Empowering Women in GIT-Pakistan

GIS concepts and applications

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What is GIS?

- An organized integration of
- Hardware
- Software and
- Geographic system
Majority of data and information are associated with some location in space or referenced to the locations on the earth.
Attributes, or the characteristics (data), can be used to symbolize and provide further insight into a given location.

**INFORMATION- Attributes**

<table>
<thead>
<tr>
<th>Month</th>
<th>Hits</th>
<th>Files</th>
<th>Pages</th>
<th>Visits</th>
<th>Sites</th>
<th>Kilobytes</th>
<th>Visits</th>
<th>Pages</th>
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<td>62</td>
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<td>10</td>
<td>332</td>
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<td>1703</td>
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<td>76</td>
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<td>11</td>
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<td>467</td>
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<td>214</td>
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<td>364</td>
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<td>Oct 04</td>
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<td>15</td>
<td>162</td>
<td>13296</td>
<td>231</td>
<td>1397</td>
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</tbody>
</table>

![Graph showing different bands with various data distributions.](image)

![Table showing top 20 countries with their hits and files.](image)
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

Data retrieval, Updation, Maintenance, Security and, Integration

Digitization, editing, topology, projection, format conversion

Database Management, Update and Retrieval
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

Spatial Information

Non-Spatial Information
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

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

Plant species distribution in Indian mainland

Legend:
- Plot SR Grid
  - 1-6: 0-124
  - 6-12: 124-250
  - 12-18: 250-373
  - 18-24: 373-498
  - 24-30: 498-623
  - 30-36: 623-746
  - 36-42: 746-871
  - 42-48: 871-995
  - 48-54: 995-1120
  - 54-59: 1120-1244
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.
Spatial Data

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.
- **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.
Spatial Data

Conversion of vector to raster

Conversion of raster to vector

Input raster

Simplified

Non-Simplified
## Spatial Data

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

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Raster</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient representation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Easy editing</td>
<td>No</td>
<td>Yes</td>
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</tr>
</tbody>
</table>
# Spatial Data

## Raster data file format

<table>
<thead>
<tr>
<th>RASTER</th>
<th>File format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esri Grid</td>
<td>.e00</td>
</tr>
<tr>
<td>Geographic Tagged Image File Format</td>
<td>.gtiff</td>
</tr>
<tr>
<td>Imagine image</td>
<td>.imr</td>
</tr>
<tr>
<td>American Standard Code for Information Interchange (ASCII)</td>
<td>.asc</td>
</tr>
<tr>
<td>Hierarchical Data Format</td>
<td>.hdf</td>
</tr>
<tr>
<td>Network Common Data Form (NetCDF)</td>
<td>.nc</td>
</tr>
<tr>
<td>Joint Photographic Experts Group</td>
<td>.jpg</td>
</tr>
</tbody>
</table>

## Vector data file format

- Shape files
- Keyhole Markup Language (KML)
- Layer
- File Geodatabase
- ArcInfo Coverage
- E00 ArcInfo Interchange
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.
Non-Spatial Data

Attribute Data Type

- **Qualitative**
  - Nominal
  - Ordinal

- **Quantitative**
  - Discrete
  - Continuous

- **Binary**
  - Symmetric
  - Asymmetric

- Related to names
- Sequence or ranking

- Both values are equally important
- Both values are not equally important

**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

<table>
<thead>
<tr>
<th><strong>Raster</strong></th>
<th><strong>Vector</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Remote sensing images</td>
<td>GPS measurements</td>
</tr>
<tr>
<td>Digital Aerial photographs</td>
<td>Survey measurements</td>
</tr>
<tr>
<td>Scanned Maps</td>
<td>Topographic surveys</td>
</tr>
<tr>
<td>DEM from Images</td>
<td>Toponymy data from atlases</td>
</tr>
</tbody>
</table>

- 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
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.
1. Mapping and monitoring a pandemic

**Overview**

- **Total cases**: 248,872 (+2,521)
  - **Active cases**: 86,975
  - **Recovered cases**: 156,700 (+3,566)
  - **Fatal cases**: 5,197 (+74)

**Trends**

- **New and fatal cases**: Expand

**Global**

- **Total cases**: 12,507,849

**Pakistan**

- **Total cases**: 248,872
Applications of GIS

Mapping and monitoring

b. Urban Growth

Land use maps of Kathmandu Valley, 1967-2000

Source: Thapa and Murayama, 2008
Applications of GIS

Mapping and monitoring

c. Vegetation type

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

Source: Tripathi et al., 2014
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- 2005

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

*Source: Matin et al., 2017*
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*
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.

$$FR = \frac{(E/F)}{(M/L)},$$
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

\[ W_i = \ln \left( \frac{\text{Density of landslide within a class of a factor}}{\text{Density of landslide within the study area}} \right) = \ln \left( \frac{\sum N_{\text{pix}(\text{SI})}}{\sum N_{\text{pix}(\text{NI})}} \right) \]

Where, \( W_i \) = Weight of a factor class;
\( N_{\text{pix}}(\text{SI}) \) = Number of pixel of landslide within class \( i \);
\( N_{\text{pix}}(\text{NI}) \) = Number of pixel of class \( i \);
\( \sum N_{\text{pix}}(\text{SI}) \) = Number of Pixel of landslide within the whole study area;
\( \sum N_{\text{pix}}(\text{NI}) \) = Number of pixel of the whole study area.

<table>
<thead>
<tr>
<th>Class</th>
<th>LSI value</th>
<th>Description</th>
<th>Area in Square Kilometers</th>
<th>% Area of Map</th>
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<tbody>
<tr>
<td>1</td>
<td>-14.1493 to -9</td>
<td>Very Low</td>
<td>23.5449</td>
<td>1.81</td>
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<tr>
<td>2</td>
<td>-9 to -4</td>
<td>Low</td>
<td>330.9489</td>
<td>25.41</td>
</tr>
<tr>
<td>3</td>
<td>-4 to 0</td>
<td>Medium</td>
<td>602.1585</td>
<td>46.23</td>
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<tr>
<td>4</td>
<td>0 to 3</td>
<td>High</td>
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<td>25.09</td>
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<tr>
<td>5</td>
<td>3 to 8.5718</td>
<td>Very High</td>
<td>18.9441</td>
<td>1.45</td>
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</tbody>
</table>

Source: Bibek et al., 2015
Applications of GIS

5. Biodiversity Analysis

\[ BR = \sum_{i=1}^{n} (DI_i \times w_i + TC_i \times w_i + SR_i \times w_i + BV_i \times w_i + EU_i \times w_i) \]

where \( BR \) = Biological Richness, \( DI \) = Disturbance Index, \( TC \) = Terrain Complexity, \( SR \) = Species Richness, \( BV \) = Biodiversity Value, \( EU \) = Ecosystem Uniqueness, and \( w_i \) = 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.