Geographical Information System

Lecture slides - I

Course Description:

The course covers about spatial data structure, modeling and database design, different techniques for capturing the real world, spatial data manipulation, analysis and visualization, spatial data infrastructure and data standardization, overview of open GIS and open source GIS data.

Course Objectives:

The main objective of this course is to provide both theoretical and practical knowledge of Geographical Information System

Mark Schema

Full Marks: 100

60 – Board Exam

20 – Pre- Board Exam (Internal Assessment)

20 – Lab

Software For LAB

QGIS is an **Open Source** Geographic Information System (GIS) and is one of the more popular and use friendly open source GIS packages available.

Geographic Information System (GIS)

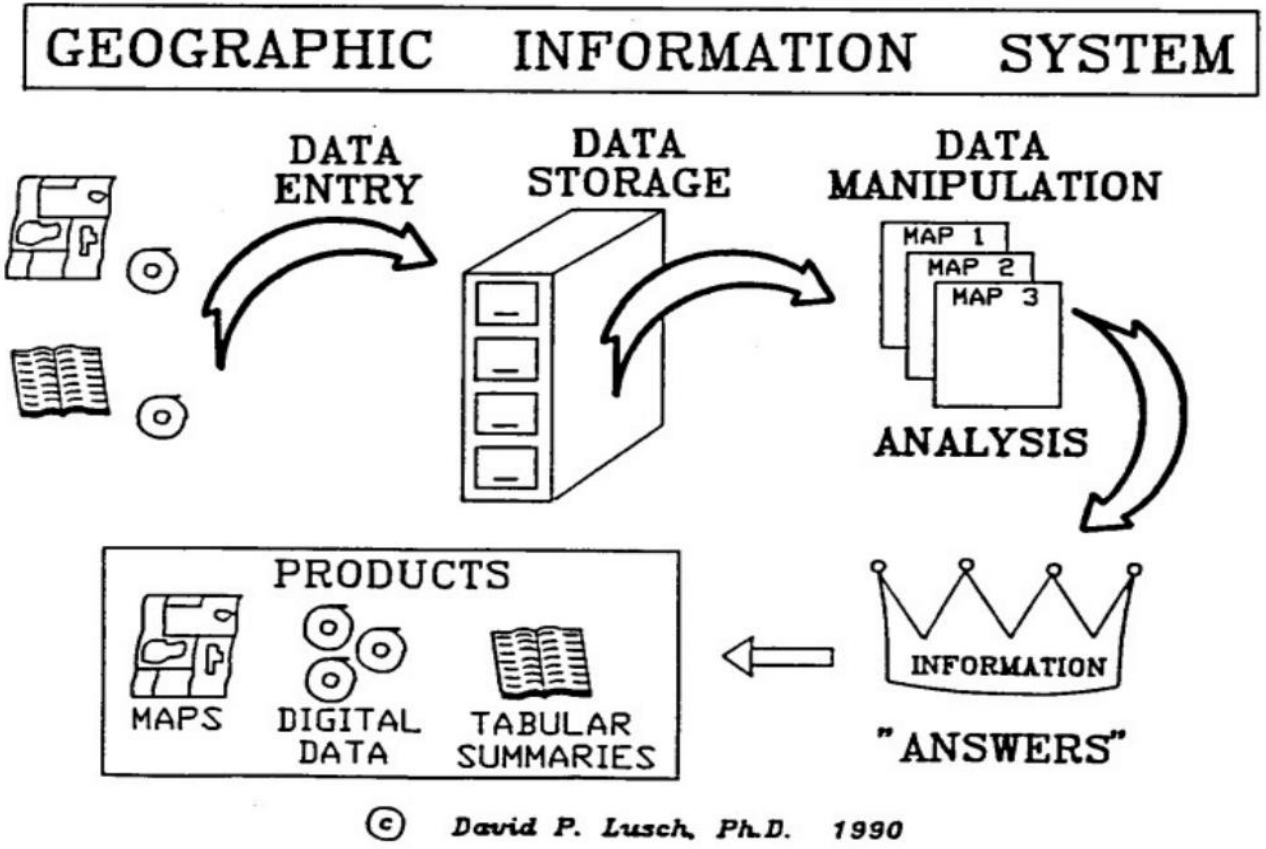
- An **information system** designed to work with **data referenced by geographic co-ordinates.**
- A **database system** with specific capabilities for **spatially-referenced data**, as well as a set of operations for working with the data.

Why needed?

Better Decision Making

- GIS is An INTEGRATED SYSTEM of COMPUTER HARDWARE and SOFTWARE coupled with PROCEDURES and a HUMAN ANALYST which together support the CAPTURE, MANAGEMENT, MANIPULATION, ANALYSIS, MODELLING, and DISPLAY of SPATIALLY REFERENCED DATA.

Geographic Information System (GIS)



Why GIS ?

1. Identify, locate, and acquire spatial data relevant to projects in their field of interest, as well as find major gaps in or problems with existing information.

Images from BBC news

Capitol Building

Locations referred in news are visualized in the image

2:15 8 Jan

The rioters' route

https://www.bbc.com/news/live/election-us-2020-55558355

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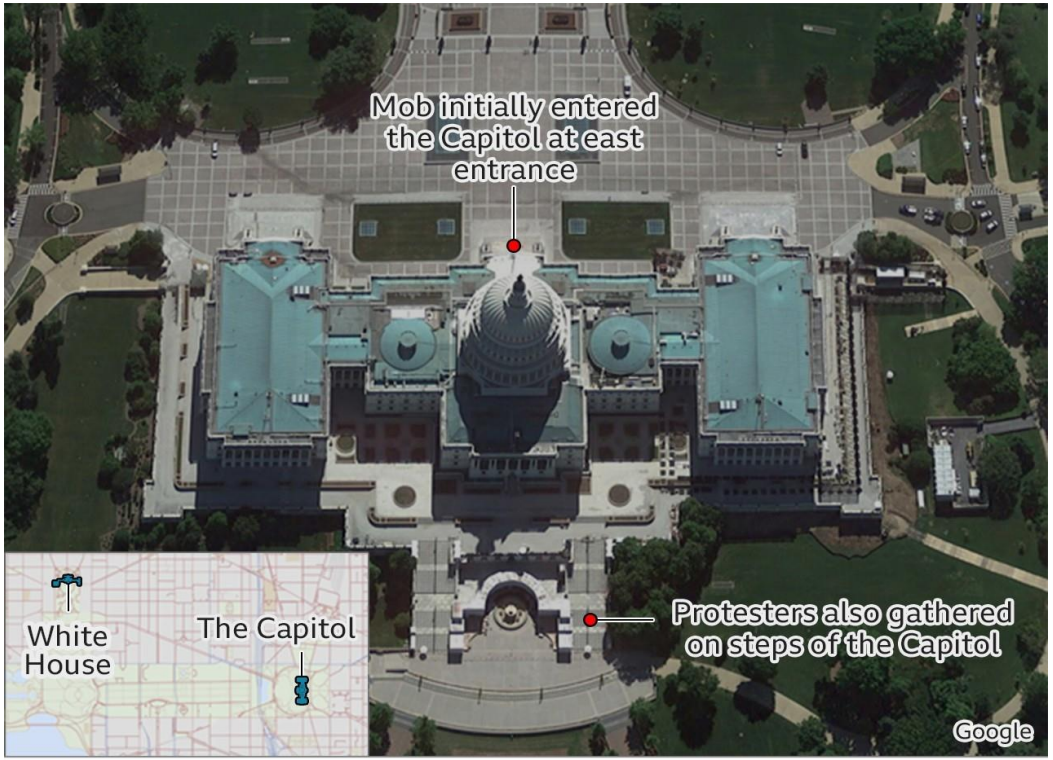


https://www.bbc.com/news/world-us-canada-55568621

1. Identify, locate, and acquire spatial data relevant to projects in their field of interest, as well as find major gaps in or problems with existing information.

Page of Pokhara from the Official website of Nepal Tourism Board

https://www.welcomenepal.com/places-to-see/pokhara.html

Pokhara is Nepal's number 1 adventure and leisure destination, a gateway to treks in the Annapurna region with plenty of entertainment for individual travellers and their families.

In Pokhara you can experience the excitement of adventure: boating, hiking, pony rides, paragliding, bungee, zipline or simply relaxing at one of the several lakes in the valley.

Pokhara will overwhelm you with its natural beauty and great photo ops. Walk along the shores of the Fewa Lake, enjoy the greenery surrounding you and gaze at the spectacular panoramic view of the Himalayan peaks of the Annapurna Massif. Brightly painted wooden boats add vibrant colors to the greenery, while paragliders float down slowly from above. Flying over the lake is probably going to be one of the highlights of your travel experience in Nepal.

Pokhara is well-known as the starting point for numerous trekking trails and expeditions in the Annapurna . Most trekkers heading for the Annapurna region make Pokhara their first stop, or as a relaxing station before heading out for some serious hiking.

So, one may enjoy boating and reading books, observing the serenity of nature, sipping on your favourite drink, either in local restaurants or at a blues bar, or one may simply enjoy sightseeing or cycling around the valley.

There are rows of souvenir shops in the market section of the city. Pokhara produces some of the finest handicrafts in the country.

Besides the many activities to engage in around the city, a short hike to Sarangkot is highly recommended. With magnificent views of astounding sunsets, sunrise, and of the entire city below, this hike is well worth the sweat. Devi's Falls or David' Fall as some like to call it, is the popular spot where the stream disappears underground, and some distance out of the city is the Mahendra Gufa, a series of caves full of stalagmites and stalactites besides the numerous bats that live within. You will also be confronted by the towering peak of Mt. Machhapuchhare (Fishtail Mountain for some) that completely dominates the view from here.

Pokhara has developed into an adventure tourism destination in the last decade, offering everything from ultra-light flights to paragliding, and from skydiving and ziplining to bungee jumping. Pokhara is the complete holiday package for thrill seekers and the adrenaline junky. But it's also ideal for spending a quiet few days recovering from a three-week, exhausting trek in high altitude.

Problems with textual description

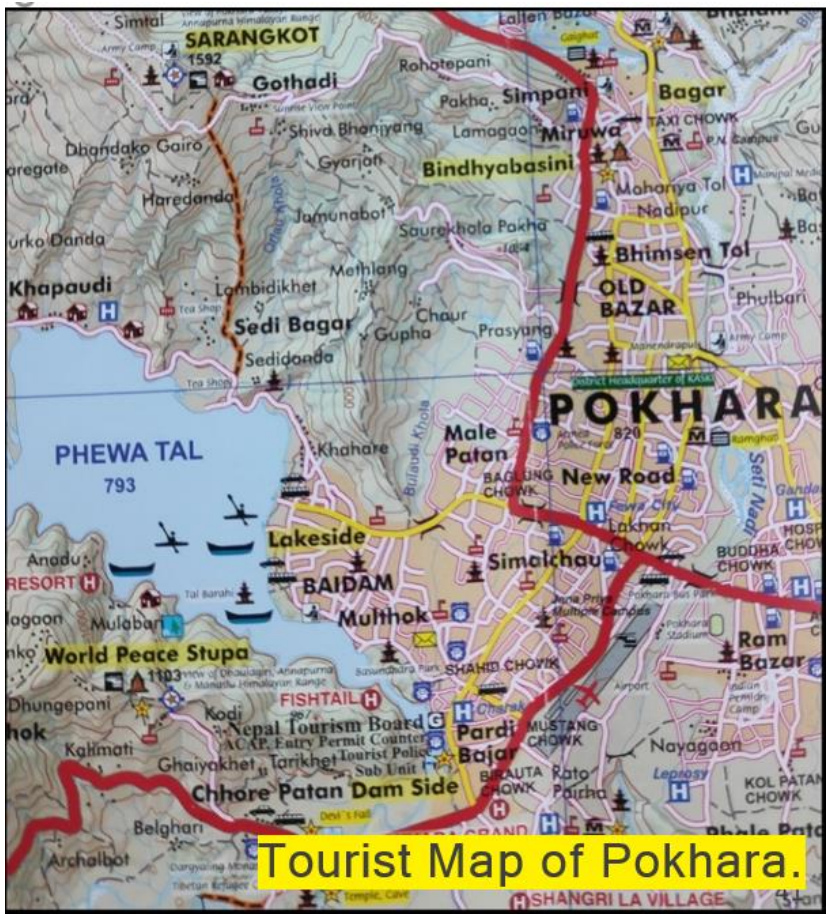
→Better with Maps.

Picture is an universal language → No problem if you cant read English!

Important spots highlighted

- Sarangkot
- Bagar
- Lakeside
- World Peace Stupa

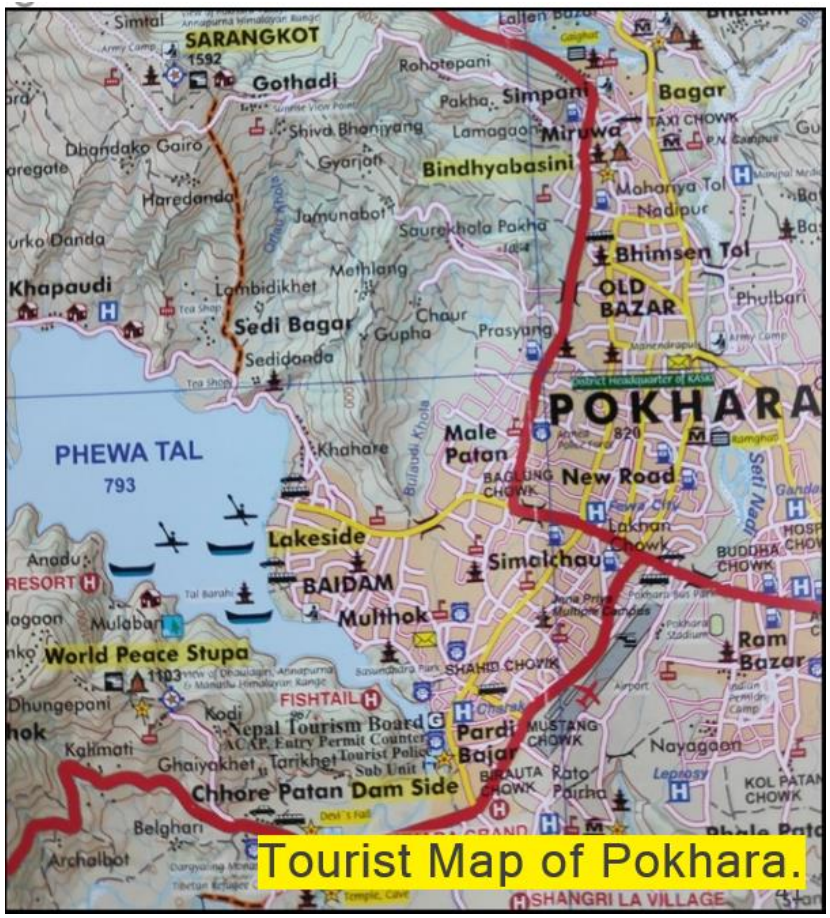
Maps more HELPFUL for travel decision making



Gaps with Maps →How to enrich it?

- Tourist Map of Pokhara.
- Bagar, Sarangkot and Lakeside are equally highlighted in this Tourist Map.
- Which spot should a Tourist visit?

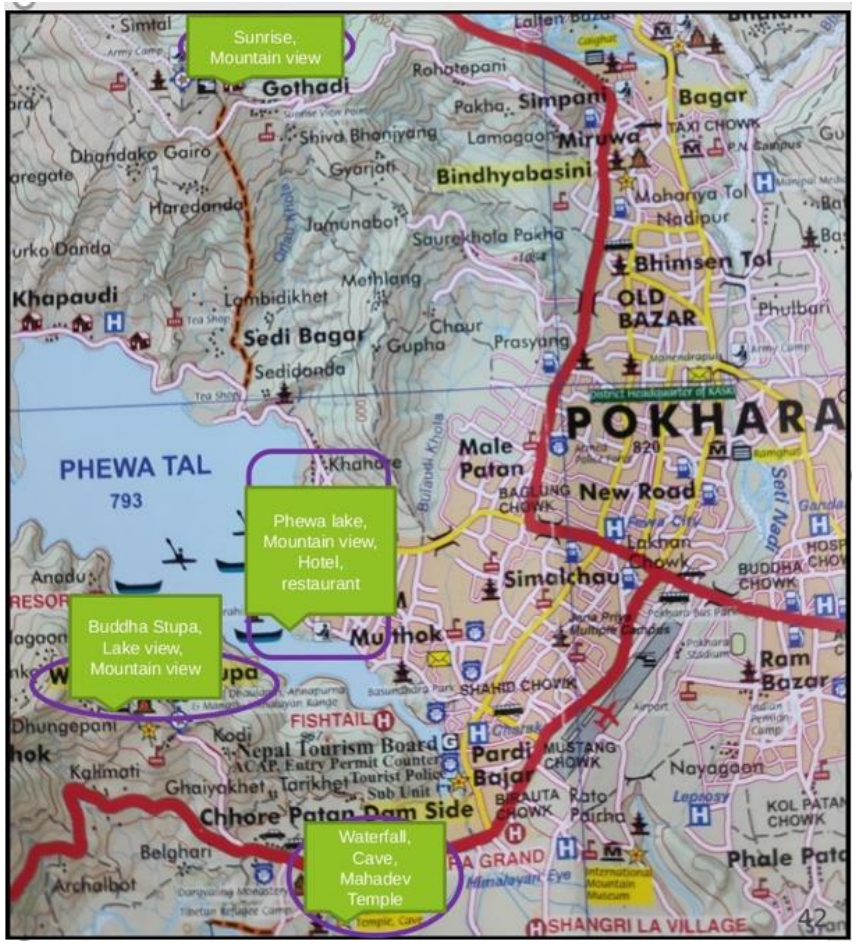
Can we enhance the map more?



Find major gaps in or problems with

Social Media mining for extracting popularity of a place?

- **Sunrise, mountains** may be better viewed from Sarangkot than other places.
- **Phewa lake** better at Lakeside.



2. Evaluate fitness for use of the existing data sources for use in a project.

- Can we use geo-tweets for counting exact number of Tourists?
- Can we use geo-tweets for counting general tourist arrival trend?

Sagarmatha National Park

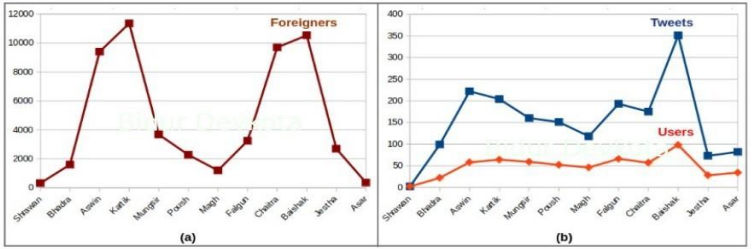
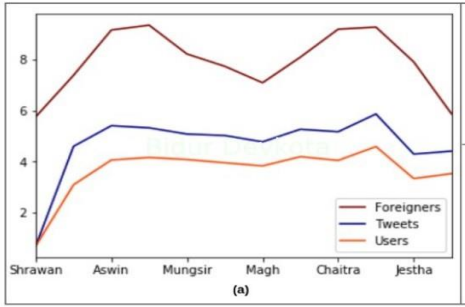


Figure 3.7: Sagarmatha National Park for fiscal year 2074-2075 (July 2017-July 2018): (**a**)Foreign Visitors (**b**) Geo-tagged Tweets



	Foreigners	Tweets	Users
Foreigners	1.00	0.86	0.81
Tweets	0.86	1.00	0.92
Users	0.81	0.92	1.00

(b)

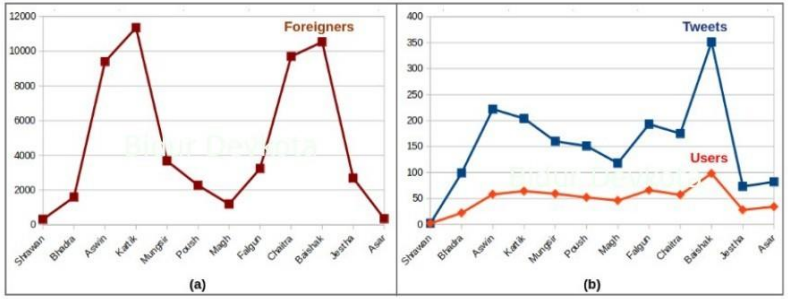
	Foreigners	Tweets	Users
Foreigners	1.00	0.74	0.72
Tweets	0.74	1.00	0.99
Users	0.72	0.99	1.00

(c)

Figure 3.8: Sagarmatha National Park for fiscal year 2074-2075 (July 2017-July 2018): (**a**) Log Plot, (**b**) Pearson Correlation, (**c**) Spearman Rank Correlation

3. Understand the data creation process and create simple data sets and/or add to existing data

Sagarmatha National Park



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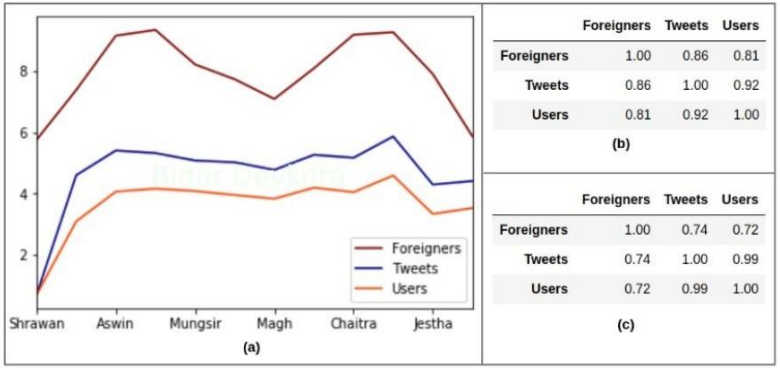

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New Data Source: Tweet

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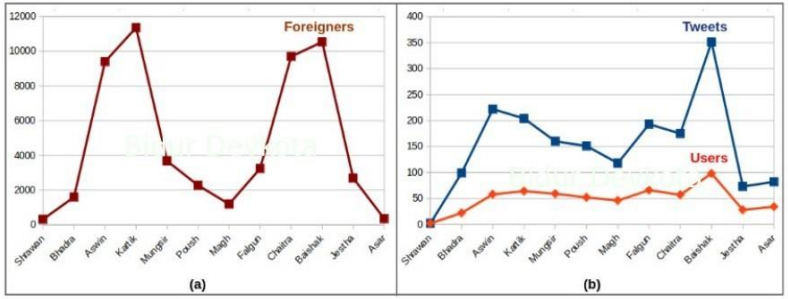

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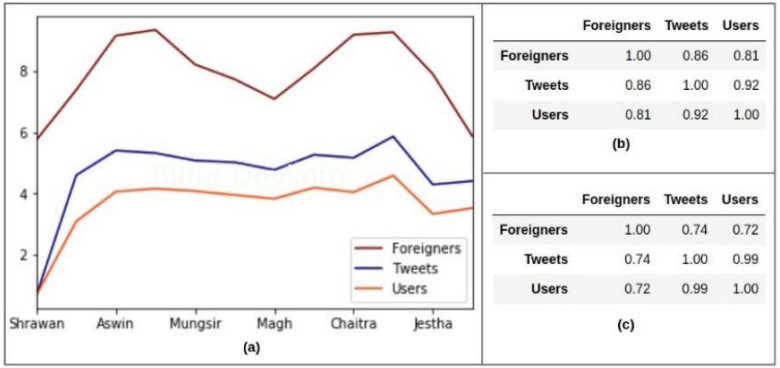

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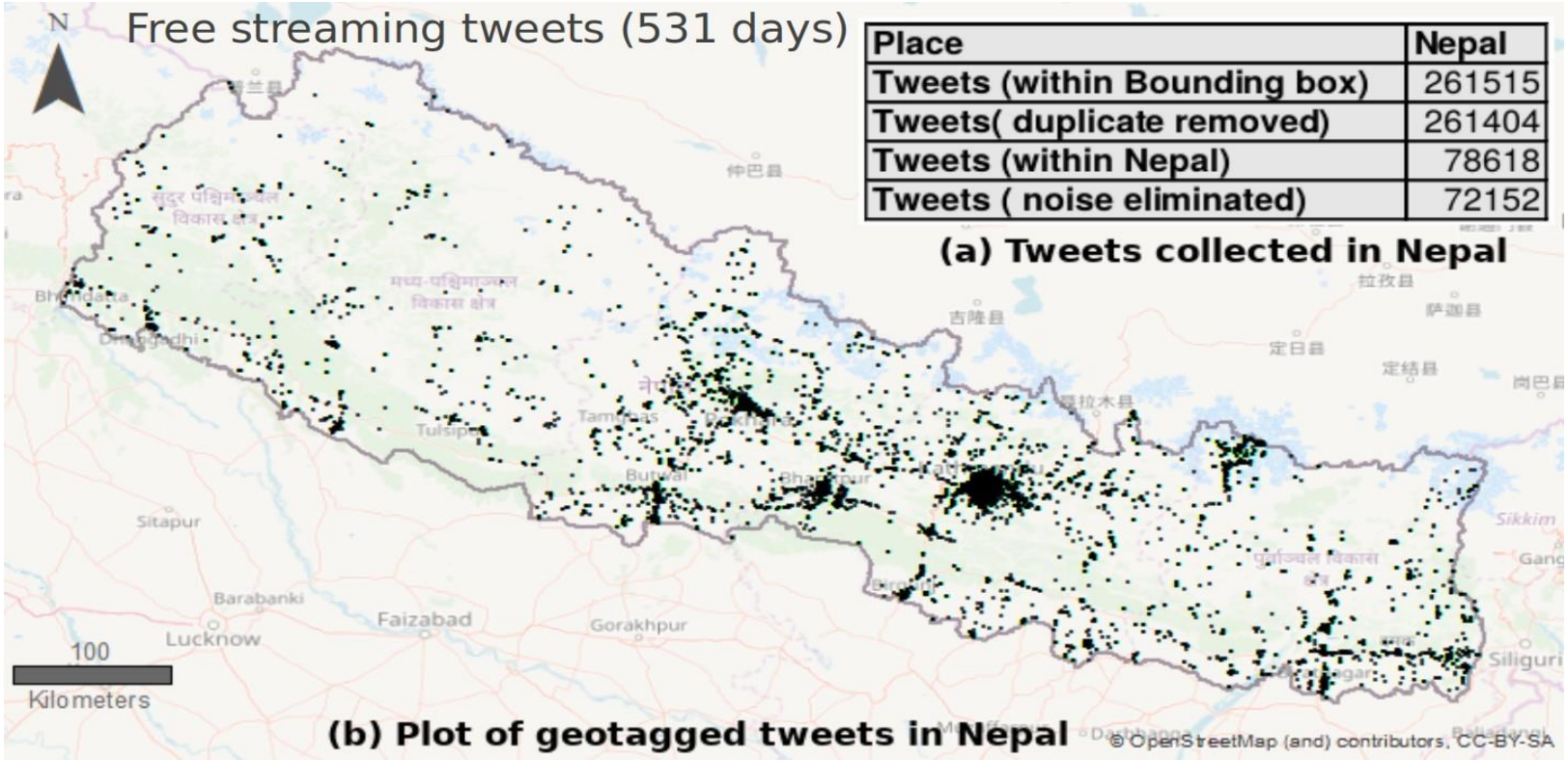
4. Perform basic spatial analyses (attribute and spatial queries, buffering, overlays) as well as linking these methods together in a more complex analytical model



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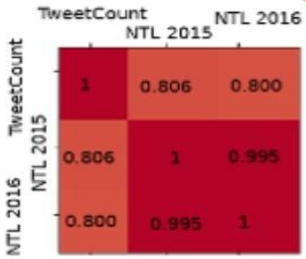
Place	Kaski	Kathmandu	ACAP	Solukhur	Nepal
TotalTweets	5986	32831	2609	2755	72152
Users	1763	6171	740	570	11799
AvgTweetByUser	3	5	3	4	6

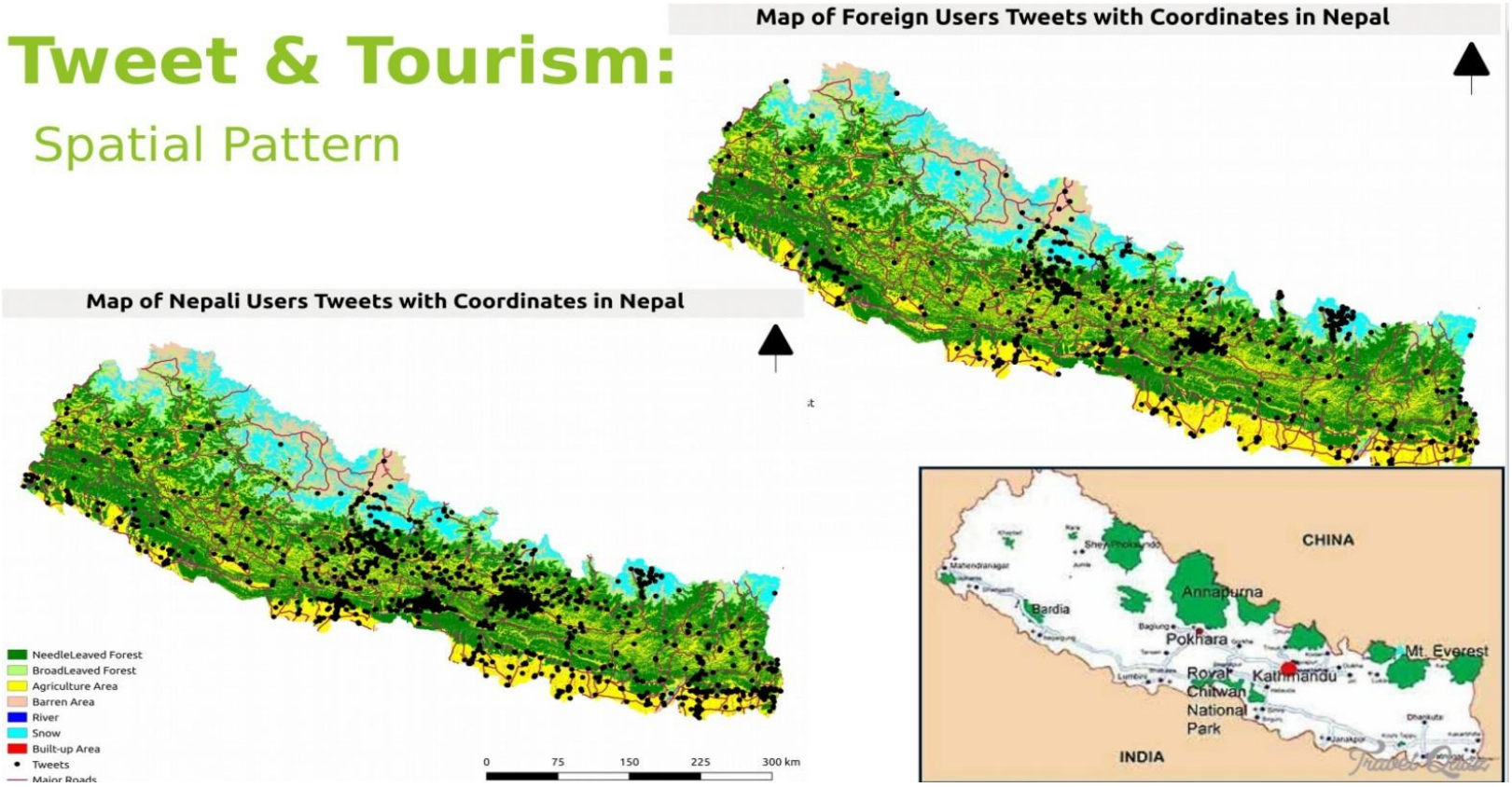
(c) Tweet Statistics in Selected Regions



(d) Tweet-NTL correlation

(e) Heatmap of geo-tagged tweets in Nepal

4. Create high-quality maps



6. Automate available GIS tools using programming language.

Land Cover Mapping using Satellite image and Machine Learning

- Tools: GDAL, QGIS, ArcGIS,
- Machine Learning → large scale LU Mapping,
- GEE -> global forest cover, etc.

K. Uddin et al. / Journal of Environmental Management xxx (2014) 1–9

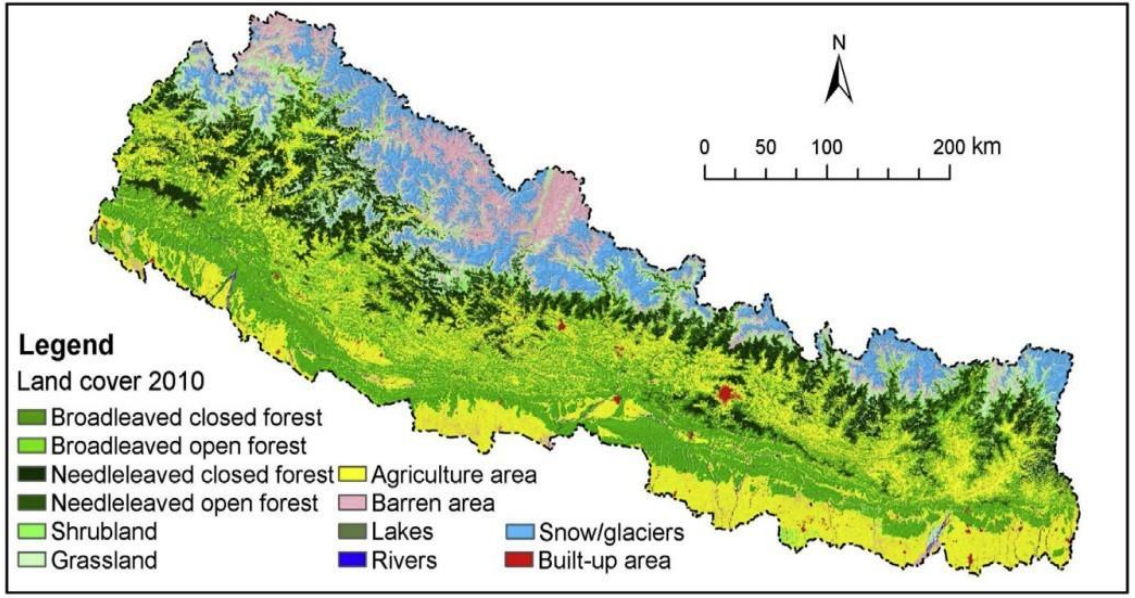


Fig. 2. Land cover map of Nepal using Landsat 30 m (2010) data.

John Snow's famous cholera analysis data in modern GIS formats

John Snow's **cholera map** → one of the earliest known examples of GIS to understand a health epidemic although his famous dot map was actually created after the cholera epidemic to show disease clusters.

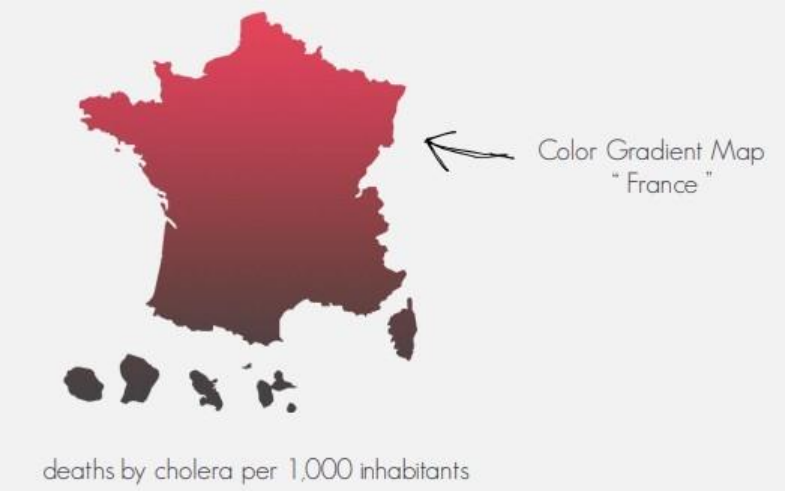
Starting on **August 31, 1854**, an outbreak of cholera hit the **London** district called Soho.

Physician **John Snow** → narrow to down the source of the disease to a **water pump on Broad Street.**

History of GIS

1832

Charles Picquet

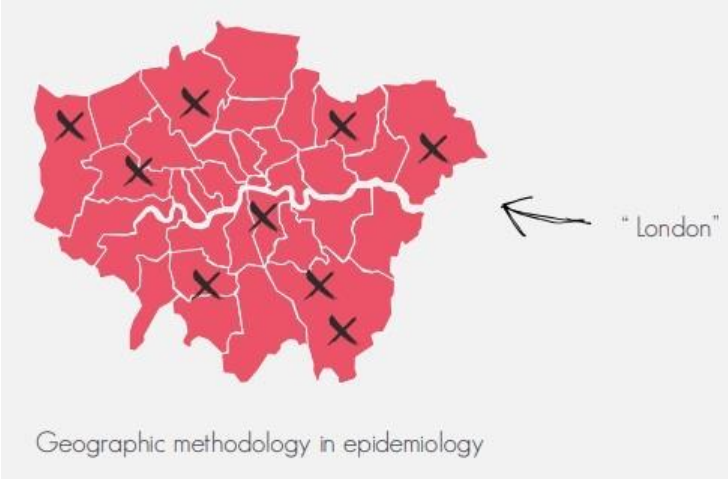


https://bit.ly/3rQGdV4

History of GIS

1854

John Snow



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History of GIS

1860

Roger Tomlinson

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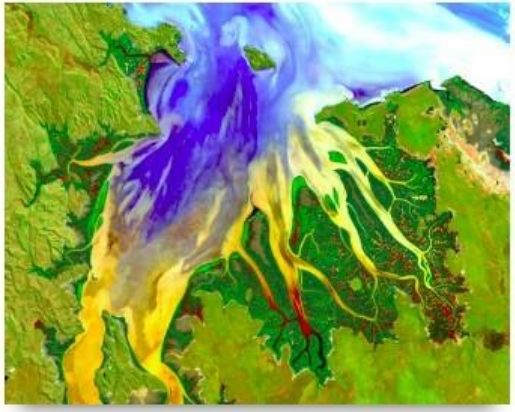
History of GIS

1972



JULY 23, 1972

FIRST LANDSAT SATELLITE LAUNCHED

The first Landsat satellite was launched on July 23, 1972, marking the beginning of over 40 years of continuous earth monitoring.

https://www.gislounge.com/gis-timeline/

History of GIS

1985

1985

GRASS GIS 1.0

GRASS, the Geographic Resource Analysis Support Software, is an open source GIS package with its roots with U.S. Army Corps of Engineers Construction Engineering Research Laboratory (USA/CERL) in Champaign, Illinois. The GIS software package has been under continuous development since 1982. In 1985, the first version, GRASS 1.0 was released.

https://www.gislounge.com/gis-timeline/

History of GIS

- **Father of GIS:**
  - English geographer and the primary originator of modern computerized geographic information systems.
  - In 1968, first known use of term “**Geographic Information System**” in his paper "*A Geographic Information System for Regional Planning*".
  - His Doctoral Thesis (1974-University of London). Geographical Information Systems, Spatial Data Analysis and Decision Making in Government.

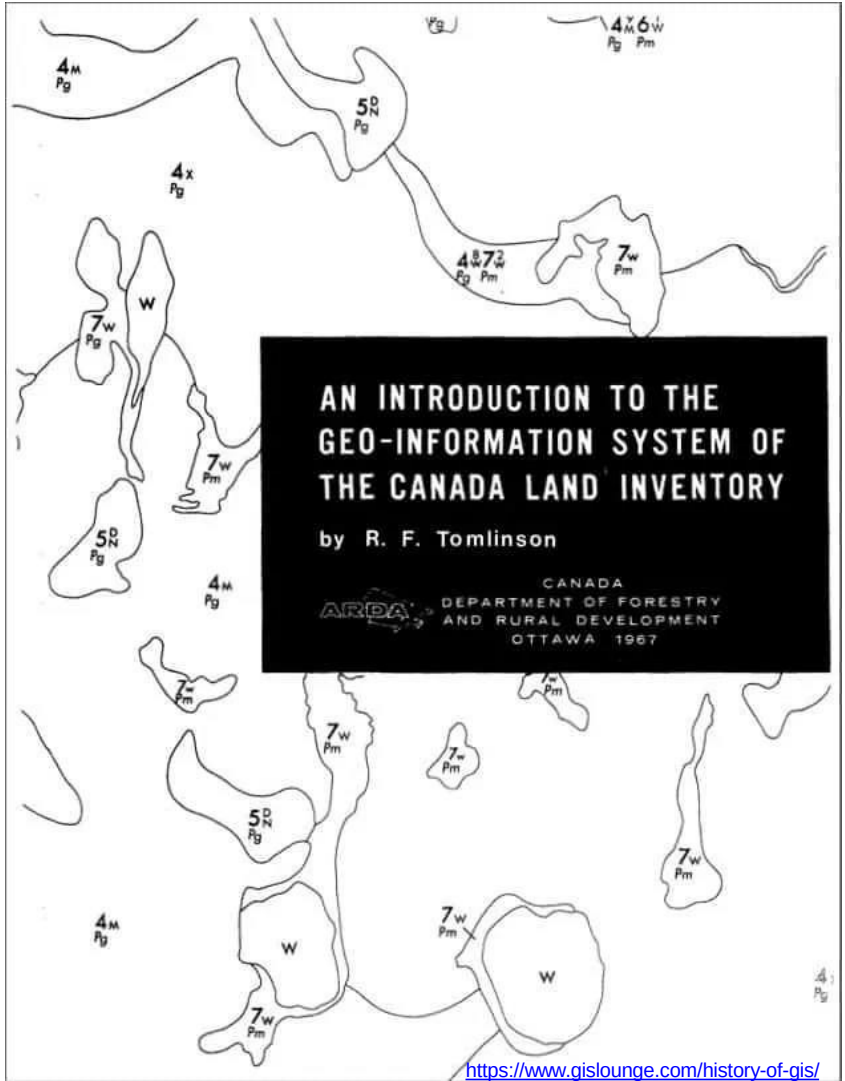
Roger Tomlinson

Born	17 November 1933 Cambridge, England
Died	7 February 2014 (aged 80) San Miguel de Allende, Mexico
Nationality	British
Alma mater	University of Nottingham, Acadia University, McGill University, University College London
Occupation	geographer

https://en.wikipedia.org/wiki/Roger_Tomlinson

History of GIS

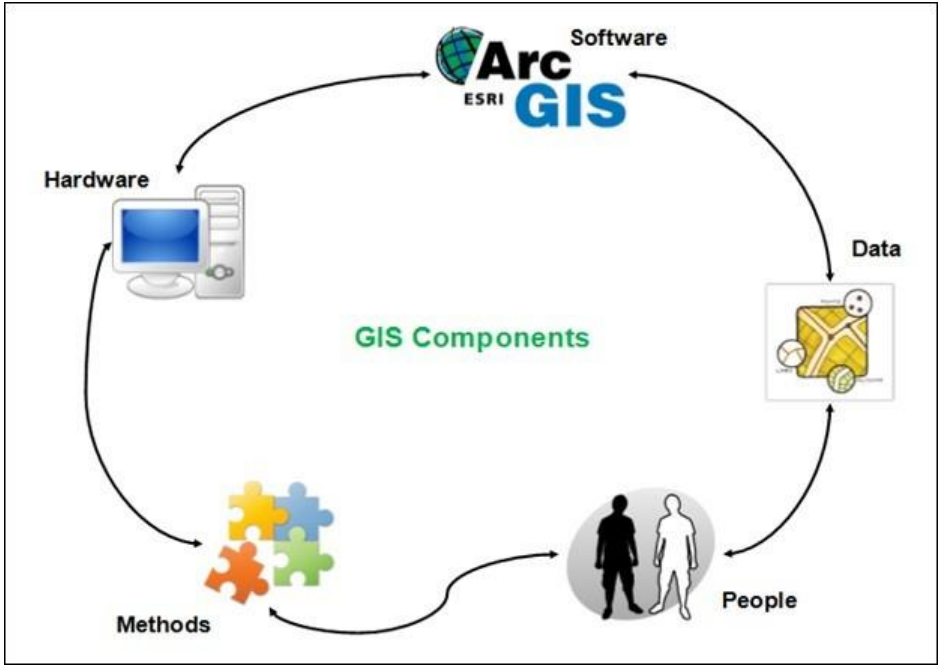
- 1960s first operational GIS had been launched in Ottawa, Canada
  - Possible due to rise to hardware and mapping applications
  - GIS was developed to store, collate, and analyze data about land usage in Canada.
- 1970s-1980s :
  - developments in spatial awareness and handing spatial data
  - Mainly academic centers like Harvard and Esri
- 1990s
  - Esri released **ArcView**- *desktop solution for producing mapping systems*
- Now, Widespread Adoption of GIS
  - Low cost of hardware, software and internet



https://www.gislounge.com/history-of-gis/

GIS Components

- **Hardware** is the computer on which a GIS operates.
- GIS **software** provides the functions and tools needed to store, analyze, and display geographic information.
  - DBMS
  - GUI- interface for Input, output, tools
- **People**:
  - manage the system
  - develop plans for applying GIS
- **Methods**:
  - GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.
- **Data**:
  - any data in relation to space, e.g. any data about anything that occur in nature



https://grindgis.com/blog/components-of-gis

GIS Functional Elements

1. Data Acquisition
2. Data Preprocessing
3. Data Management
4. Data Manipulation and Analysis
5. Data Product Generation

GIS Functional Elements

1. Data Acquisition

Process of identifying and gathering the data required for the application.

2. Data Preprocessing

- Manipulating data in several ways to be able to prepare it for further modeling.
- Converting Format
- Georeferencing
    - Geometric Correction
    - Resampling
- Establishing a consistent system for recording – Data model

GIS Functional Elements

3. Data Management

- Helps in creating and assessing the database.
- Consistent method for data entry, update, deletion and retrieval.

4. Data Manipulation and Analysis

- Working within database to derive new information.
- Statistical tool.
- Modeling.
- Logical and Boolean tools.

GIS Functional Elements

5. **Data Product Generation**

- Soft Copy
- Hard Copy
- Cartographic principles built-in Computer Aided Drafting Tool

Product Presentation

- Report - (Table, Map, Write-up)
- Multimedia

What are the functions of a GIS?

The questions that a GIS is required to answer :

- What is at.....? (Locational question ; what exists at a particular location)

- Where is it.....? (Conditional question ; which locations satisfy certain conditions)
- How has it changed.....?

(Trendy question ; identifies geographic occurrence or trends that have changed or in the process of changing)

- Which data are related .....?

(Relational question : analyzes the spatial relationship between objects of geographic features)

- How has it changed ?

(Trendy question ; identifies geographic occurrence or trends that have changed or in theprocess of changing)

Functions of a GIS

Table 1.2 Basic Functions of GIS

Functions	Sub-functions
Data Aquisition and preprocessing	Digitizing Editing Topology Building Projection Transformation Format Conversion Attribute Assignment etc.
Database Management and Retrieval	Data Archival Hierachical Modeling Network Modeling Relational Modeling Atrribute Querry Object-oriented Database etc.
Spatial Measurement and Analysis	Measurement Operations Buffering Overlay Operations Connectivity Operations etc.
Graphic Output and Visualization	Scale Transformation Generalization Topographic Map Statistical Map 3D Birdís Eye View etc.

GIS capabilities

- **Query for Location**

  "Show me all the countries of South America that have a population greater than 20,000,000. "

- **Query for Condition**

  "Display the population of each country I point to on the map."

GIS capabilities

- **Trend Analysis**

  "Show me where the census blocks are that have experienced more than a 50% population change between 1980 and 1990."

- **Patterns Analysis**

  "Calculate the fragmentation index for all the forest patches in the municipio."

- **Modelling**

  "Which route for the new highway has the lowest cost in terms of losses of housing, prime farmland, and wetlands, while minimizing the needs for cutting and filling."

Top Five Benefits of GIS

1. Cost savings resulting from greater efficiency.
2. Better decision making
3. Improved communication
4. Better geographic information recordkeeping
5. Managing geographically

Major Applications of GIS Technology

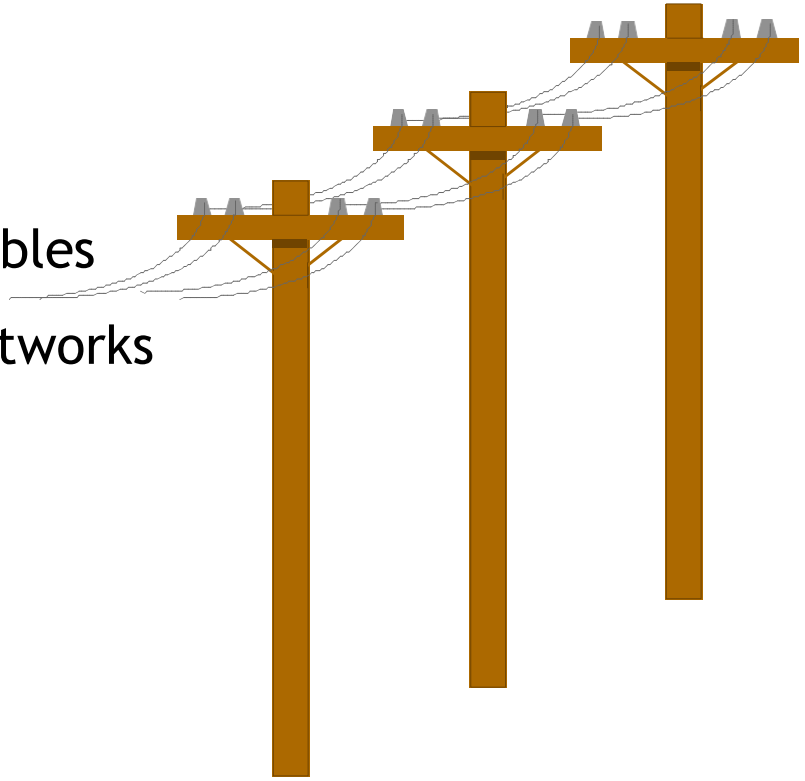
1. **Street Network-Based**

- Address matching
- Vehicle routing and scheduling
- Location analysis, site selection
- Development of evacuation plans

Major Applications of GIS Technology

2. Facilities Management

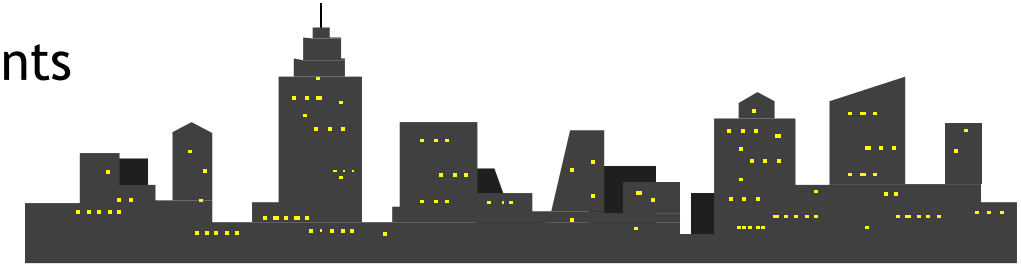
- Locating underground pipes, cables
- Balancing loads in electrical networks
- Planning facility maintenance
- Tracking energy use



Major Applications of GIS Technology

3. Land Parcel-Based

- Zoning, subdivision plan review
- Land acquisition
- Environmental impact statements
- Water quality management
- Ownership of maintenance



Major Applications of GIS Technology

4. Environment and Natural Resource

- Forest management
- Wildlife habitat, migration routes management
- Wild and scenic rivers preservation
- Recreation resources planning
- Floodplain management
- Wetland preservation
- Agricultural lands management
- Groundwater modeling and contamination tracking
- Environmental impact analysis
- Viewshed analysis

Data base management system (DBMS) and concept of spatial and attribute data

ASPATIAL QUERIES: Queries that in being answered do not use the stored X & Y location of the feature, nor does it describe where the places are in relation to each other.

Example:

- How many people are working with GIS in Thailand

SPATIAL QUERIES: Queries that can only be answered using the stored X & Y location of the feature and its relationship to other features on the earth's surface.

Spatial queries can not be answered without geography and topology.

Examples:

- How many people are working with GIS in the major population centers in Thailand?
- Which centers are within 50 Km of each other?
- What is the shortest route that passes through all of these centers?

Data base management system (DBMS) and concept of spatial and attribute data

- A ***spatial* database** includes **location**.

- It has geometry as points, lines and polygons. GIS combines spatial data from many sources with many different people.
- Databases connect users to the GIS database.

- *For example, a city might have the wastewater division, land records, transportation, and fire departments connected and using datasets from common spatial databases. Let's take a closer look at spatial databases and how they are used in GIS:*

Data base management system (DBMS) and concept of spatial and attribute data

- By default, spatial vector features are always associated with non-spatial attribute tables in a GIS.
- Spatial features store ***where*** objects are located on a map.

- Non-spatial attribute tables explain ***what*** the objects on the map represent. Attribute tables are similar to spreadsheets.

LATITUDE	LONGITUDE
48.1°N	11.6°E
50.1°N	13.4°E
52.5°N	8.7°E

Data base management system (DBMS) and concept of spatial and attribute data

Attribute Data in GIS

Data in GIS are stored as features AND tabular info

- Tabular information can be associated with features OR
- Tabular data may NOT be associated with any specific feature

“Tabular” means stored in a table with rows and columns

- Rows are called “RECORDS” in GIS
- Columns are called “ATTRIBUTE FIELDS” or “FIELDS”

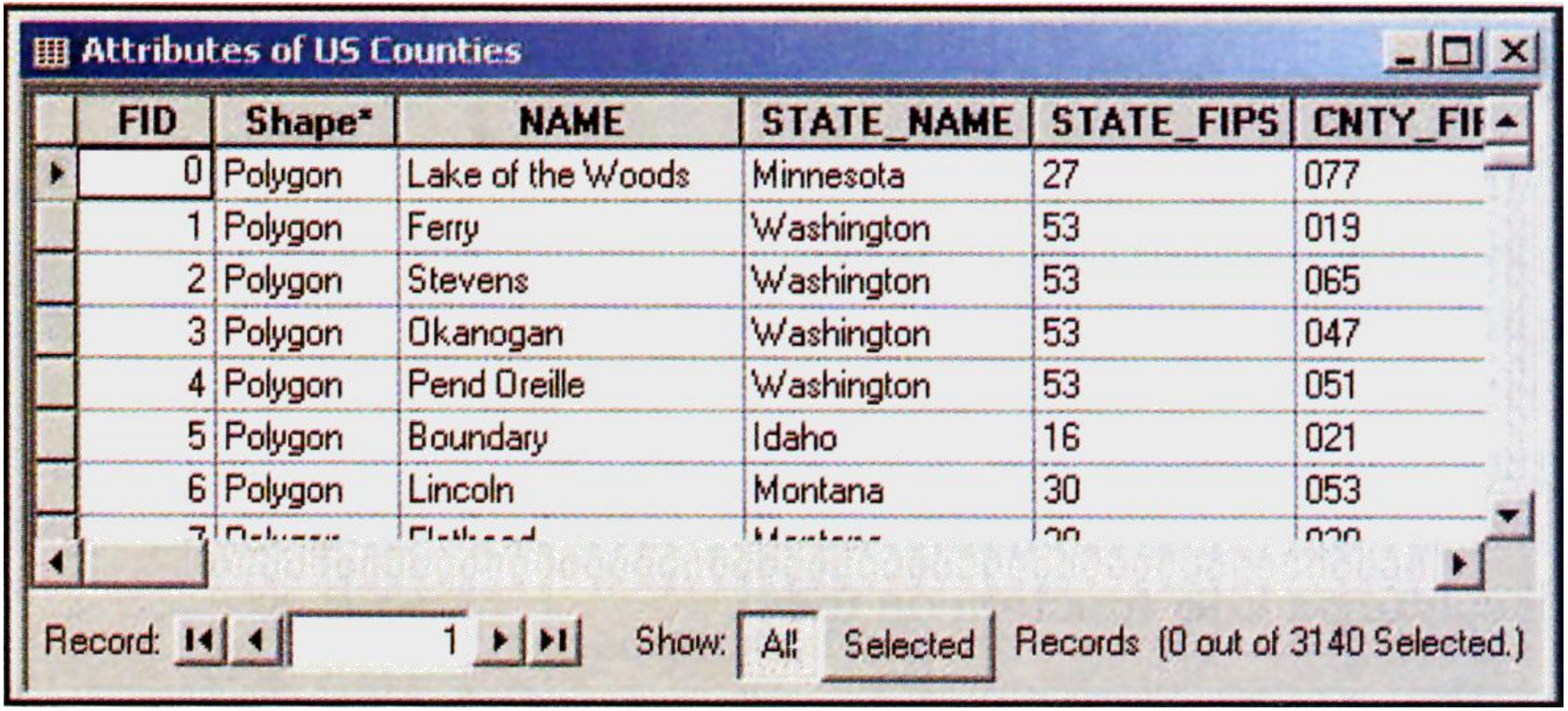
Data base management system (DBMS) and concept of spatial and attribute data

Tables

Tables are classified as being “Attribute” or “Stand Alone”

- Attribute table- a table that contains data about a specific features in a set of geographic data
  - ONLY 1 record for each feature; can and typically does have multiple fields for specific features
- Depending on the type of model, the table contains different types of information
  - Georelational- each record relates to a feature in a separate file through an FID
    - Feature Identification
  - Object-oriented model - the feature’s attributes and geographical location (x,y coordinates) are stored in the same table and has OID (object Identification numbers

Data base management system (DBMS) and concept of spatial and attribute data



Data base management system (DBMS) and concept of spatial and attribute data

Database Management

GIS uses a management system similar to those used by nearly all large institutions

- e.g., the state and federal government, BMV, universities, hospitals, etc.

Three types of database management systems

1. flat file database- stores rows of information as text or binary coded data in text strings
   - Simple but not efficient

2. Hierarchical- multiple tables stored as separate files, each of which has multiple records and fields. Each table has a hard linked relationship to other tables
   - e.g., courses, with students, linked by course ID number

3. Relational- multiple tables stored as separate files but they are NOT hard-linked.
   - shared fields (columns) become the joining key

Data base management system (DBMS) and concept of spatial and attribute data

Queries on tabular data

Information may need to be subdivided into desired packages

- e.g., parcels of land zoned commercial in a county

Queries use a language of logical expressions to delineate wanted data from larger data files into a “selected set”

- SQL (Standard Query Language)

e.g.,**SELECT*FROM landuse WHERE[ZONE]=492**

“landuse” is the table name; “ZONE” is the Field to search; 492 is the numeric code designating property as commercial