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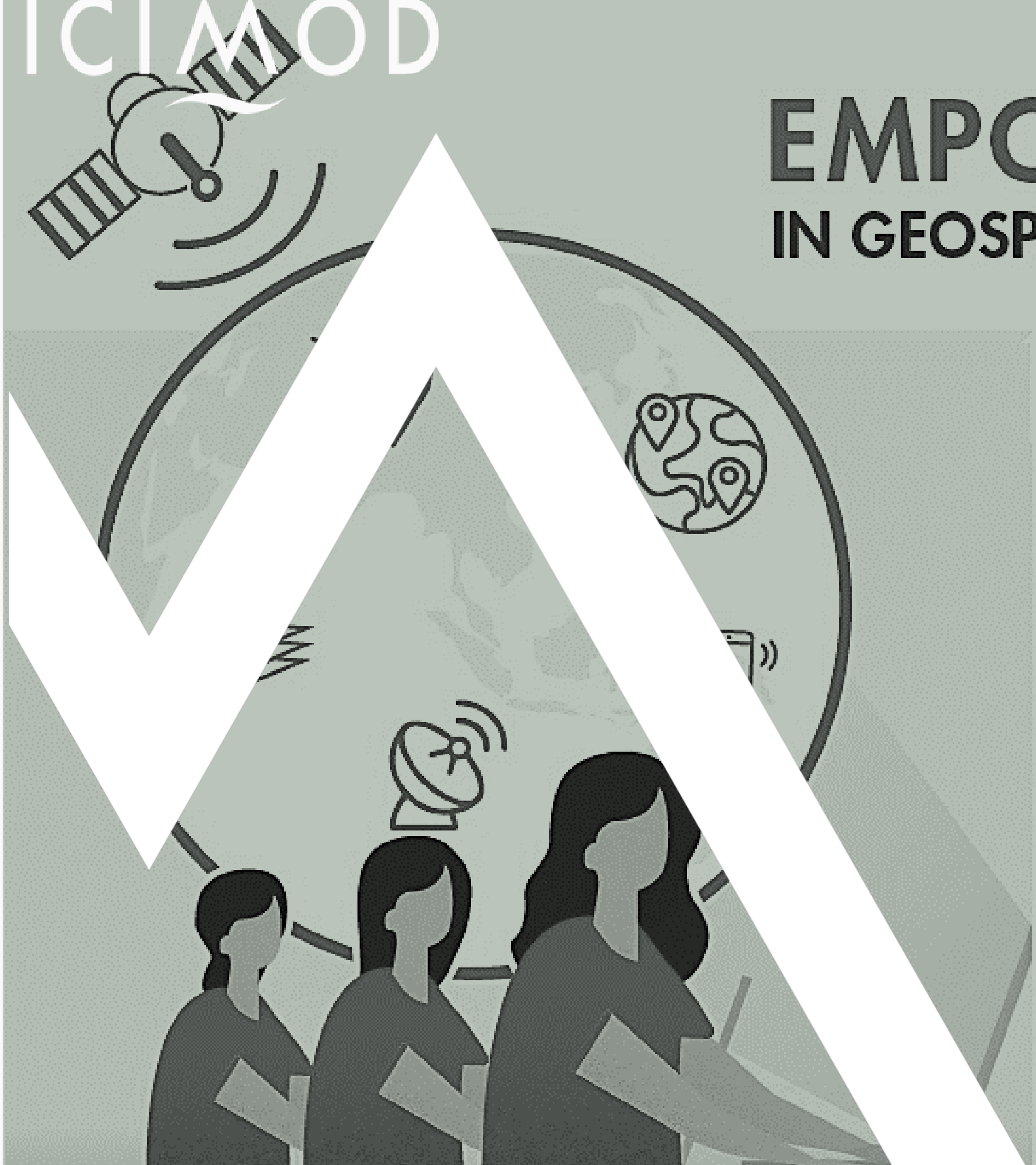


EMPOWERING WOMEN
IN GEOSPATIAL INFORMATION TECHNOLOGY

GIS concepts and applications

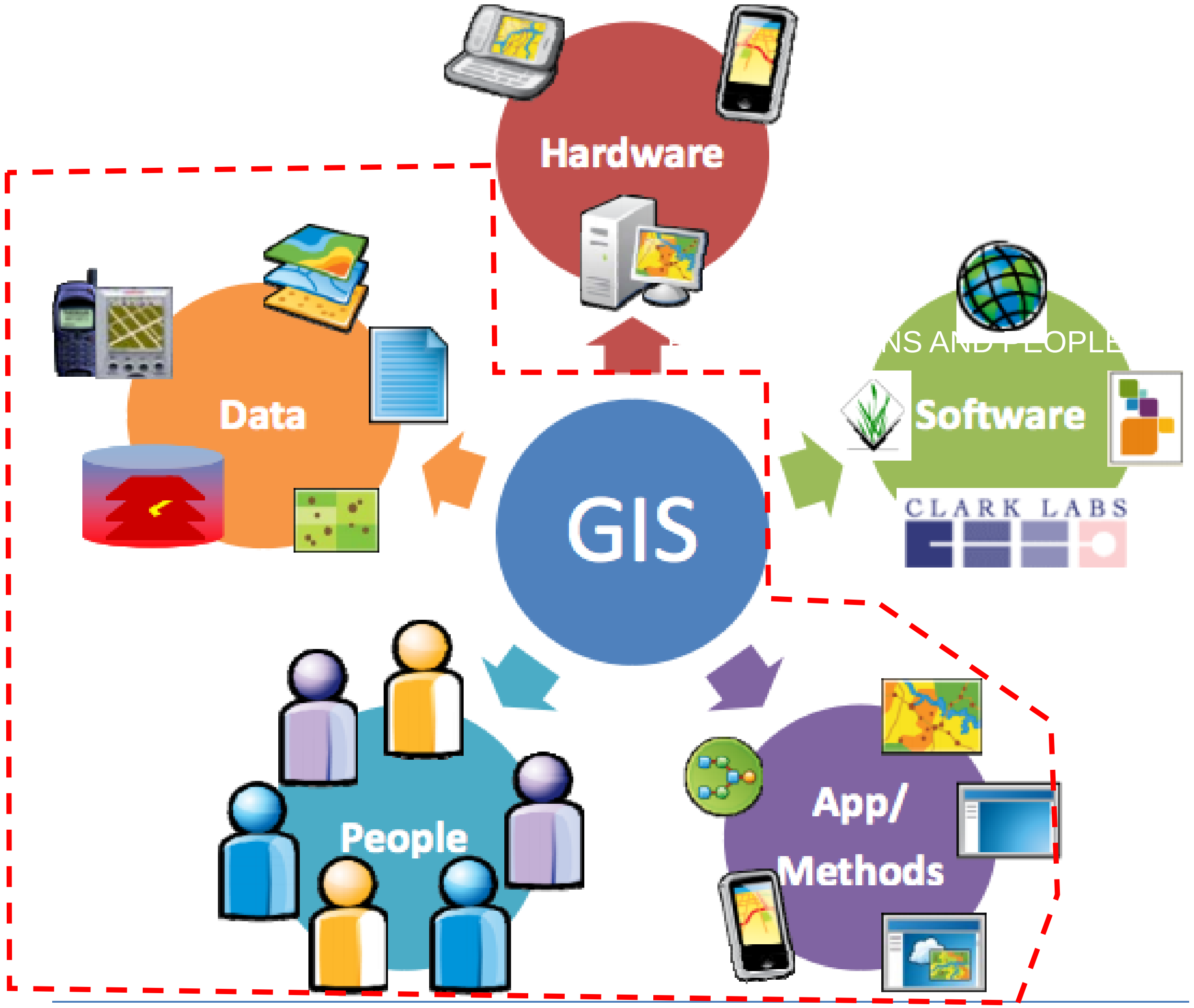
19 May 2020

Dr. Poonam Tripaathi
Training Analyst,
Geospatial Solutions, ICIMOD

What is GIS?

An organized integration of

- Hardware
- Software and
- Geographic system



GEOGRAPHIC- Location

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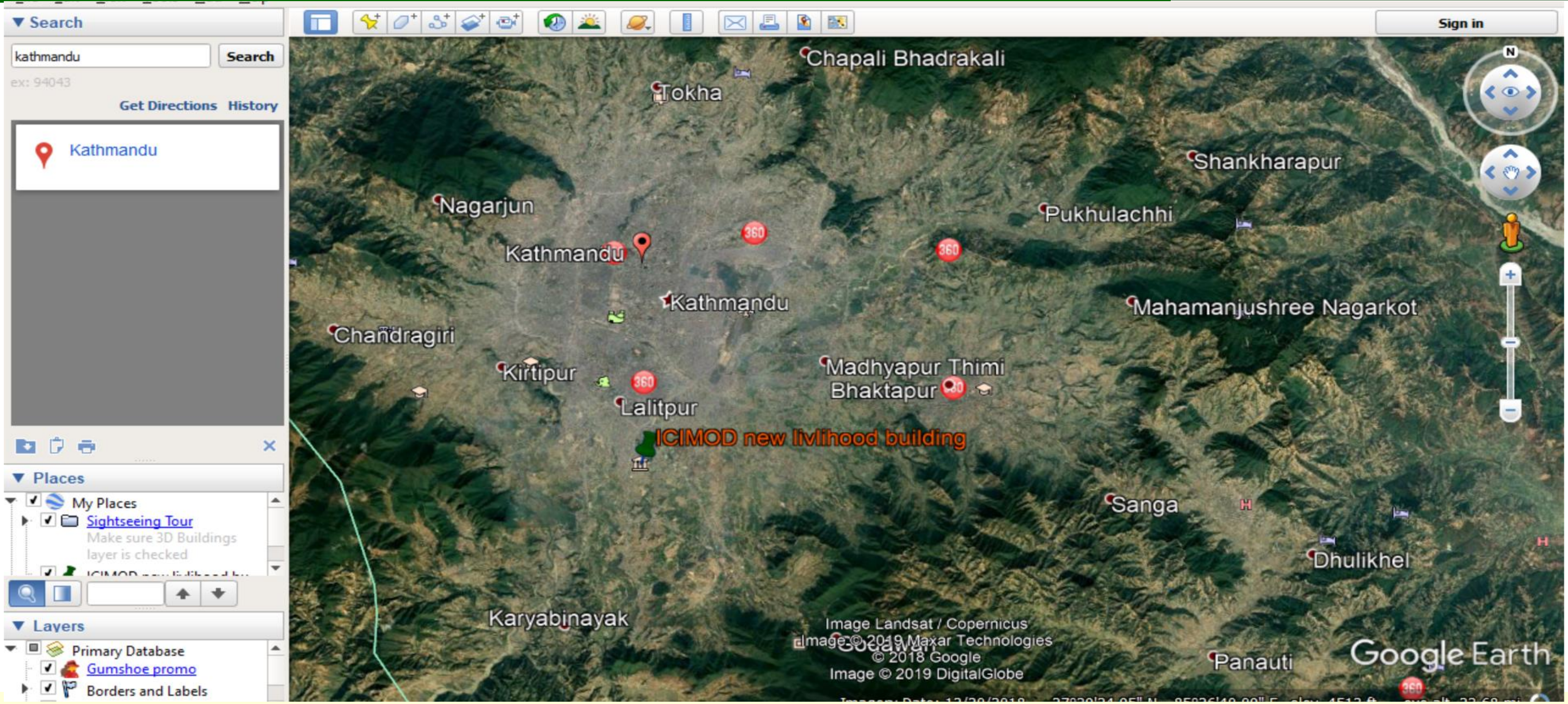

Majority of data and information are associated with some location in space or referenced to the locations on the earth

INFORMATION- Attributes

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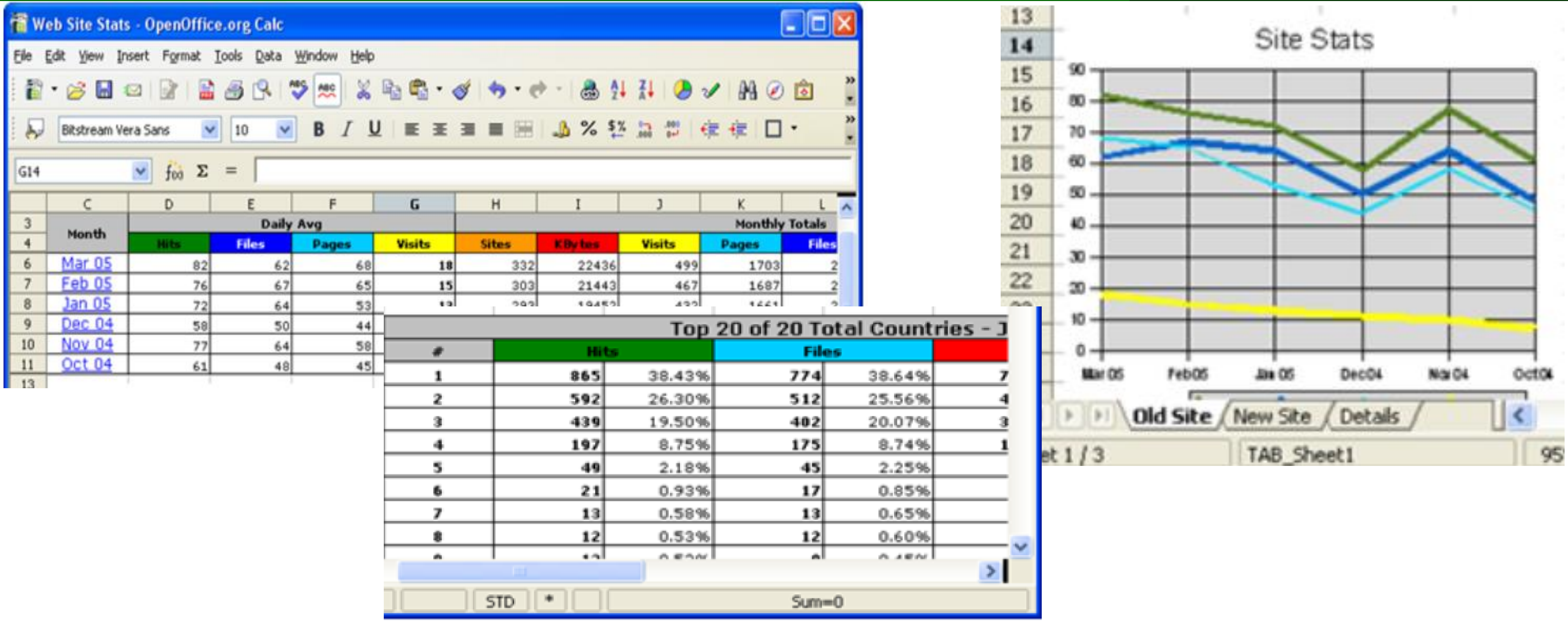

Attributes, or the characteristics (data), can be used to symbolize and provide further insight into a given location

SYSTEM- Manipulation

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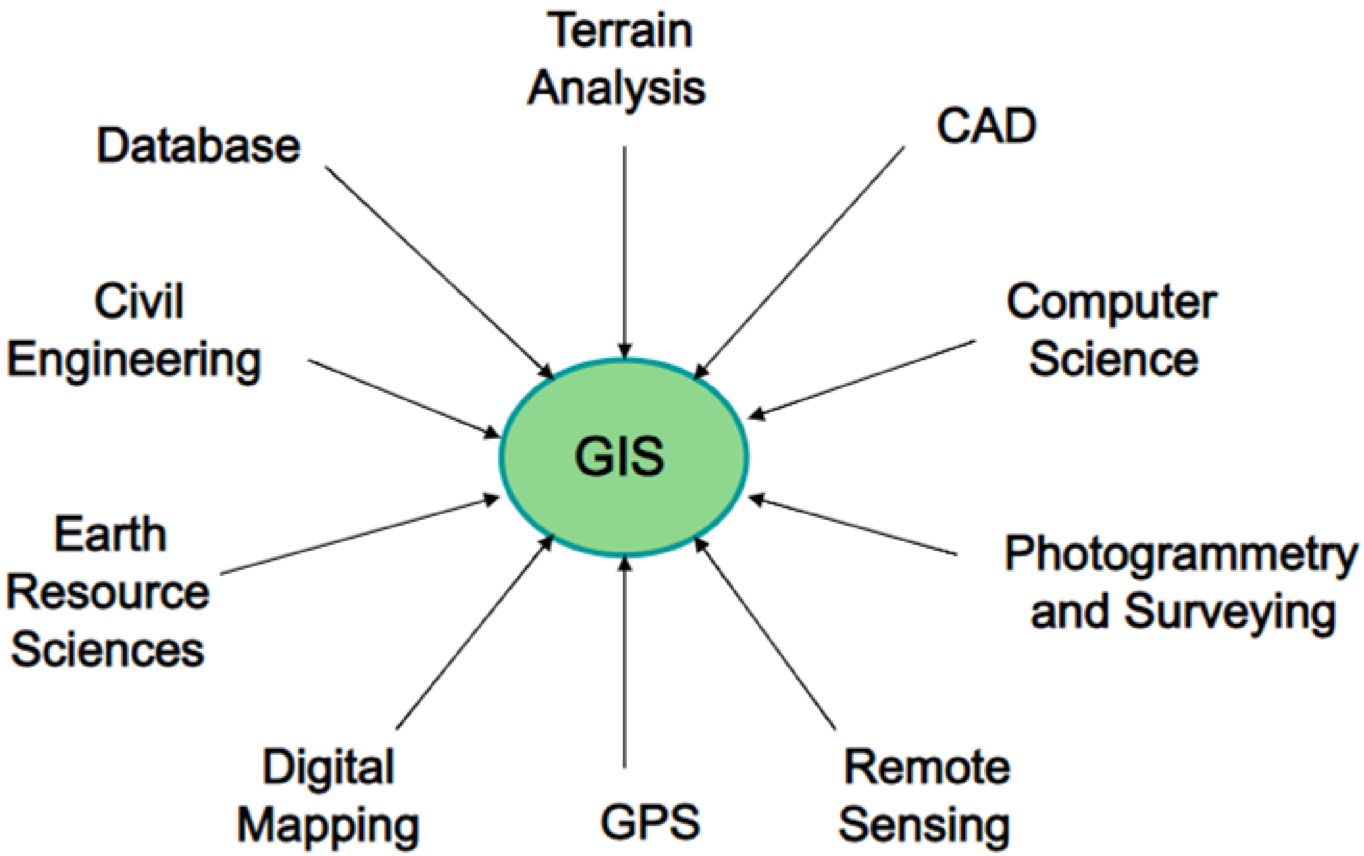
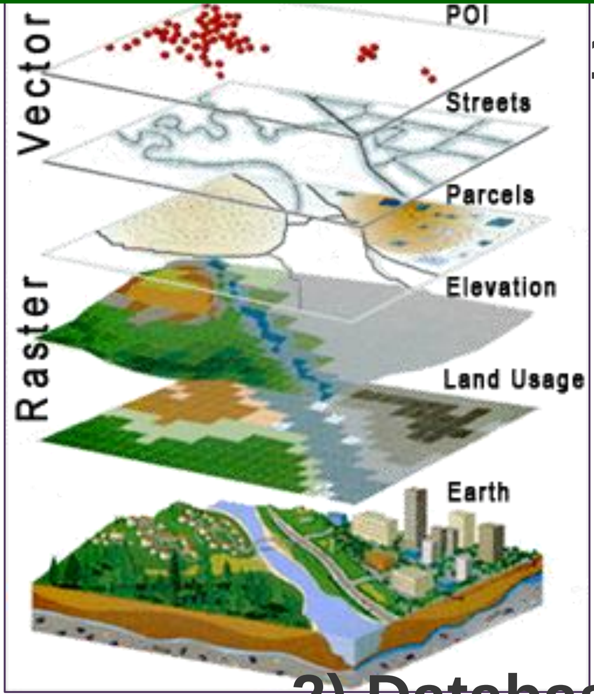


A seamless operation linking the information to the geography – which requires hardware, networks, software, data, and operational procedures

Functions of GIS

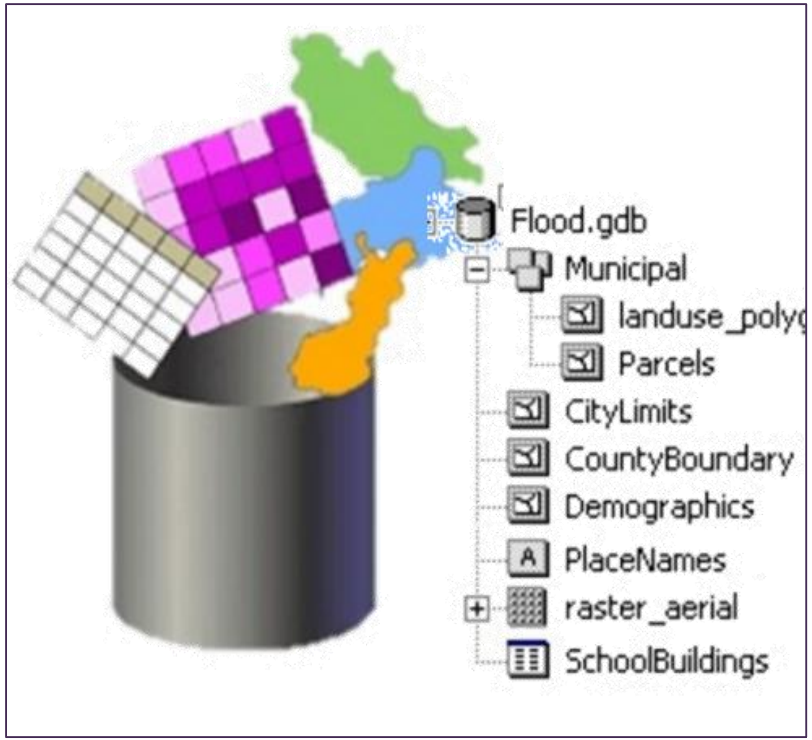


1) Data Acquisition and Preprocessing

- ➢Digitization
- ➢Editing
- ➢Topology
- ➢Projection
- ➢Format conversion etc.

2) Database Management, Update and Retrieval

- ➢ Data retrieval
- ➢ Updation
- ➢ Maintenance
- ➢ Security and, Integration



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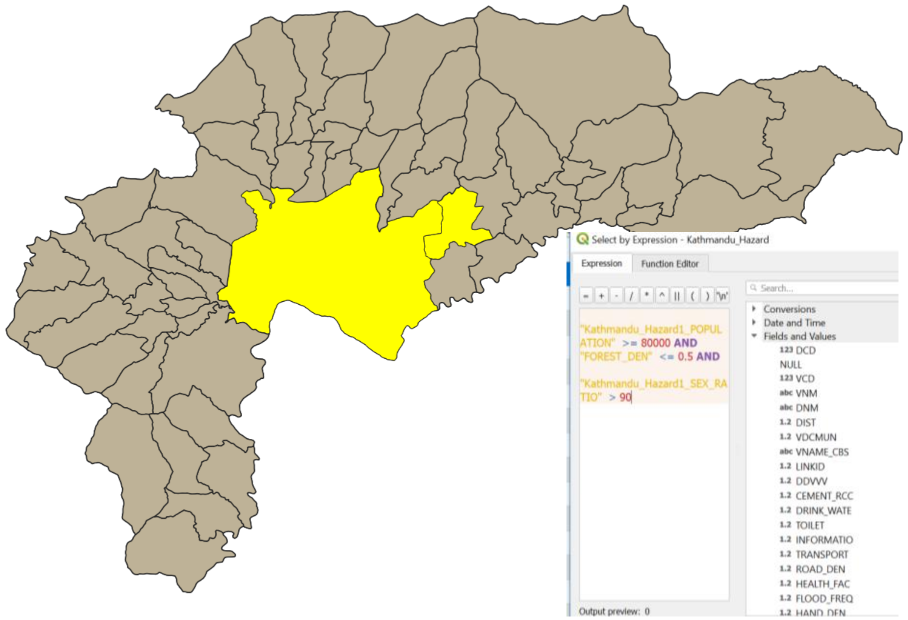
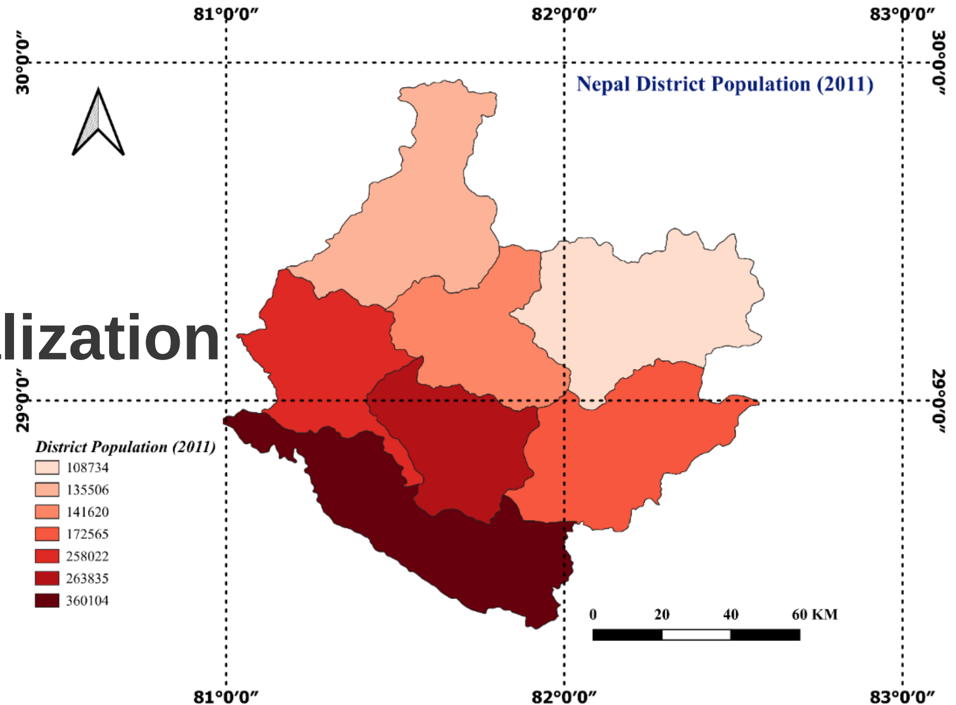
Functions of GIS



3) Spatial Modeling, Measurement and Analysis

- Hierarchical modelling
- Network modelling
- Relational modelling
- Attribute query etc.



4) Presenting Results – Graphical output and Visualization

- Scale transformation
- Generalization, Map
- Statistical representation etc.

Fundamental Data types

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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

For example, area, length & population

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

Fundamental Data types

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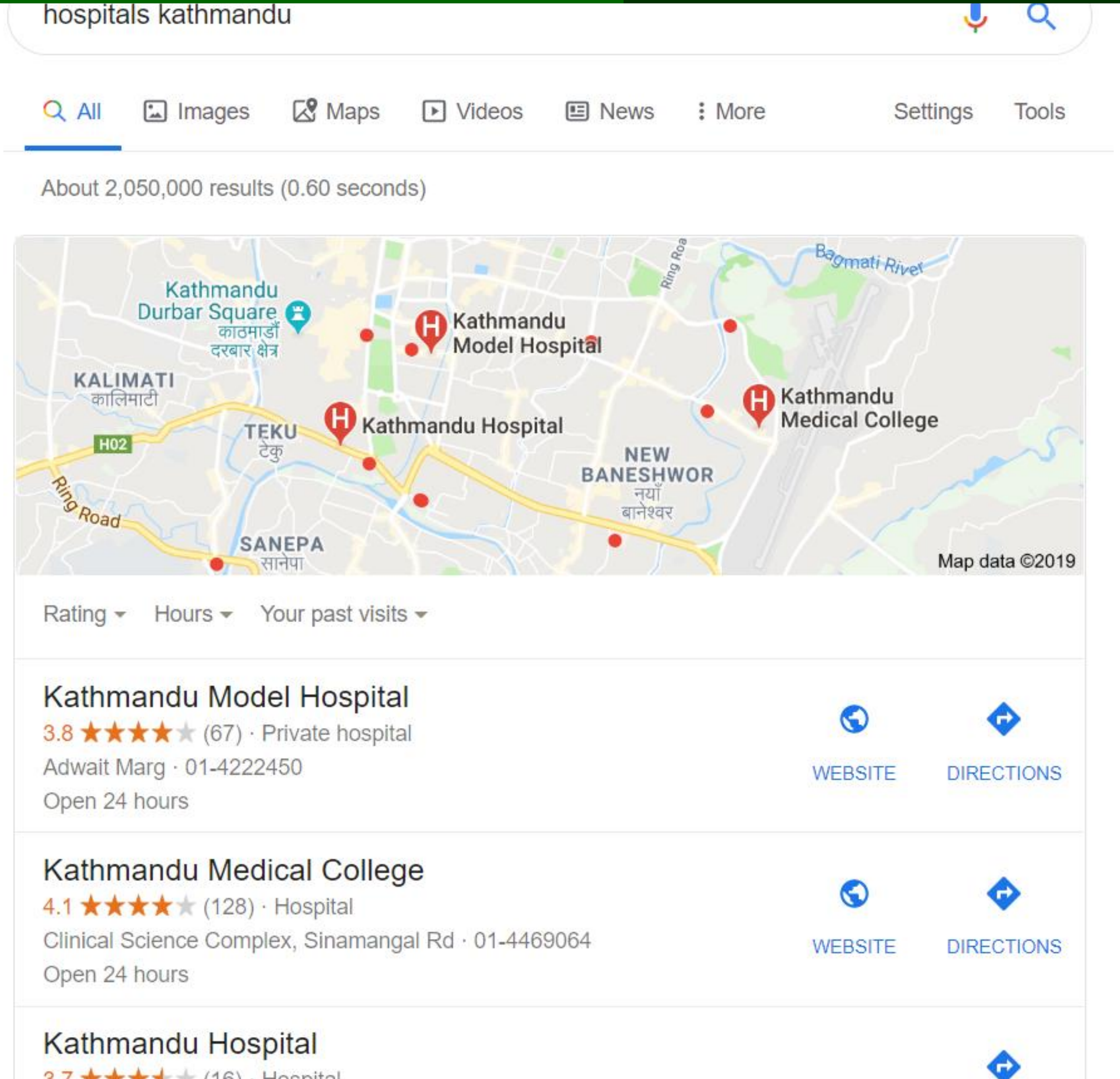
Spatial Information

Non-Spatial Information



Spatial Data

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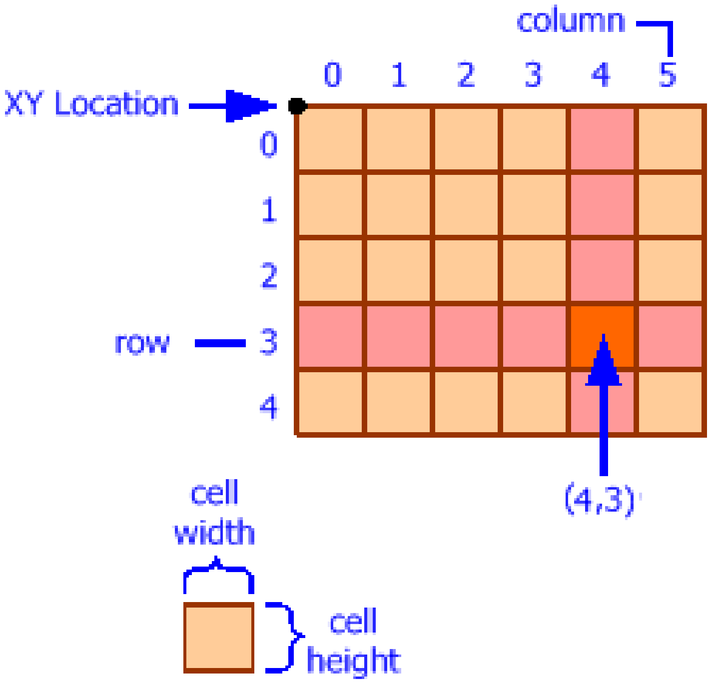
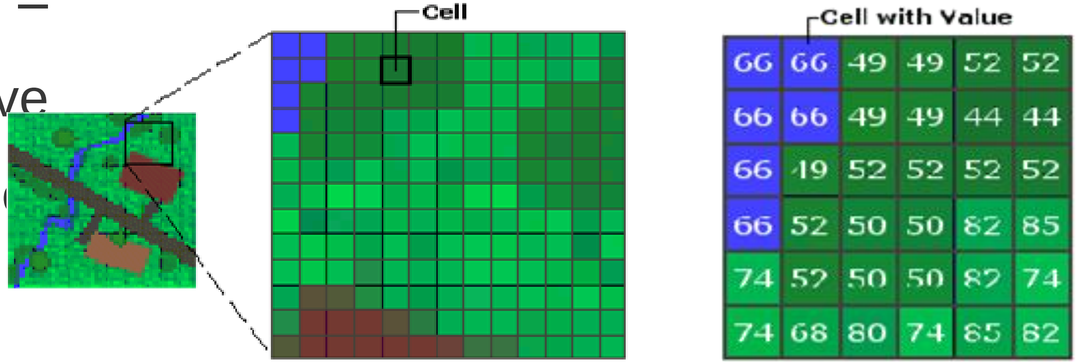
Spatial Data Models

(1) Raster

- Defines space as an array of **equally sized cells** arranged in **rows and columns**. Each cell contains an **attribute value** and **location coordinates**
- The spatial resolution is determined by the **size of the cell**
- Data values for a given parameter are stored in each cell – these values may represent an elevation in meters above sea level, a land use class, a plant biomass in grams pe square meter, and so forth





Spatial Data

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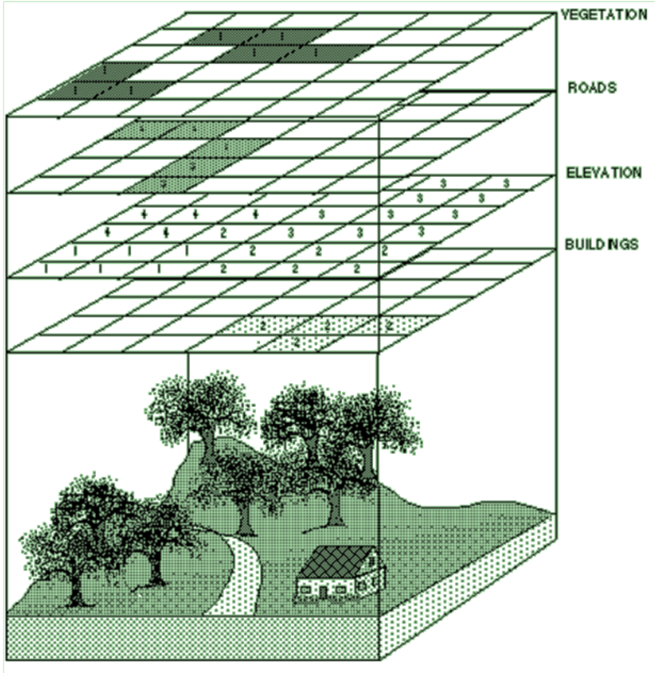

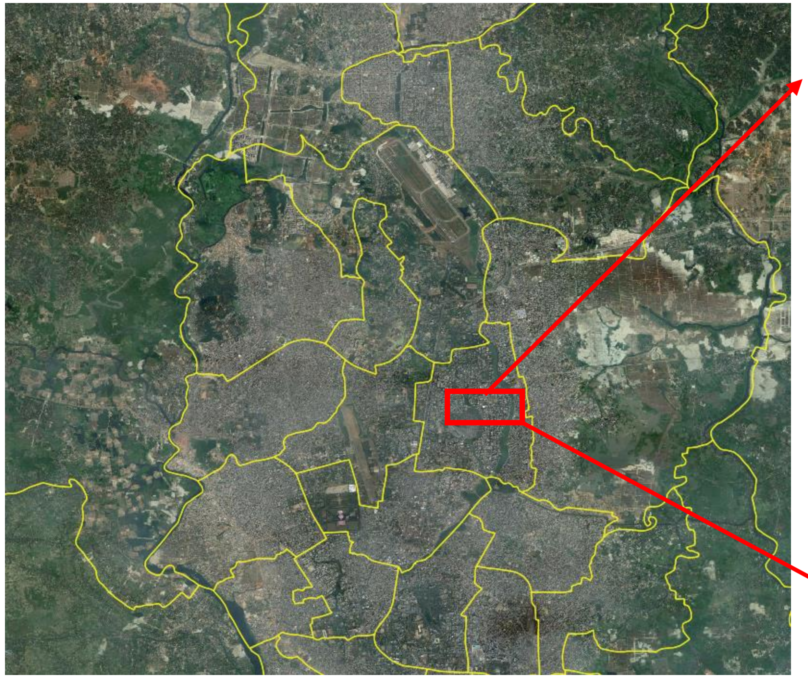

Structure of raster data model showing the matrix structure into row and column of the cells

Spatial Data

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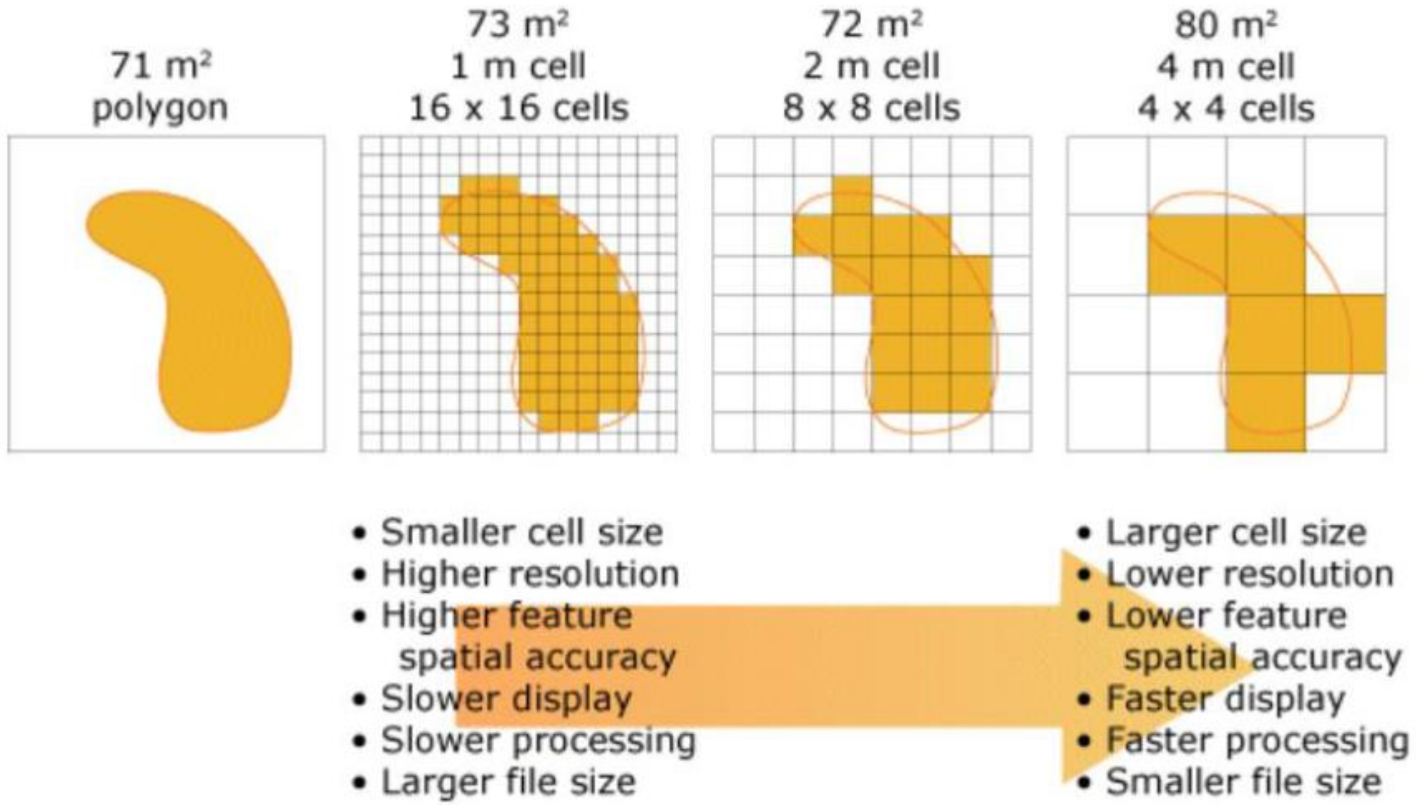

The spatial resolution is determined by the size of the cell

Spatial Data

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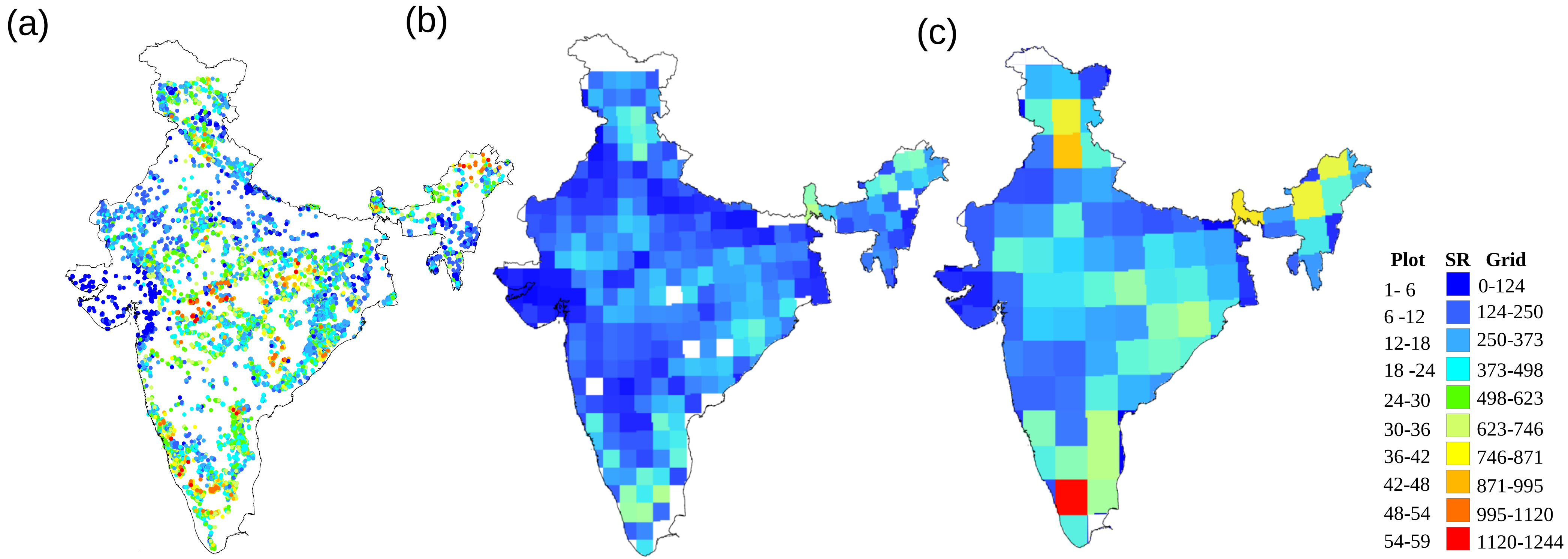

Plant species distribution in Indian mainland

(a) plot level (0.04hac), (b)1 degree grid, (c) 2 degree grid

Spatial Data

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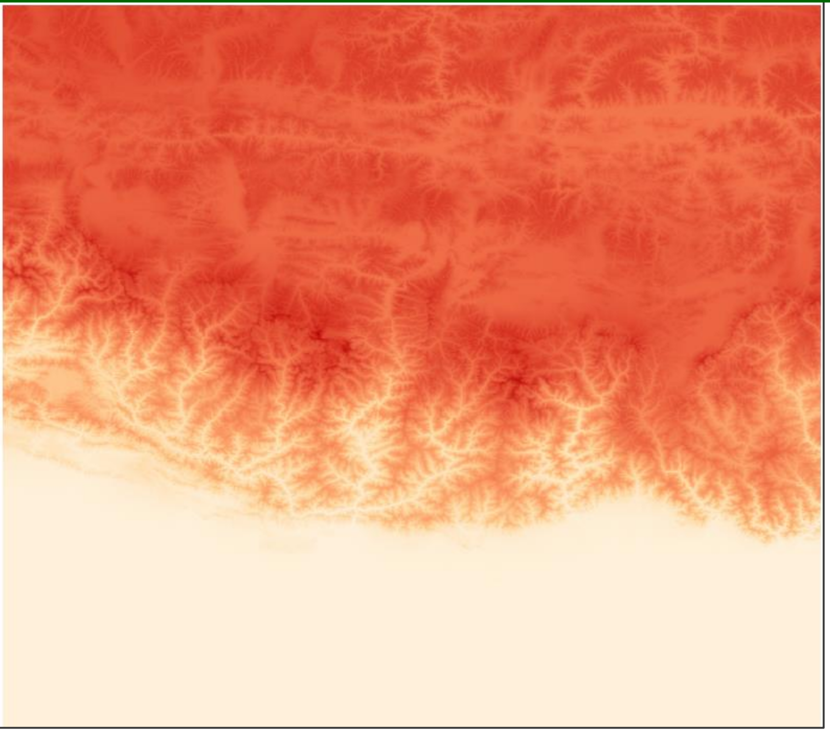
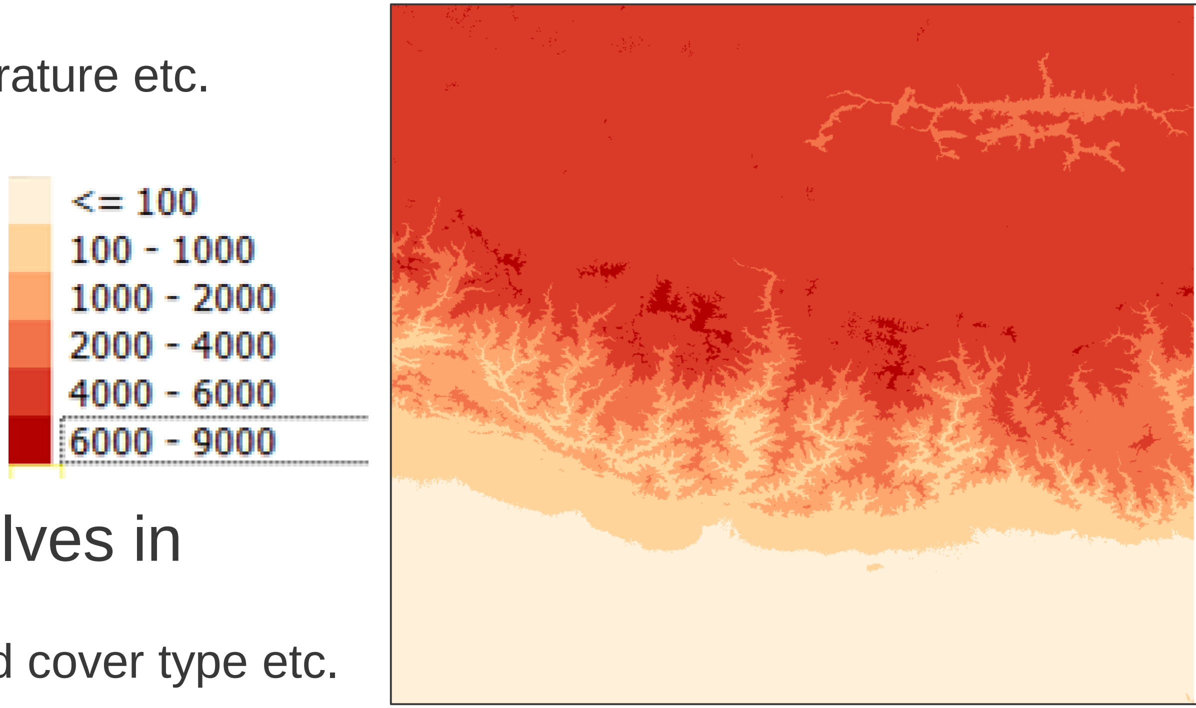


Two forms of raster data

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

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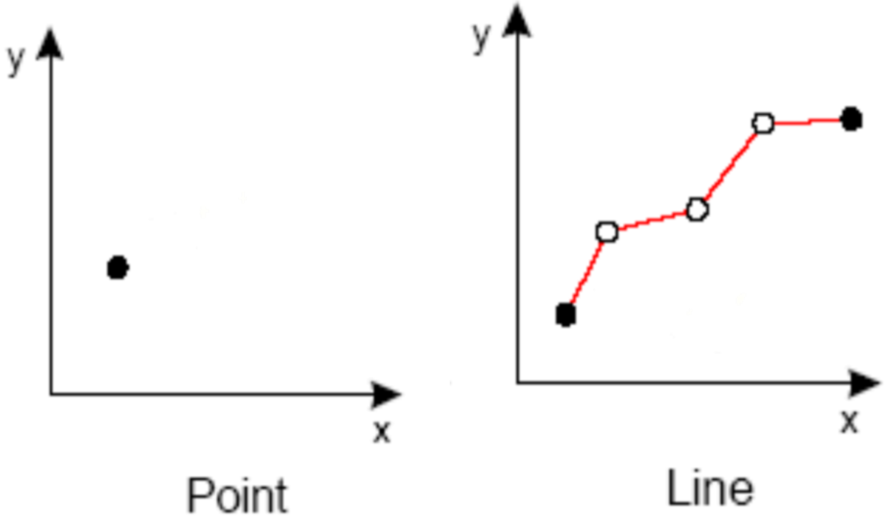
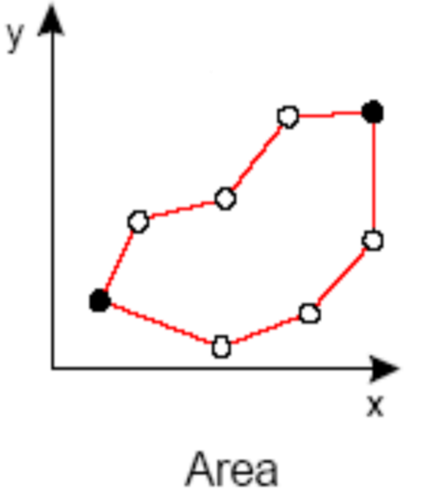
Spatial Data Models

(2) 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 is described by a set of coordinate pairs and by its name and label e.g. streams, streets, sewers
- An area, also called a Polygon, is described by a set of a coordinate pairs and by its name and label, with the difference that the coordinate pairs at the beginning and the end are same **.e.g.** Land parcels, cities, countries, forest, rock type etc.





Spatial Data

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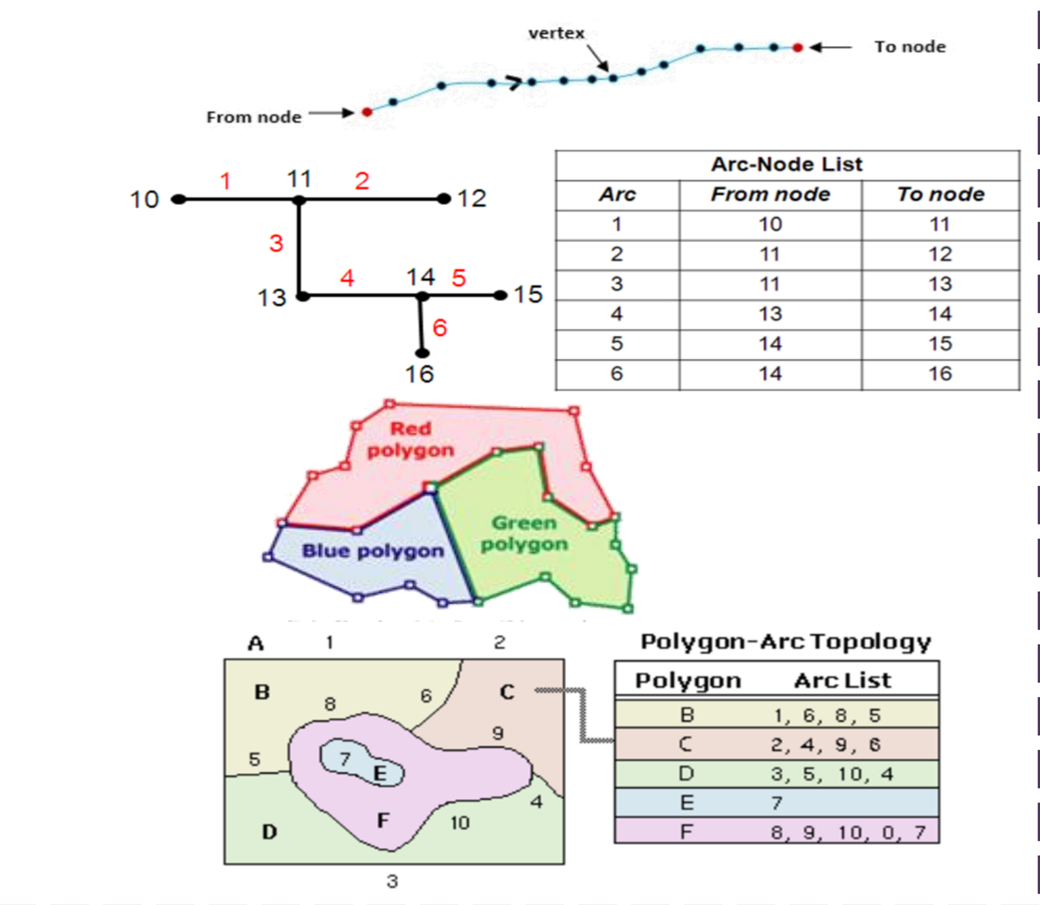
Topological property of vector data model

Connectivity: 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****. Connected arcs are determined by common node numbers*

Contiguity: Polygons *share a* ***common arc****. Contiguity allows the vector data model to determine adjacency*

Containment: *Geographic features cover distinguishable area on the surface of the earth. An area is represented by one or more boundaries defining a polygon*



Arc-Node List		
Arc	*From node*	*To node*
1	10	11
2	11	12
3	11	13
4	13	14
5	14	15
6	14	16

Polygon-Arc Topology

Polygon	Arc List
B	1, 6, 8, 5
C	2, 4, 9, 6
D	3, 5, 10, 4
E	7
F	8, 9, 10, 0, 7

Set of rules that model the relationships between neighboring points, lines, and polygons and determines how they share geometry

Spatial Data

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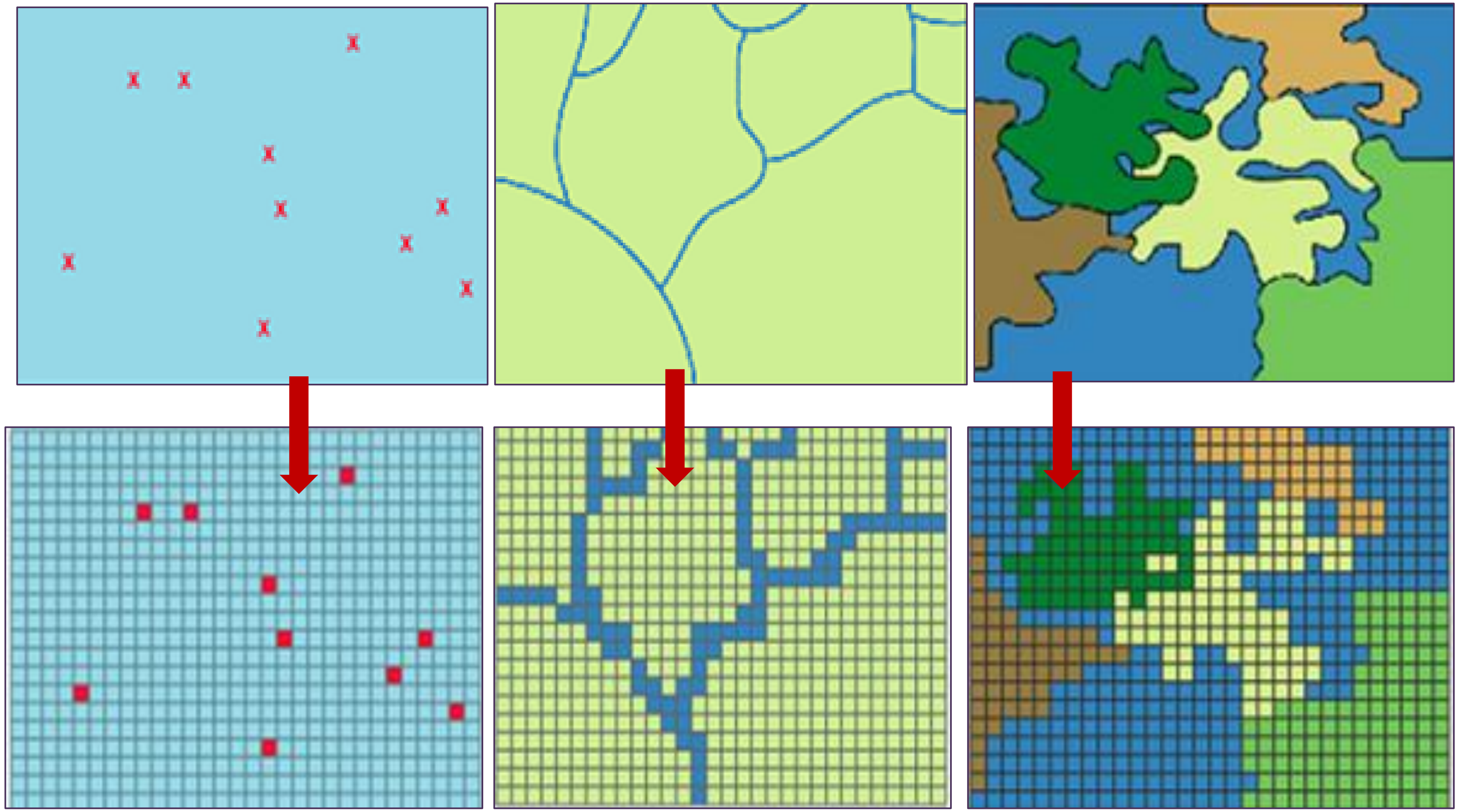
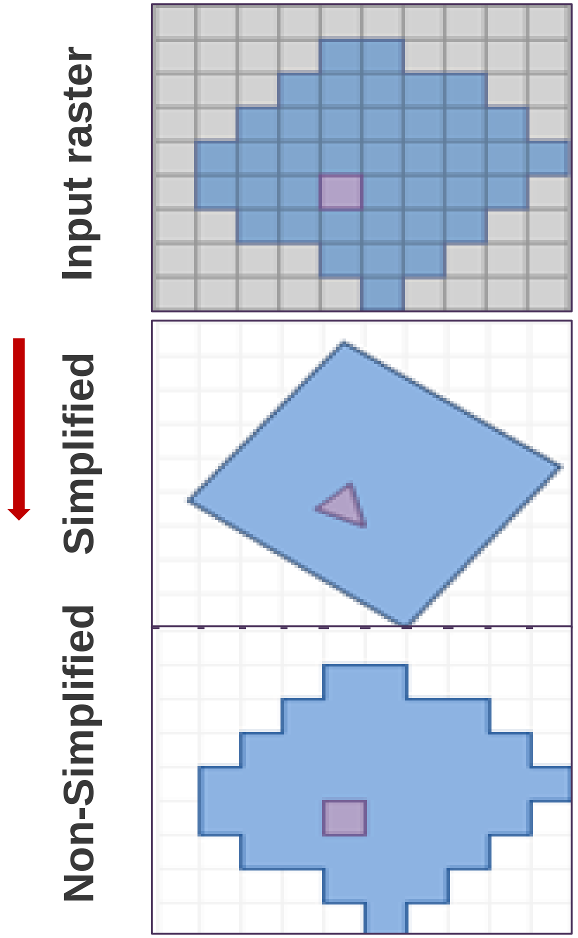
Conversion of vector to rater



Conversion of raster to vector



Spatial Data

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		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.rrd RRD 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, Point, Polygon → Feature Class Relationship → Relationship
ArcInfo Coverage	coverage arc label polygon region.area tic
E00 ArcInfo Interchange	polygon.e00

Non-Spatial Data

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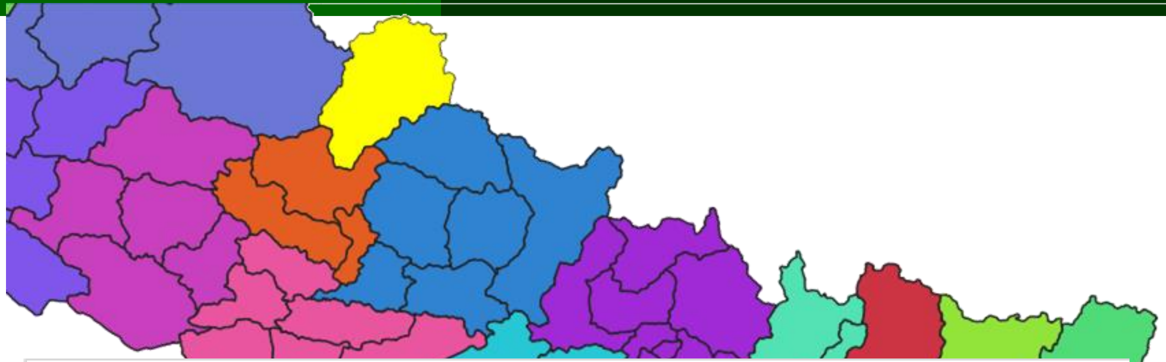
Attribute Data

- 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

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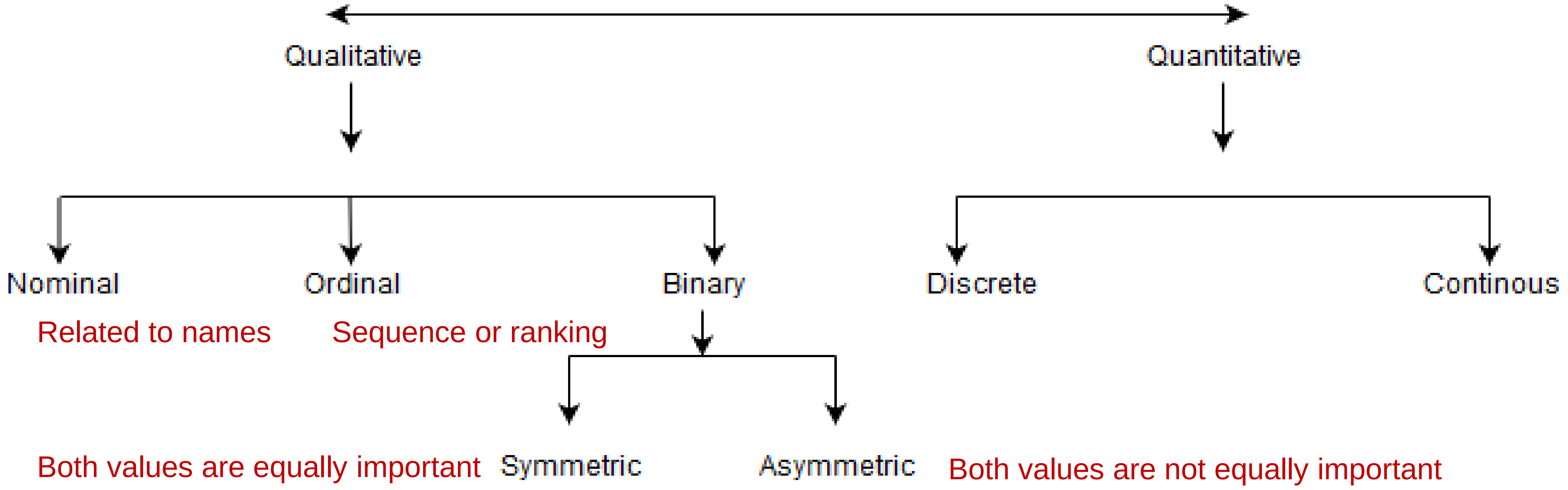
Attribute Data Type



- **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

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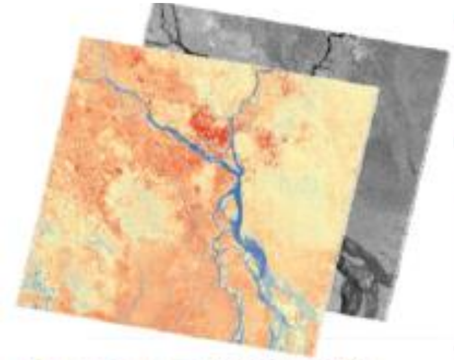

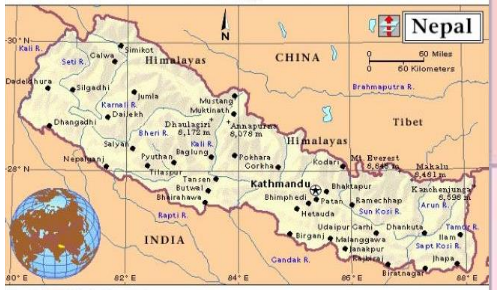

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Raster		Vector
Digital Remote sensing images	Primary	GPS measurements
Digital Aerial photographs	Primary	Survey measurements
Scanned Maps	Secondary	Topographic surveys
DEM from Images	Secondary	Toponymy data from atlases

- LULC
- Crop types
- Census
- Biomass

GIS data capture and update of vector features

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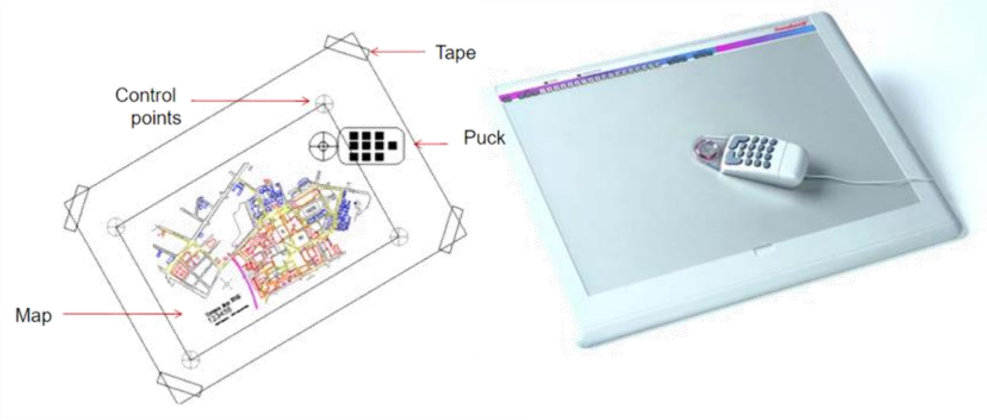
Digitization: Process of converting geographic data into vector data by tracing the features from a hardcopy, digital or a scanned image



a) Manual

(i) Tablet Digitization

- Uses hard copy maps in GIS
- Involves placing a digitizing puck (a multiple button mouse) over a location on the tablet and presses one of the buttons on the puck to record the location of the feature of interest

(ii) 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

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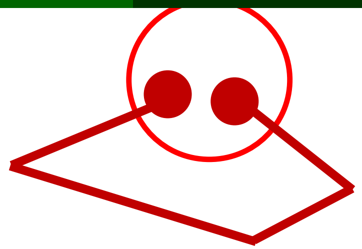
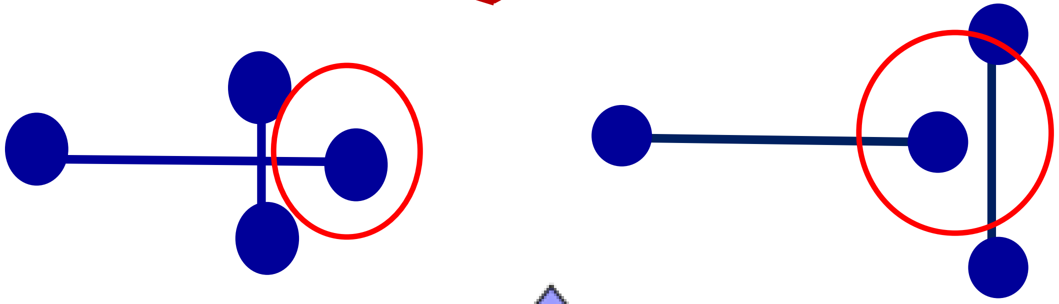
(1) Dangles: Lines that are not connected

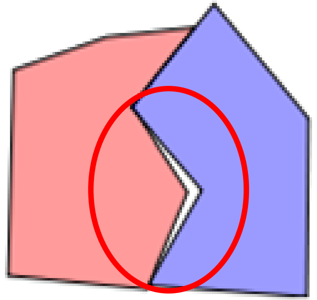


(2) Overshoots: Overextended line

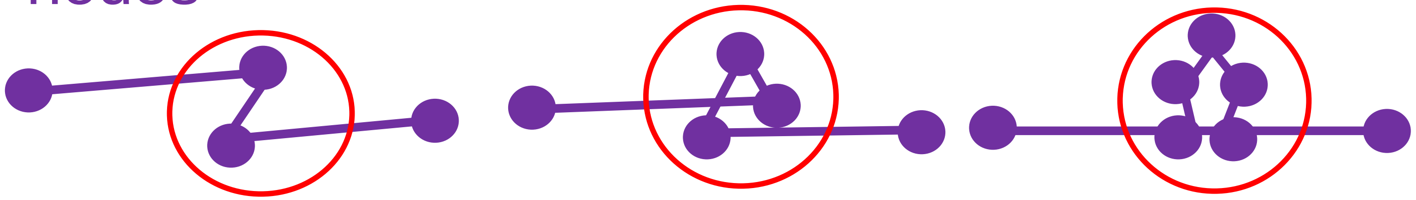
(3) Undershoots: Gap exists between two intersecting line



(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

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A reference system to represent the locations of geographic features

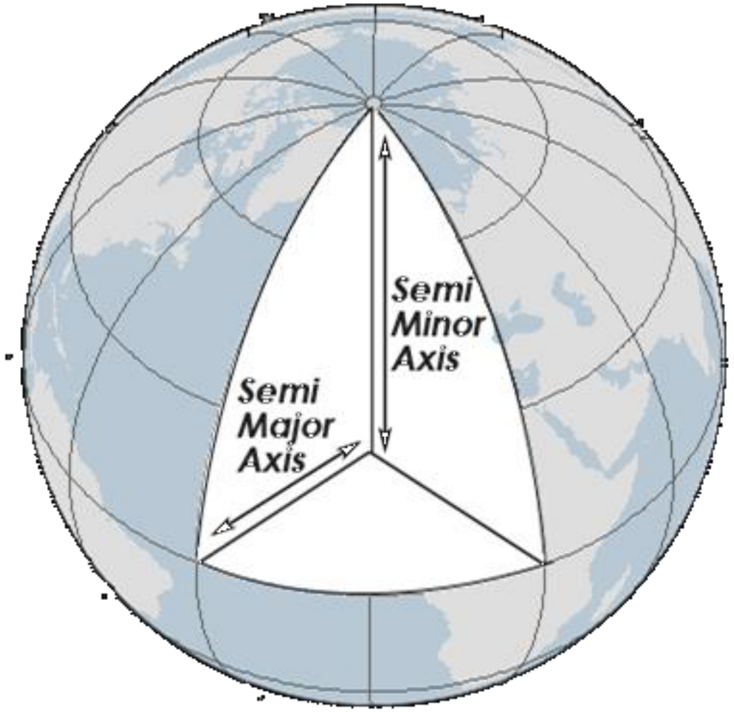
Each coordinate system is defined by:

- **Measurement framework**

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

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

- **Unit of measurement**
- 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

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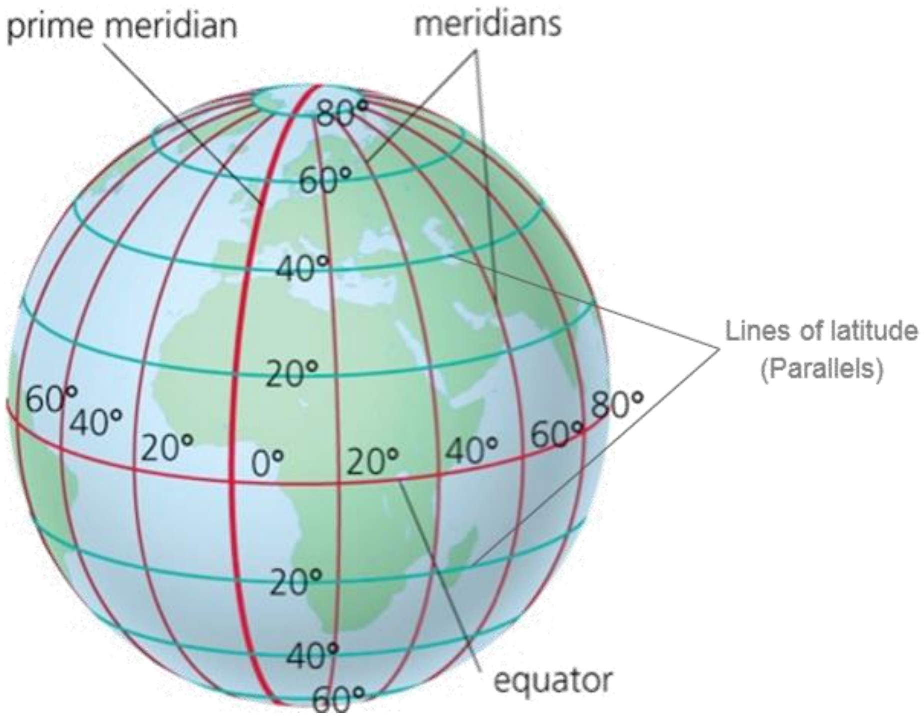
Geographic Coordinate System (GCS)

- 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

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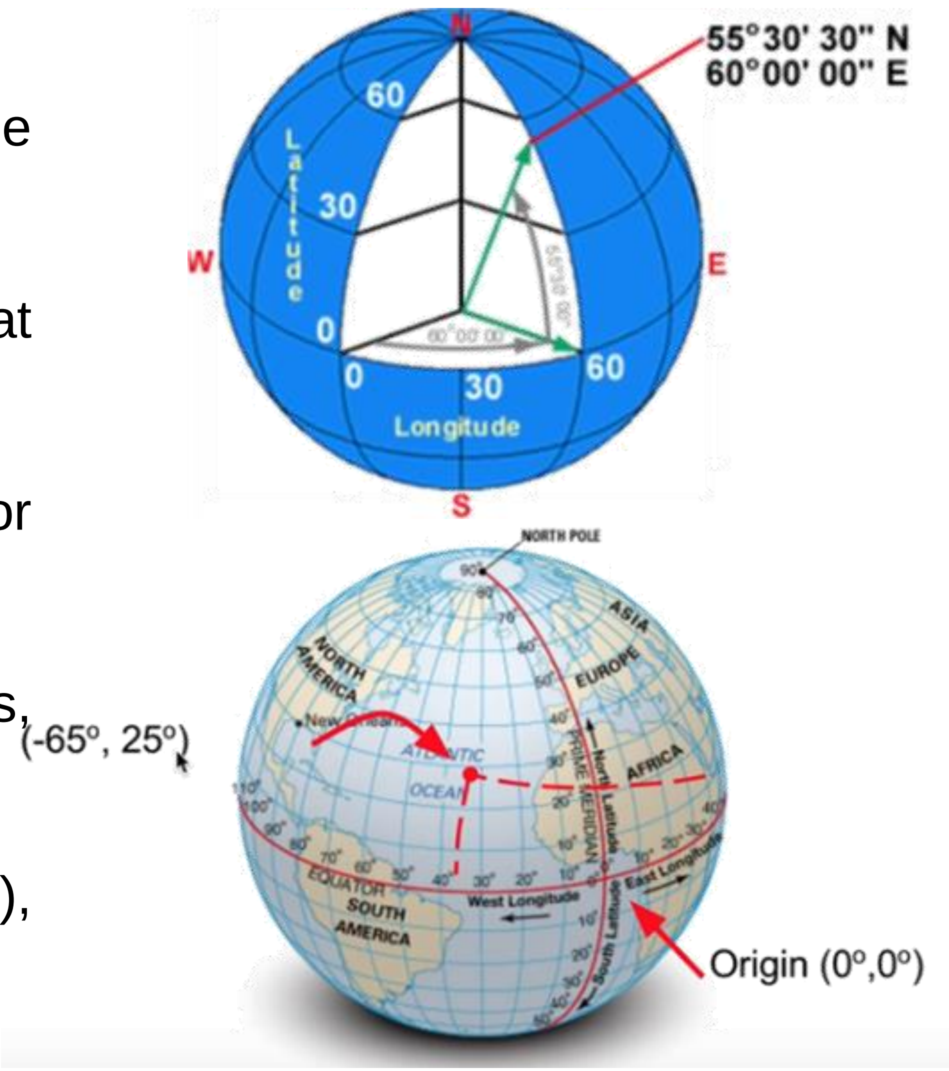
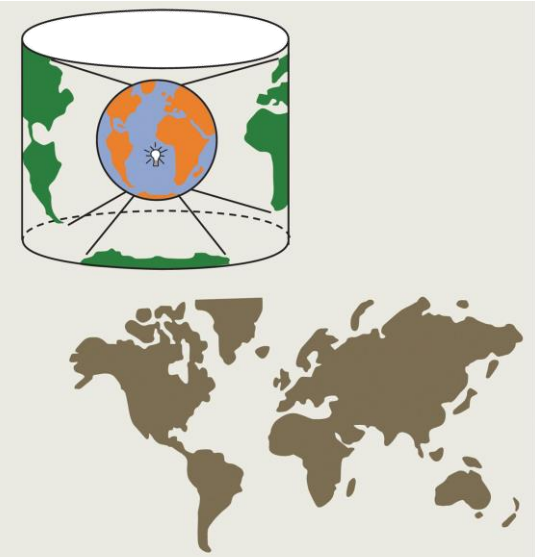
Geographic Coordinate System (GCS)

- 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 decimel)
- Directions can be specified using **E** (east), **W** (west), **N**(north), **S**(south) or by sign **plus** (+) or **minus** (-)

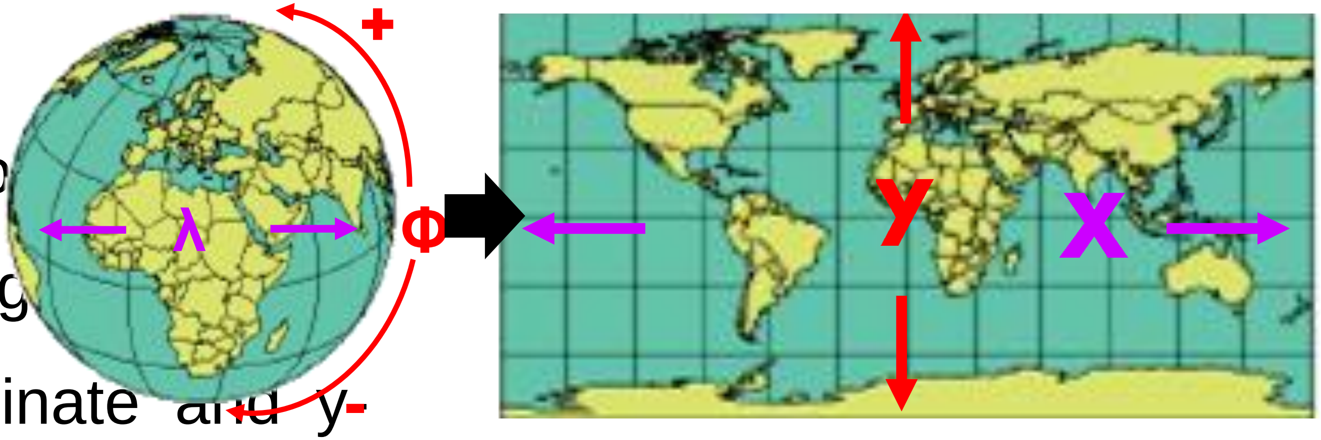


Coordinate systems



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 co
  a grid, with the origin at the center of the g
- The two values are called the x-coordinate and y-



Map Production

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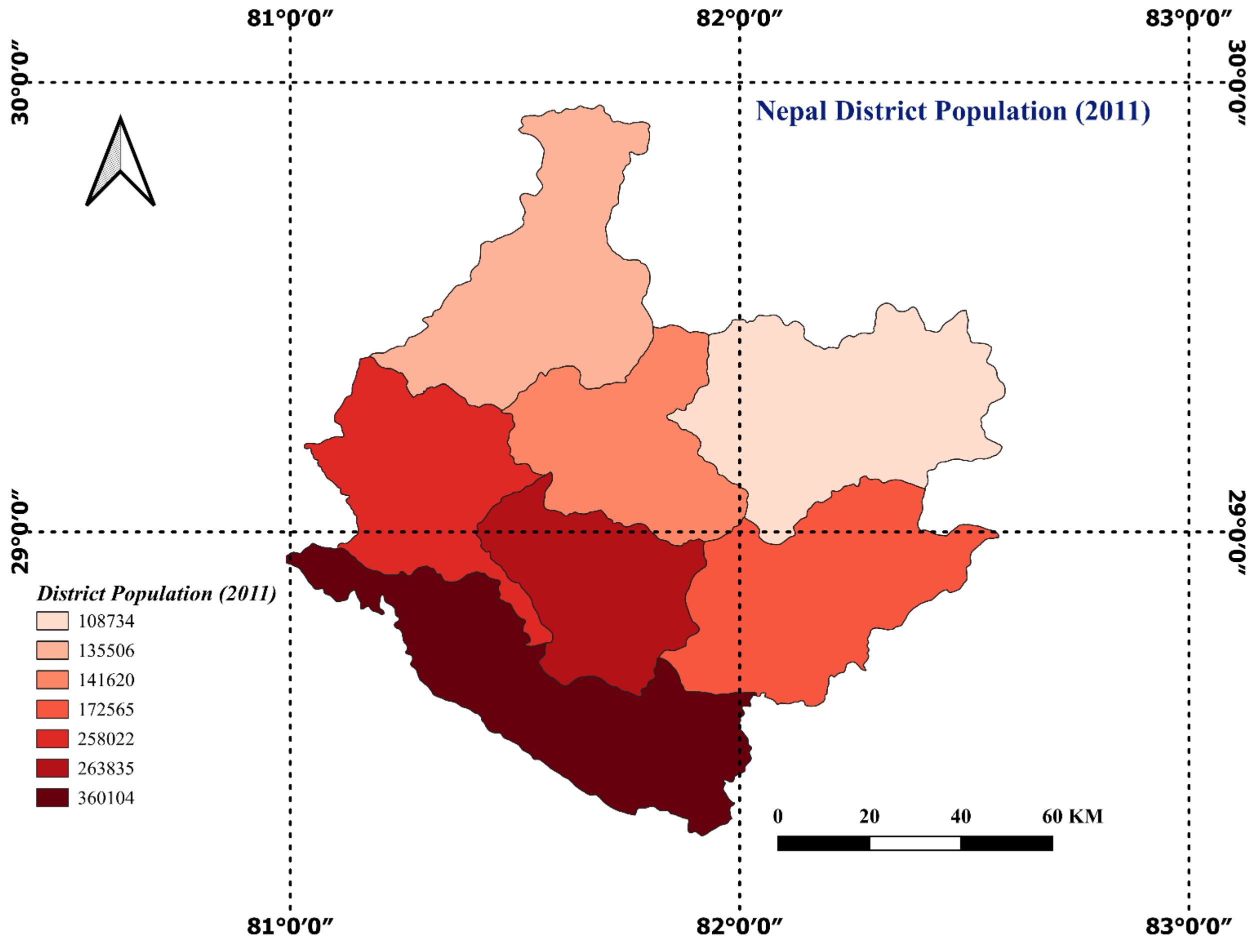
Process of arranging Map elements on a sheet of paper

Properties

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



Applications of GIS

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- 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.

Applications of GIS

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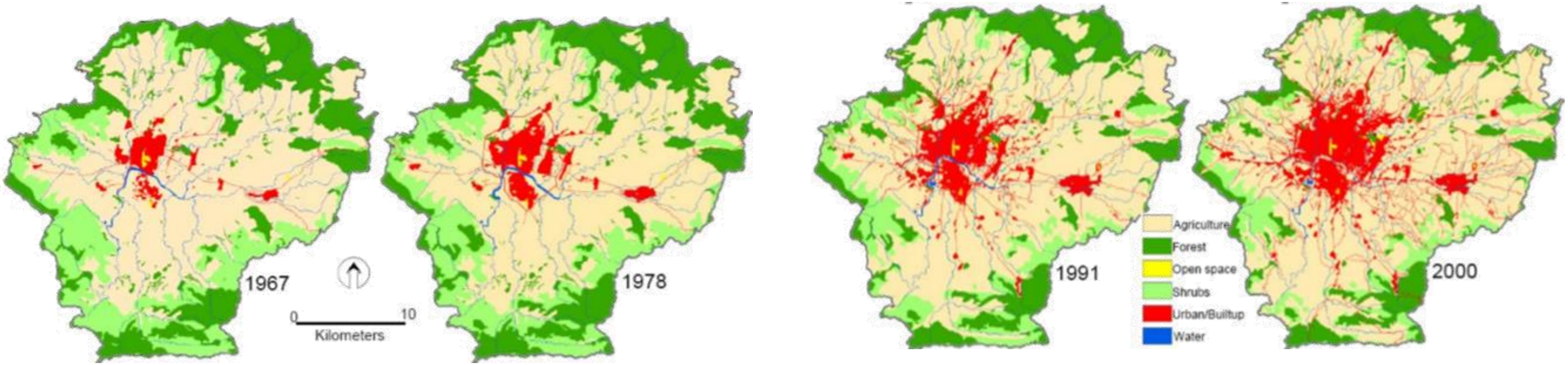
Mapping and monitoring

Urban Growth



Land use maps of Kathmandu Valley, 1967-2000

Source: *Thapa and Murayama, 2008*

Applications of GIS

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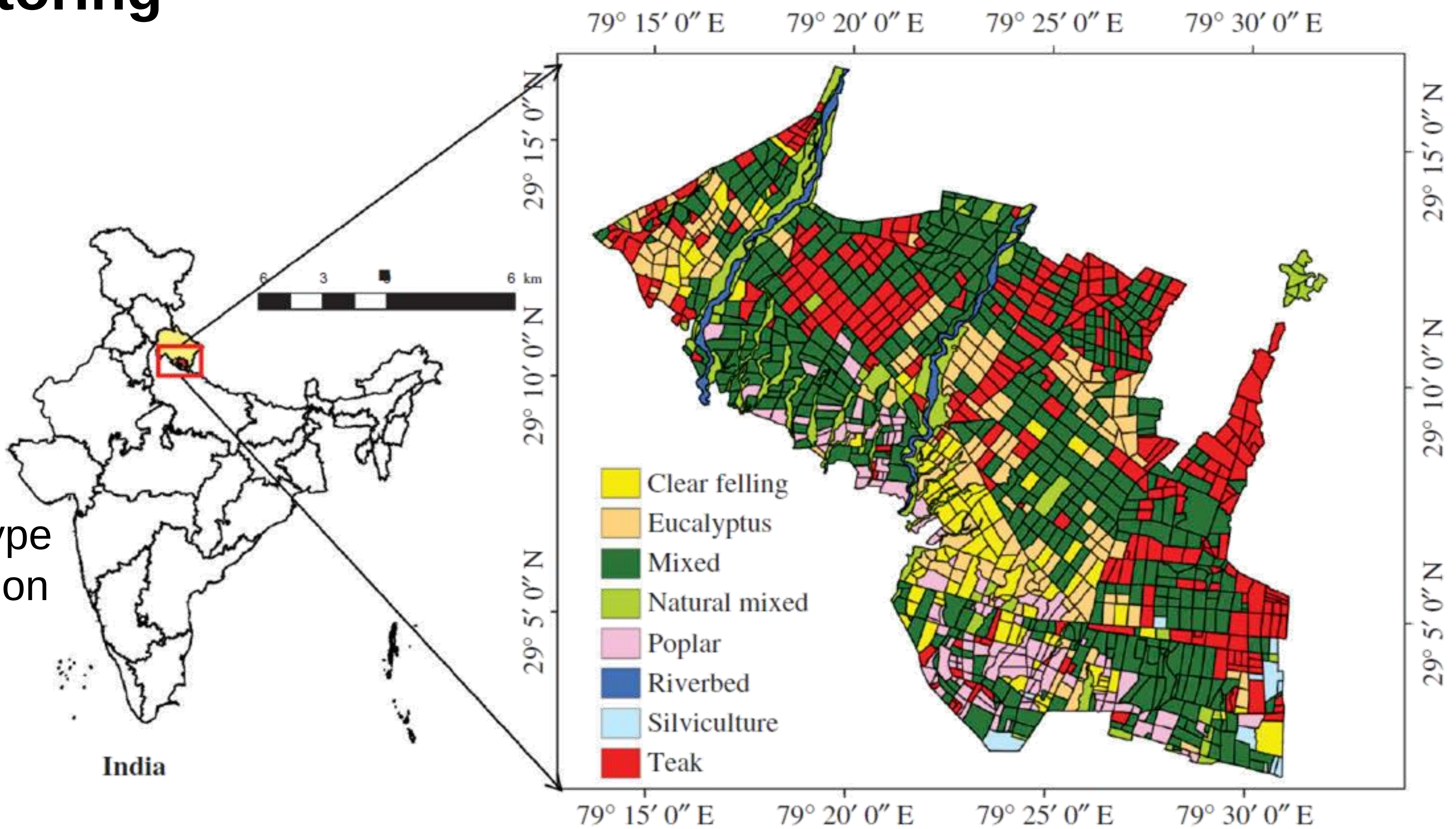
Mapping and monitoring

Vegetation type



Map of different plantation type of Terai Central Forest Division Nainital, Uttarakhand, India

Source: *Tripathi et al., 2014*

Applications of GIS

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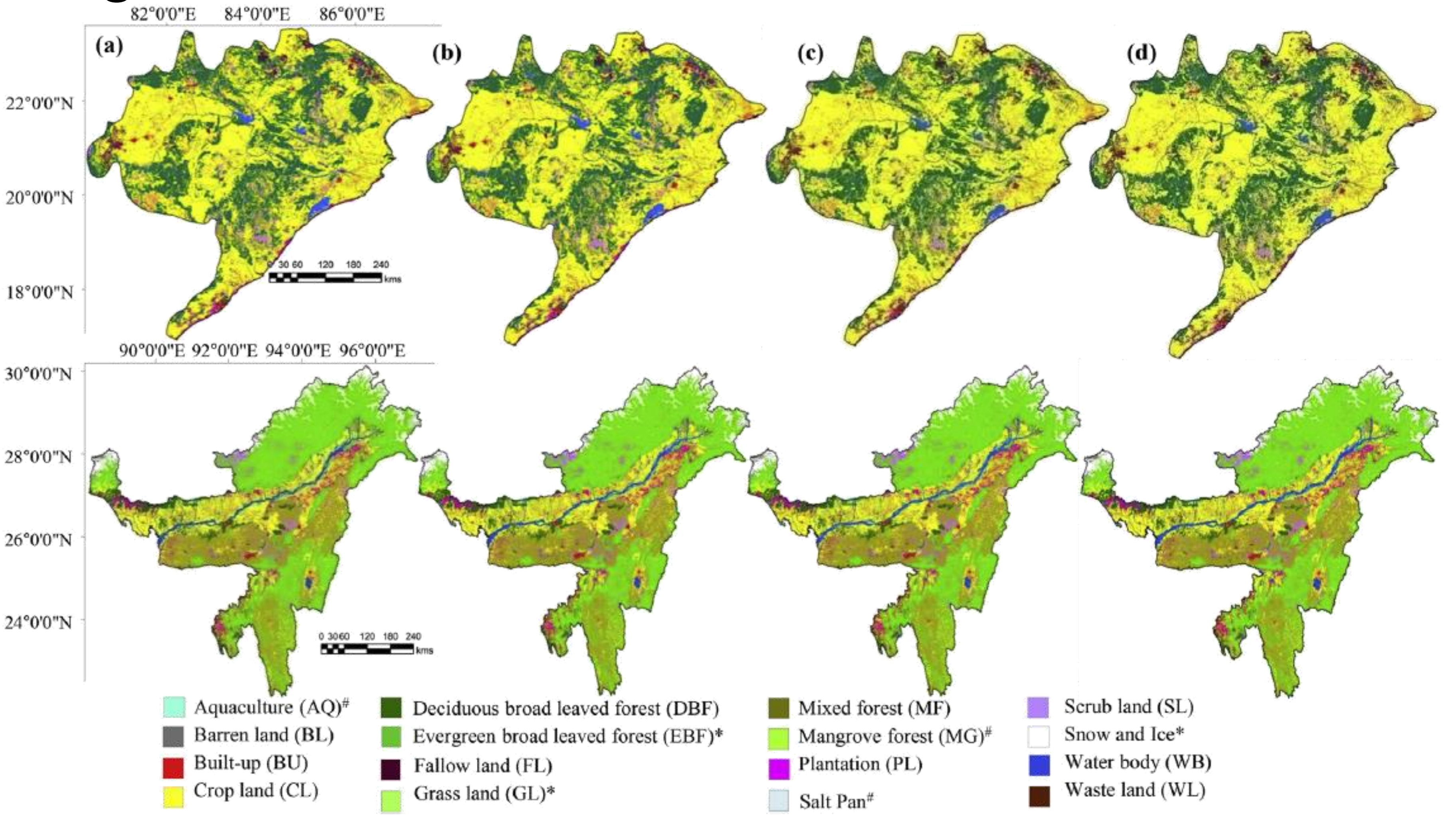
Mapping and monitoring

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- 2005



Source: *Behera et al., 2017*

Applications of GIS

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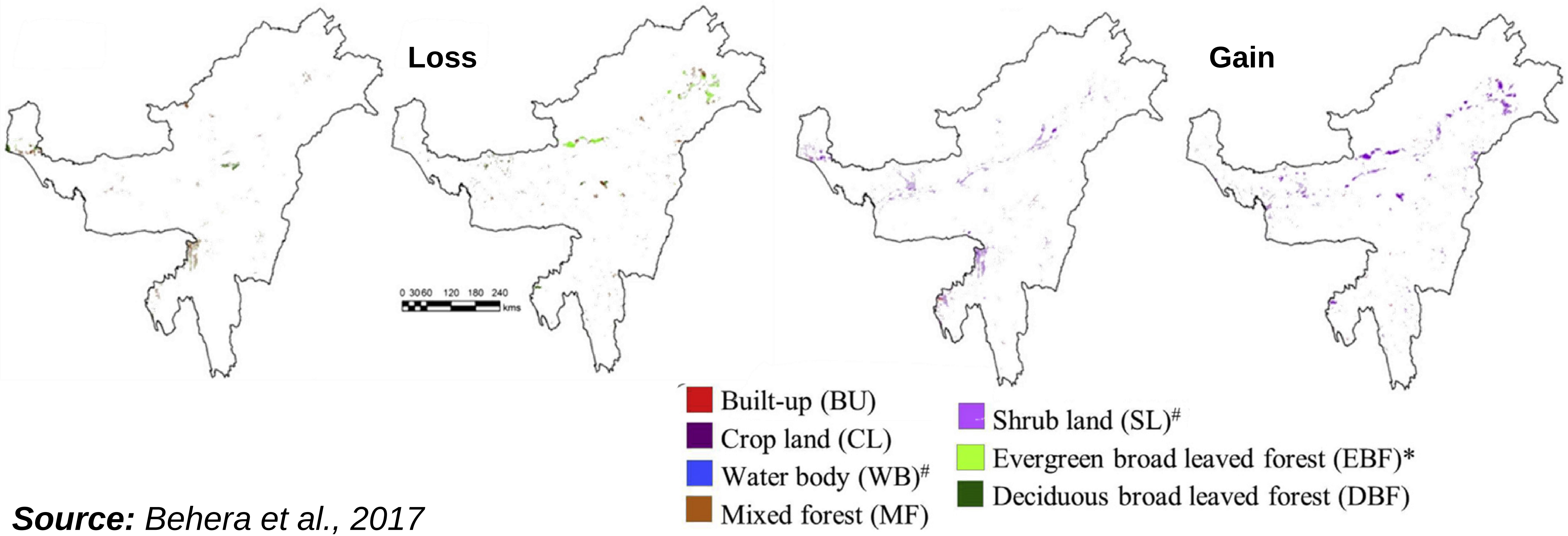
Mapping and monitoring

Change dynamics



Source: *Behera et al., 2017*

Applications of GIS

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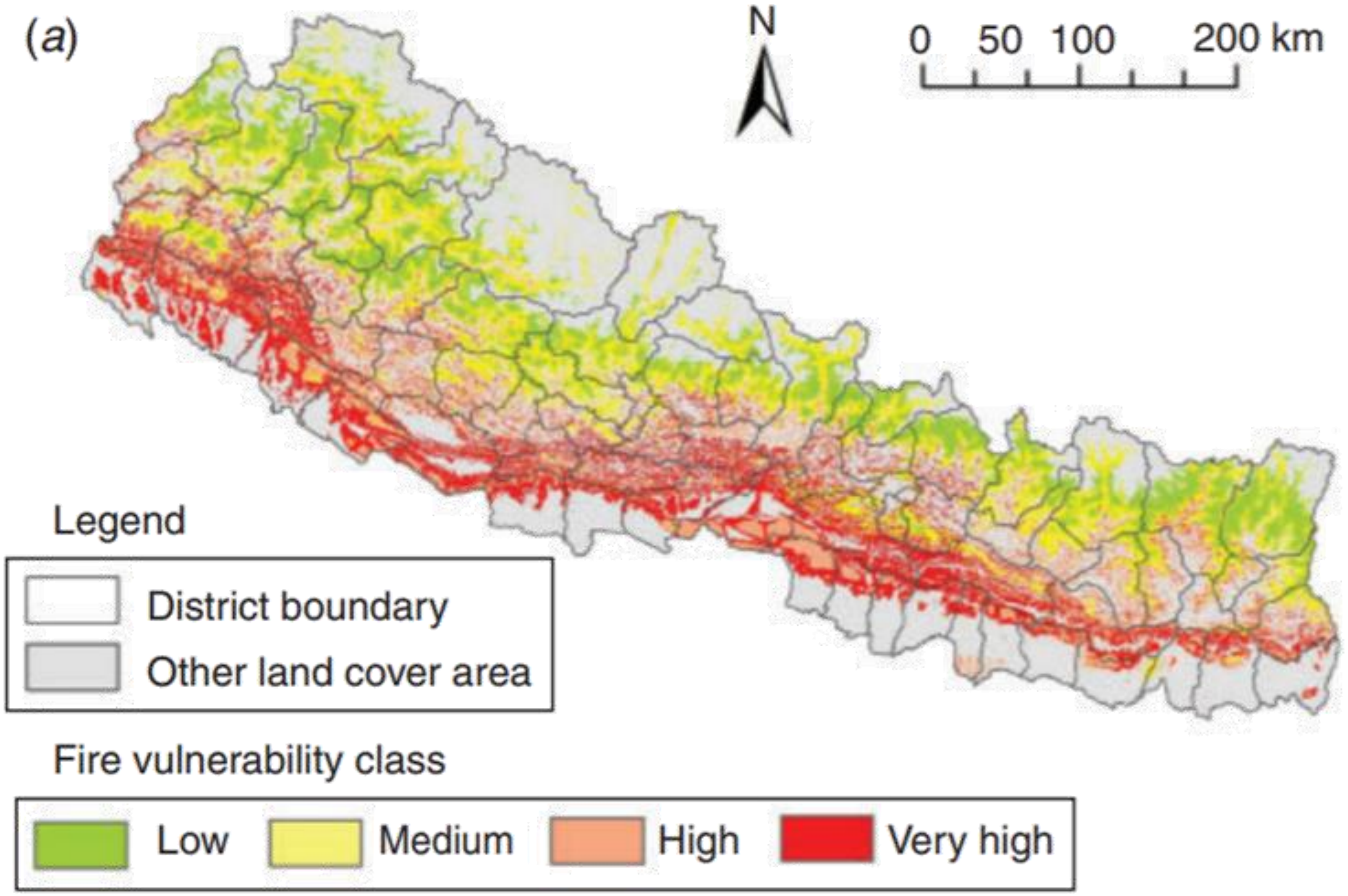
Fire risk modeling

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



Source: *Matin et al., 2017*

Applications of GIS

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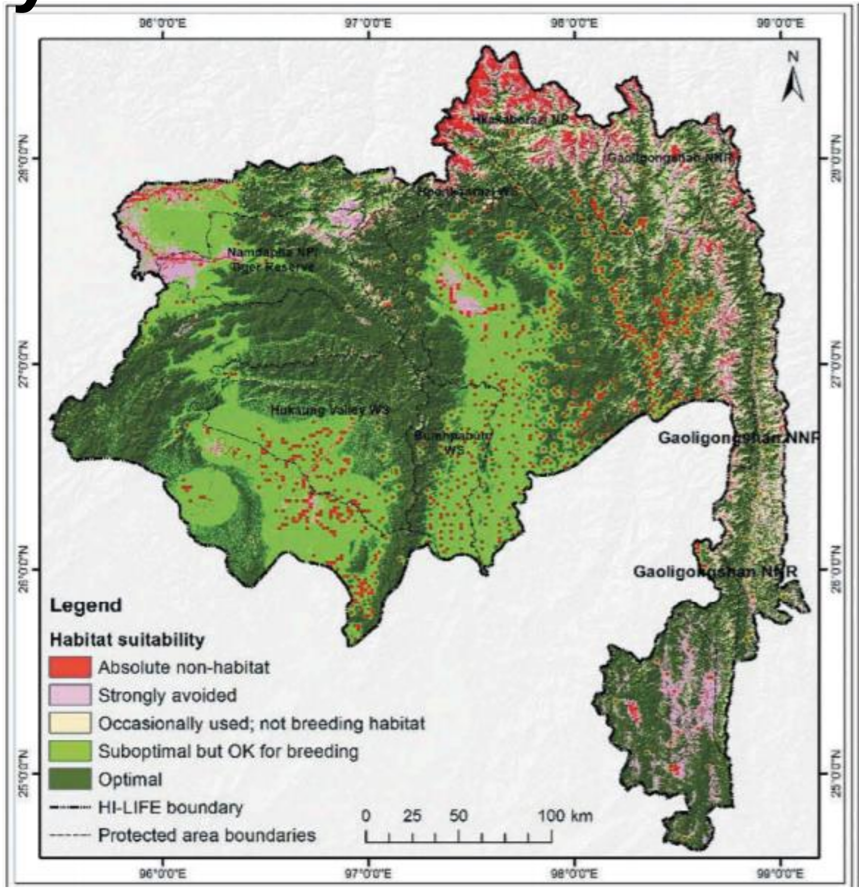
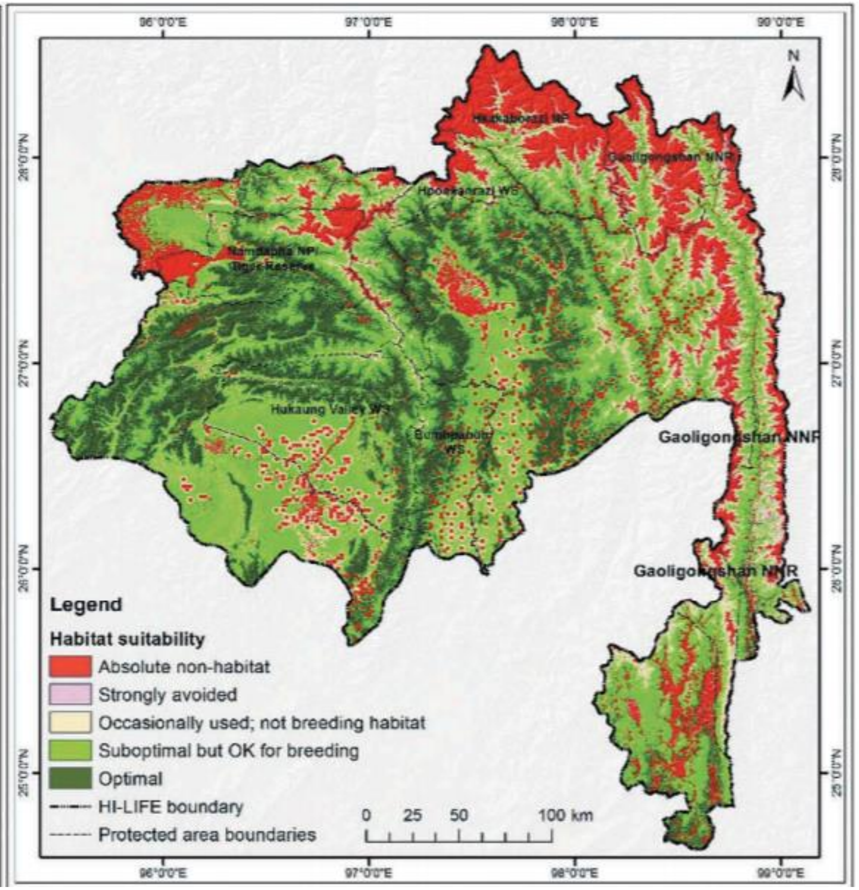
Habitat Suitability Analysis

- 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 dear

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Risk & Hazard Analysis

Flood susceptibility analysis

(Markham river basin, New Guinea)

Equation used for modelling

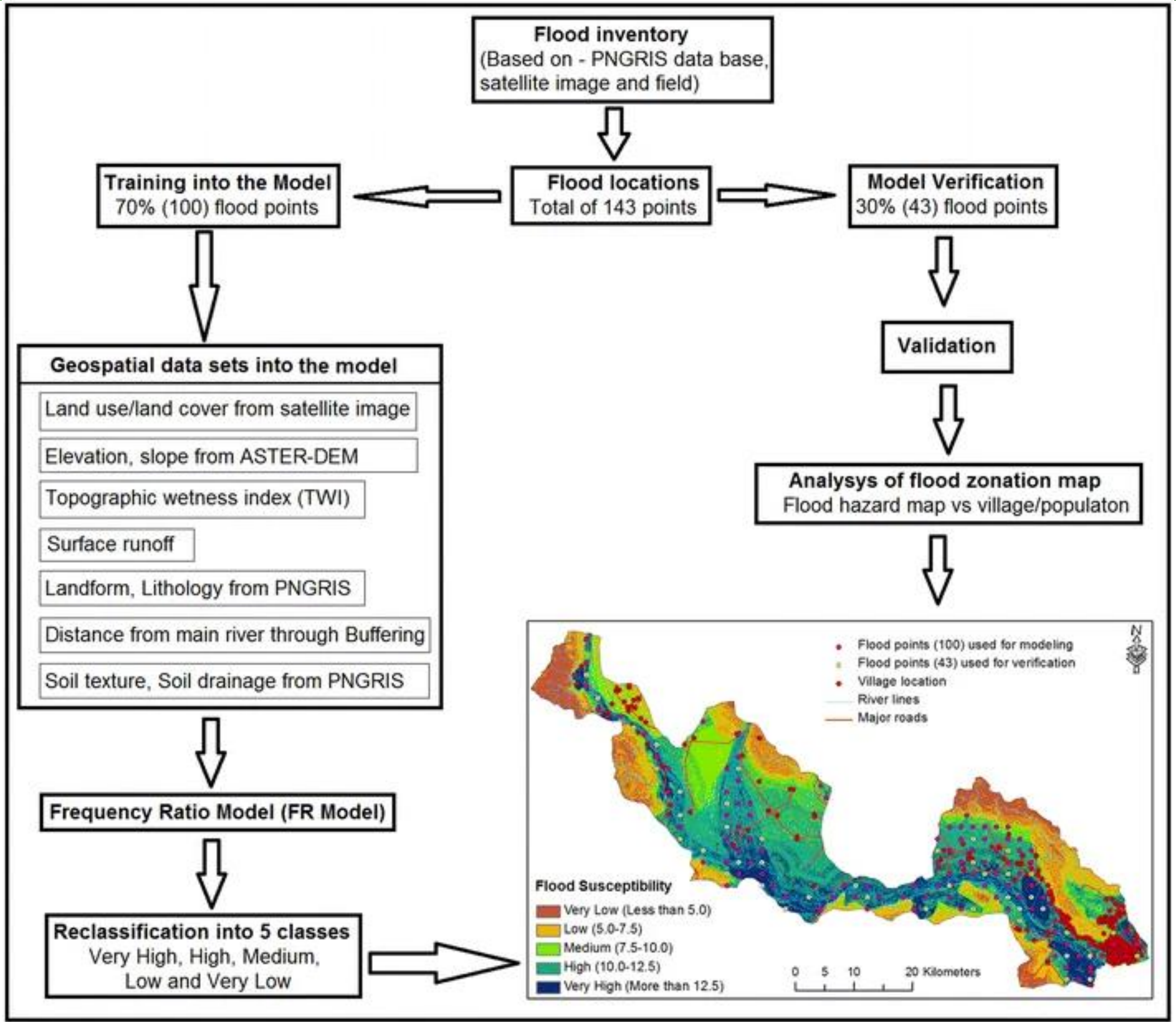
$$FSI = \sum FR,$$

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*



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Risk & Hazard Analysis

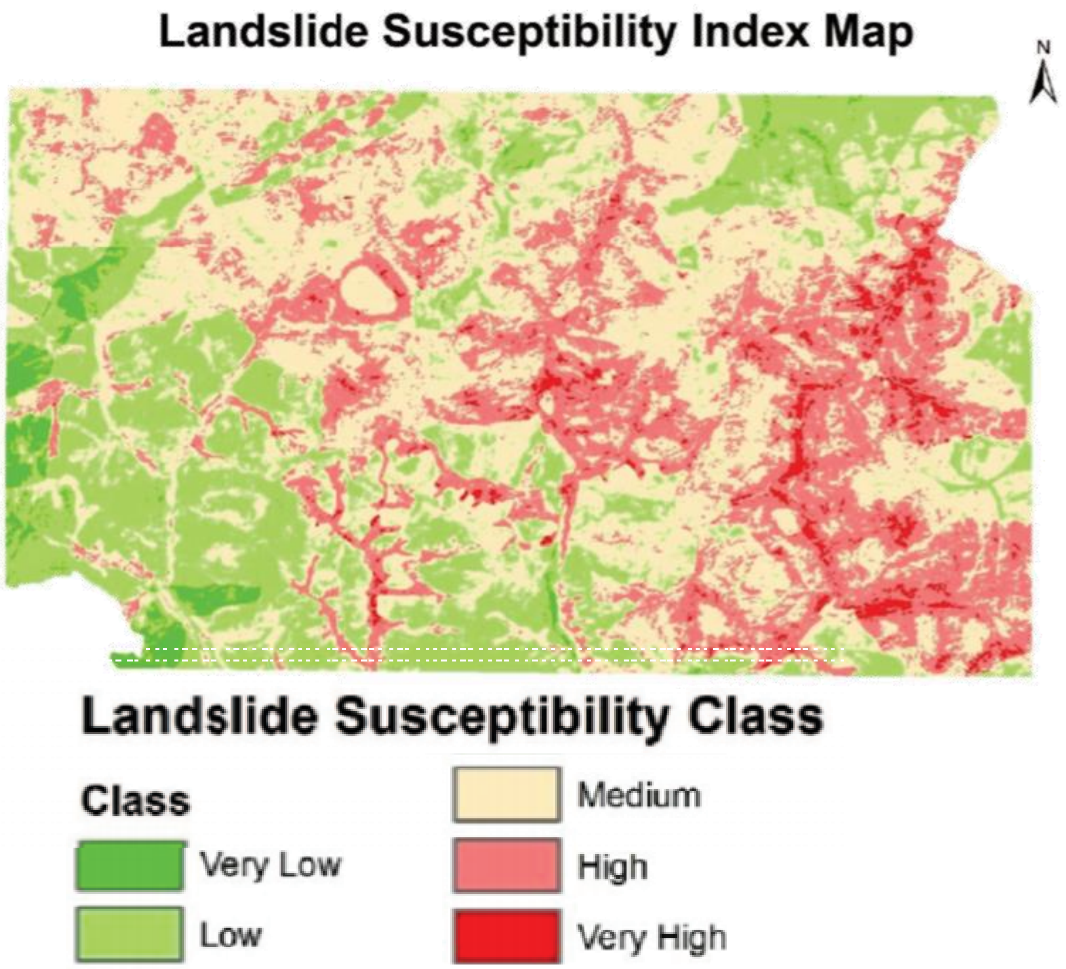
Landslide susceptibility analysis

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

$$= \ln \frac{\frac{Npix_{(Si)}}{Npix_{(Ni)}}}{\frac{\Sigma Npix_{(Si)}}{\Sigma Npix_{(Ni)}}}$$

Where, W_i = Weight of a factor class;
$Npix_{(Si)}$ = Number of pixel of landslide within class i;
$Npix_{(Ni)}$ = Number of pixel of class i;
$\Sigma Npix_{(Si)}$ =Number of Pixel of landslide within the whole study area;
$\Sigma Npix_{(Ni)}$ = 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



Source: *Bibek et al., 2015*

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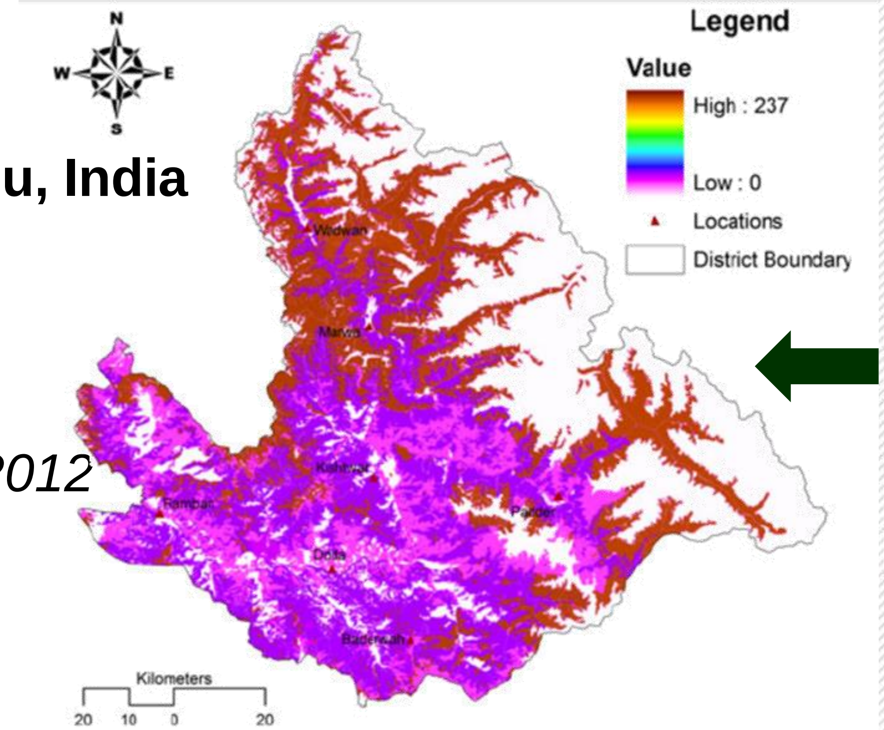
Biodiversity Analysis

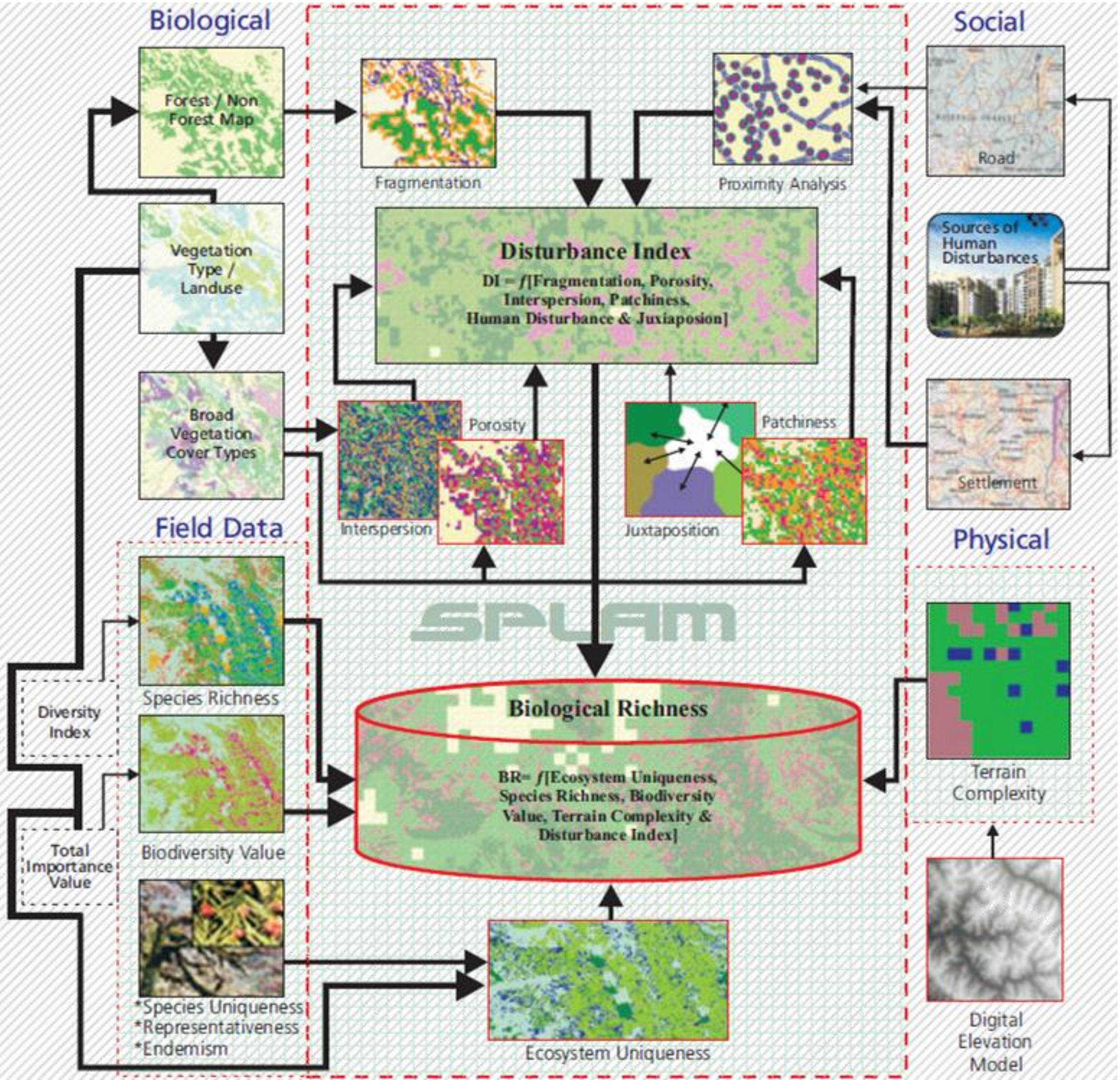
$$BR = \sum_{i=1}^{n} (DI_i \times wt_{i1} + TC_i \times wt_{i2} + SR_i \times wt_{i3} + BV_i \times wt_{i4} + EU_i \times wt_{i5})$$

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*





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THANK YOU

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