Introduction to GIS

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Faculty Profile

Brief Profile : Dr. Sameer Saran

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Dr. Sameer Saran is M.Sc Physics and PhD in Geoinformatics. He did Advanced Research at Wagenningen University, The NL. He is Course Director of IIRS-ITC JEP on Geoinformatics (M.Sc & PGD) with University of Twente, The Netherlands

His area of expertise focuses on 3D CityModels, Web GIS, Geohealth, Spatial Database Management and Citizen Science. He has 20 years of research experience in Geoinformatics. He has published more than 50 papers in peer reviewed national and international journals. He is recipient of many national and international awards to his credit like National Geomatics Award for Excellence, Indian National Geospatial Award, Outstanding Contribution Award, ISRO and ASI Award

Module- 3: Geographical Information System

Module/ Course Module/Course Coordinator: Shri. Prabhakar Alok Verma

Date	Topic	Speaker
28/09/2020	Introduction to GIS	Dr. Sameer Saran
29/09/2020	Geographic Phenomena, Concepts and examples	Shri Prasun Kumar Gupta
30/09/2020	Data Inputting and Editing in GIS	Shri K. Shiva Reddy
01/10/2020	GIS Data Models (Spatial and Non spatial)	Shri Ashutosh Kumar Jha
05/10/2020	Map Projection Concepts & Use in RS & GIS	Dr. Ashutosh Srivastav
06/10/2020	Spatial Analysis - Introductory Concepts and Overview	Shri Prabhakar Alok Verma
07/10/2020	Spatial Analysis - Functionality and Tools	Shri Kapil Oberai
08/10/2020	Open Source Software Technology & Tools	Shri Prasun Kumar Gupta
09/10/2020	Advanced Geospatial Modeling	Shri Ashutosh Kumar Jha
12/10/2020	Uncertainty in GIS and Error Propagation	Shri Prabhakar Alok Verma
13/10/2020	Overview of Big Data Analytics Overview of Machine Learning for GIS	Shri Kapil Oberai Shri Prabhakar Alok Verma
14/10/2020	Recent Trends in Geoinformatics	Dr. Sameer Saran
15/10/2020	Panel Discussion of Module 3	All Module -3 Faculty

Outline

- Define GIS & its Characteristics
- Sources of Input Data
- Concept of Geographic phenomena
- Spatial Data Models
  - Raster
  - Vector
- Topology and Spatial relationships
- Data Types and Values
- Spatial data analysis
- GIS Applications

Defining GIS

GEOGRAPHICAL

INFORMATION

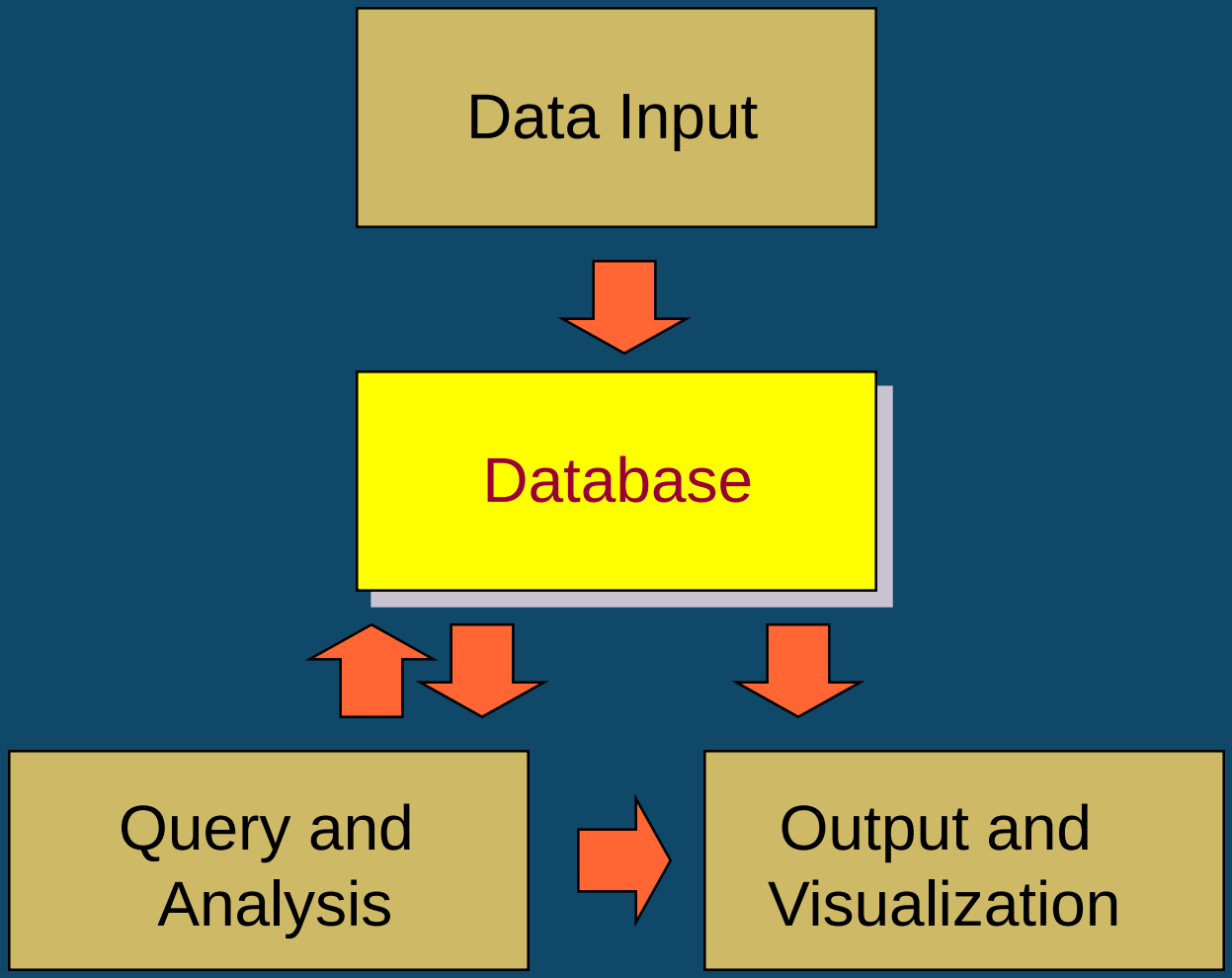
SYSTEM

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

- Input
- Data management (storage and retrieval)
- Manipulation and analysis
- Output."

(Aronoff, 1989)

GIS Functional Modules



Defining GIS (2)

Toolbox based
- set of tools
- a system
- an information system

for capturing, storing, retrieving, analyzing and displaying which are spatially referenced to earth

Database definitions
- a database system in which most of the data are spatially indexed, and upon which a set of procedures are operated in order to answer queries about spatial entities in the database.

Organization based definitions
- a DSS involving the integration of spatially referenced data for problem solving.

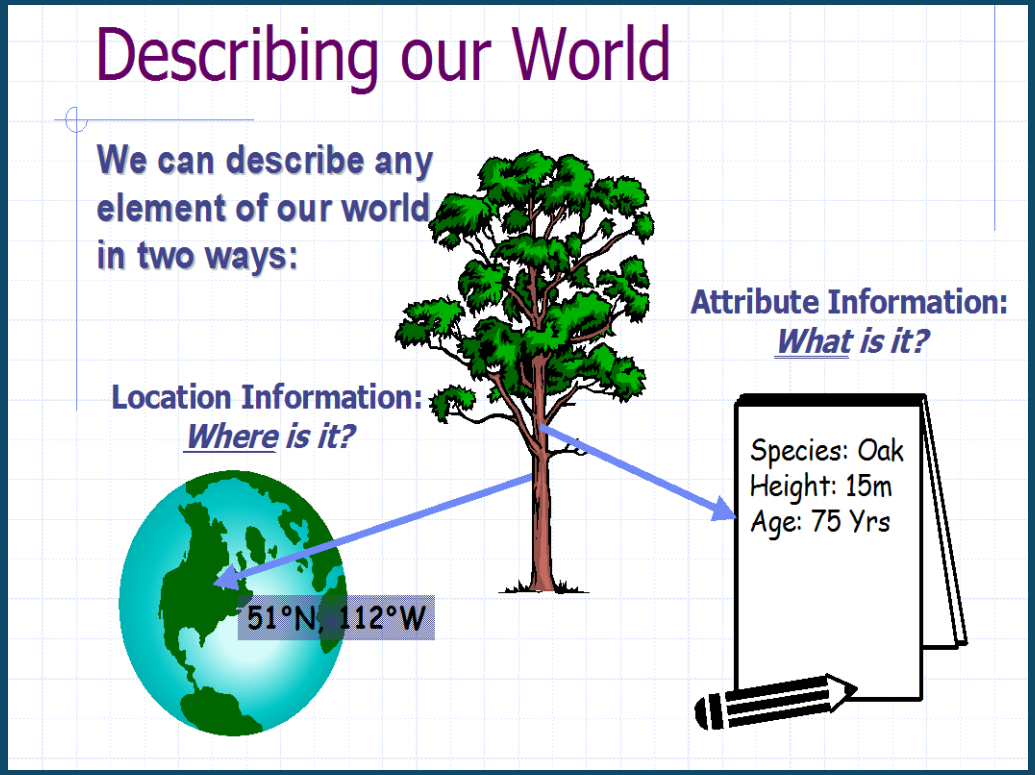
Characteristics of Geographic Data

- Spatial data: features orientation shape, size & structure
- Non-Spatial data: Information about various attributes like area, length & population

Geospatial Data

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

(Chang, 2009)



Characteristics of Spatial Data

- spatial reference
- attributes
- spatial relationships
- temporal component

- where?
- what?
- how?
- when?

Components of GIS

Hardware

+

Software

+

Data

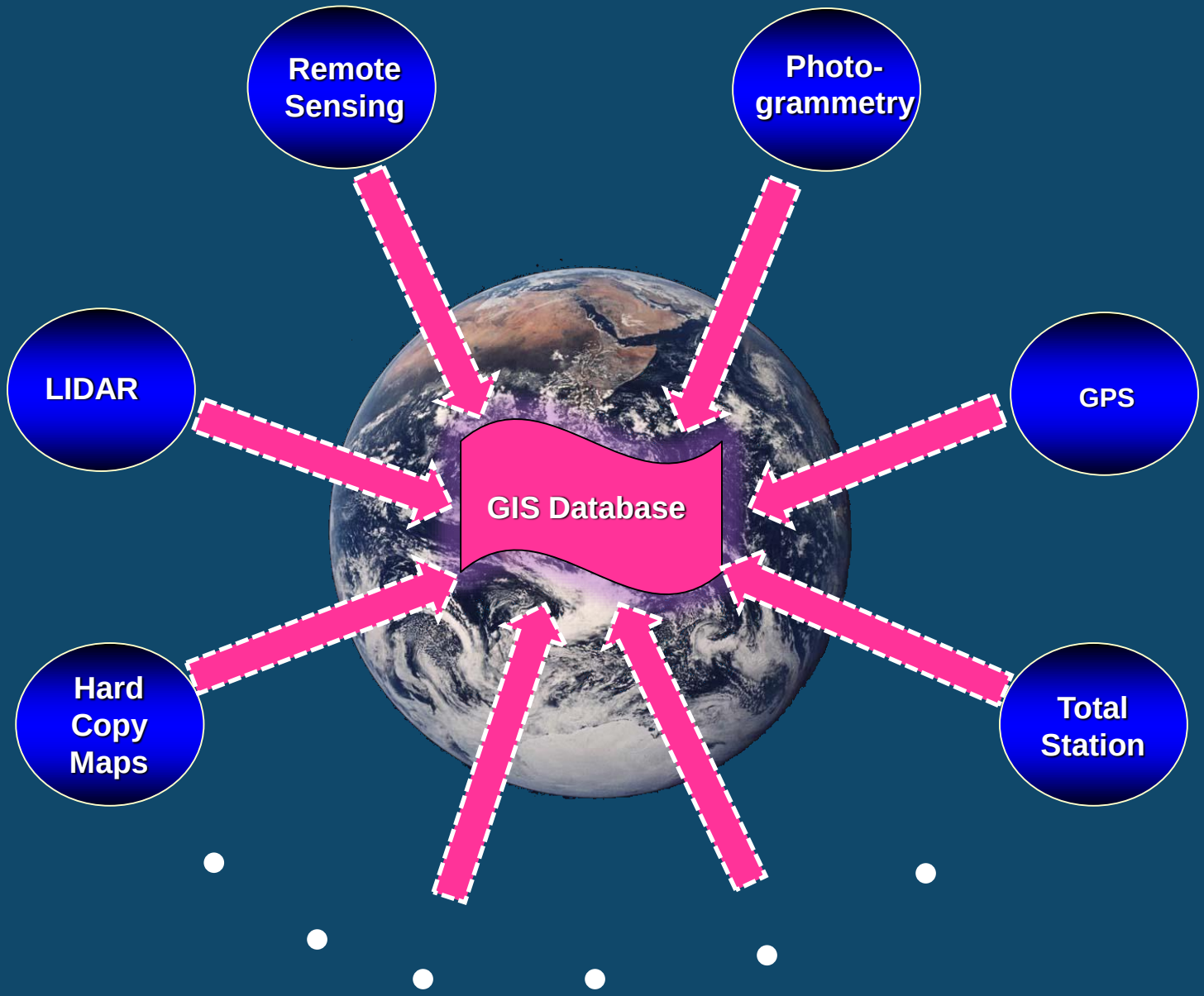
+

People

=

GIS

Sources of Input Data



Geographic phenomenon defined

geographic phenomenon is a manifestation of an entity or process that:

- Can be *named* or *described*
- Can be *georeferenced*
- Can be assigned a *time (interval)* at which it is/was present

What if one is missing?

El Nino: Sea Surface temperature, Wind Speed and location of buoys

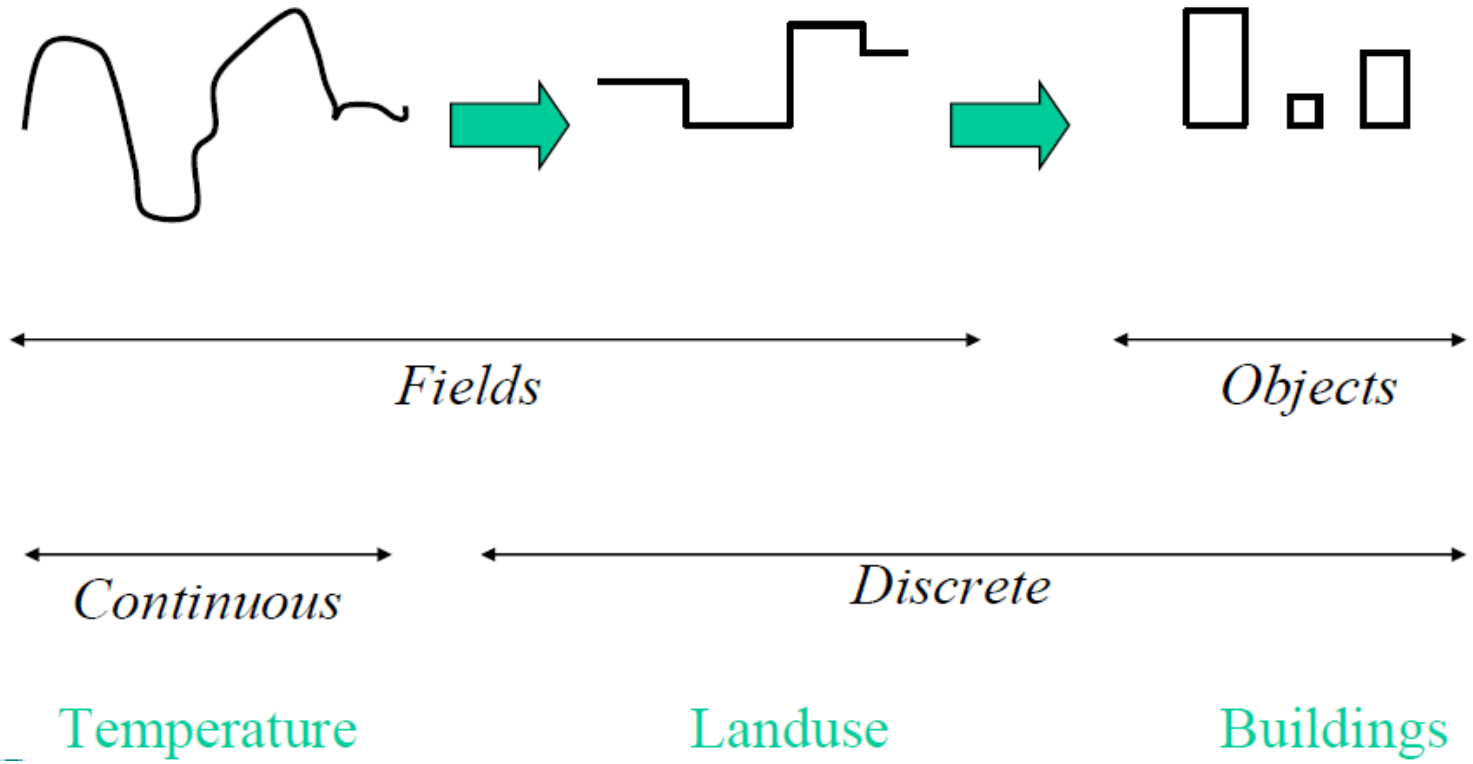
Relevant spatial phenomena exist in two- or three-dimension *Euclidean space*

Euclidean space is a model in which locations are represented by coordinates (x,y) or (x,y,z) and distance and direction can be defined

In 2-D this is known as the *Euclidean plane*

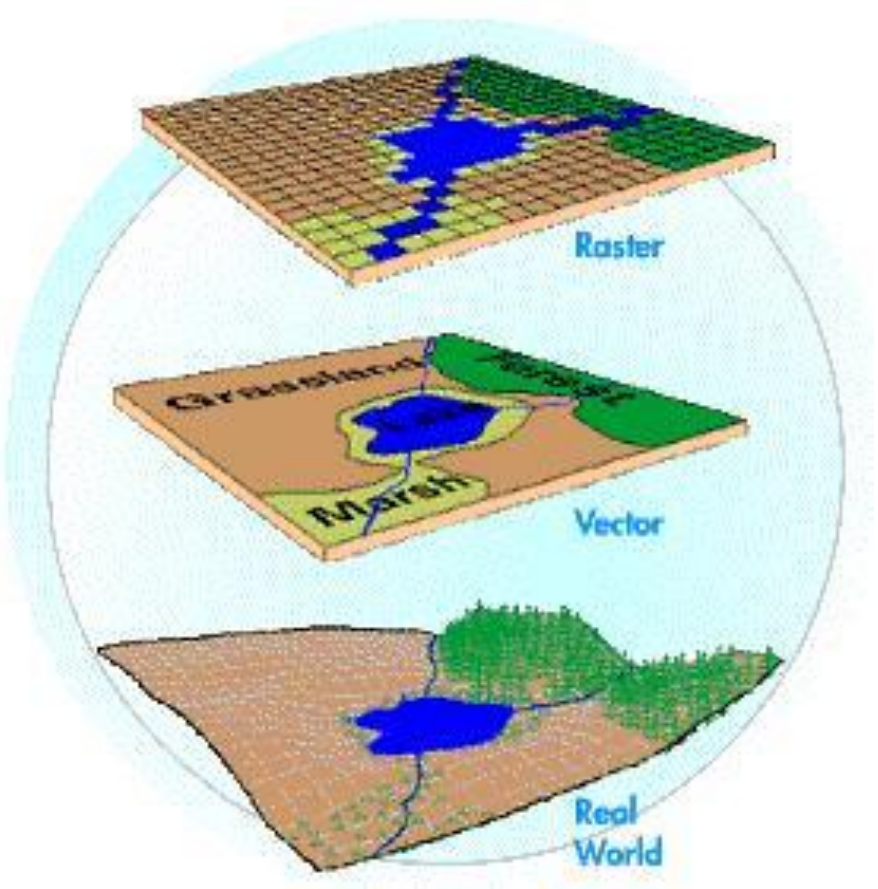
ITC

Different types of geographic phenomena

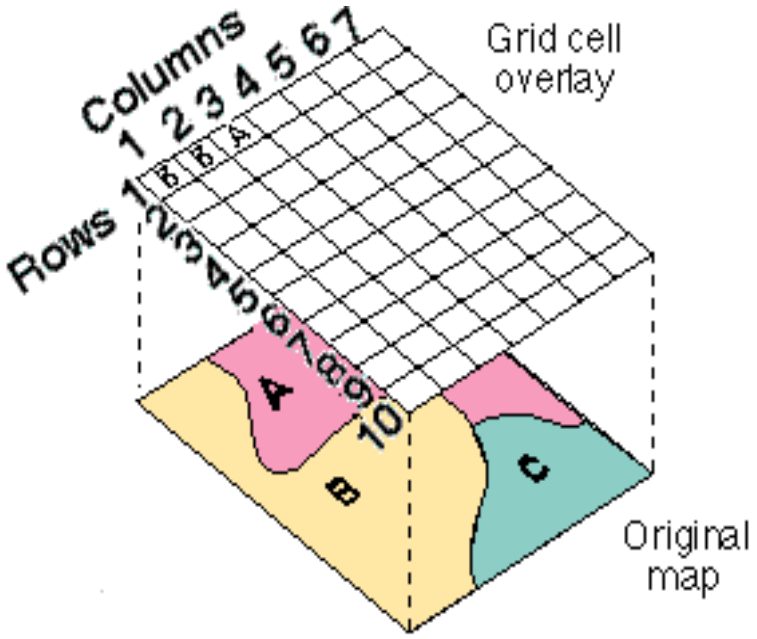


spatial data models

- two fundamental approaches:
  - raster model
  - vector model



raster model



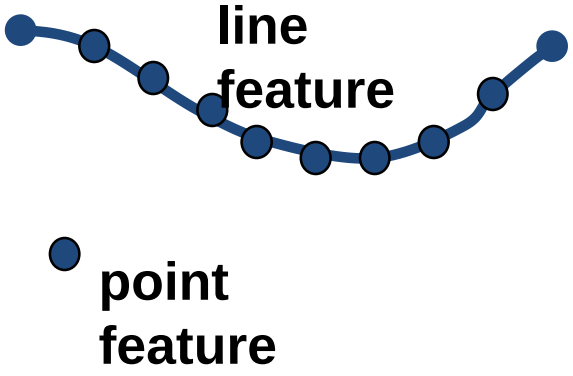
Raster data file

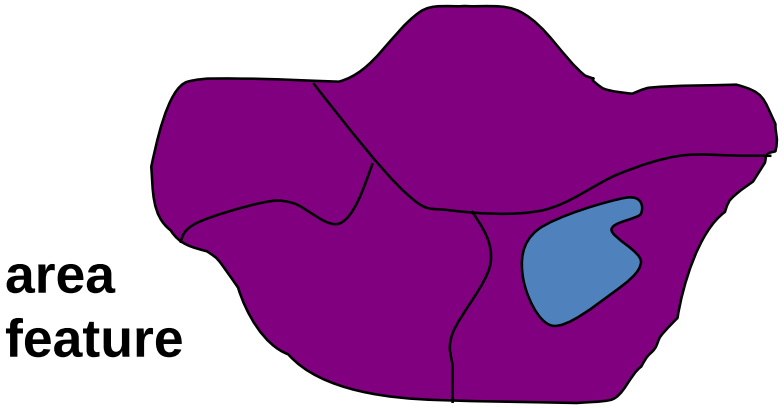
ROW	COLUMN	ATTRIBUTE
1	1	B
1	2	B
1	3	A

The entity information is explicitly recorded for a basic data unit (cell, grid or pixel)

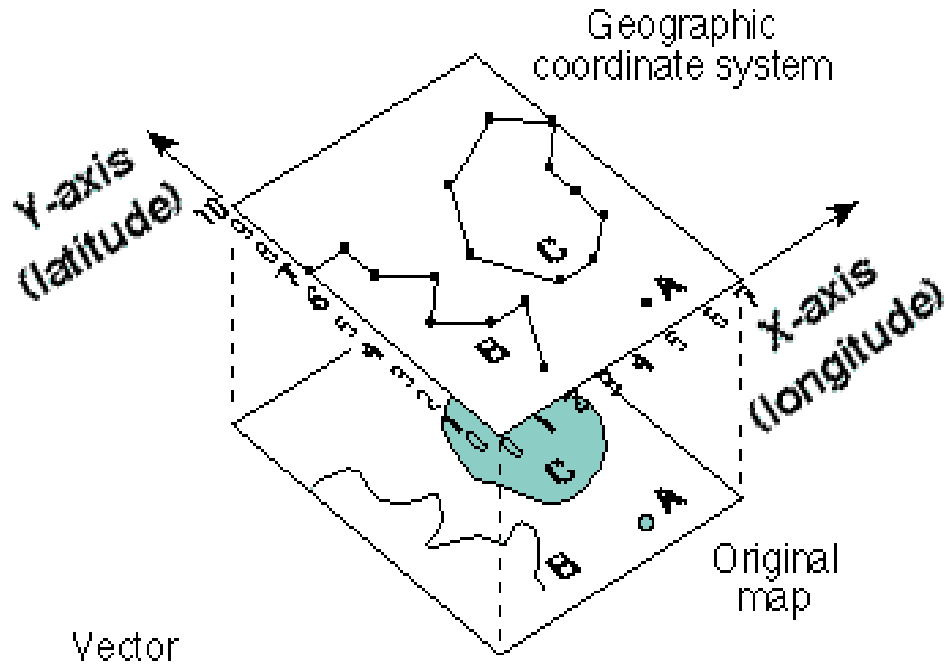
vector model

- 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)**





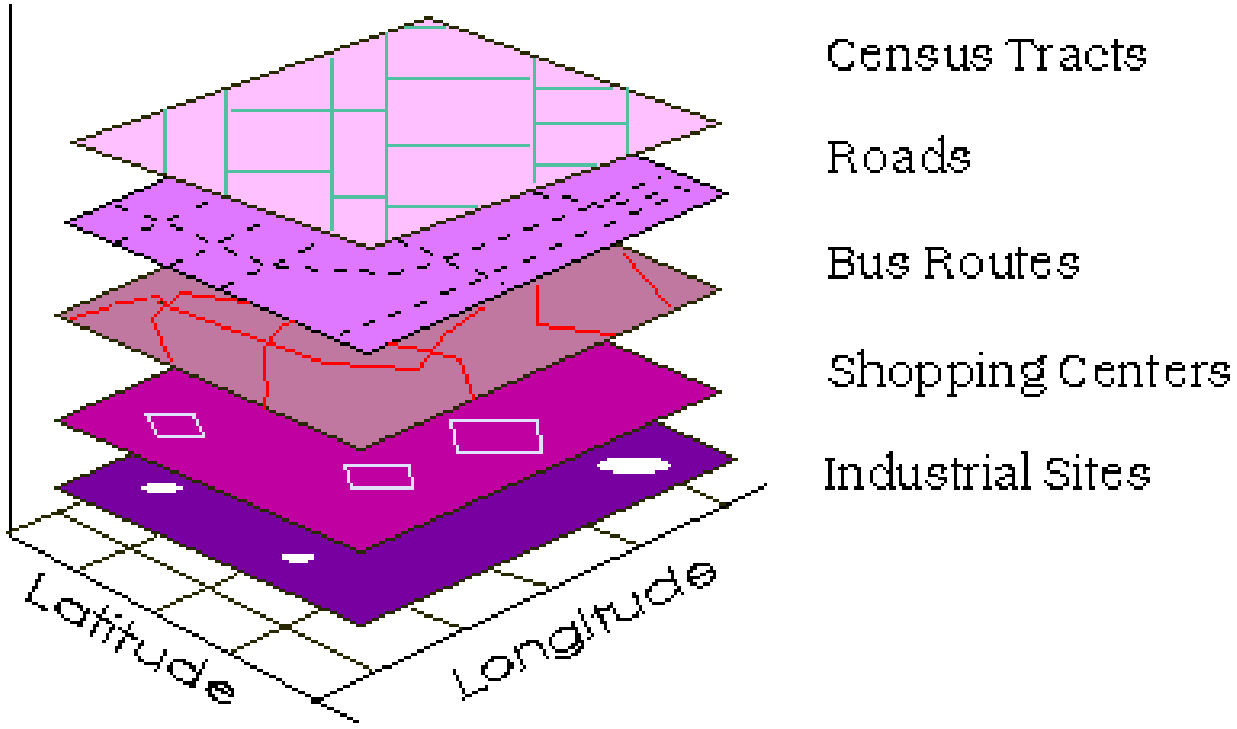
vector model



Vector
data file

ENTITY	X,Y COORDINATES	NAME
A	5,1	well
B	0,7; 1,7; 1,6; 2,5; 1,4; 2,3; 3,3; 2,1	stream
C	4,3; 5,3; 6,4; 6,5; 6,6; 7,7; 6,8; 4,7; 3,5; 4,3	lake

layers in an vector-based model (2)



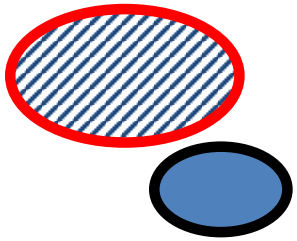
Topology

Topology is a branch of mathematics that deals with properties of space that remain invariant under certain transformations.

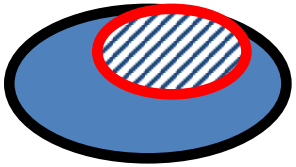
Properties : Three spatial relationships

Area: Polygons can be defined by set of lines enclose them
Contiguity: Identification of polygons which touch each other or connect identify contiguos polgons (left or right)
Connectivity: Identification of interconnected arcs, starting point & end point of network analysis

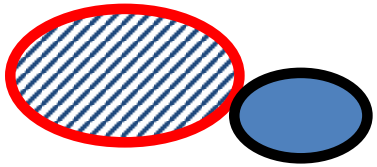
Spatial Relationships



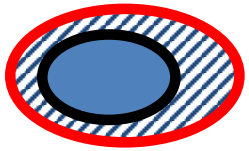
disjoint



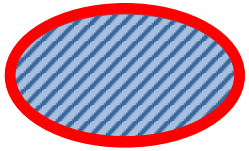
covered by



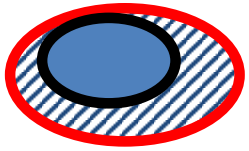
meet



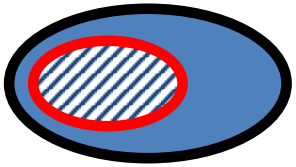
contains



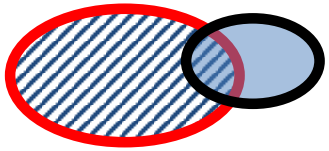
equal



covers



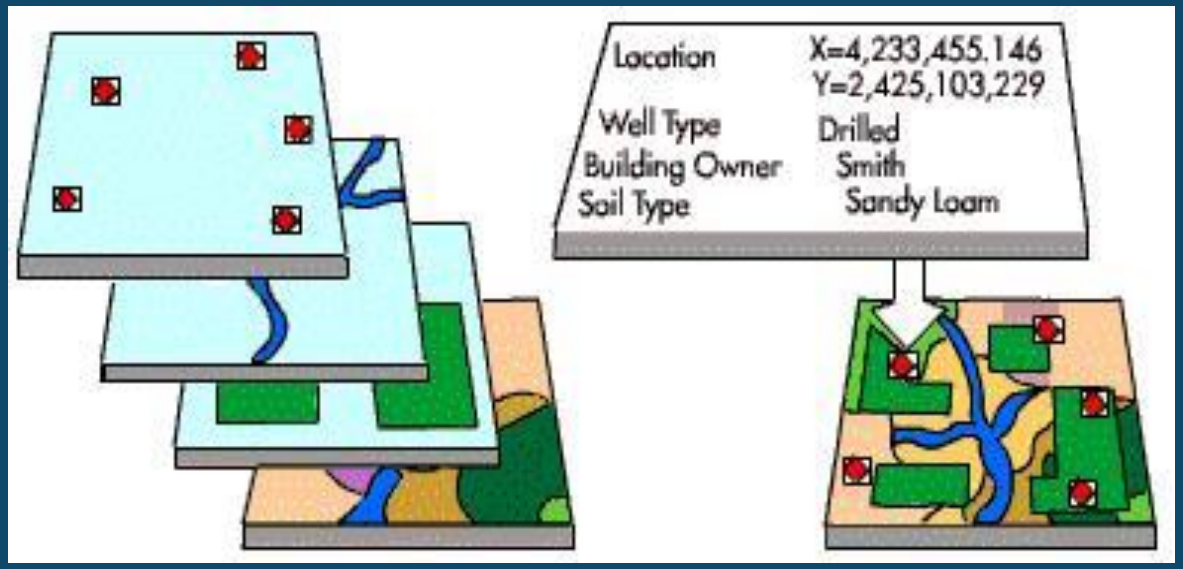
inside



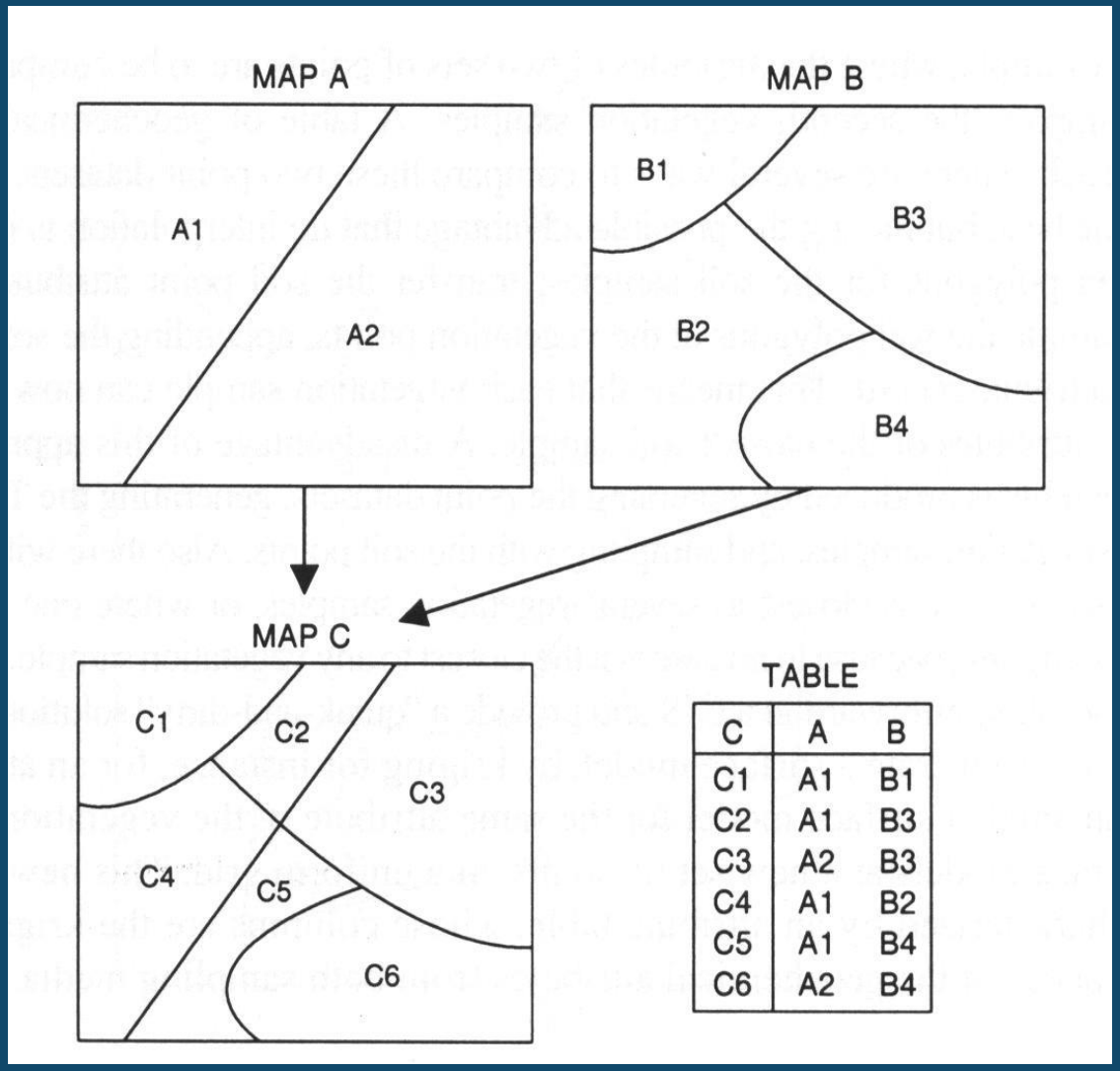
overlap

Overlay Operation

- Map overlaying involves the integration of multiple data layers
  - **vector based**
  - **raster based**



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

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

MapC= MapA + 10

Map C

15	15	12	12
15	15	15	12
16	12	12	12
16	16	16	16

MapC1= MapA + MapB

Map C1

9	9	10	10
9	9	9	10
7	3	3	10
7	7	14	14

MapC2= ((MapA - MapB)/(MapA + MapB)) *100

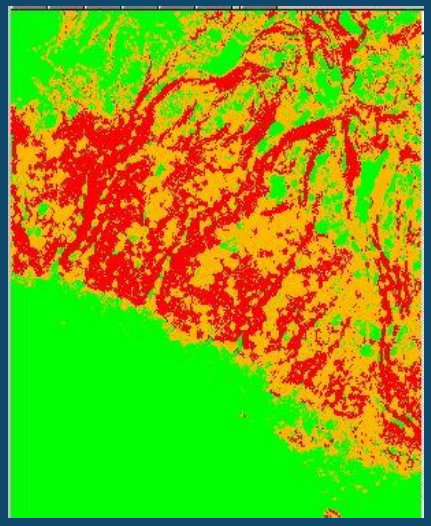
Map C2

11	11	60	60
11	11	11	60
71	33	33	60
71	71	14	14

Landuse = forest

AND

Slope = steep



raster versus vector data model

Raster model	Vector model
Simple data structure	Complex data structure
Easy and efficient overlaying	Difficult to perform overlaying
Compatible with Remote Sensing imagery	Not compatible with RS imagery
High spatial variability is efficiently represented	Inefficient representation of high spatial variability
Simple for programming by user	
Same grid cell definition for various attributes	
Inefficient use of computer storage	Compact data structure
Errors in perimeter and shape	Efficient encoding of topology
Difficult to perform network analysis	Easy to perform network analysis
Inefficient projection transformations	
Loss of information when using large pixel sizes	
Less accurate and less appealing map output	Highly accurate map output

Data Types and Values

Different kinds of data values which we can use to represent different "phenomena"

1. Qualitative Data

(i) Nominal/ Categorical Data – describe data of different categories (e.g. soil data)

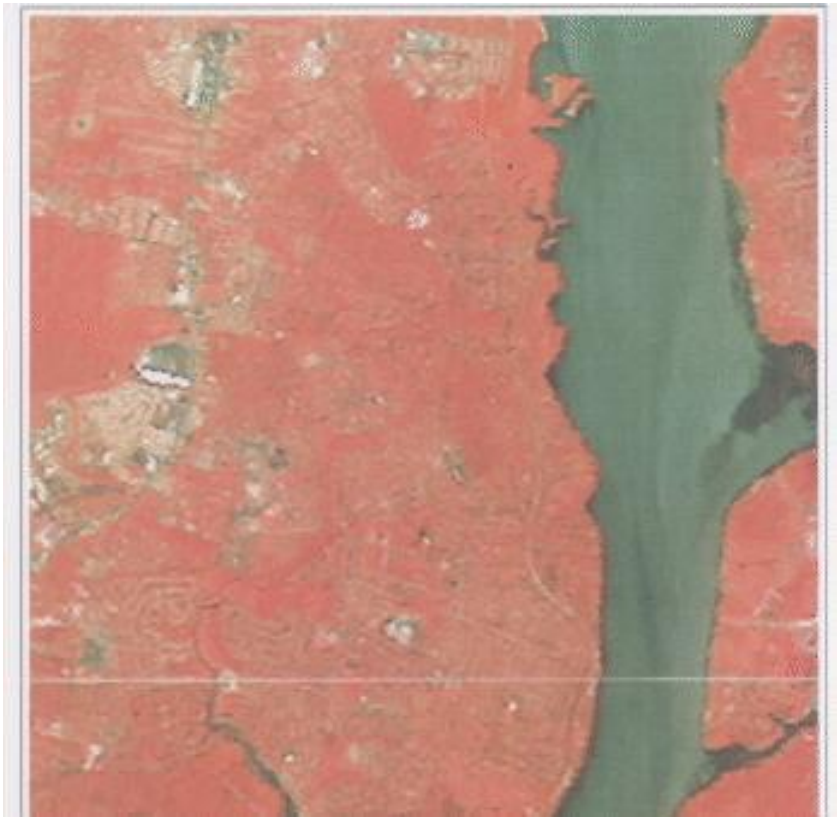
(ii) Ordinal Data – differentiate data by a ranking relationship (e.g. soil erosion, road network)

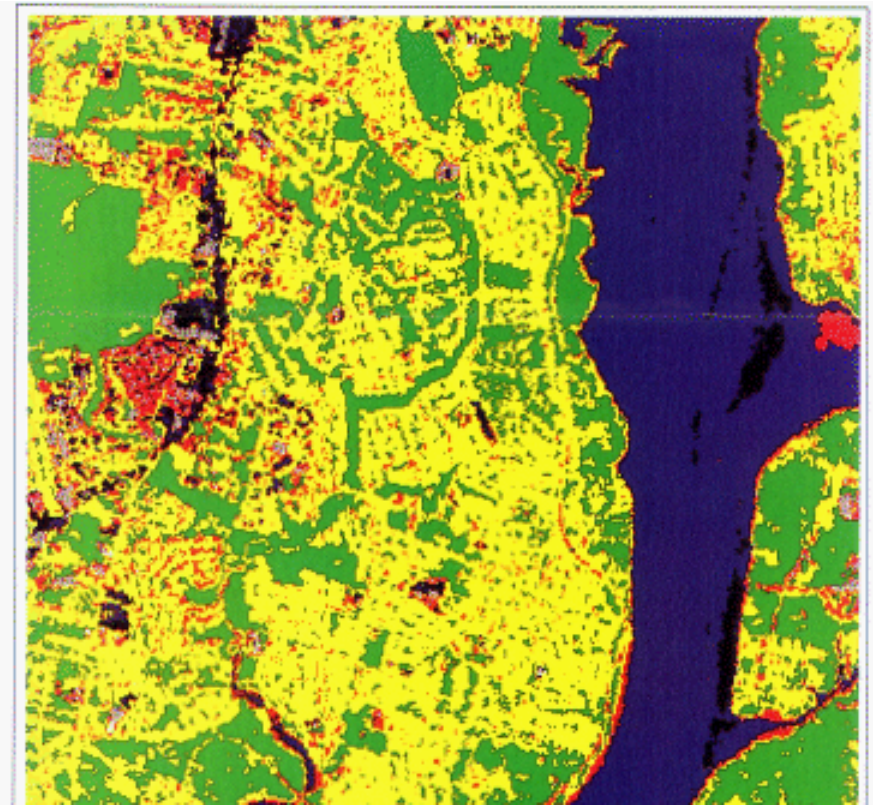
2. Numeric Data

(iii) Interval Data – data having known interval between values (e.g. temperature)

(iv) Ratio Data – data having absolute values (e.g. population density)

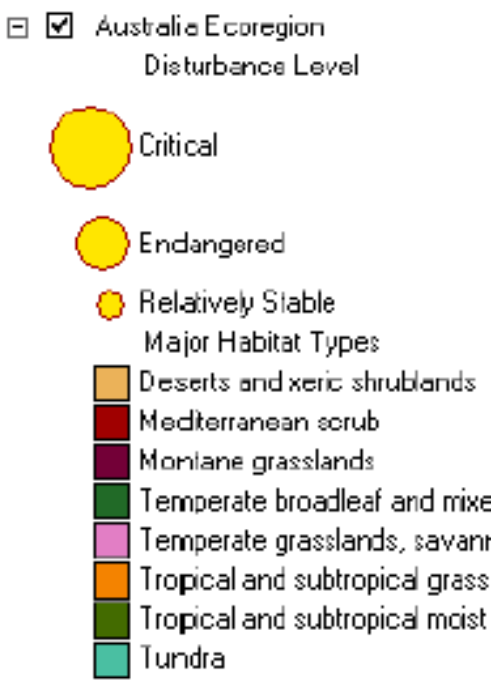
Different kinds of Data & Data Values

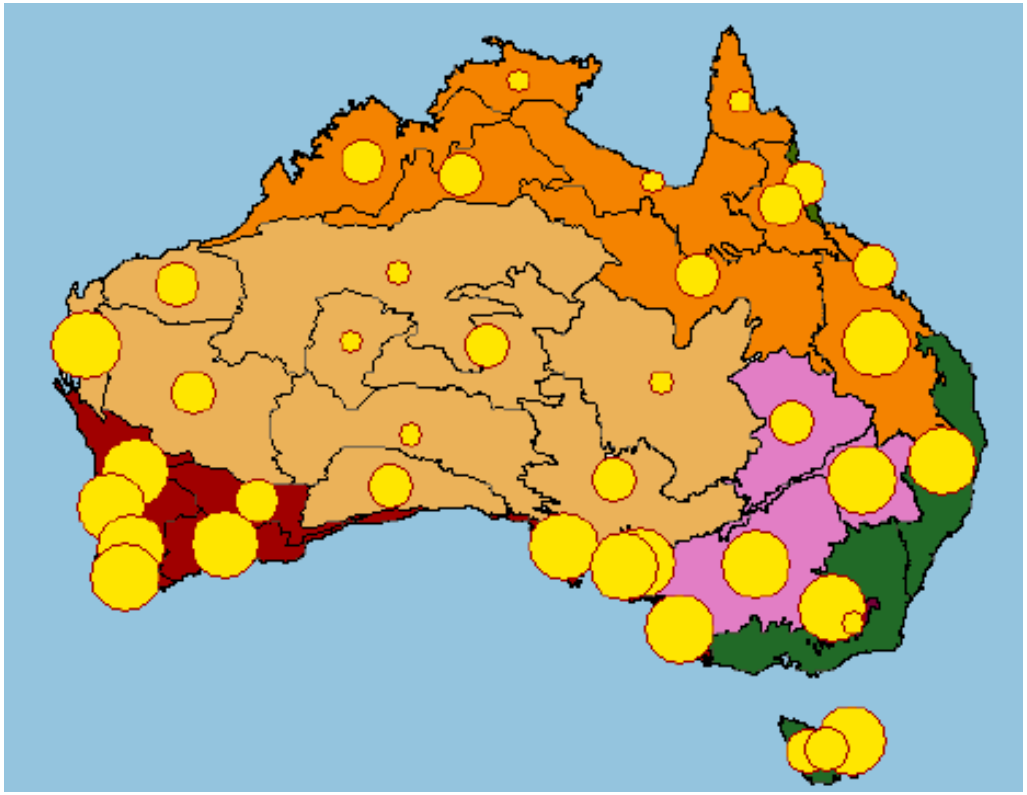




- **Land Use / Land cover extracted from the image**

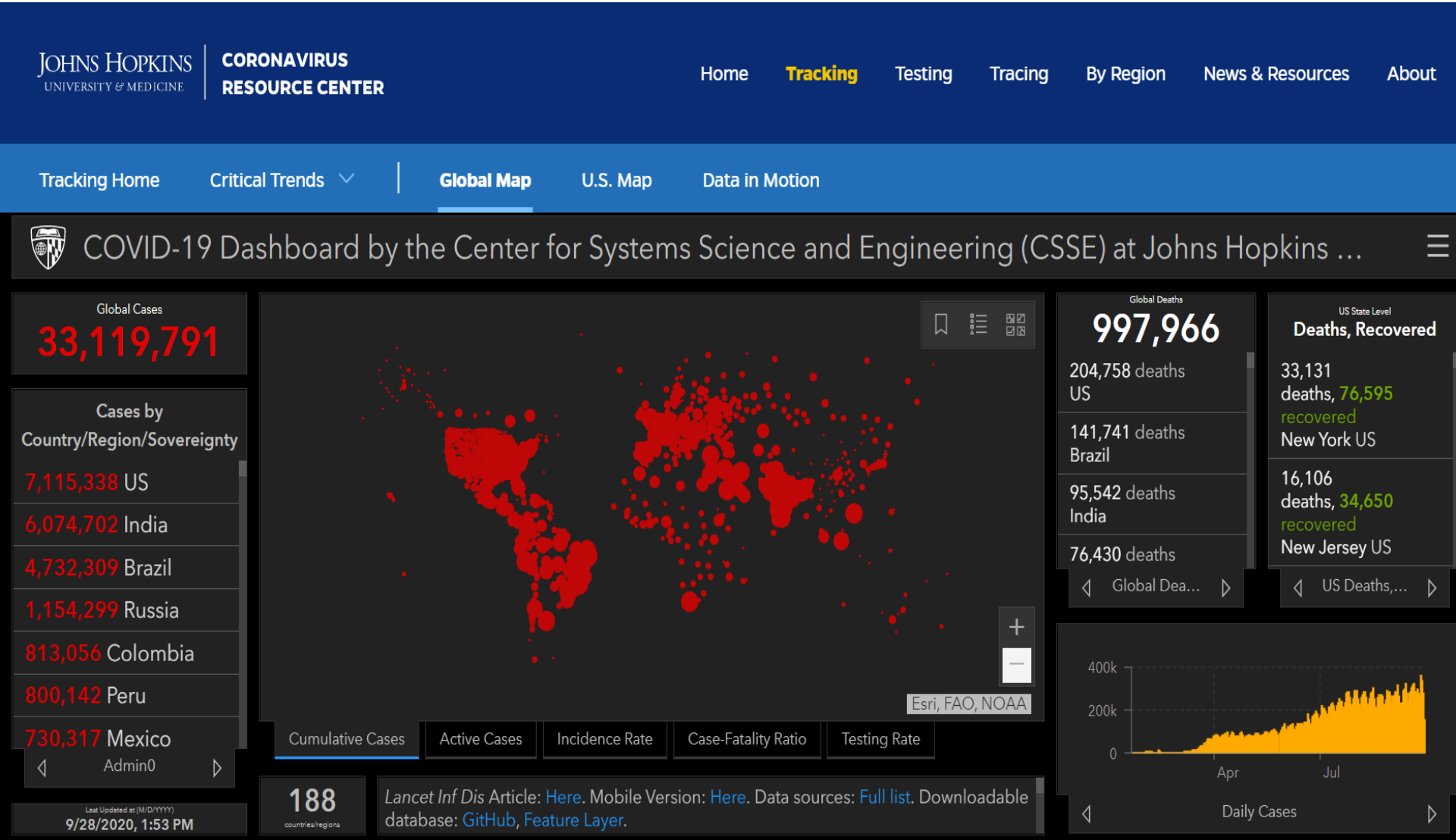
Different kinds of data values



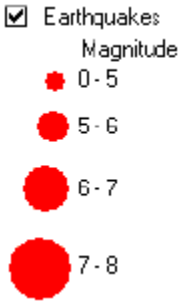


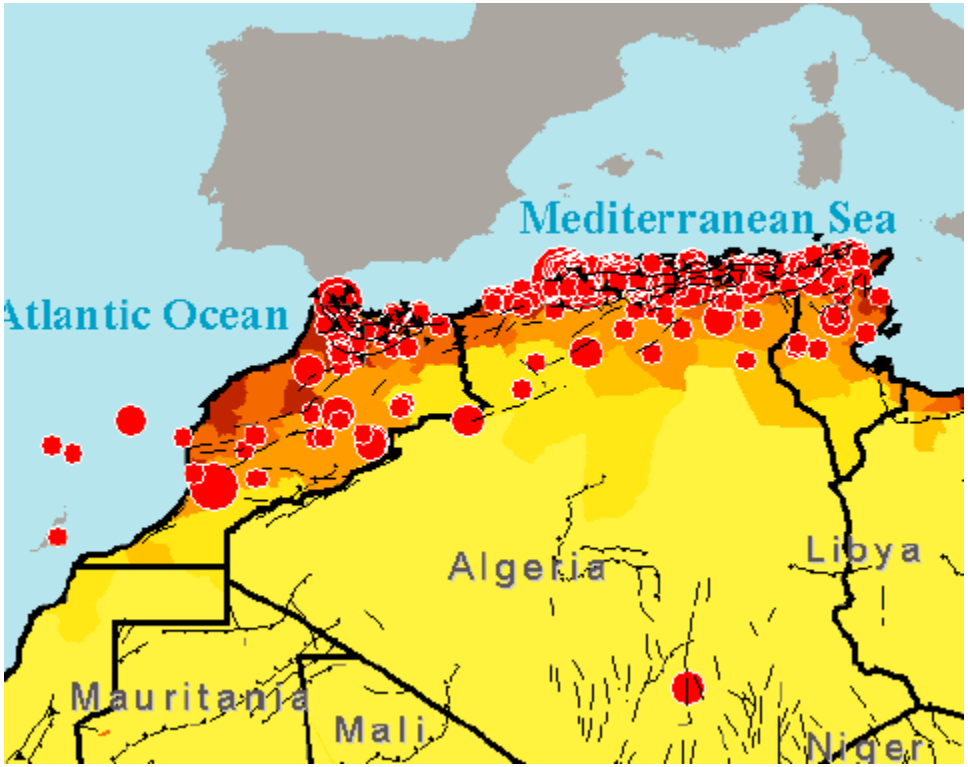
Ref: ESRI documents – Using ArcMap

COVID-19 Dashboard by John Hopkins University (JHU)
https://coronavirus.jhu.edu/map.html



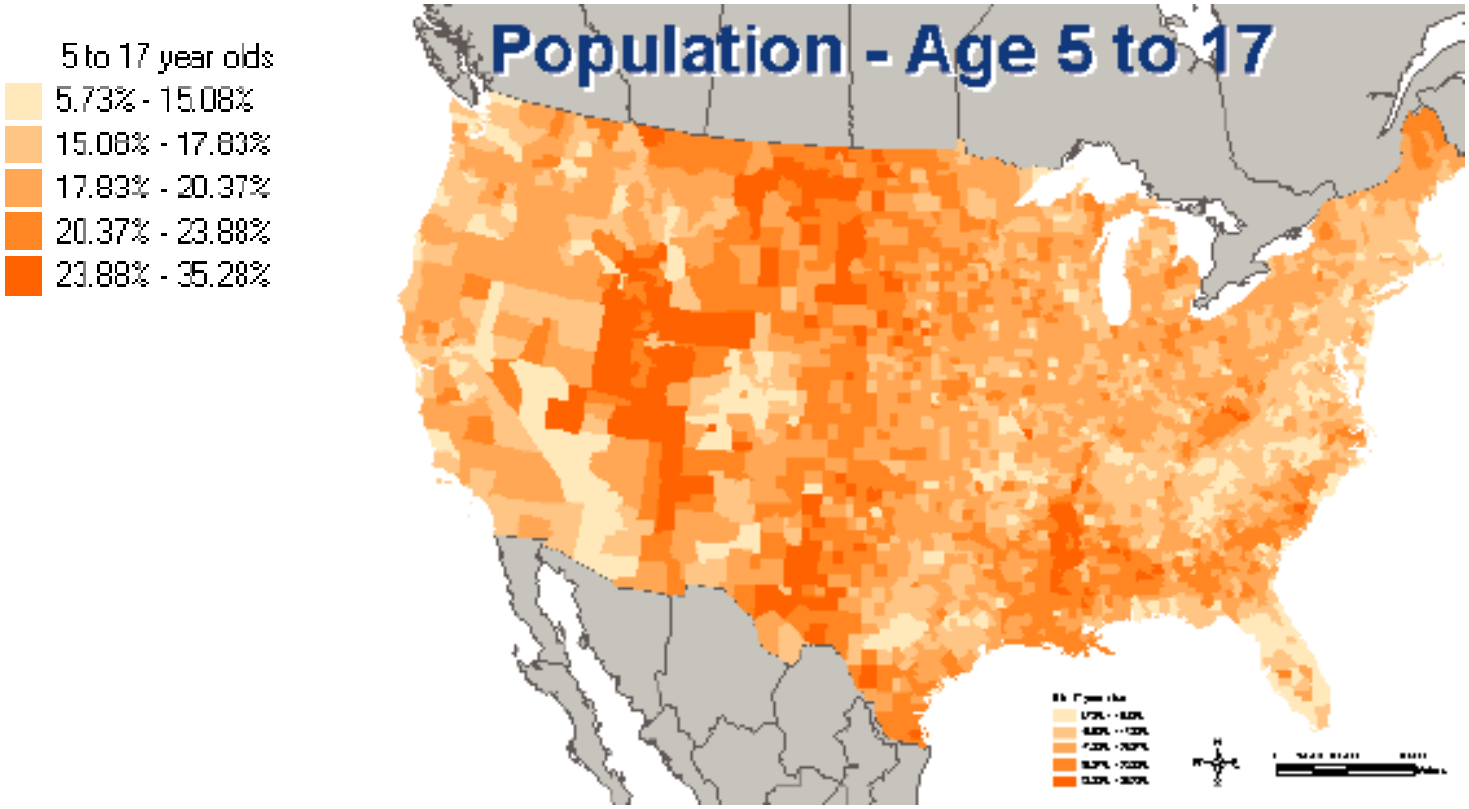
Different kinds of data values





Ref: ESRI documents – Using ArcMap

Different kinds of data values



Ref: ESRI documents – Using ArcMap

Spatial Analysis: Vector & Raster based

VECTOR BASED ANALYSIS

- **Map Overlay**
  - Union, Intersect
  - Point in Polygon, Line in Polygon, Polygon on 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**

Questions a GIS can Answer?

- ☆ LOCATION (Question: What is at ...?)
- ☆ CONDITION (Question: Where is it....?)
- ☆ TRENDS (Question: What has changed since....?)
- ☆ PATTERN (Question: What spatial pattern exists..?)
- ☆ MODELING (Question: What if....?)

Geospatial Analysis contd.

Why?

Answer geographic questions

- *Where is the nearest school to my home?*

Make informed decisions

- *Choosing where to locate a new refinery*

Take action, make changes

- *Change an intended hiking route*

Build accurate models

- *Modeling effects of change of LULC on soil erosion*

Methods?

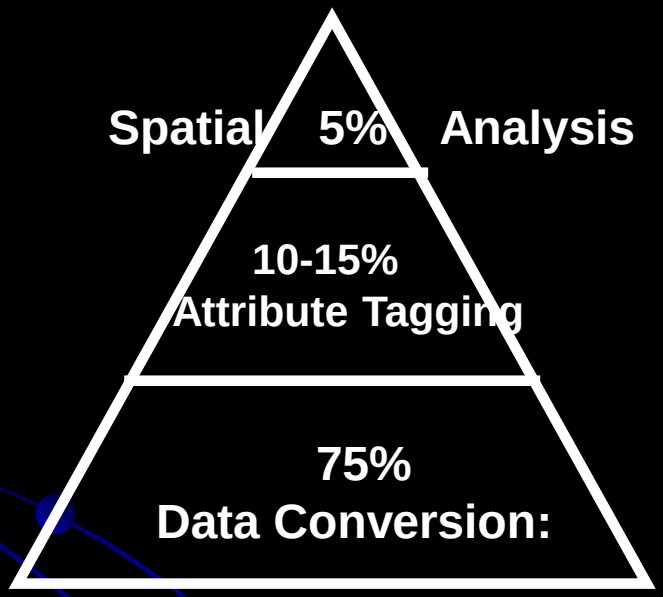
- SIMPLE QUERY
- SPATIAL QUERY
- SINGLE LAYER OPERATION
- MULTIPLE- LAYER OPERATIONS
- SURFACE ANALYSIS
- NETWORK ANALYSIS
- POINT PATTERN ANALYSIS
- SPATIAL MODELING

Applications of GIS

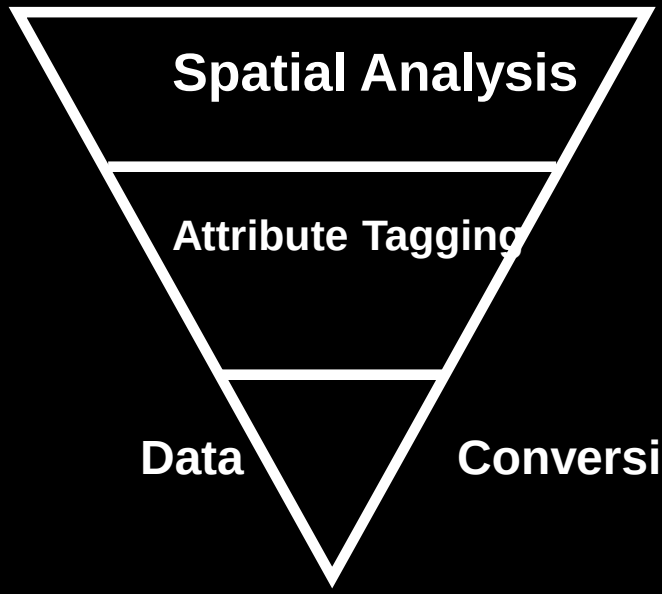
- Natural resource management
- Disaster Management
- Land use planning
- Infrastructure development
- Utility services
- e-governance
- Health GIS
- Tourism GIS
- …….

Changing Emphases:

…From Data to Analysis



Past



Present/Future

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..

The application of GIS is limited only by the imagination of those who use it

Jack Dangermond

Thank you..