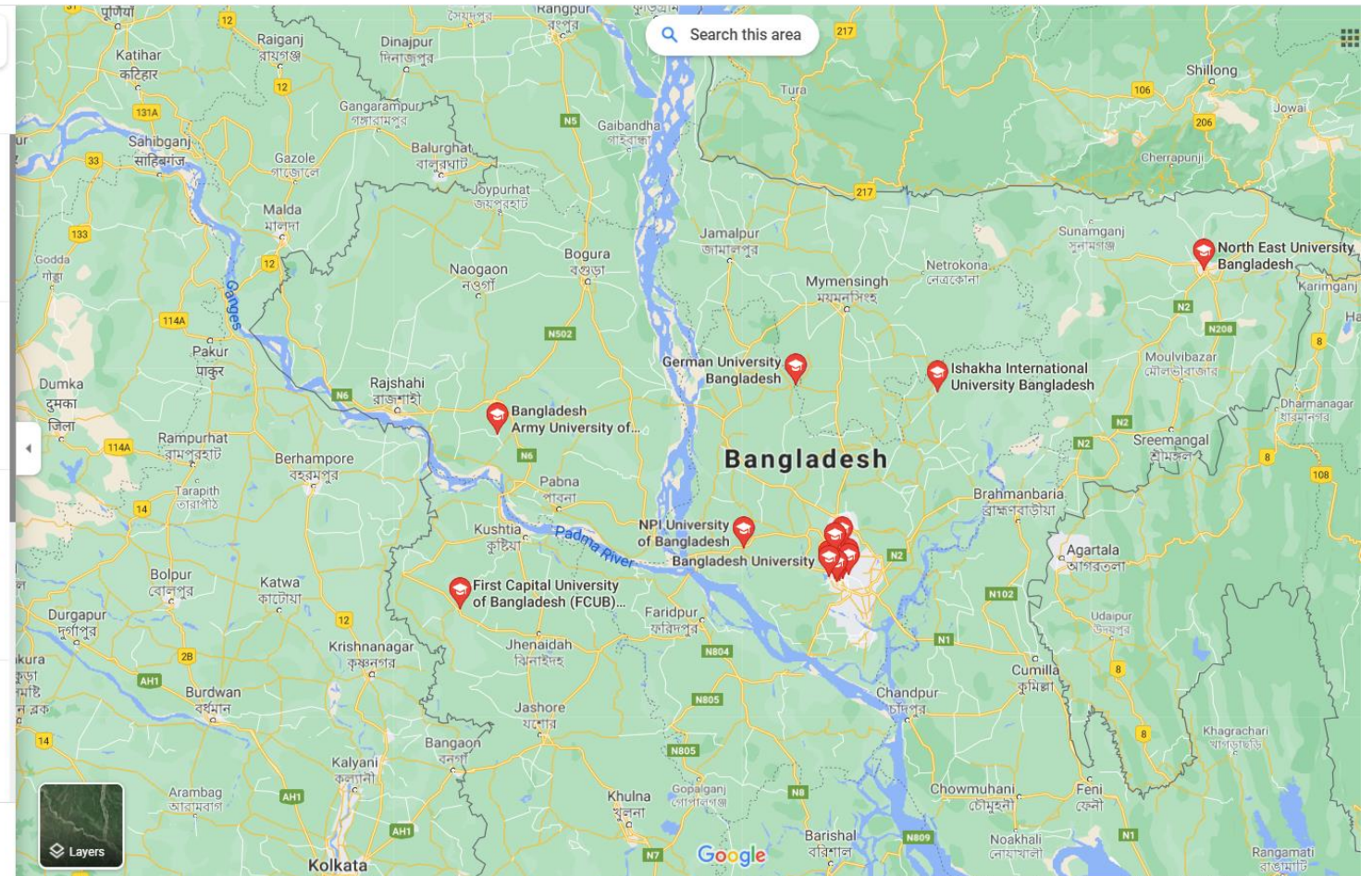
স্টেট ইউনিভার্সিটি অব বাংলাদেশ
4.1 ★★★★★ (226)
Private university · Sobhan Tower, 138 Mirpur Rd
Closed · Closed · Opens 9AM Thu · +880 1757-567992

World University of Bangladesh (WUB)
4.2 ★★★★★ (378)
Private university · Avenue 6 Lake Drive Uttara Sector 17H
Temporarily closed · +880 1752-102855

NPI University of Bangladesh
4.4 ★★★★★ (34)
University · V2C3+R52
Closed · Closed · Opens 9AM Thu · +880 1703-444111

Showing results 1 - 20

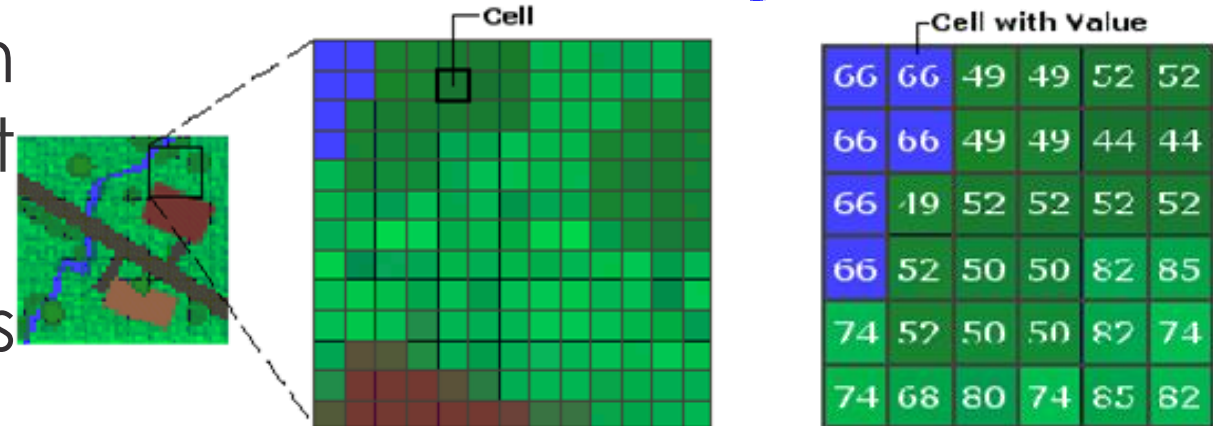
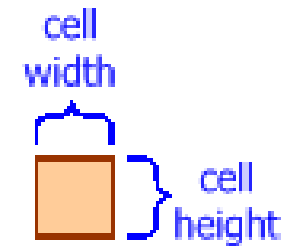
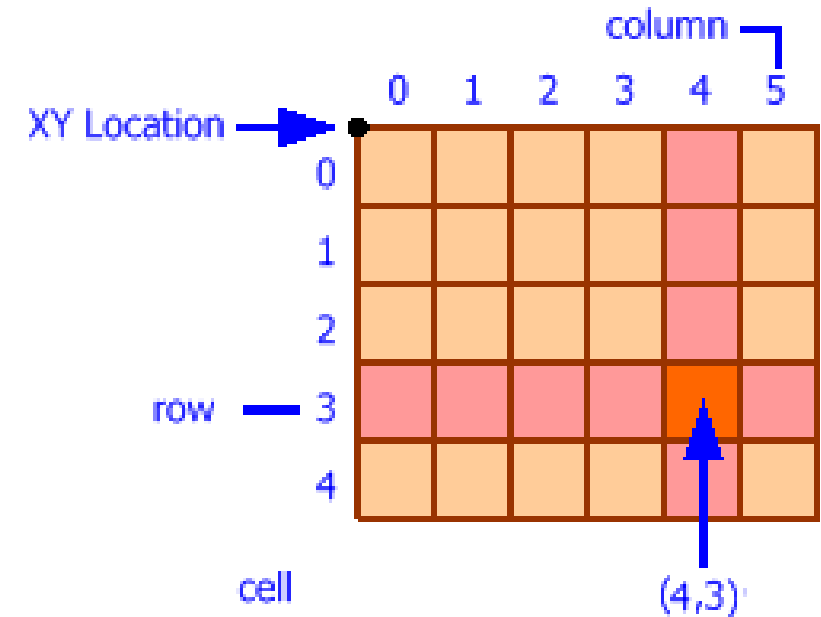
☐ Update results when map moves



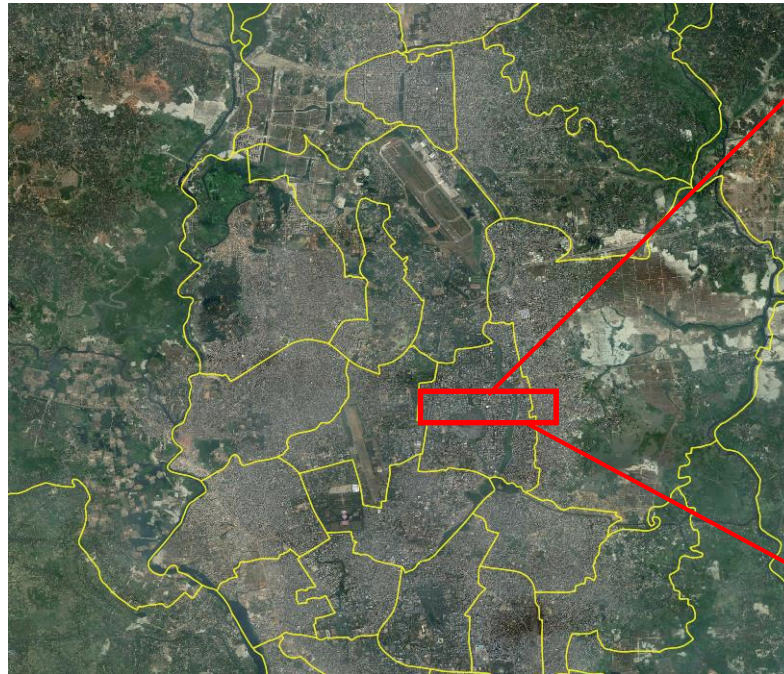
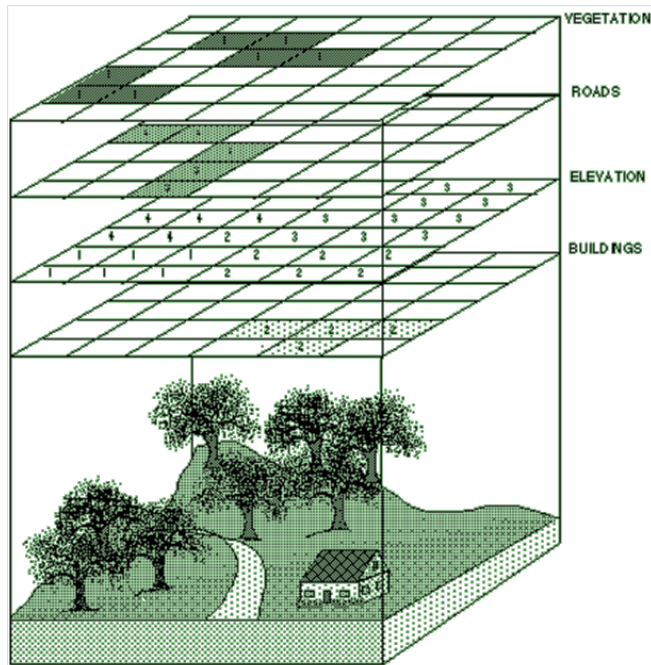
Spatial Data

Raster

- Defines space as an array of equally sized cells arranged in rows and columns.
- Each cell contains an attribute value and location coordinates
- Attribute value may be an elevation, land use class, plant biomass etc.
- The spatial resolution is determined by the size of the cell

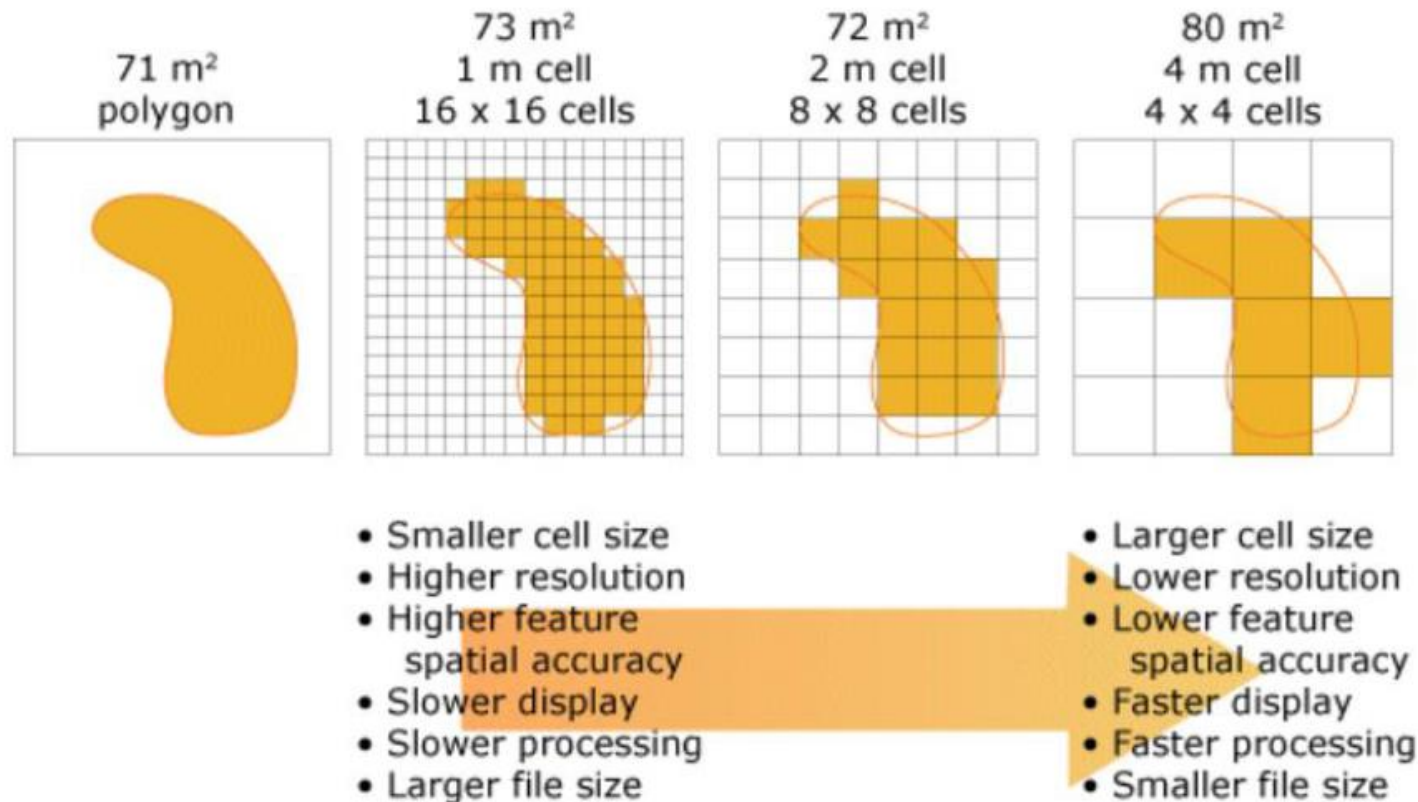


Spatial Data



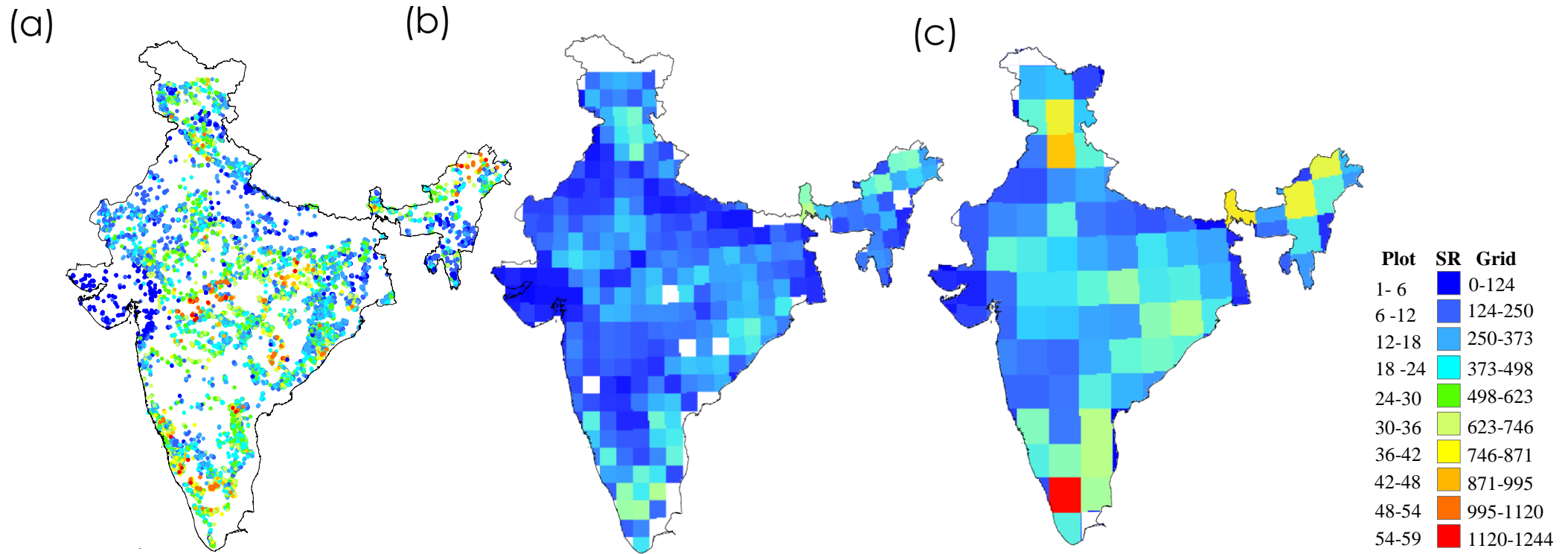
Structure of raster data model showing the matrix structure into row and column of the cells

Spatial Data



The spatial resolution is determined by the size of the cell

Spatial Data

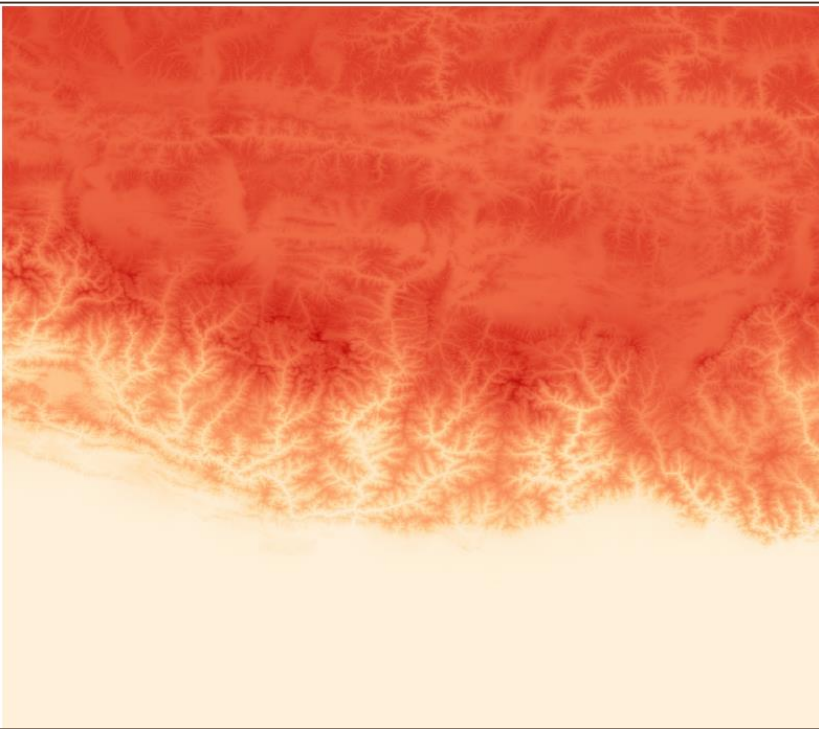


Plant species distribution in Indian mainland
(a) plot level (0.04 hac), (b) 1 degree grid, (c) 2 degree grid

Source: Tripathi et al., 2017



Spatial Data



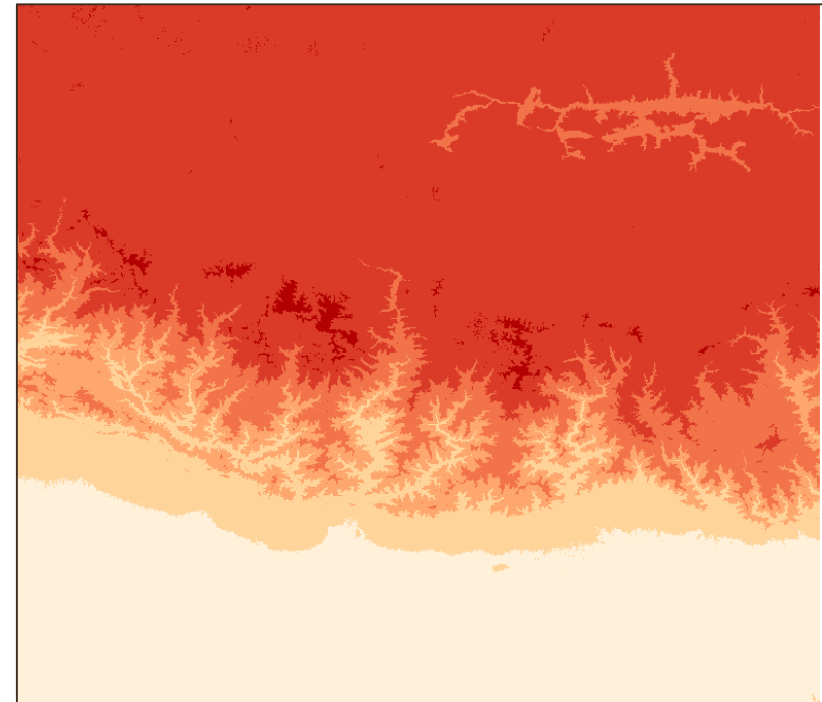
Two forms of raster data

1) Continuous Raster

- Numeric values ranges smoothly from one location to another
e.g. DEM, temperature etc.

2) Discrete Raster

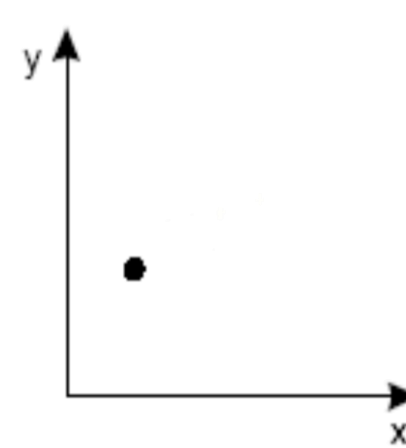
- Relative few possible values to repeat themselves in adjacent cells.
e.g. Soil type, Land use land cover type etc.



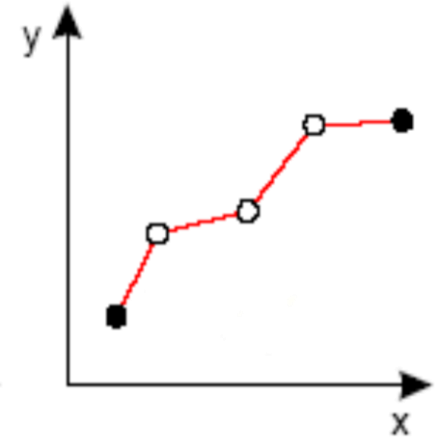
Spatial Data

Vector

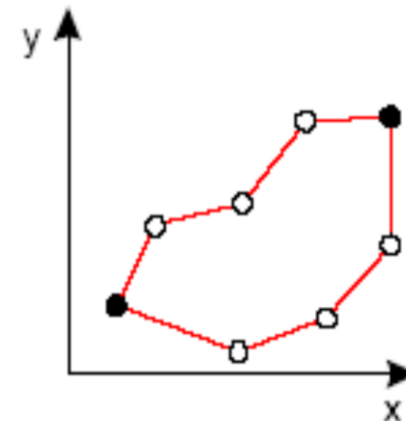
- Objects are represented as Points, Lines or Polygon
- The position of each object is defined by a (series of) coordinate pairs
- A point is described by a single X-Y coordinate pair and by its name or label e.g. buildings, trees etc.
- A line and polygon are described by a set of coordinate pairs and by their name and label e.g. streams, streets, sewers, forest, rock type etc.



Point



Line



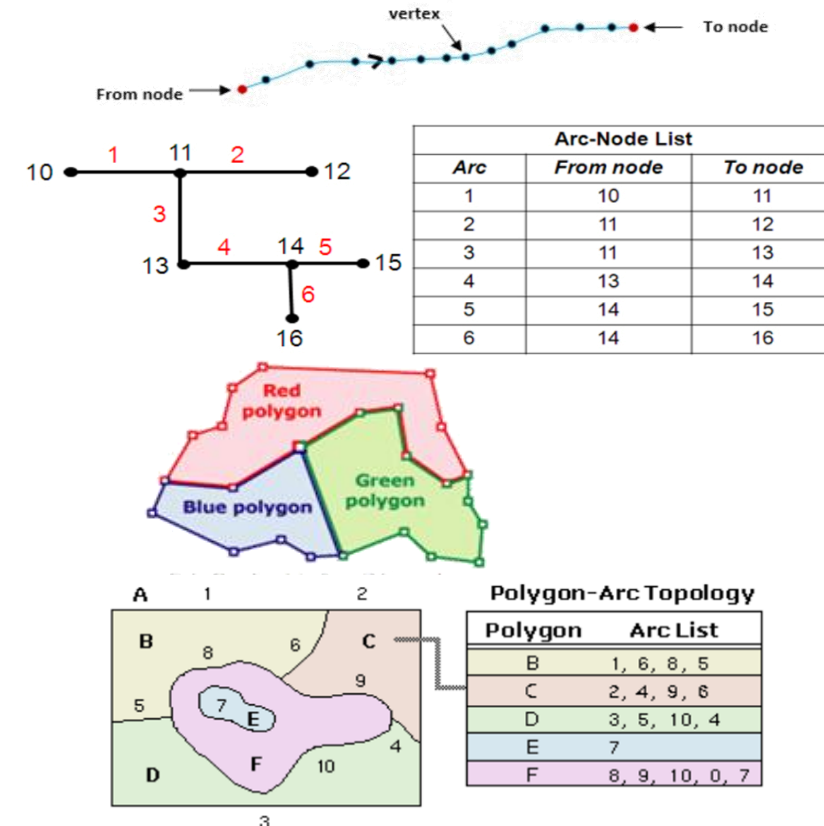
Area



Spatial Data

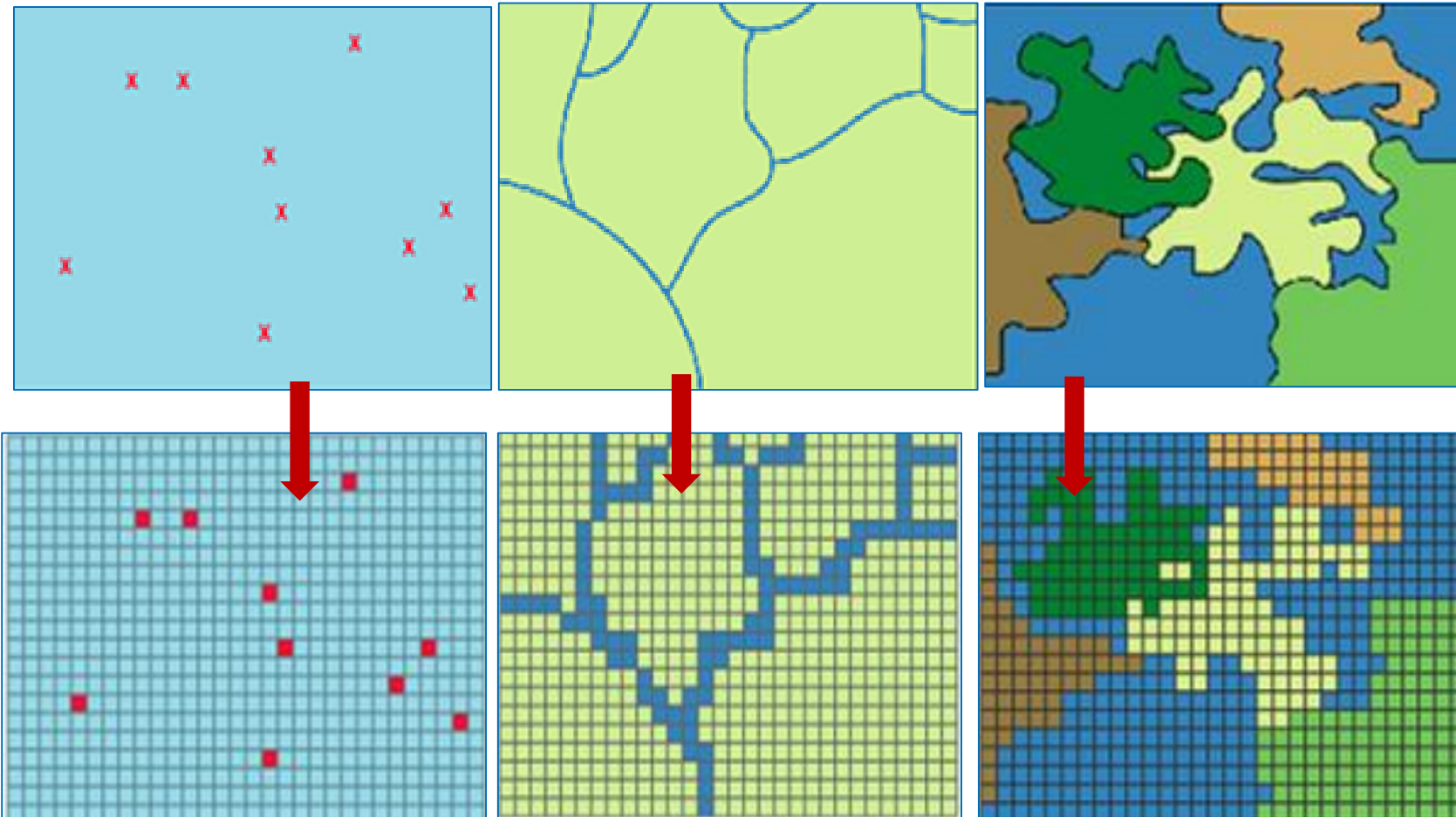
Topological property of vector data model

- **Connectivity** (Arc-node) : Information about linkages among spatial objects.
- Arc node topology supported through an arc-node list. For each arc in the list there is a from node and a to node.
- **Contiguity**: Polygons share a common arc. Contiguity allows the vector data model to determine adjacency
- **Containment** (Polygon-Arc) : Geographic features cover distinguishable area on the surface of the earth. An area is represented by one or more boundaries defining a polygon

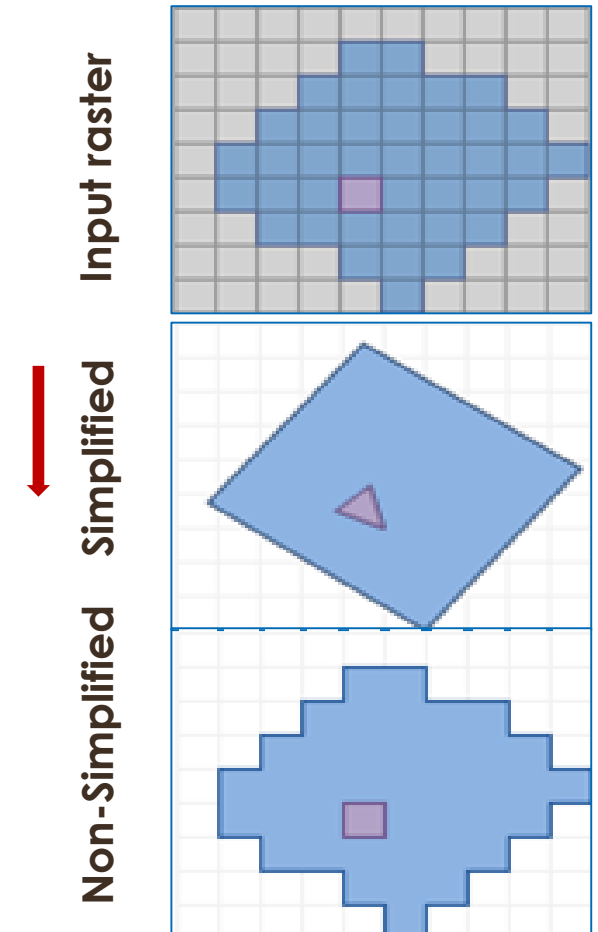


Spatial Data

Conversion of vector to raster



Conversion of raster to vector














Spatial Data





















		Raster	Vector	
Data structure	Advantage	Simple	Complex	Disadvantage
Overlaying		Easy and efficient	Difficult to perform	
Compatible with RS imagery		Yes	No	
High spatial variability		Efficient representation	In-efficient representation	
Programming by user		Yes	Complex	
Compact data structure	Disadvantage	No	Yes	Advantage
Efficient encoding of topology		No	Yes	
Easy editing		No	Yes	
Network analysis		In-efficient	Efficient	
Map output		Less accurate	Accurate	
Projection transformation		In-efficient	Efficient	

Spatial Data

Raster data file format

RASTER	File format
Esri Grid	 info File folder  tif1 File folder  TIF1.aux.xml XML Document  TIF1.ovr OVR File
Geographic Tagged Image File Format	 3/7/2019 3:19 PM TFW File  3/7/2019 3:19 PM TIF File  3/7/2019 3:19 PM XML Document  3/7/2019 3:19 PM OVR File
Imagine image	 TIF2.img Disc Image File  TIF2.img.aux.xml XML Document  TIF2.rdr RDR File
American Standard Code for Information Interchange (ASCII)	.asc
Hierarchical Data Format	.hdf
Network Common Data Form (NetCDF)	.nc
Joint Photographic Experts Group	.jpg

Vector data file format

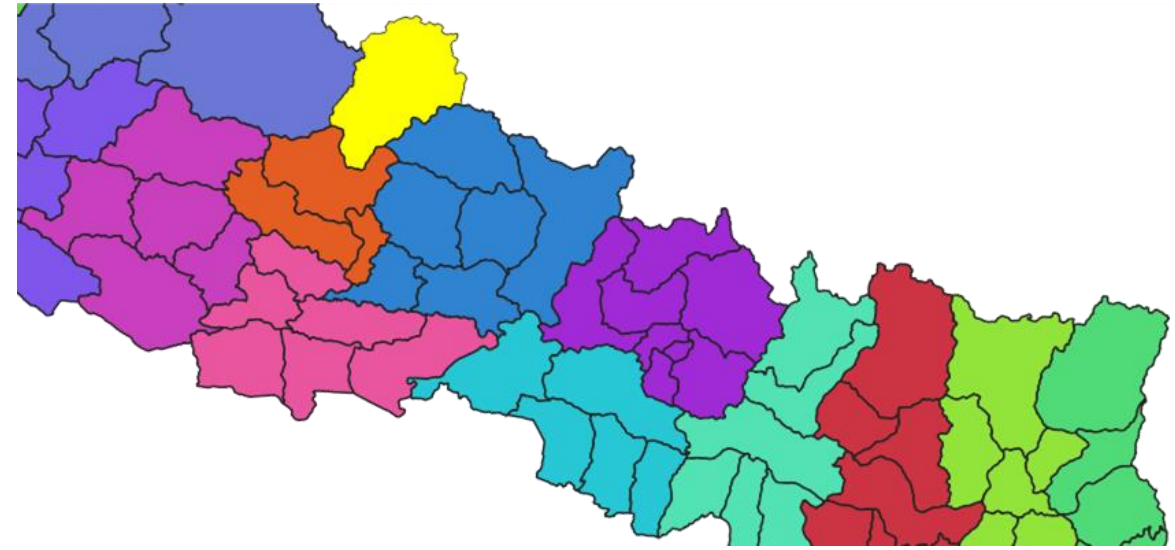
VECTOR	File format
Shape files	 Name  Lines.shp  Lines.dbf  Points.shp  Lines.shp  Polygons.shp  Lines.shx
Keyhole Markup Language (KML)	 FireStations.kmz
Layer	 Rivers.lyr
File Geodatabase	 geodatabase.gdb  data  Line } Feature Class  Point }  Polygon }  Relationship } Relationship
ArcInfo Coverage	 coverage  arc  label  polygon  region.area tic
E00 ArcInfo Interchange	polygon.e00



Non-Spatial Data

Attribute Data

- Commonly arranged in tables where a row is equivalent to one entity and a column is equivalent to one **attribute, or descriptor**, of that entity
- Typically, each row relates to a **single object** and a geospatial data model
- Usually each object will have **multiple attributes** that describe the object

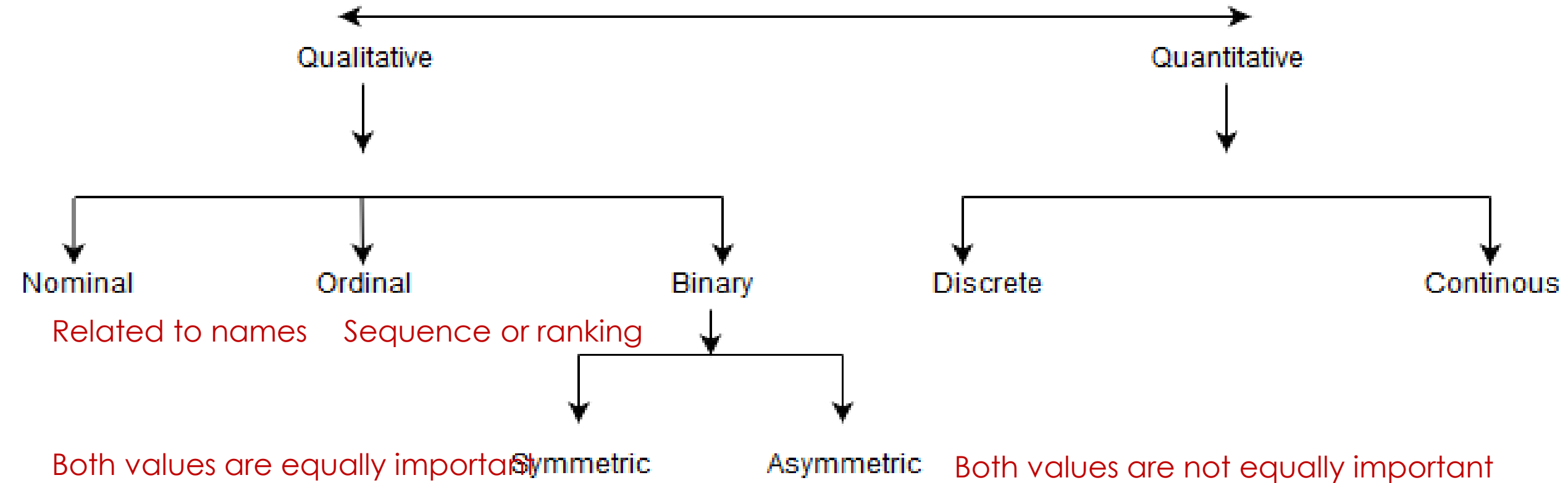


Nepal_population :: Features Total: 75, Filtered: ...

	DISTRICT▼	POP_91	POP_81	TPOP_01	POP_011	st_COI	ZONE
31	MUSTANG	14292	12930	14981	13799	48	DHAWALA...
32	MUGU	36364	43705	43937	55311	53	KARNALI
33	MORANG	674823	534692	843220	964709	9	KOSHI
34	MANANG	5363	7021	9587	6527	39	GANDAKI
35	MAKAW...	314599	243411	392604	427494	34	NARAYANI
36	MAHOTT...	440146	361054	553481	646405	21	JANAKPUR
37	LAMJUNG	153697	152720	177149	169104	37	GANDAKI

Non-Spatial Data

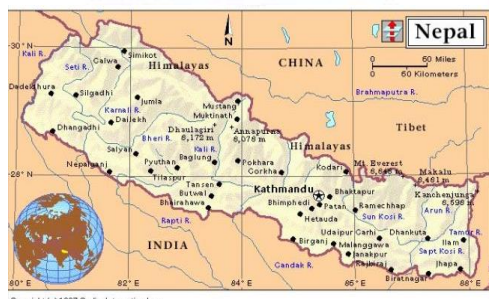
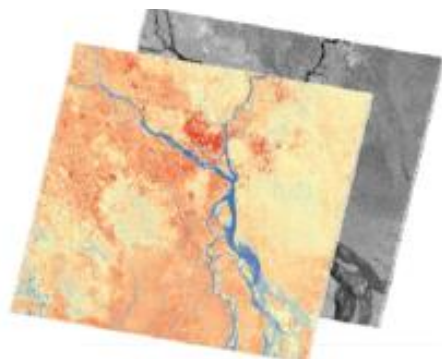
Attribute Data Type



- **Date:** This data type stores dates and times in the format as 'mm/dd/yyyy hh:mm:ss'



GIS data capture and update of Vector feature



Raster		Vector
Digital Remote sensing images	Primary	GPS measurements
Digital Aerial photographs		Survey measurements
Scanned Maps	Secondary	Topographic surveys
DEM from Images		Toponymy data from atlases



- LULC
- Crop types
- Census
- Biomass



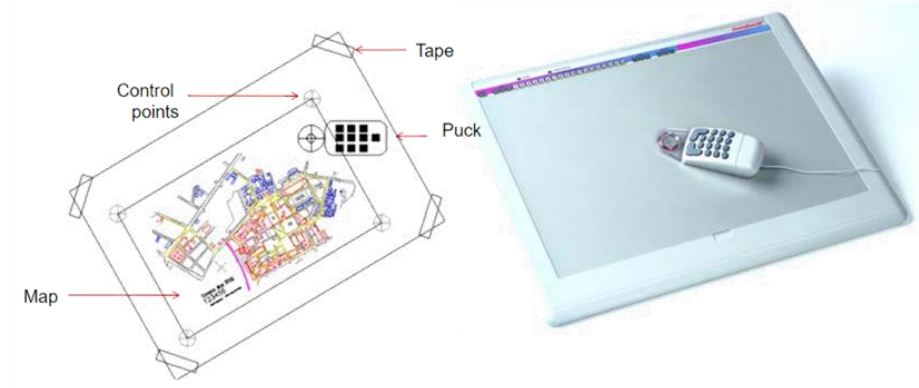
GIS data capture and update of Vector feature

Digitization: Process of converting geographic data into vector data by tracing the features from a hardcopy, digital or a scanned image

a) Manual:

- 1) **Tablet Digitization** :Involves placing a digitizing puck over a location on the tablet and presses one of the buttons on the puck to record the location of the feature of interest
- 2) **On-screen Digitization**: User generates vector data on desktop GIS by clicking on features that defines the entity

b) Automated digitization : Scanning and vectorization



Digitalization Errors

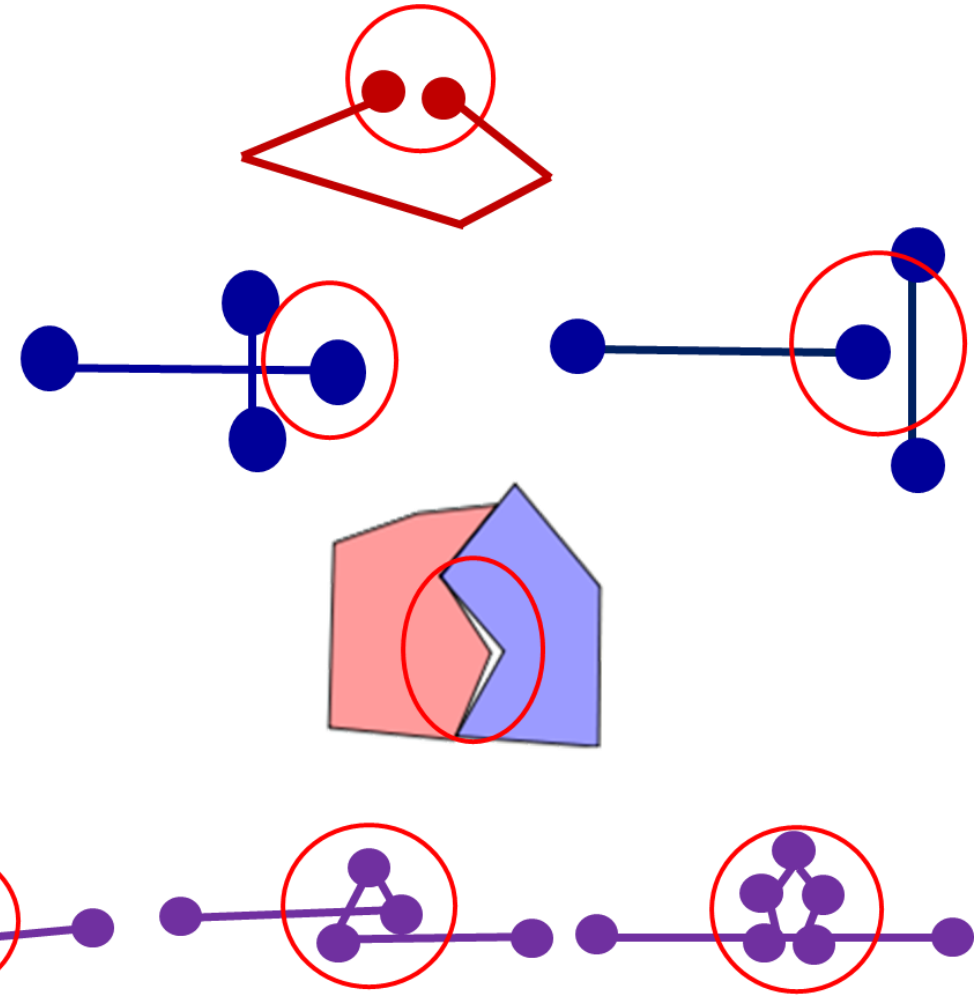
(1) Dangles: Lines that are not connected

(2) Overshoots: Overextended line

(3) Undershoots: Gap exists between two intersecting line

(4) Slivers: Gaps between two adjoining polygons

(5) Switchbacks, Knots, and Loops: Digitized line with extra vertices and/or nodes due to unsteady hand of the digitizer



Coordinate systems

A reference system to represent the locations of geographic features

Each coordinate system is defined by:

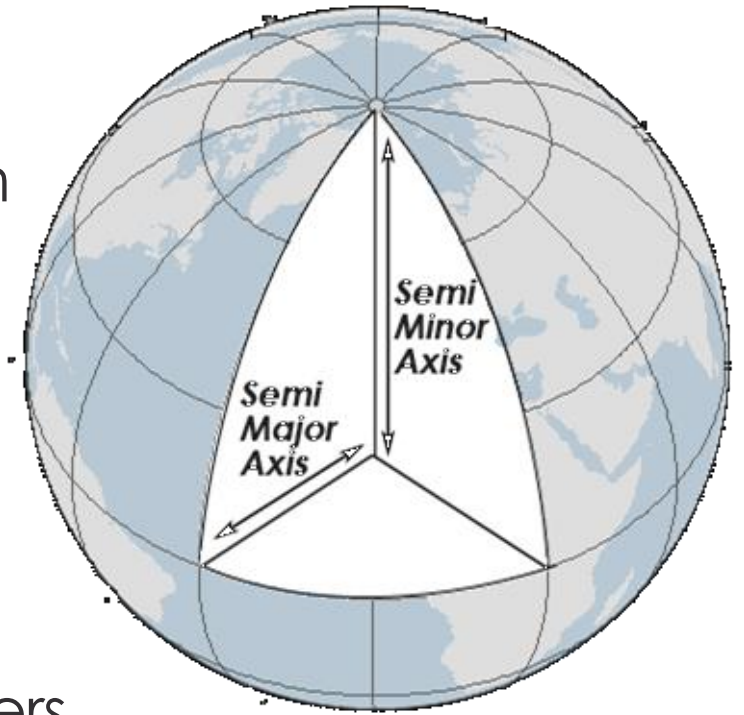
1) Measurement framework

a) Geographic: Spherical coordinates are measured from the earth's center

b) Planimetric: Earth's coordinates are projected onto a two-dimensional planar surface

2) Unit of measurement

3) Other measurement system properties such as a spheroid of reference, a datum, and projection parameters like one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions

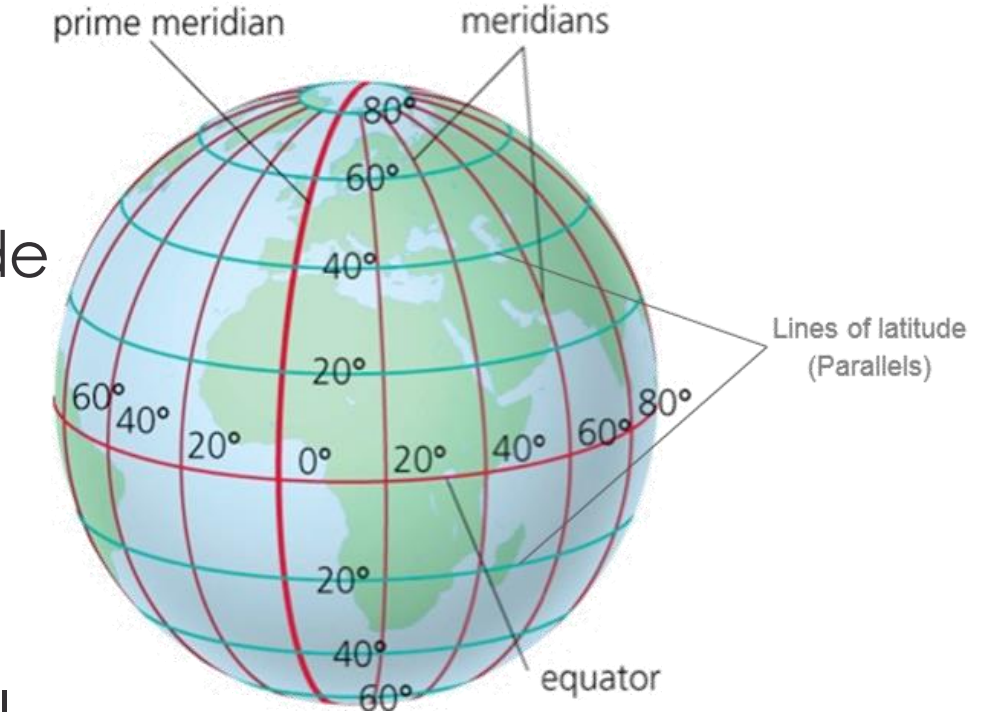


Representation of globe showing parallels and meridians lines

Coordinate systems

Geographic Coordinate System (GCS)

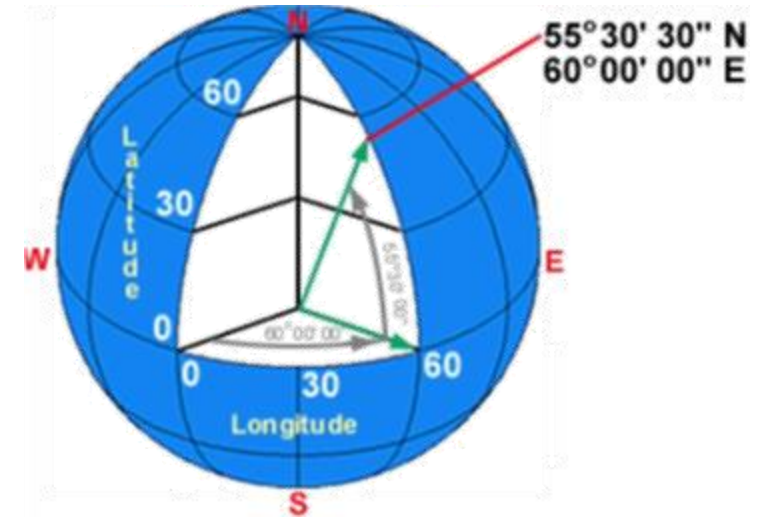
- Three-dimensional spherical surface to define locations on the earth
- A point is referenced by its longitude and latitude values that are the angles measured from the earth's center to a point on the earth's surface
- Vertical lines (north–south) are the lines of longitude, or meridians
- Horizontal lines (East–West) are the lines of equal latitude, or parallels



Coordinate systems

Geographic Coordinate System (GCS)

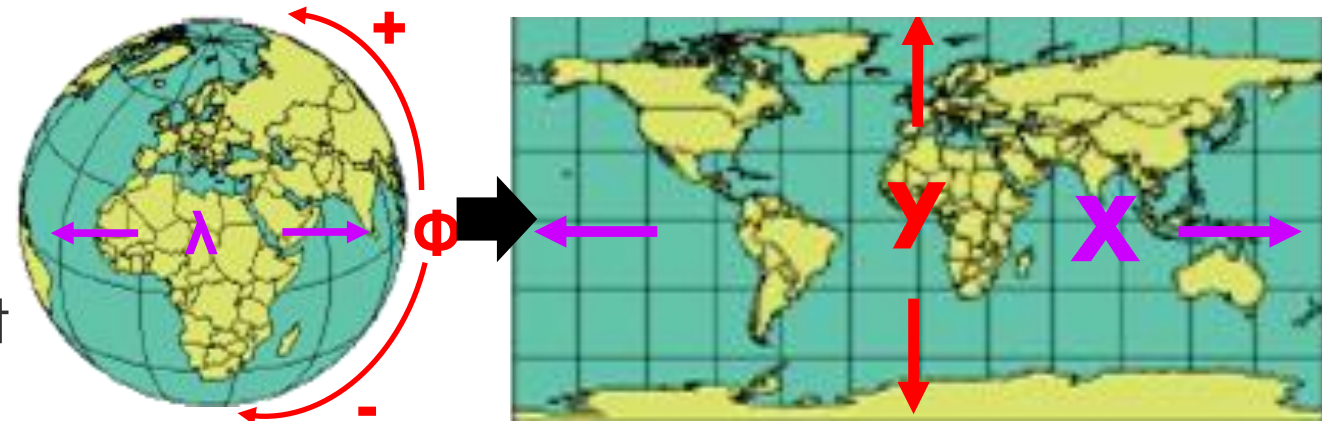
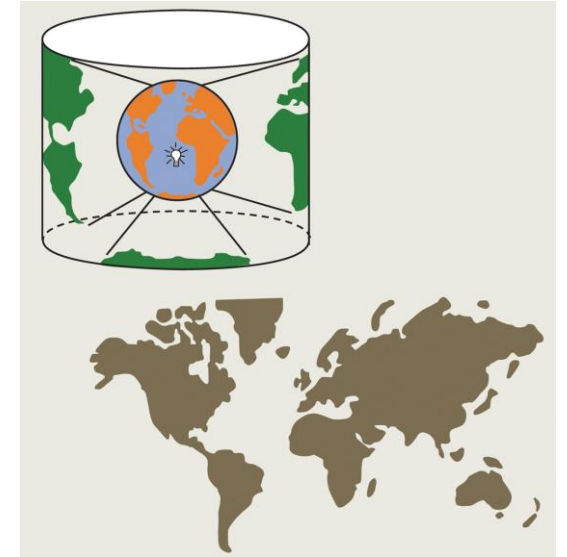
- The line of **latitude** midway between the poles is called the **equator**
- The **prime meridian (zero longitude)** is the longitude that passes through Greenwich, England
- The origin of the graticule (0, 0) is defined by where the equator and prime meridian intersect
- Coordinate value can be specified in **DMS**(degree, minutes, seconds) or DD (degree decimal)
- Directions can be specified using **E** (east), **W** (west), **N** (north), **S**(south) or by sign **plus (+)** or **minus (-)**



Coordinate systems

Projected Coordinate System (PCS)

- PCS is a reference system for transforming the spherical three-dimensional earth into two-dimensional planar surfaces
- Measuring features on a flat (map) surface
- PCS has constant lengths, angles, and areas across the two dimensions
- Locations are identified by planar x, y coordinates on a grid, with the origin at the center of the grid
- The two values are called the x-coordinate and y-coordinate

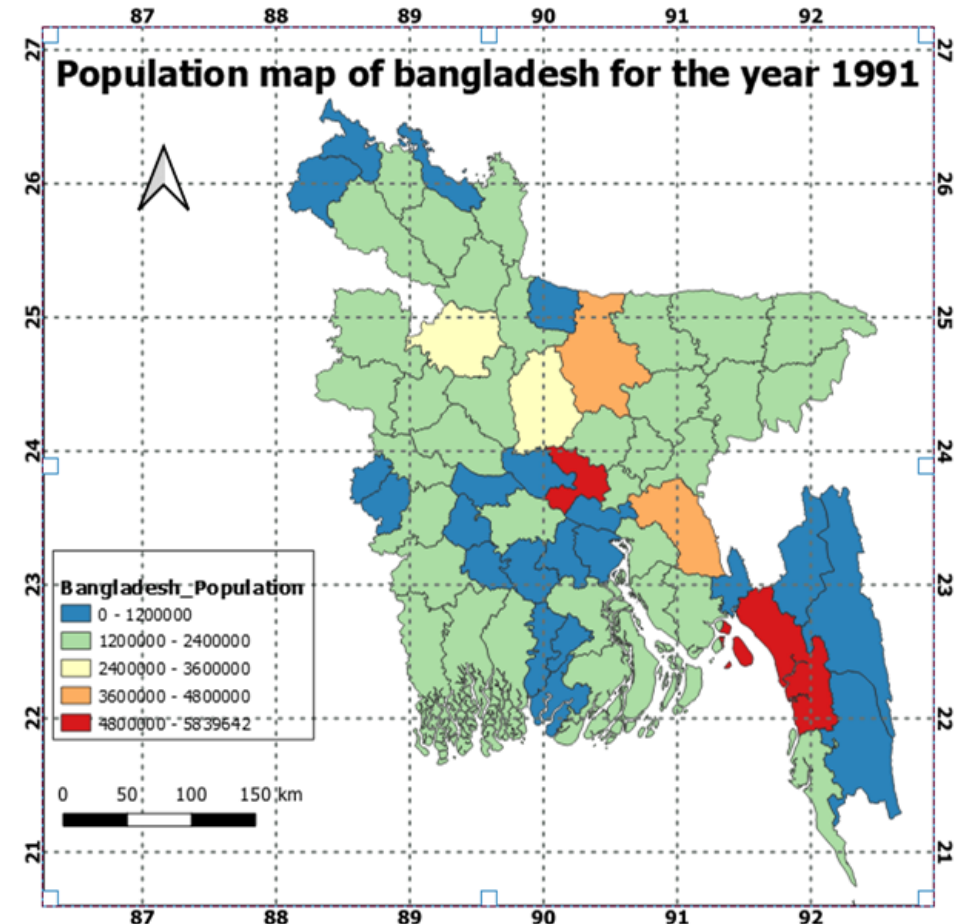


Map Production

Process of arranging Map elements on a sheet of paper

Properties

- Data frame
- Title
- Legends
- Scale
- North Arrow
- Co-ordinates



Applications of GIS

- Mapping and monitoring
- Environmental Impact Analysis
- Biodiversity Assessment
- Agricultural Applications
- Fire Risk Modelling
- Disaster Management and Mitigation
- Hazard and risk modelling
- GIS for Planning and Community Development etc.



Vaccine doses administered worldwide
4,76,10,25,054

Confirmed cases worldwide
20,78,82,955 +5,34,127

● Active cases
● Fatal cases
Updated 15 min ago

Browse Sort

- Filter to a location
- Global 20,78,82,955
 - Bangladesh 14,25,861
 - United States 3,73,45,854
 - India 3,22,49,900

Bangladesh ☆

Cases Vaccines News & Videos Graphs

Overview

Vaccine doses administered

2,09,92,637

Fully vaccinated 3.48%
Received at least one dose 9.97%

Total confirmed cases

14,25,861 +6,959

Active cases 99,546 -2,483
Fatal cases 24,349 +174

Trends

spread trends

New cases

All time

Bangladesh

Total cases 14,25,861
Active 99,546
Recovered 13,01,966
Fatal 24,349

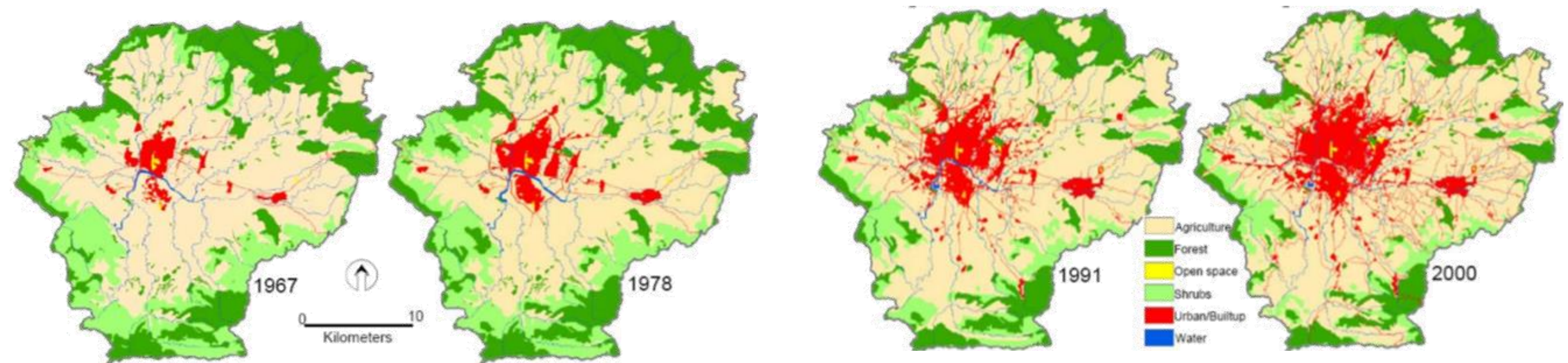
1. Mapping and monitoring a. Pandemic



Applications of GIS

Mapping and monitoring

b. Urban Growth

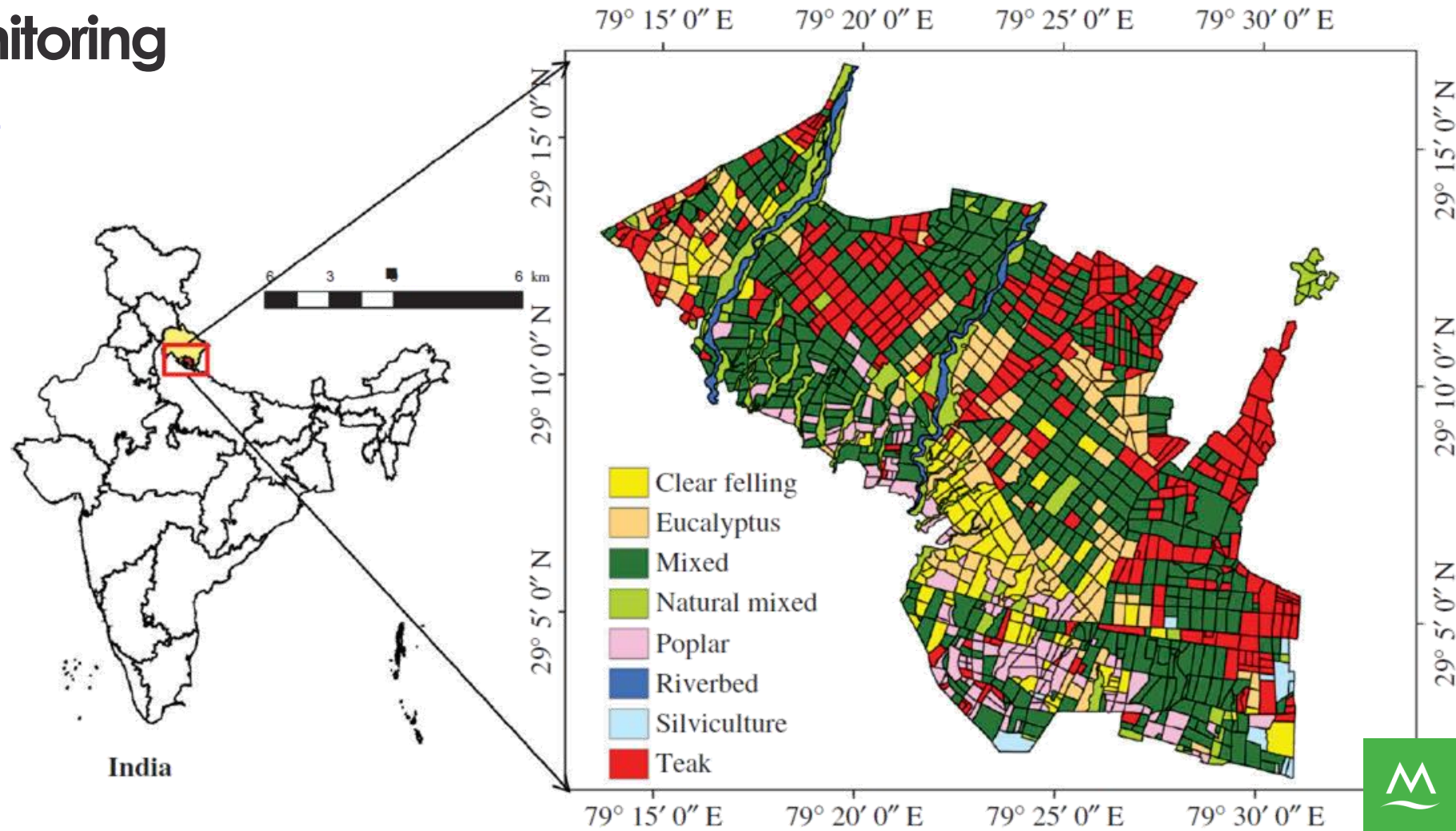


Land use maps of Kathmandu Valley, 1967-2000

Applications of GIS

Mapping and monitoring c. Vegetation type

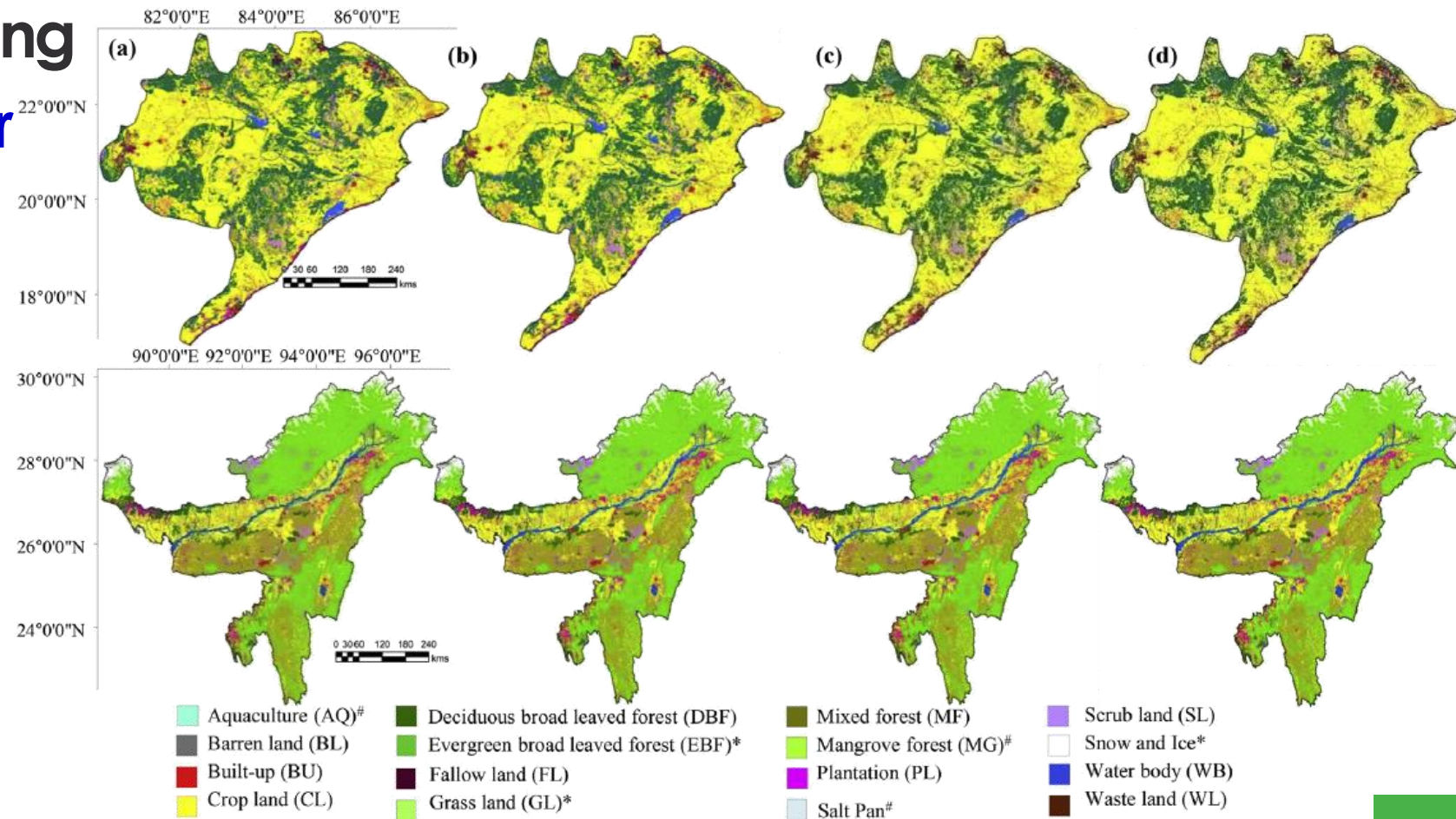
Plantation types of
Terai Central Forest
Division Nainital,
Uttarakhand, India



Applications of GIS

Mapping and monitoring d. Land use land cover

Classified LULC map of Mahanadi and Brahmaputra river basins for the year (a) 1985 (b) 1995 (c) 2005; and (d) predicted- 2025



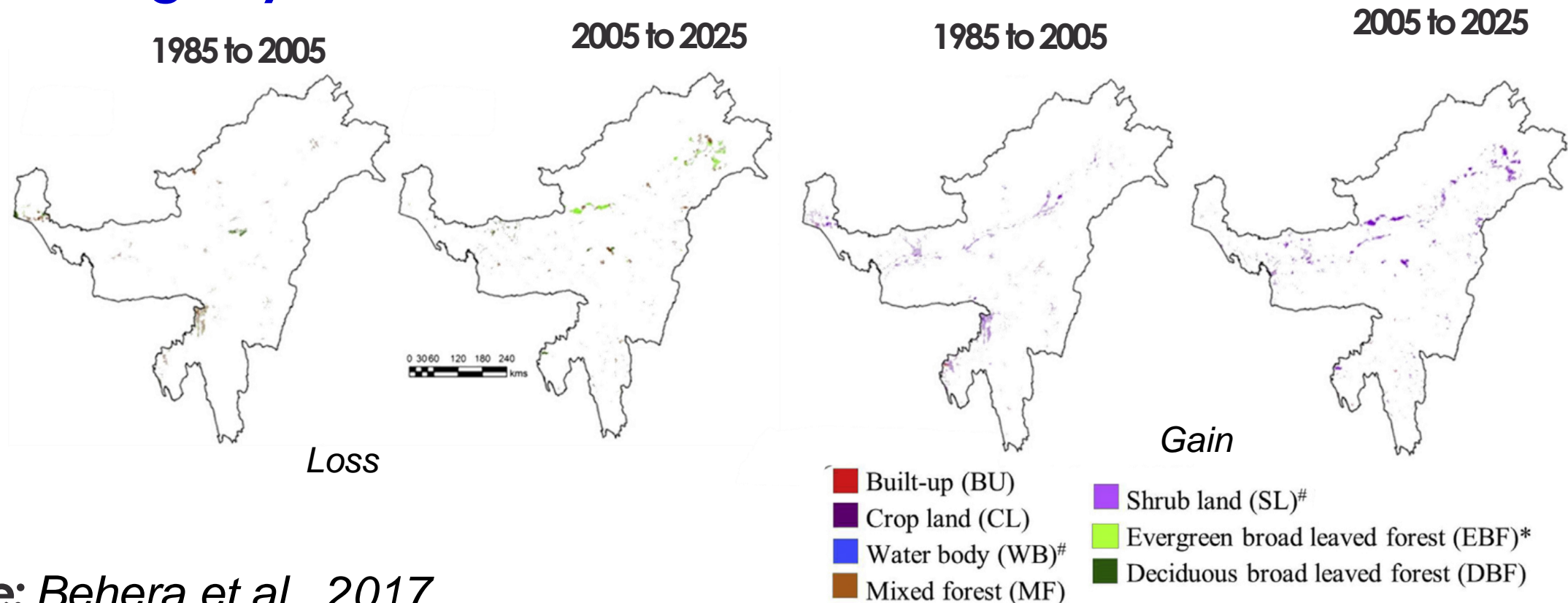
Source: Behera et al., 2017



Applications of GIS

Mapping and monitoring

e. Change dynamics



Source: Behera et al., 2017



Applications of GIS

2. Fire risk modeling

Equation used for modelling

$$FRI = 10LCR + 6TR + 4(SDR + RDR) + 2(ER + SLR)$$

LCR: land cover rating

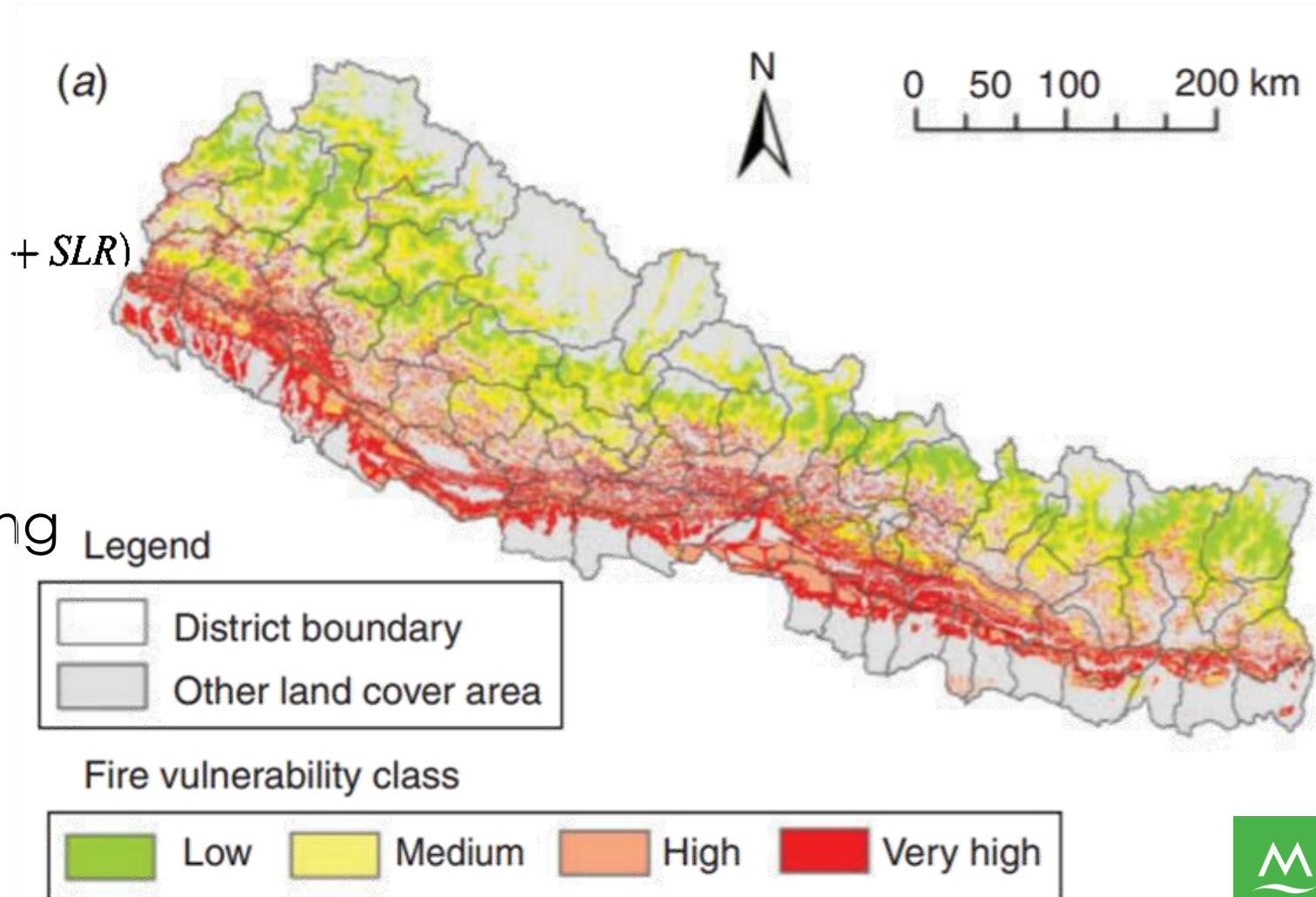
TR: temperature rating

SDR: settlement distance rating

RDR: road distance rating

ER: elevation rating

SLR: slope rating

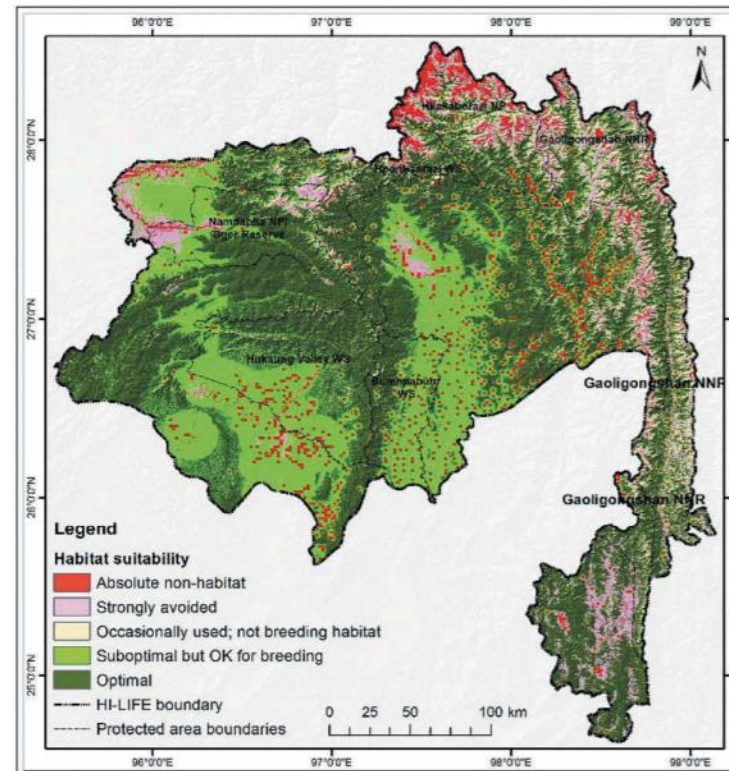


Applications of GIS

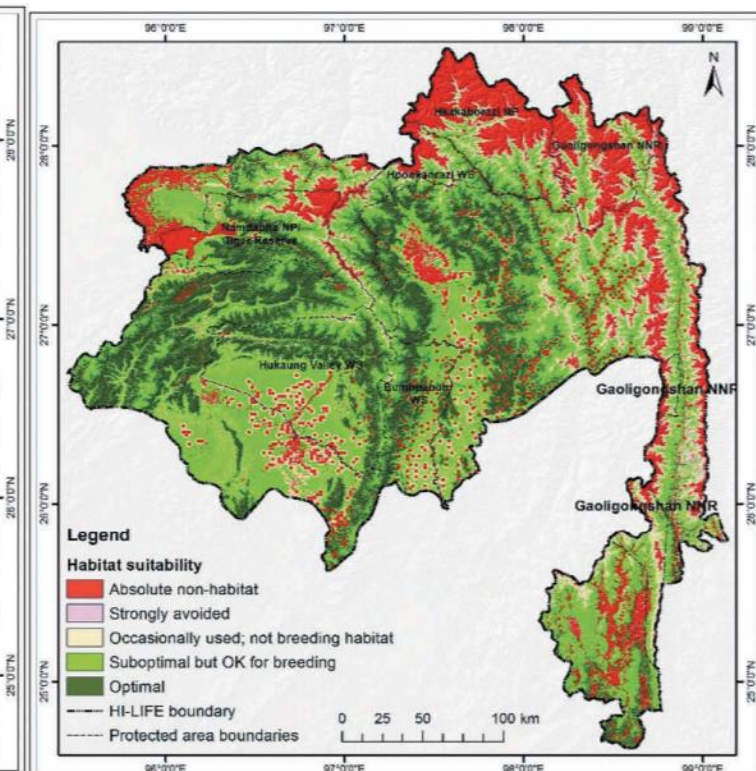
3. Habitat Suitability Analysis

- Suitability scores assigned to each of the factors (e.g., land cover types, topographic position classes) paying particular attention to the suitability
- A numerical **weighting factor** was assigned to each thematic layer according to the relative importance of habitat suitability.

Source: Uddin et al., 2019



Himalayan black bear



Leaf deer



Applications of GIS

4. Risk & Hazard Analysis

Flood susceptibility analysis

(Markham river basin, New Guinea)

Equation used for modelling

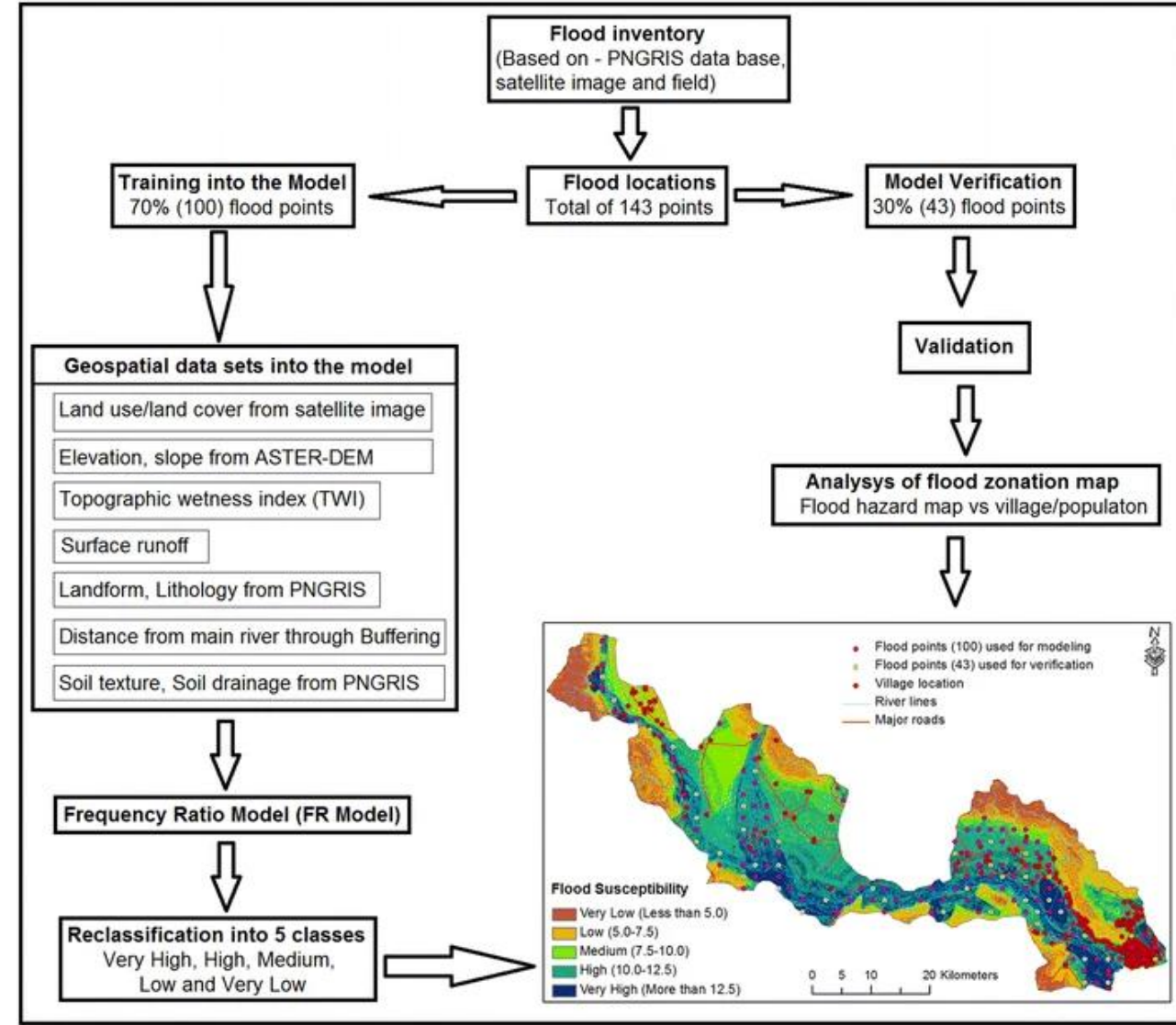
$$FSI = \sum FR,$$

where FSI is the flood susceptibility index and FR is the frequency ratio for each factor.

$$FR = (E/F)/(M/L),$$

where E is the number of flood episodes for each factor; F is the total number of flood episodes; M is the histogram of a class; L is the total histogram of the study area.

Source: Samanta et al., 2018



Applications of GIS

4. Risk & Hazard Analysis

$$W_i = \ln \frac{\text{Density of landslide within a class of a factor}}{\text{Density of landslide within the study area}}$$

$$= \ln \frac{\frac{N_{pix}(S_i)}{N_{pix}(N_i)}}{\frac{\sum N_{pix}(S_i)}{\sum N_{pix}(N_i)}}$$

Where, W_i = Weight of a factor class;

$N_{pix}(S_i)$ = Number of pixel of landslide within class i;

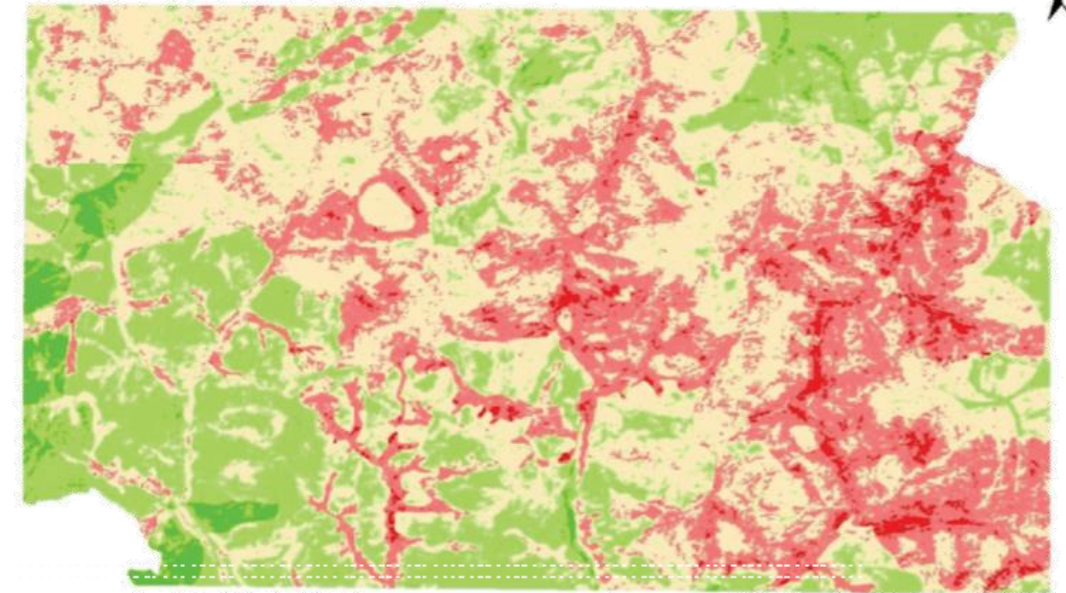
$N_{pix}(N_i)$ = Number of pixel of class i;

$\sum N_{pix}(S_i)$ = Number of Pixel of landslide within the whole study area;

$\sum N_{pix}(N_i)$ = Number of pixel of the whole study area.

Class	LSI value	Description	Area in Square Kilometers	% Area of Map
1	-14.1493 to -9	Very Low	23.5449	1.81
2	-9 to -4	Low	330.9489	25.41
3	-4 to 0	Medium	602.1585	46.23
4	0 to 3	High	326.8251	25.09
5	3 to 8.5718	Very High	18.9441	1.45

Landslide Susceptibility Index Map



Landslide Susceptibility Class



Source: Bibek et al., 2015



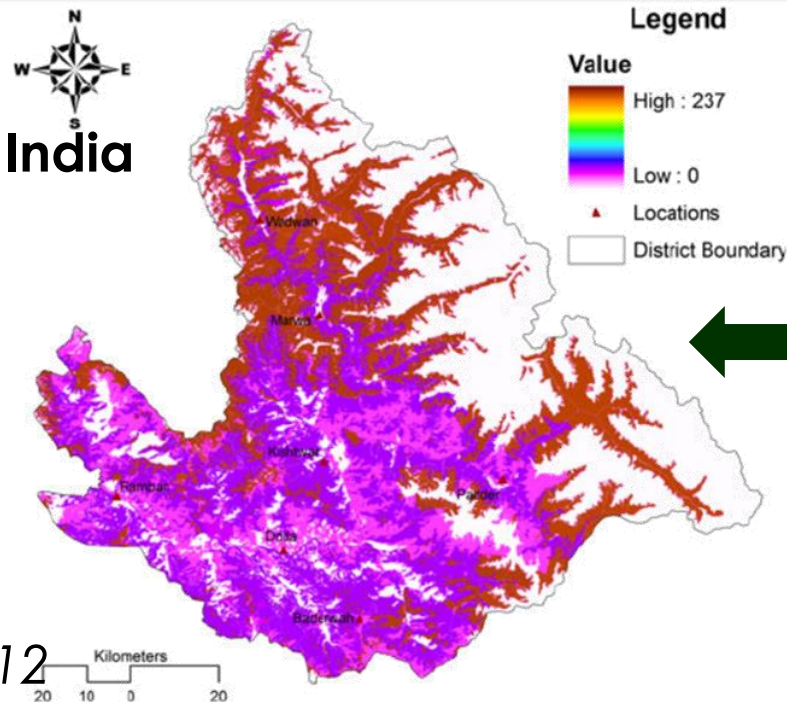
Applications of GIS

5. Biodiversity Analysis

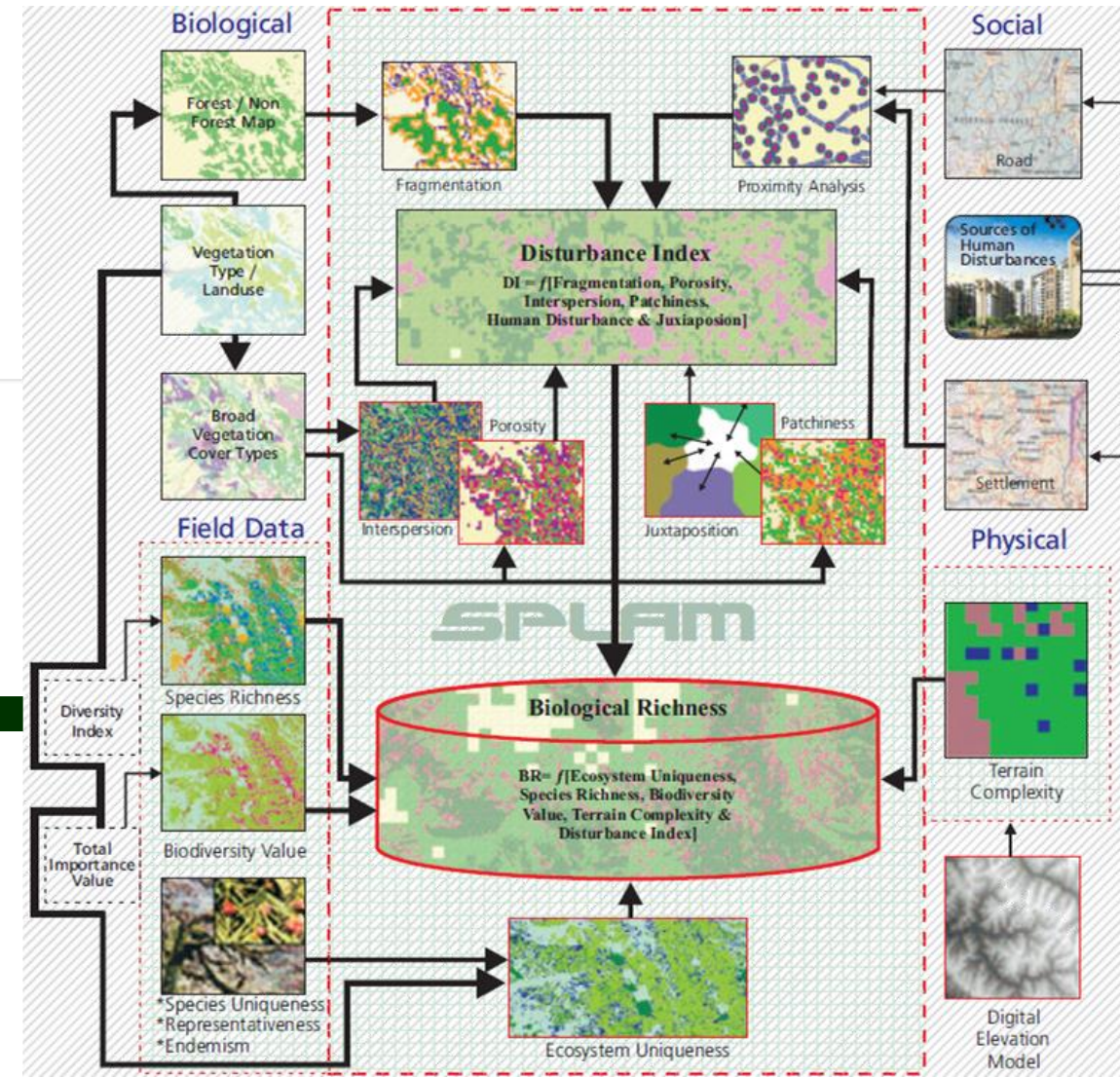
$$BR = \sum_{i=1}^n (DI_i \times wt_{i1} + TC_i \times wt_{i2} + SR_i \times wt_{i3} + BV_i \times wt_{i4} + EU_i \times wt_{i5})$$

where BR = Biological Richness, DI = Disturbance Index, TC = Terrain Complexity, SR = Species Richness, BV = Biodiversity Value, EU = Ecosystem Uniqueness, and wt = Weights.

Doda district, Jammu, India

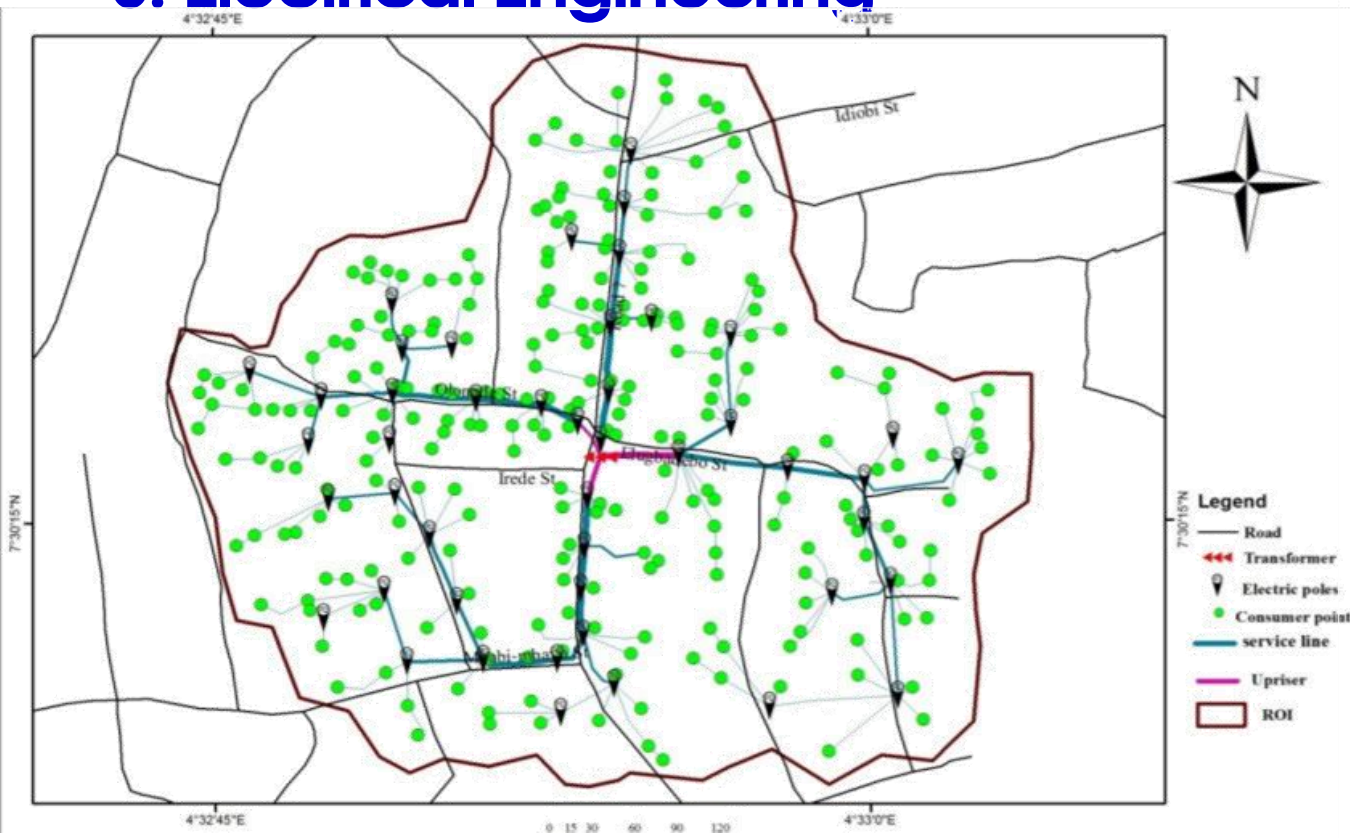


Source: Roy et al., 2012



Applications of GIS

6. Electrical Engineering



Electricity distribution network map



Power consumption map

Source: Adejoh et al., 2015





Thank you

Let's protect
the pulse.