Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

M.Tech. Remote Sensing and GIS

Course : 24MTRS-05

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Unit-1 Basics of GIS

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24MTRS-05: GEOGRAPHIC INFORMATION SYSTEM **--- 4 credits**

UNIT I **Basics of GIS** - Definition - Evolution of GIS - Geospatial, spatial and non-spatial data - Components of GIS - Computer Hardware, Software Modules and Organisational Context of GIS - Data Structure in GIS - Types of Data (Points, Lines and Polygons) - Data sources - Ground and remote sensing survey - Data Structures (Raster data structures and Vector data Structures) – Database Structures.. 12 Hrs.

UNIT II **GIS Data Input, Verification, Storage and Output** - Spatial Data Input Processes and Devices (Sources of data, - Different Types of Data Entry methods, viz., Manual input, Run length code, Digitization, Automated Scanning, etc. – Vector to Raster conversion - Raster to Vector conversion - Input devices) - Entry of non-spatial data – Linking of Spatial & Non-spatial data – Element generation - Geodatabase creation - Data Verification (Errors of different types) - Correction (Rubber Sheet Transformation, Bilinear interpolation, Cubic Convolution, etc.) - GIS capabilities for Data correction – Data output (Types of Output, GIS Capabilities for output, Output devices) - File formats for raster and vector. 14 Hrs.

UNIT III **Raster and vector data Interpolation and Analyses** - Raster data analysis: Local, neighborhood and regional operations - Map algebra - Vector data analysis: Topological analysis, point-in-polygon, line-in-polygon, polygon-in-polygon - Proximity analysis: Buffering, Thiessen polygon - Non topological analysis: Attribute data retrieval and analysis – Concepts of SQL – ODBC - Basic Principles of Interpolation – Methods of Interpolation - Global Methods of Interpolation, Local Interpolation (Trend Surface Analysis) – Local Interpolation (Splines) - Optimal Interpolation (Kriging). 12 Hrs.

UNIT IV **Surface Analysis, 3D Visualization and Network Modelling** - Need for Three Dimensional Models - Methods of DEM & TIN - Products of DTM (Contour Maps, Shaded Relief Map, Maps Related to Slopes, Line Sight Maps, Drainage Analysis, Volume Estimation etc.) Usefulness of DEM/DTM. Overlay analysis, Capabilities (Point Operations, Regional Operations, Neighbourhood Operations) - Networking and Dynamic Segmentation – Applications, Minimum Distance Model, Maximum Covering Model (P-median model), Urban Transportation Planning Model. 14 Hrs.

UNIT V **Data Classification & Advanced GIS** - Principles – Types of Classification (Exogenous, Arbitrary, Idiographic & Serial) – Multivariate Analysis. Artificial Intelligence - Expert Systems - Object Oriented GIS - Web based GIS: Definition, merits - Architecture - Map server - Spatial data infrastructure - Spatial data standards - Free and open source - Proprietary GIS software. 12 Hrs.

UNIT VI **Current Contours – GIS - Case studies (Not for Final Exam only for Discussion)** - Recent scientific and technological development, advancement, Industrial application and Job opportunities.

REFERENCES

1. Burrough, P.A 1986: Principles of Geographical information Systems for Land Resources Assessment, Clarandone Press, Oxford.
2. Avery, T.V,Interpretation of Aerial Photography Burgass, Publishing Company.
3. Gautham, N.C 1970: Urban Landuse Study Through Aerial Photo binterpretations Techniques, Pink Publishing House, Mathura.
4. American Society of Photogrammetry, 1983: Manual of Remote Sensing (2nd Edition), ASP Falls Church, Virginia.
5. Campbell, J 1984: introductory Cartography, Printers Hall Englewood Cliffs, N.J
6. Dent B.D 1985: Principles of Thematic Map Design, Addition - Wesley, Reading, Mass.
7. Freeman, H and GG.Pieroni 1980: Map Data Processing, Academic Press, New York.
8. Monmonier, M.A 1982: Computer Assisted Cartography - Principles and Prospects, Prentice Hall, Englewood Cliffs, NJ
9. Tomlinson, RF Calkins, HS and D.F.Marble 1976: Computer Handling of Geographic Data, UNESCO, Geneva.
10. Graeme F. & Bonham – Carter; Geographic information Systems for Geoscientists; Modelling with GIS, Pergamon.
11. Lo, C.P. and Yeung, Albert K.W., “Concepts and Techniques of Geographic Information Systems”, Pearson, 2016.

OBJECTIVE

To understand the fundamentals, data handling, analysis techniques, and advanced applications of Geographic Information Systems (GIS).

COURSE OUTCOMES

- The concepts of GIS, including data types, components, and data structures.
- Develop proficiency in GIS data input, verification, storage, and output processes.
- Gain knowledge in raster and vector data analysis, including interpolation methods and proximity analysis.
- Understand three-dimensional modeling, surface analysis, and network modeling techniques.
- Explore classification methods, AI integration, web-based GIS, and the use of open-source and proprietary GIS software.

Evolution of GIS

During the 1960s & 1970s, new trends arose

- Computer assisted cartography - Application of computer methods to larger and larger scales mapping,
- Use of mapped data for resource assessment, land evaluation and planning by simple spatial overlay analyses (SYMAP – Synagraphic MAPping program)
- Manipulating them to produce choropleth or isoline interpolations from point data and
- Displaying the results in many ways – overprinting of lineprinter characters to produce suitable grey scales, preparing films for printing maps.
- GRID and IMGRID – grid-cell / raster mapping programs
- Computer programs in the automation of existing manual techniques such as data capture (Remote Sensing technology based surveying and photogrammetry), data analysis and presentation.
- During 1980s – GIS was emerged with more expectations – represent a model of the real world – test bed for studying environemental processes / analysing the results of trends / anticipating the possible results of planning decisions…..

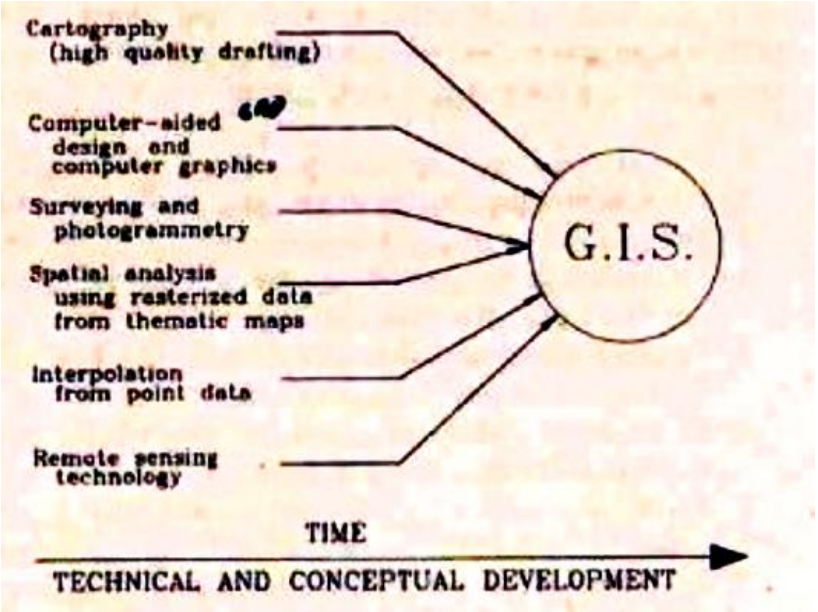


Fig. 1.3 Geographical information systems are the result of linking parallel developments in many separate spatial data processing disciplines.

- ***Burrough PA (1986)****. Principles of Geographic Information Systems for Land Resources Assessment.*

Why do we need GIS?

It is necessary to have a customized and automated digital spatial platform wherein we do:

- **Mapping of surface / space / subsurface properties in 2D / 3D**
- **Analysing of spatial data, Routing to a new area, Vehicle Tracking**
- **Modelling of actual Earth System Processes that are responsible for ongoing activities strategically and preparing pragmatic action plans immediately through**
  - **Database generation, storage and manipulation digitally**
  - **Visualizing, analyzing, comparing, modelling, predicting, forecasting, representing and sharing of data and information by all**
- **Calibrating the model developed and Validating the results &**
- **Implementing the results pragmatically & monitoring impacts.**

1.1 GIS: Defined simply

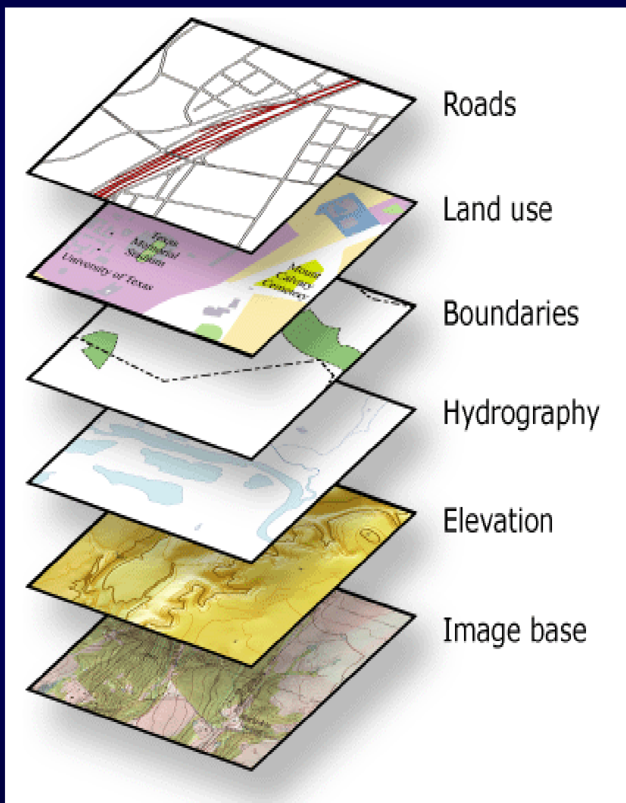
- **A computerised spatial information system on resources and hazards**

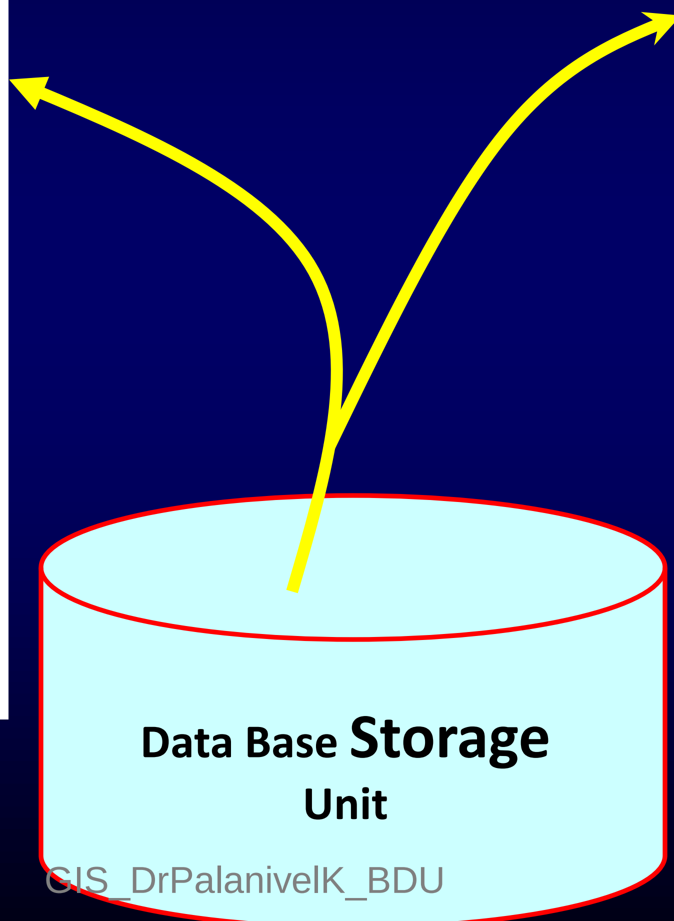
GIS can also be defined based on it's Capabilities or Virtues or Usefulnesses or Credibilities

Virtues of GIS

1. GIS Can hold large amount of geospatial data / maps and non-spatial / aspatial data

Geospatial data / maps





Non spatial / Attribute / Aspatial data

1	BLOCK_NAME	BK_AREA	SALI_AREA	PERCENTAGE	SALINITY_TYPE
2	AGASTISWARAM	97755036.16	47651257.35	48.75	COASTAL SALINE SOIL
3	ALWARTHIRUNAGARI	314587683.28	13483201.16	4.29	COASTAL SALINE SOIL
4	ARANTANGI	546979186.79	19699964.93	3.60	COASTAL SALINE SOIL
5	ARIMALAM	382442584.63	38056.28	0.01	COASTAL SALINE SOIL
6	AVUDAIYARKOIL	317311598.56	124505284.05	39.24	COASTAL SALINE SOIL
7	BHUVANAGIRI	198728518.35	26522056.91	13.35	COASTAL SALINE SOIL
8	CHENNAI	173276620.57	116210285.58	67.07	COASTAL SALINE SOIL
9	CHITHAMUR	266707327.11	82036026.70	30.76	COASTAL SALINE SOIL
10	CUDDALORE	301090086.77	234349321.02	77.83	COASTAL SALINE SOIL
11	GUMMDIPOONDI	418232625.80	198485820.68	47.46	COASTAL SALINE SOIL
12	KADALADI	801377568.81	518714059.26	64.73	COASTAL SALINE SOIL
13	KANDAMANGALAM	233537210.04	3561928.61	1.53	COASTAL SALINE SOIL
14	KEELAIYUR	173072850.20	9083648.32	5.25	COASTAL SALINE SOIL
15	KEERAPALAYAM	123066985.35	50184462.65	40.78	COASTAL SALINE SOIL
16	KILLIYOOR	27797205.53	975230.88	3.51	COASTAL SALINE SOIL
17	KOLLIDAM	272680537.73	465285.90	0.17	COASTAL SALINE SOIL
18	KOTTUR	321190878.64	437653.63	0.14	COASTAL SALINE SOIL
19	KURINJIPADI	403874698.25	102104013.42	25.28	COASTAL SALINE SOIL
20	KURUNTHENCODE	150643684.38	76575441.17	50.83	COASTAL SALINE SOIL
21	LATHUR	378322678.78	227214144.85	60.06	COASTAL SALINE SOIL
22	MANAMELKUDI	187969286.34	90731336.29	48.27	COASTAL SALINE SOIL
23	MANDAPAM	221958482.90	221958448.74	100.00	COASTAL SALINE SOIL
24	MARAKKANAM	423770925.99	169722836.98	40.05	COASTAL SALINE SOIL
25	MINJUR	459683083.78	452608481.54	98.46	COASTAL SALINE SOIL
26	MUNCHIRAI	187408797.71	123207679.80	65.74	COASTAL SALINE SOIL
27	MUTHUPETTAI	372762749.08	275672726.32	73.95	COASTAL SALINE SOIL
28	NAINARKOIL	265298425.88	5869174.18	2.21	COASTAL SALINE SOIL
29	OTTAPIDARAM	789985062.30	58580178.42	7.42	COASTAL SALINE SOIL
30	PARANGIPETTAI	232530511.68	202813776.86	87.22	COASTAL SALINE SOIL
31	PATTUKKOTTAI	414210092.49	142415280.27	34.38	COASTAL SALINE SOIL
32	PONDI	304809120.44	168067150.78	55.14	COASTAL SALINE SOIL
33	PUZHAL	134550930.49	77517267.23	57.61	COASTAL SALINE SOIL
34	RADHAPURAM	309678174.59	151774863.02	49.01	COASTAL SALINE SOIL
35	RAJAKKAMANGALAM	147554170.04	86895022.01	58.89	COASTAL SALINE SOIL

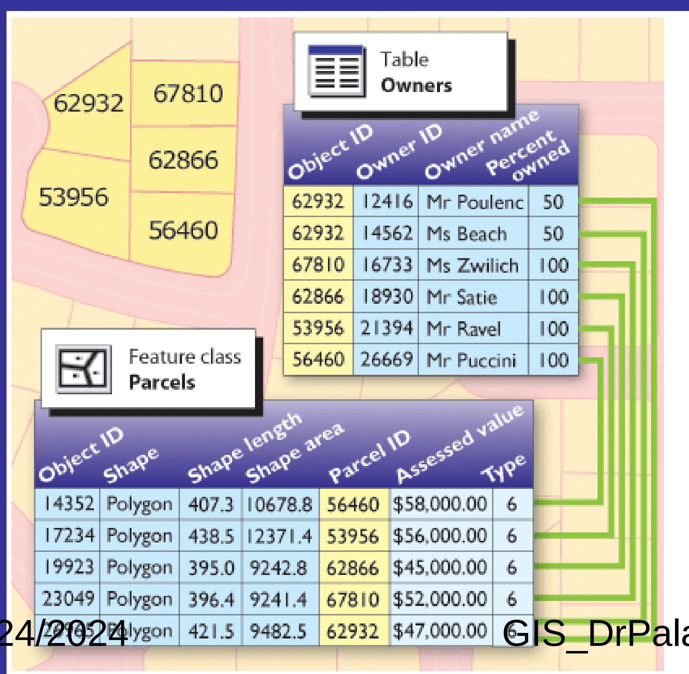
2. GIS can Store, Edit, Manage, Manipulate and Retrieve data / maps

Data Base Management

Spatial Data

Non Spatial Data

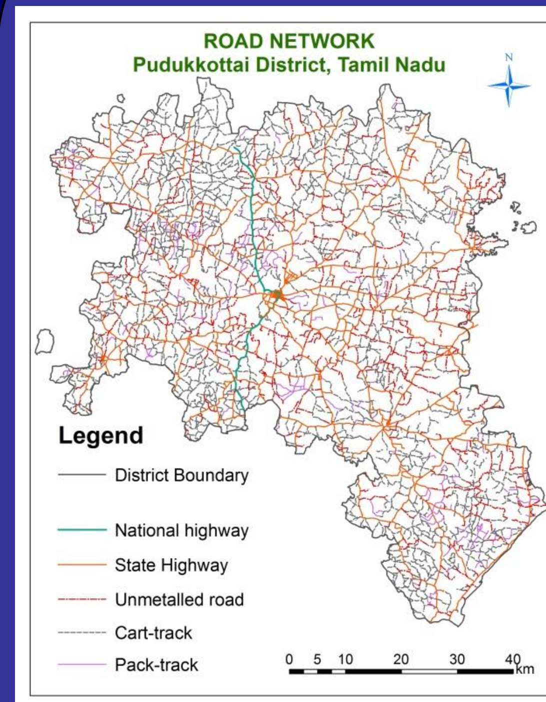
Provide Link using Join & Relate methods



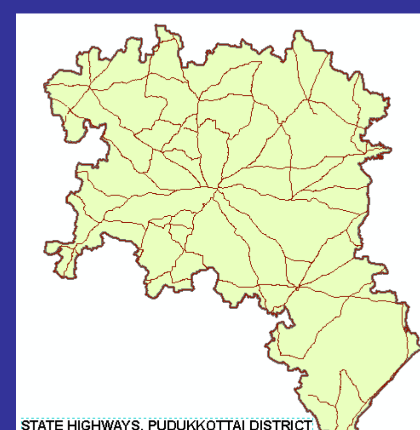
Object ID	Owner ID	Owner name	Percent owned
62932	12416	Mr Poulenc	50
62932	14562	Ms Beach	50
67810	16733	Ms Zwilich	100
62866	18930	Mr Satie	100
53956	21394	Mr Ravel	100
56460	26669	Mr Puccini	100

Object ID	Shape	Shape length	Shape area	Parcel ID	Assessed value	Type
14352	Polygon	407.3	10678.8	56460	$58,000.00	6
17234	Polygon	438.5	12371.4	53956	$56,000.00	6
19923	Polygon	395.0	9242.8	62866	$45,000.00	6
23049	Polygon	396.4	9241.4	67810	$52,000.00	6
[illegible]	Polygon	421.5	9482.5	62932	$47,000.00	6

Preferential display of map



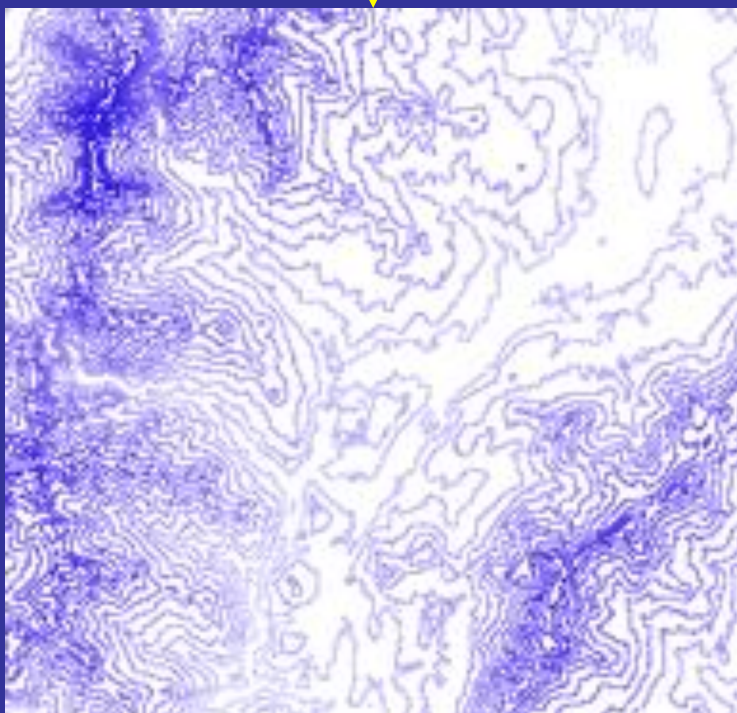
National Highway
State Highway
District Road
Panchayat Road
Unmetalled Road
Cart Track
Pack Track
Foot Path
Concrete pavement
Village Road - Metal



State Highway alone

3. DATA MANIPULATION

Contouring



Filling of Data Gaps

Providing continuity

Viewing 3 Dimensionally

4. DATA SORTING and PERFORMING STATISTICAL OPERATIONS

Data Sorting

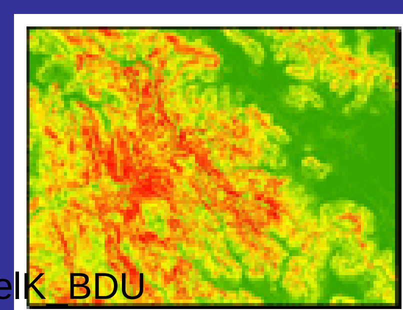
Classification of Data

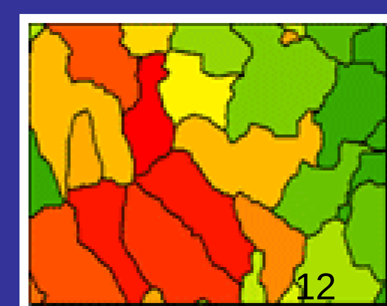
Mean, Mode, Average, Regression

Bring out relationship amongst Data

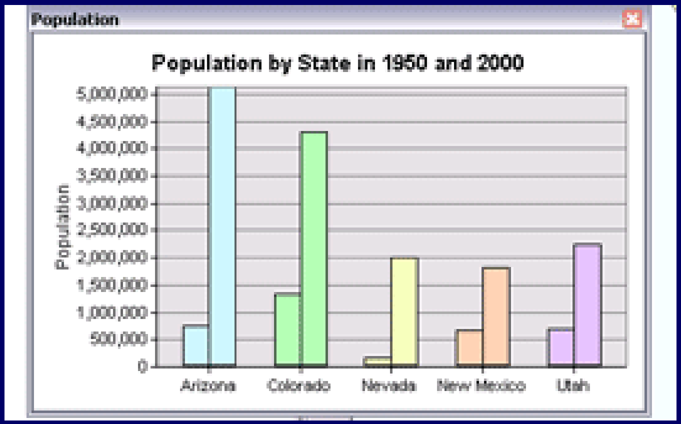
5. DATA CONVERSION

Raster ⇄ **Vector**

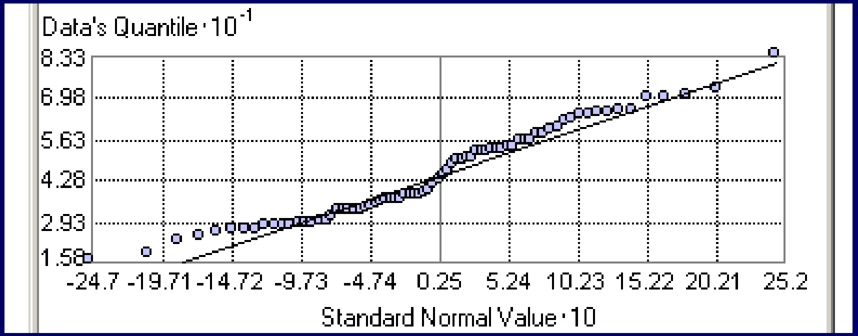




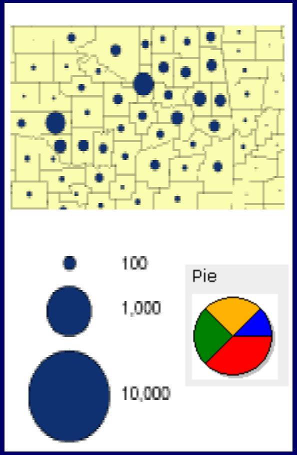
6. GIS can Display data (Output) in multiple forms - Maps, Charts, Histograms, 3D visualized outputs, DEM, Fly through models, etc,.

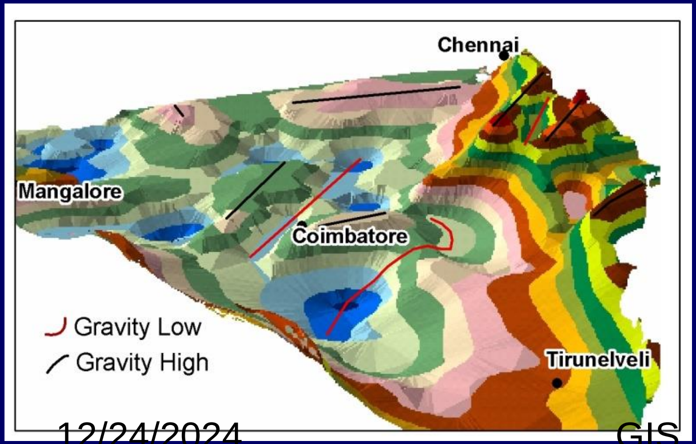


Charts

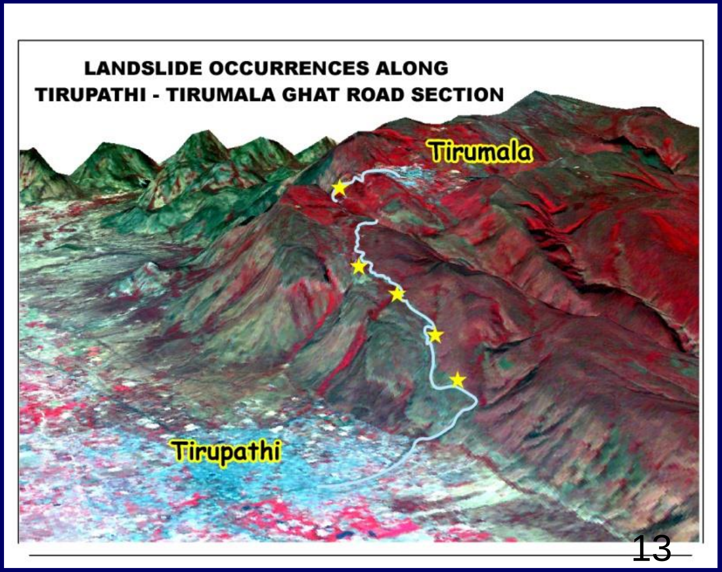


Histograms

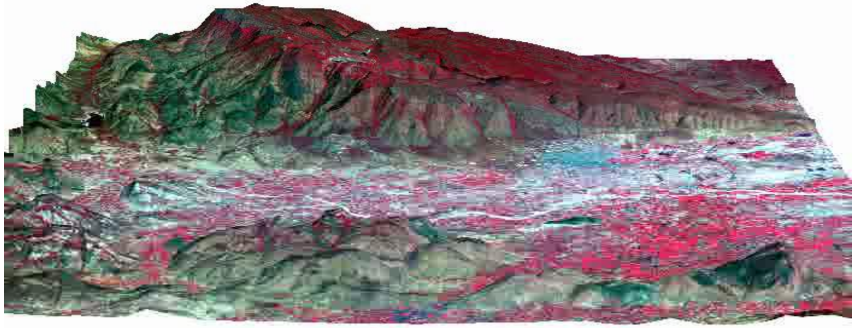


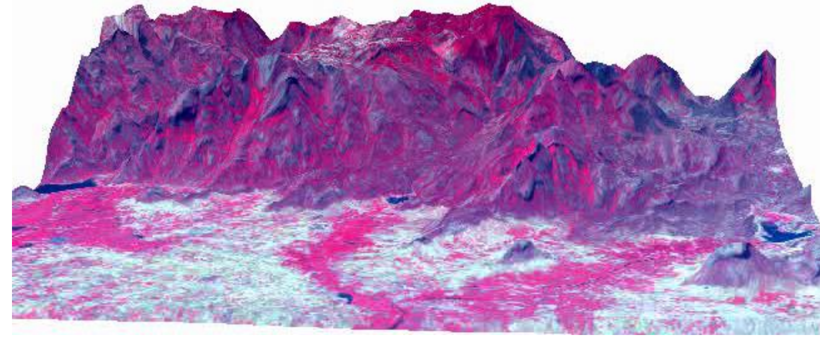


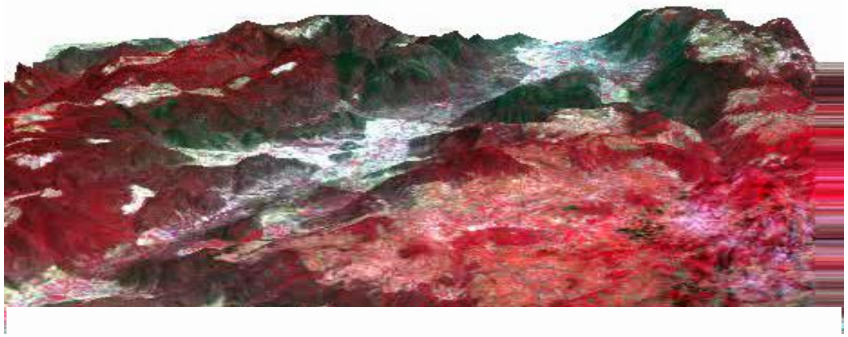
3D - DEM

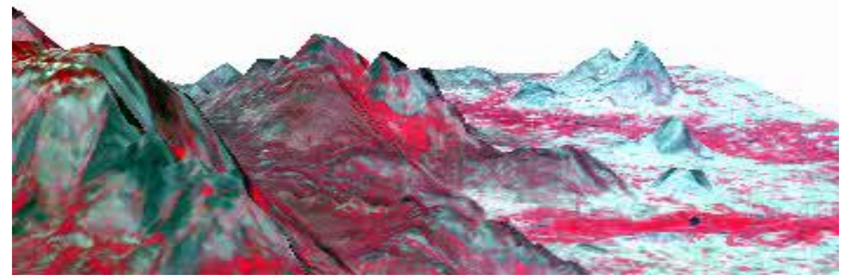


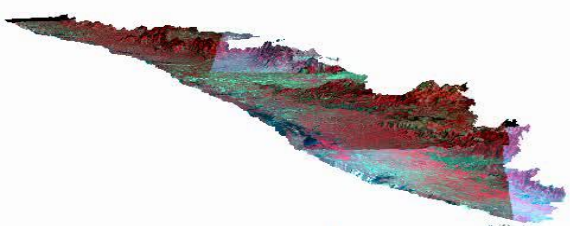
3D - DTM

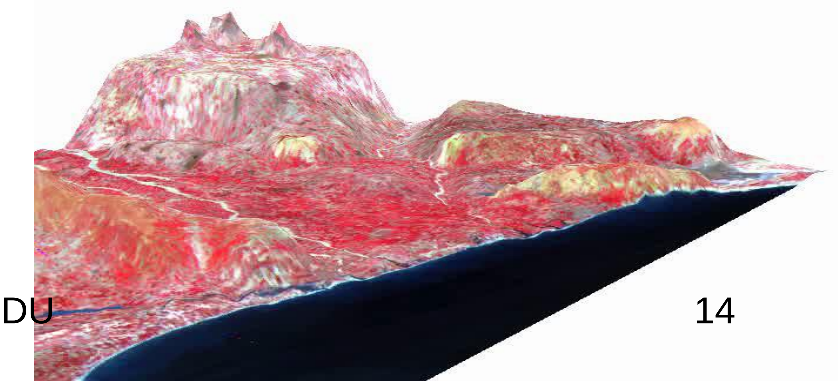


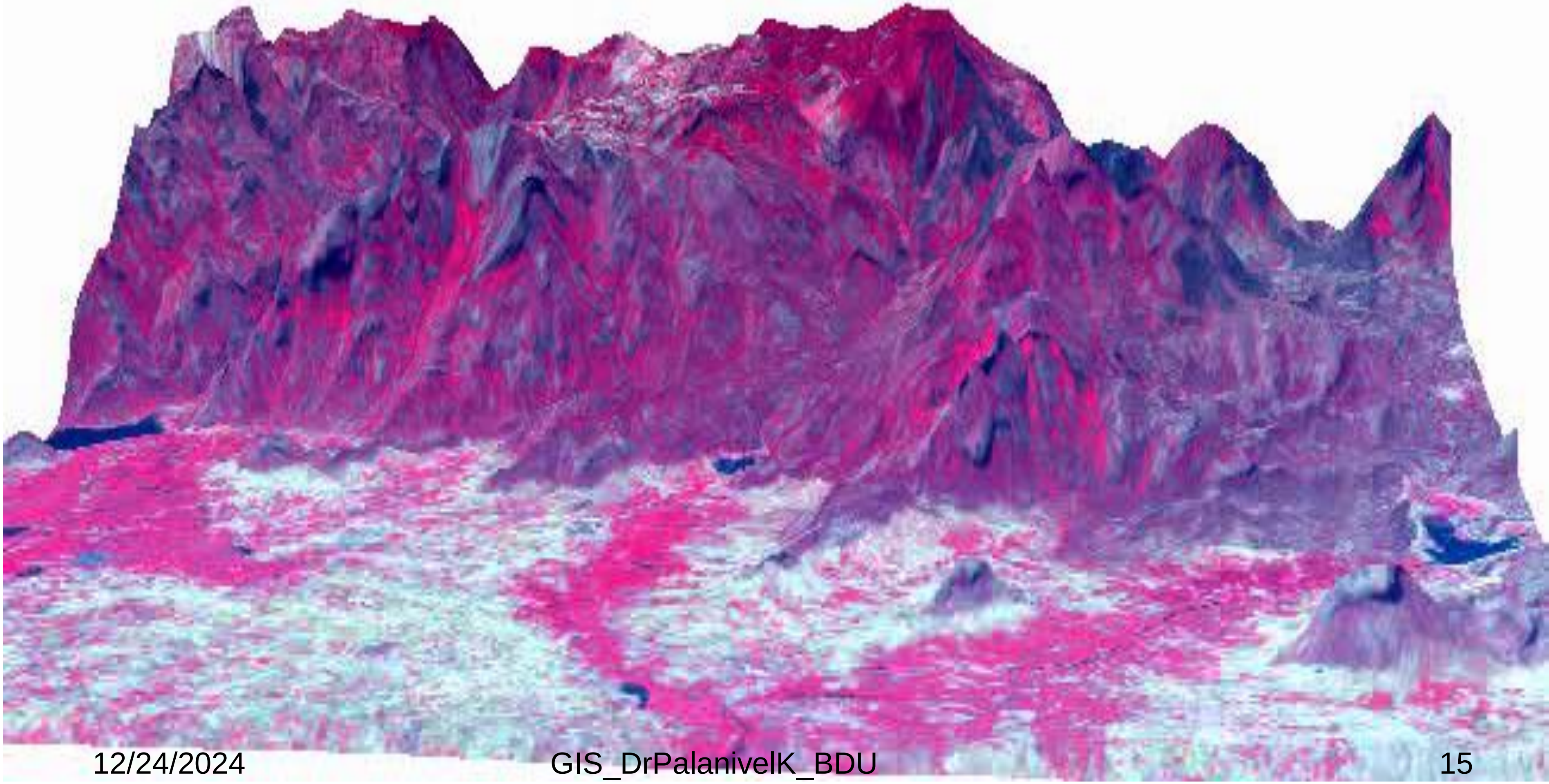












BACK

7. GIS Can do many more operations / **Analyses** like add, subtract, multiply, divide, square, buffer, corridor, integrate multiple layers, etc.

Raster Based Addition

InRaster1

1	1	2	2	2
3	1	3	4	4
3	3	2	4	4
3	2	2	1	4
3	2	2	1	1

\+

InRaster2

3	3	1	2	2
2	3	1	1	1
2	4	3	3	1
2	2	3	4	4
1	2	1	1	4

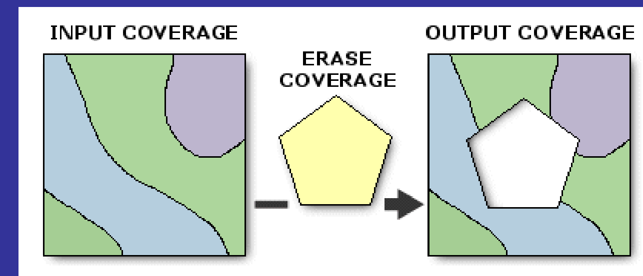
=

OutRaster

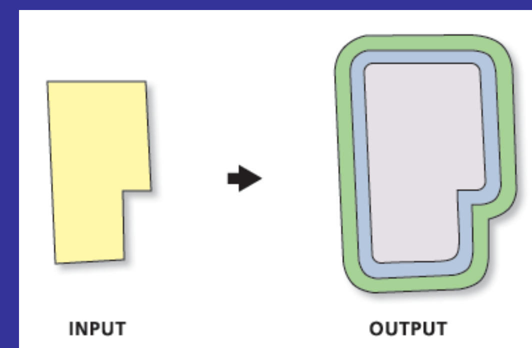
4	4	3	4	4
5	4	4	5	5
5	7	5	7	5
5	4	5	5	8
4	4	3	2	5

InRaster1 + InRaster2 = OutRaster

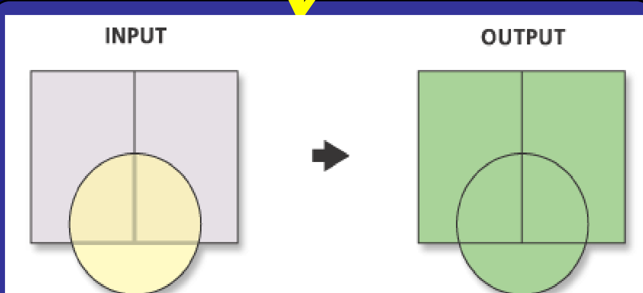
Vector Based Layer Integration



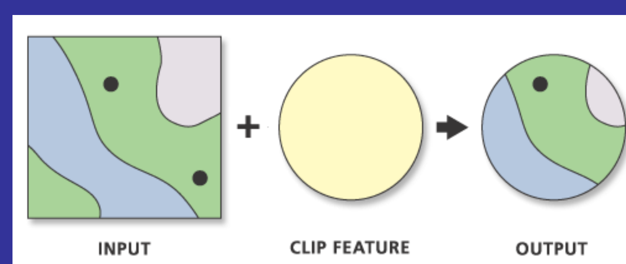
ERASE



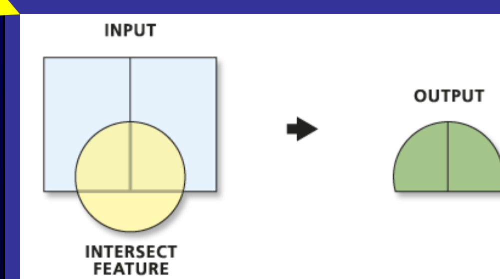
BUFFER



UNION

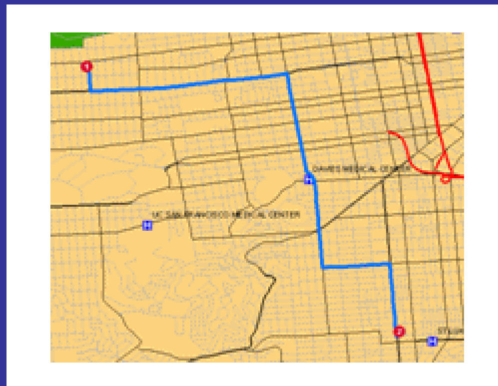


CLIP



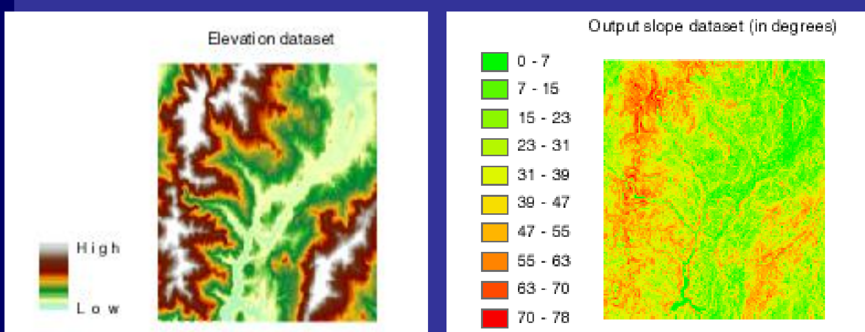
INTERSECT

NETWORK ANALYSIS



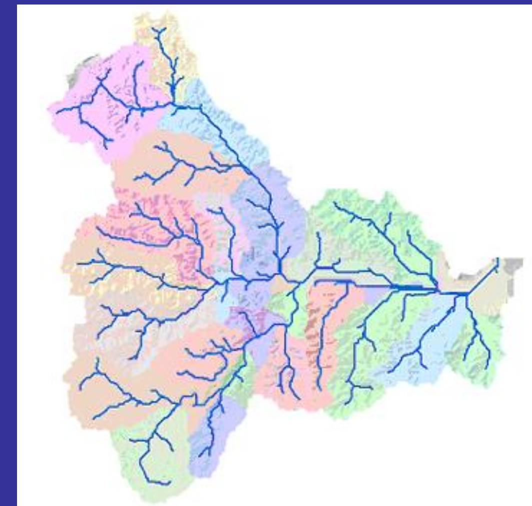
Route Identification

SLOPE ANALYSIS



Slope Categories, Slope Length, 3D Fly-through, Inter-visibility / Line-of-sight Analysis, etc.

DRAINAGE ANALYSIS



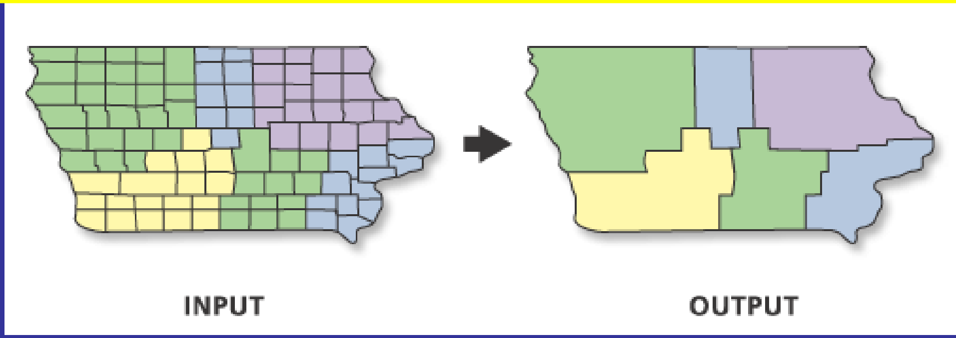
Identification of drainages, Demarcation of drainage basins, Watershed mapping, Runoff estimation, etc.

TIME SERIES ANALYSIS

TREND SURFACE ANALYSIS

Change detection, Pattern of change, Modelling, Simulation…

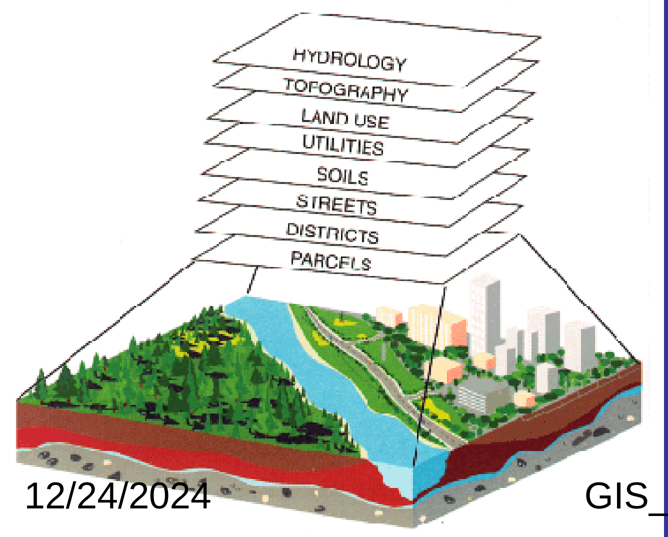
8. Data Pre-processing and Post-processing capabilities Classification/Grouping , Regrouping,/Reclassification



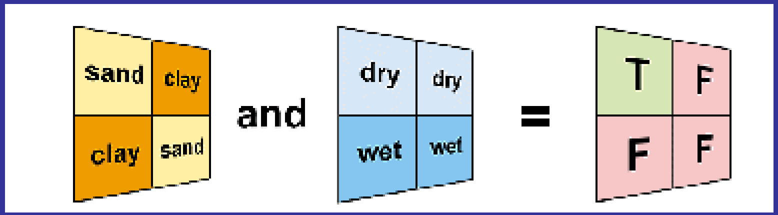
9. MODELLING

For e.g.,

Representation Model



Process Model



Yes / No, True / False, 1 / 0, etc.

10. CUSTOMIZATION

Building up of new working environments through programming in GIS as backend using frontends such as VB, Dartnet, Python, etc.

11. AUTOMATION

GIS Can provide AUTOMATION OF SEVERAL ANALYSIS COMPONENTS FOR VARIOUS NATURAL RESOURCES / DISASTERS MITIGATION

For, example,

AUTOMATED RUNOFF ESTIMATION MODEL can do,

- **Delineation of drainages and watersheds – from elevation raster data,**
- **Generation of Rainfall map – from rain gauge stations through websites**
- **Generation of Hydrological soil group map – from pre-existing data**
- **Generation of Landuse / Land cover map – from satellite data**
- **preparation of watershed wise calculation of all above parameters, and finally Runoff Estimation by applying the values into the formula, automatically.**

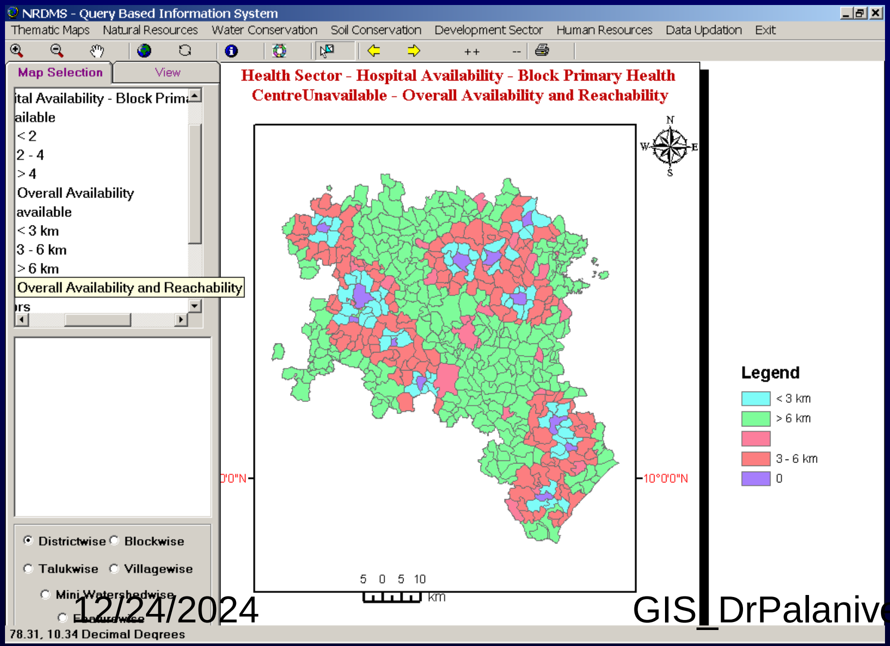
12. Advancements in GIS
a. **Internet / web GIS**

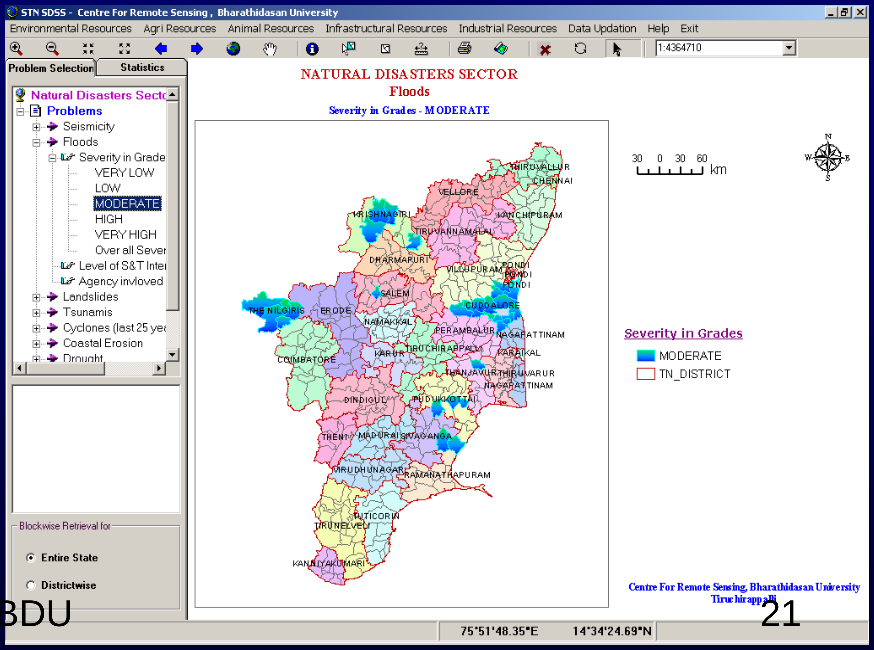
- Open source GIS
- Non-Commercialisation
- Increase data usability
- Decrease work duplication
- Easy access by GIS community
- Quick and easy planning during crisis

12.b GIS can provide Spatial Decision Support System (SDSS) for various developmental planning

- ➔ User defined, query based, spatial data retrieval / map display
- ➔ Display of non spatial data by linking spatial data
- ➔ Data listing, map wrapping
- ➔ Programming for automated mapping, spatial database generation, spatial / tabular analysis, spatial modeling and suggestion of remedial measures / providing action plan map, etc.

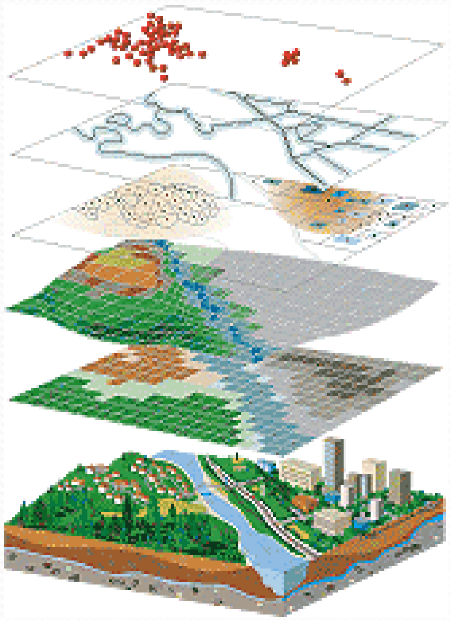
NRDMS SDSS





Capability based definition of GIS

GIS is a computerized / digital system for



- **Capturing / generating,**
- **editing,**
- **manipulating,**
- **systematically storing,**
- **analyzing,**
- **integrating,**
- **modeling,**
- **visualizing,**
- **sharing,**
- **retrieving, and**
- **representing / displaying**

huge quantity of both *spatial* and associated *attribute data* with customization and automation capabilities.

1.2 ADVANTAGES OF GIS over Manual Cartography

1. All data can be stored in digital formats in computer
2. It occupies less space in contrast to very larger maps and data sheets
3. Data / maps doesn’t shrink or damage
4. Does not require large storage cabins
5. Data searching and retrieval is easy

6. Preferential filtering of selective data

➔ From the set of various road type digitised with labels separately as:

* National Highways
* State Highways
* District roads alone
* Village roads – metalled
* Village roads - unmetalled, etc.,

- the planner required roads for further developmental activity can alone (for e.g., **VILLAGE ROADS - Unmetalled alone**) be retrieved / shown as preferential layer.

How GIS differs from other related Systems?

- **DBMS—**typical data base contains implicit but not explicit locational information
  - city, county, zip code, etc. but no geographical coordinates
  - is 100 N. High around the corner or across town from 200 E Main?
- **Automated Mapping (AM)** --primarily two-dimensional display devices
  - thematic mapping (choropleth, etc., such as SAS/GRAPH, DIDS, business mapping software) unable to relate different geographical layers (e.g. Aadhaar & Location)
  - automated cartography--graphical design oriented; limited database ability
- **Facility Management (FM) systems**--
  - lack spatial analysis tools
- **CAD/CAM** (computer aided design/drafting)--primarily 3-D graphic creation (engineering design) & display systems
  - don't reference via geographic location
    - CAD sees the world as a 3-D cube, GIS as a 3-D sphere
  - limited (if any) database ability (especially for non-spatial data)
- **Scientific Visualization Systems**--sophisticated multi-dimensional graphics, but:
  - lack database support
  - lack two-dimensional spatial analysis tools.

But **GIS** offers a holistic platform possessing all possibilities from DBMS, Map, 3D visualization, Spatial Analyses combined with Statistical Models, Networking, WebGIS, to QUBIS & SDSS, and its advancements.

IMAGINE THE FOLLOWING SITUATIONS:

- My village has got very good fertile soil, man power, facilities, etc.,
  - ***but, there is less rain.***

- Undulating hilly terrain covered with dense vegetation looks like a green carpet–a scenic beauty - is my area,
  - ***now-a-days affected frequently by forest fire, soil erosion, landslides and flash floods.***

- In my very calm and wealthy village,
  - ***due to continuous burglary / robbery problem in many nights of a month and also during day time recently, most people are decided to shift their families.***

Some… more …requirements.

- A Highway Patrol officer likes to know ***a feasible route to take the ambulance to the nearest hospital having a particular Life-saving-treatment Facility***.
- A Forest Officer immediately wants to ***preserve the forest from a fast spreading tree disease.***
- A Fireman has to ***reach the target within short time and to know about the water/other relevant facility therein nearby.***
- A district level Planner (the Collector), plans to ***utilize the fund for development on priority basis.***
- Election Commissioner, wants to ***identify/install possible booths based on the population, reacheability, etc.***

Can GIS help in dealing the above important tasks?

- Resource Management
- Resource Conservation
- Resource Exploitation
- Resource Planning – Integrated and Sustainable manner
- Resource Estimation
- Resource Prospecting / Exploration

- Disaster Management
- Disaster Mitigation
- Disaster Prevention
- Disaster Inducing Parameter (s) Identification
- Disaster Vulnerability Assessment
- Disaster Relief fund distribution / Rehabilitation
- Disaster Damage Assessment

All the tasks can be dealt together?

If yes, How? Using GIS – by exploring its capabilities.

FUNDAMENTALS OF GIS

- GIS works on the basis of both location data as well as attribute data
- Spatial data have been generated on par with world real coordinates and defined with specific projection to maintain accuracy in all measurements
- Attribute data have been linked with location data and spatial layers can be created on the attribute data and
- Analysis can be done with both by spatial integration techniques
- 2D / 3D visualization can be done based on interpolation techniques.

TEN Important challenges in solving issues

In every case, we need to

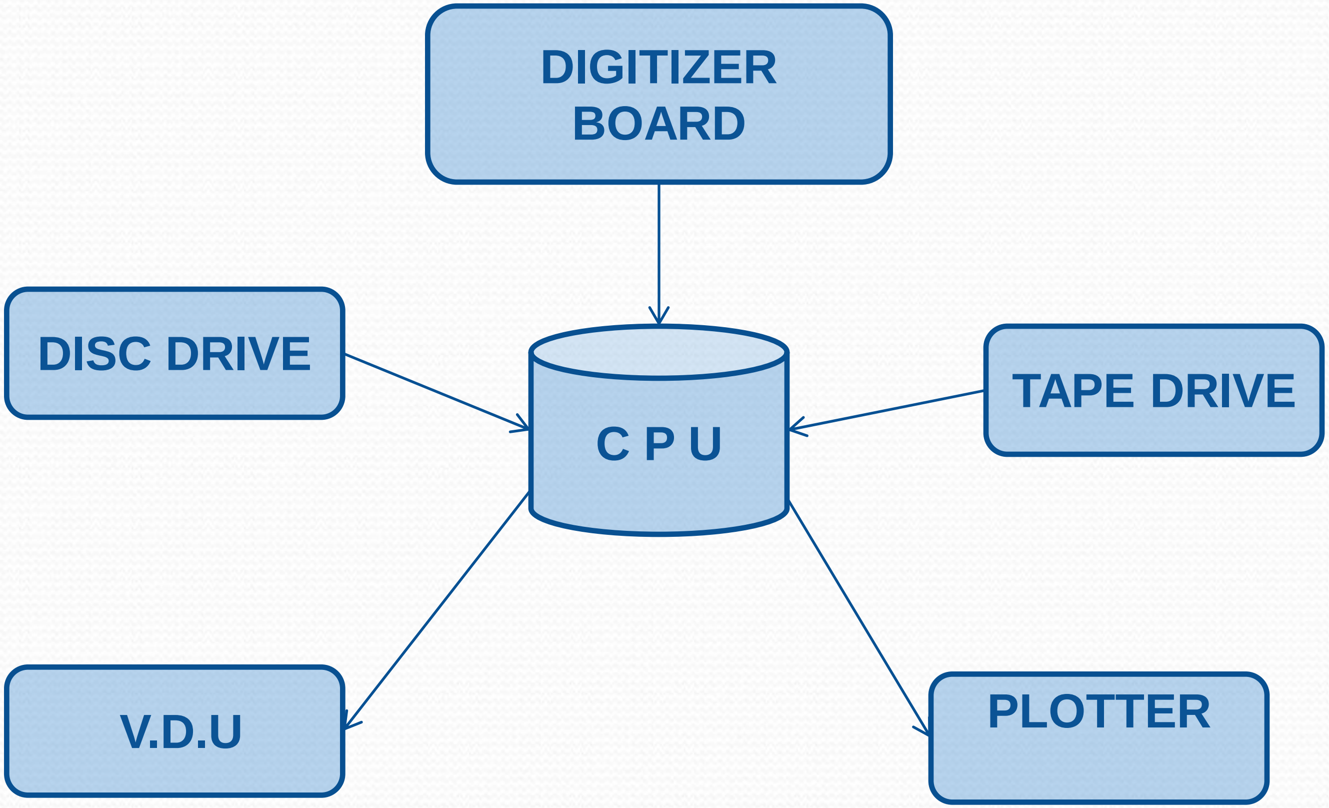
1. Collect, store & Preprocess the relevant data
2. Prepare a genuine database
3. Regroup / Reclassify the data
4. Analyze through comparison, integration, classification, prioritization, buffering, etc.
5. Derive the fact / information by post-processing techniques
6. Identify / understand the reasons – qualitative / quantitative – to develop model
7. Prepare pragmatic plans, ways & means for precise, efficient & economic for implementation,
8. Implement properly in correct location
9. Follow-up / monitor its functionality
10. Update / Manage the mechanism to work properly.

All the above tasks can be easily done in GIS environment…

1.2 COMPONENTS OF GIS

- **1.2.1 COMPUTER HARDWARE**
- **1.2.2 APPLICATION SOFTWARE**
- **1.2.3 PROPER ORGANIZATIONAL CONTEXT**

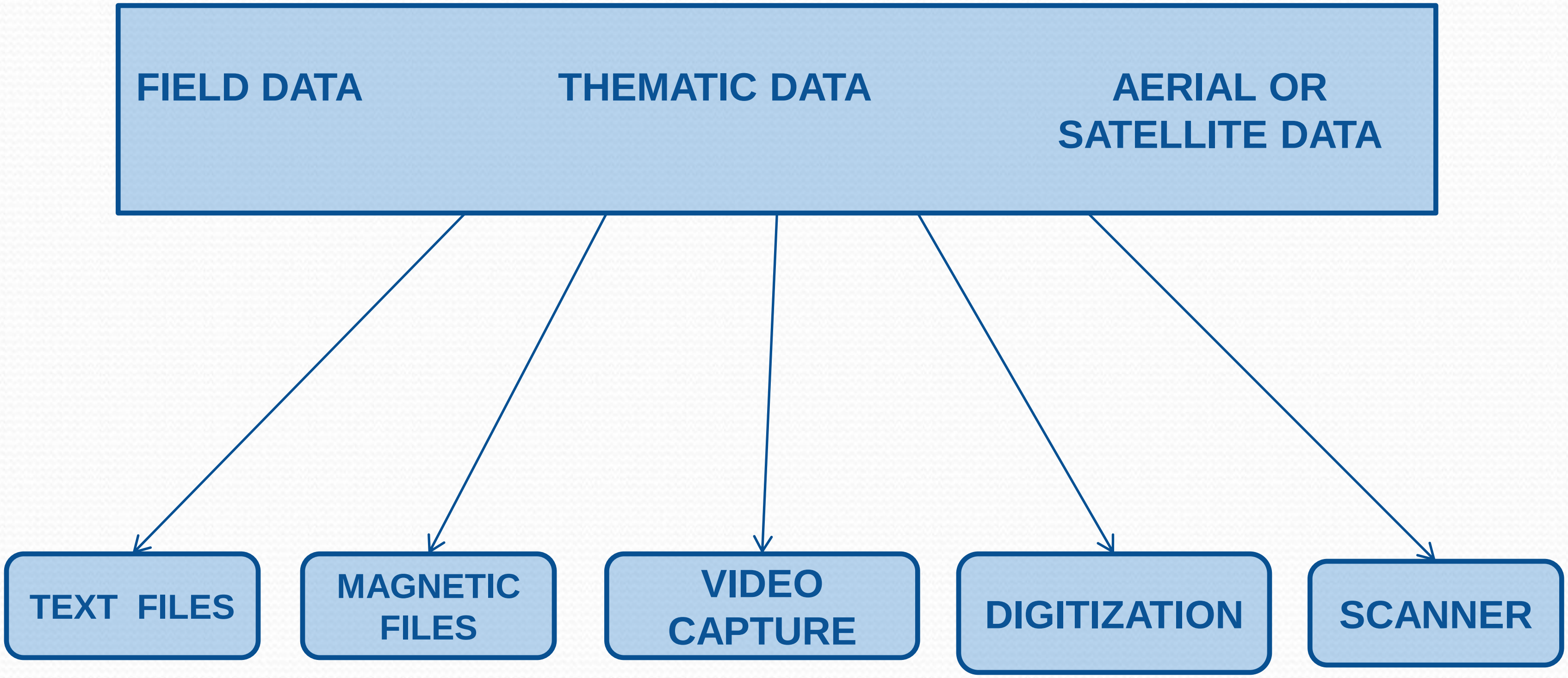
1.2.1 COMPUTER HARDWARE



1.2.2 APPLICATION SOFTWARE

- 1. Data input and verification
- 2. Data transformation
- 3. Data analysis and modelling
- 4. Data output and presentation
- 5. Data storage and database management &
- 6. Interaction with user.

1.2.2.1(a) DATA INPUT



1.2.2.1(b) DATA VERIFICATION

- **Topology** – Generating details as separate files containing **geometric properties** of spatial data such as,
  - Containment
  - Connectivity / Continuity / Contiguity
  - Adjacency …. etc.

Building of Topology details to any spatial data can **identify, locate** and then **remove** all the geometrical errors such as **open polygons**, **sliver polygons, multiply digitized features**, **undershoots, overshoots, unlabeled features, multi-labeled features**, etc., quickly.

GIS has options for Editing / Updating of spatial data sets and making them accurate and error free.

1.2.2.2 DATA TRANSFORMATION

TRANSFORMATION

TRANSFORMATION TO REMOVE ERRORS, UPDATING AND MATCHING WITH OTHER DATASETS

* SCALE CHANGING
* FITTING DATA TO NEW PROJECTIONS
* LOGICAL RETRIEVAL
* VARIOUS CALCULATIONS

TRANSFORMATION TO CREATE ANSWERABILITY

1. WHAT IS A?
2. A's RELATION WITH B
3. AREA OF A
4. PERIMETER OF A, etc.

1.2.2.2 DATA TRANSFORMATION … CONTD…

1. **Updation of ground control points**

- **Raw digital data are either in digitizer board unit or display screen unit**
- **Update their coordinate values with decimal degrees**
  - **DD = (degree + (minute / 60) + (seconds / 3600))**

2. **Project them to the required projection system**

Details required:

Input data details

- Projection type – geographic
- Units – DD

Output data details required (after projection)

- Projection type (expected) – polyconic …
- Units – meters
- Central meridian in dms (max – min longitude/2)
- Lattitude of projections origin in dms

1.2.2.2 DATA TRANSFORMATION ... CONTD...

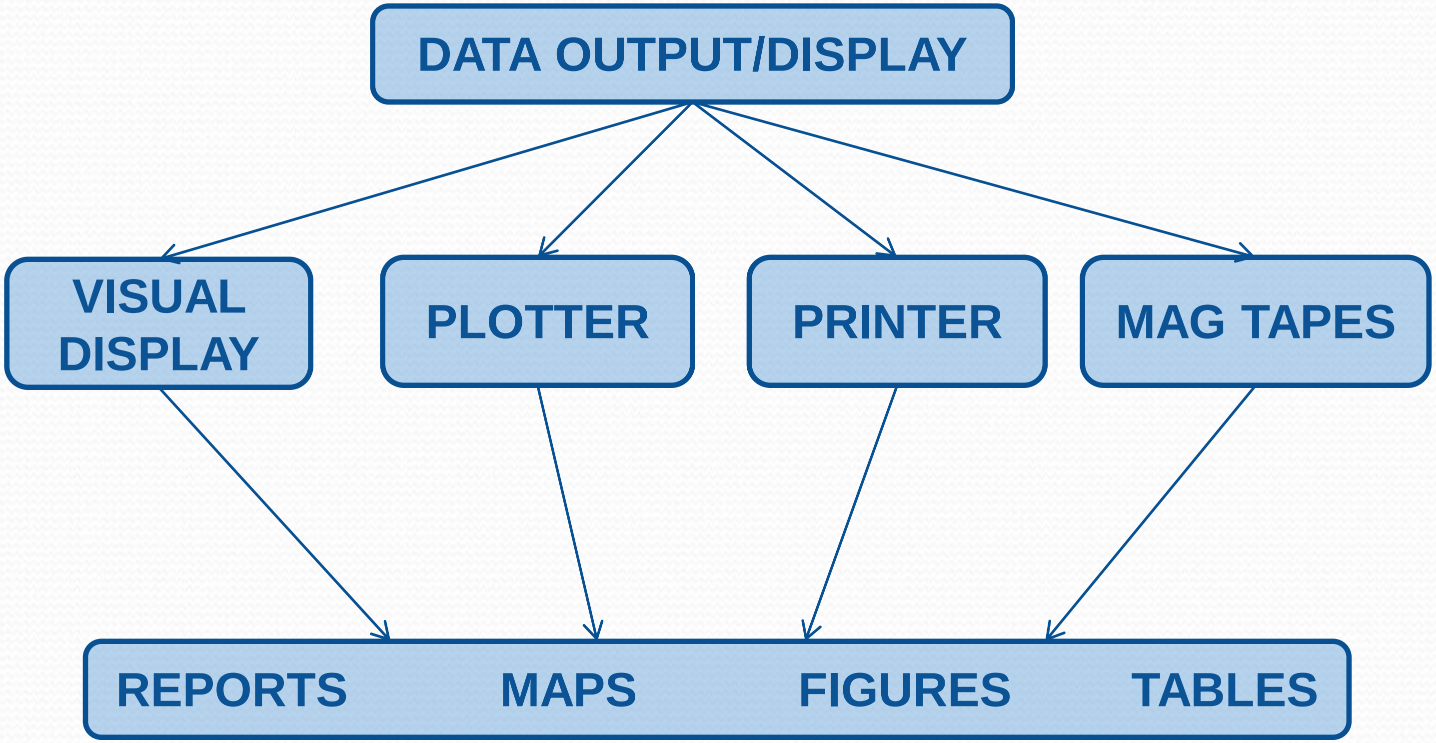
3. TRANSFORMATION OF ALL DIGITAL SPATIAL DATA (using Import Spatial References option)

- **Making a copy of projected coordinates pertaining to the same study area**
- **Transformation of all themes to the projected real world coordinates using "transform" option**
- **In addition, the spatial data can be transformed or converted to any type from Vector to Raster (rasterisation) or vice-versa .**
- **Similarly, from one format to other format transformation (export and import of data) is also possible. For e.g., Shape file to layer file or coverage file, compressed formats, etc., So as to use them in any GIS s/w.**

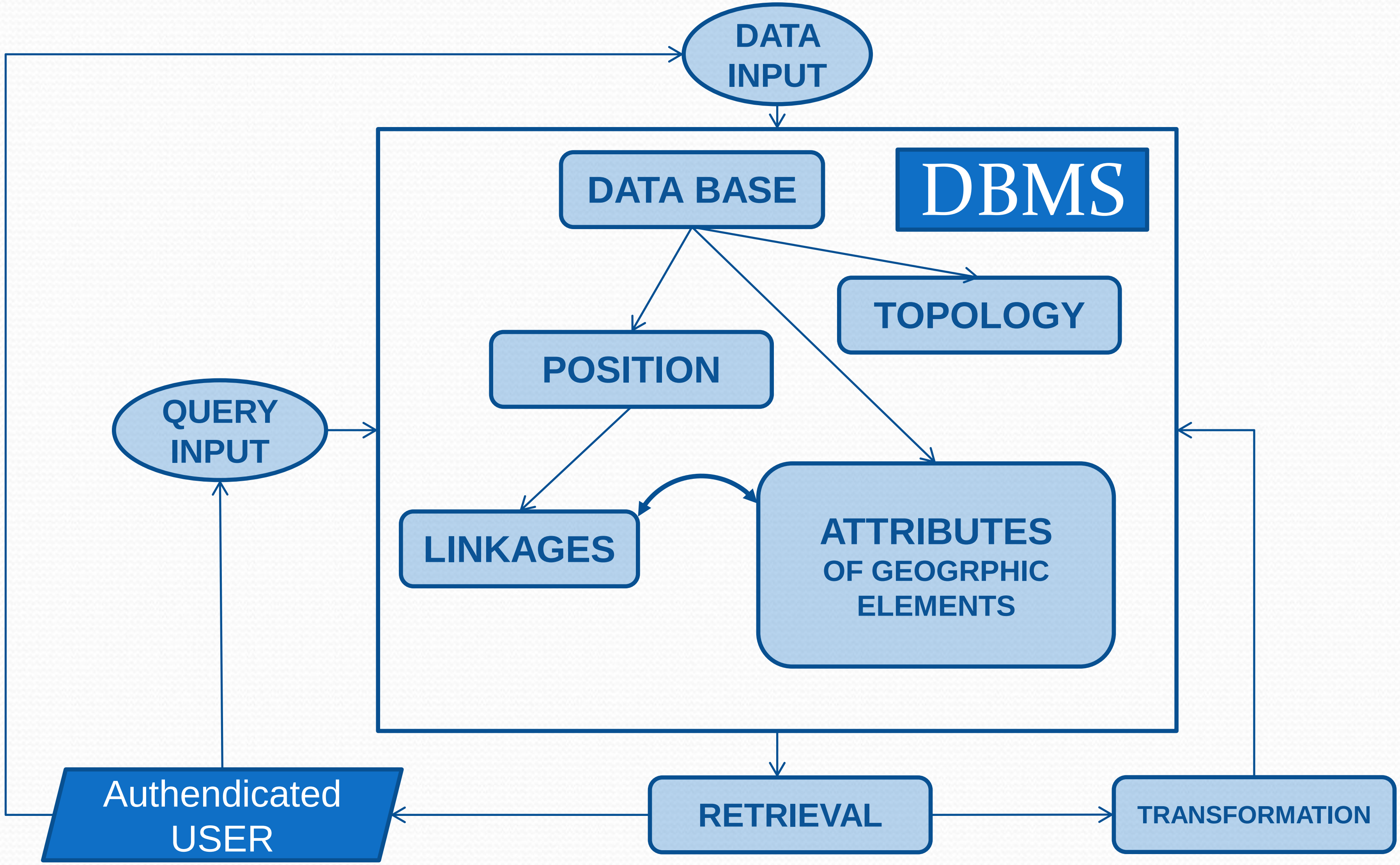
1.2.2.3 DATA ANALYSIS AND MODELLING

- **SPATIAL OVERLAY**
  - UNION
  - INTERSECTION
- **STATISTICAL ANALYSES**
  - CORRELATION
  - LINEAR/ MULTIPLE REGRESSION
- **RASTER ANALYSES**
  - MATHEMATICAL OPERATIONS: ADD, SUBTRACT, MULTIPLY…..
- **NETWORK ANALYSES**
- **DRAINAGE MORPHOMETRIC ANALYSES**
- **SLOPE ANALYSES**
- **SPATIAL MODELLING**
  - BINARY
  - INDEX
  - PROCESS
  - REGRESSION

1.2.2.4 DATA OUTPUT AND DISPLAY MODULE



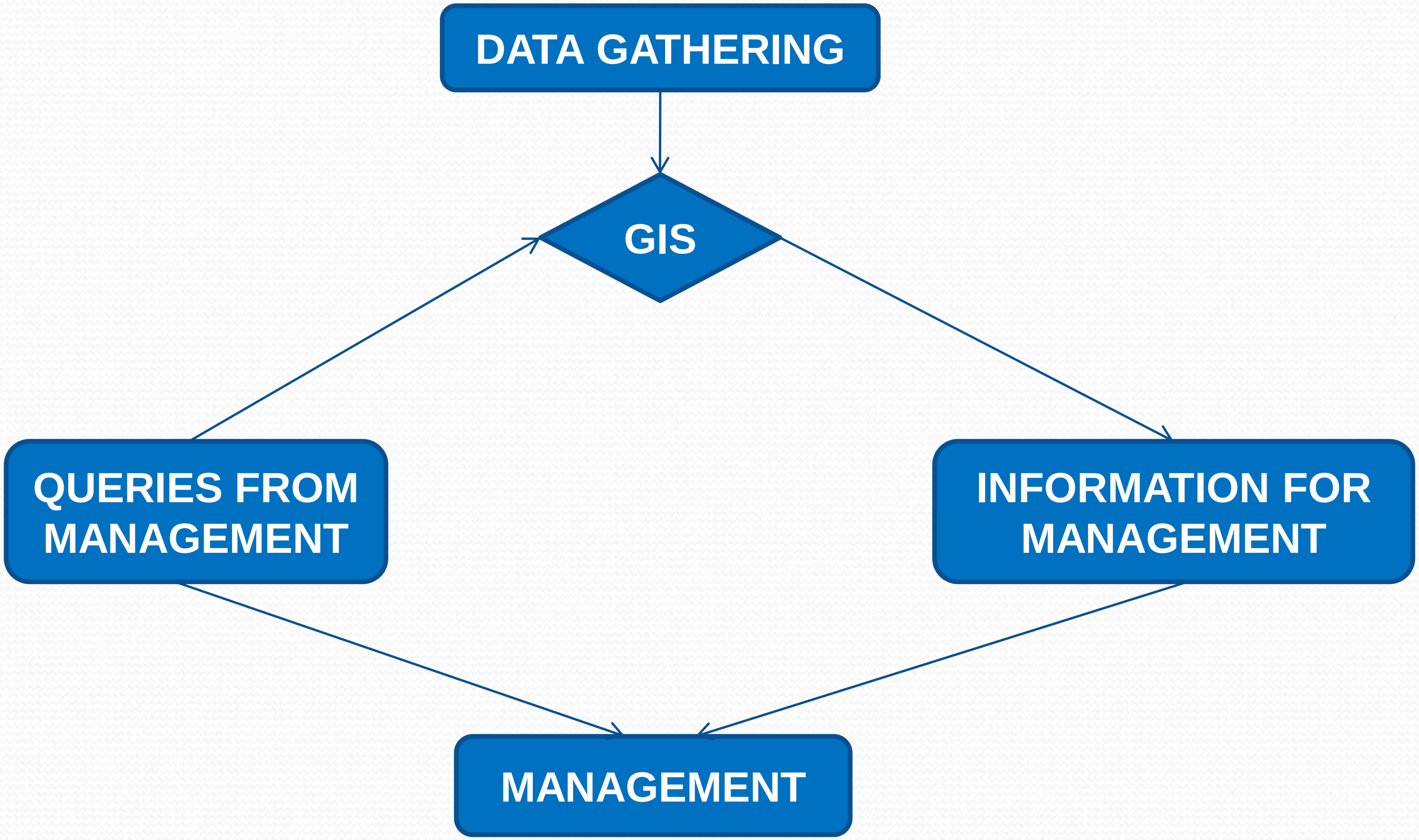
1.2.2.5 DATA STORAGE AND MANAGEMENT



1.2.2.6 INTERACTION WITH USER

- **General interaction**
- **Query input**
- **Commands &**
- **Menu driven systems.**

1.2.3 ORGANIZATIONAL ASPECTS OF GIS



ORGANIZATIONAL ASPECTS OF GIS ...contd...

1. **PROPER INTEGRATION OF DATA WITH GIS INVOLVES, THE PROPER DATA ORGANIZATION,**

For SPATIAL DATA SETS

- **RASTER - CONVERSION POSSIBLE**
- **VECTOR - -DO-**
  - Points
  - Lines
  - Polygons – For e.g. Continuous data - Surface & Subsuface …
    Discontinuous data

ORGANIZATIONAL ASPECTS OF GIS ...contd...

- **CONTINUOUS DATA**
  - Surface
    - **Slope**
      - **Degree / radiance / percent**
      - **Length**
      - **Aspect / direction**
        - **Consequent**
        - **Subsequent**
        - **Obsequent**
      - **Geometry**
        - **Plain**
        - **Convex**
        - **Concave**
      - **Vegetal cover**
        - **Active**
        - **Passive**
  - Subsuface
    - **Ground Water Level**
    - **GW Quality (**40+ Parameters)
    - **Subsurface Lithology**
      - **TTS – Thickness of Top Soil**
      - **TWZ – Thickness of Weathered Zone**
      - **TFZ – Thickness of Weathered Zone**
      - **DBR – Depth to Bed Rock**
    - **Aquifer Characters**
      - **T - Transmissivity**
      - **K - Permeability**
      - **S - Storage Coefficient**
      - **SY - Specific Yield**
  - **Etc…..**

- **Discontinuous / Choropleth data**
  - **Lithology**
    - **Igneous**
    - **Metamorphic**
    - **Sedimentary**
  - **Structure**
  - **Geomorphology**
  - **Landuse / land cover**
  - **Soil types, etc….**

cover parts of surface

For Non-spatial data sets

organise attributes for proper linkage with spatial data

- **For spatial display of non-spatial data**
- **Provide unique identifier**

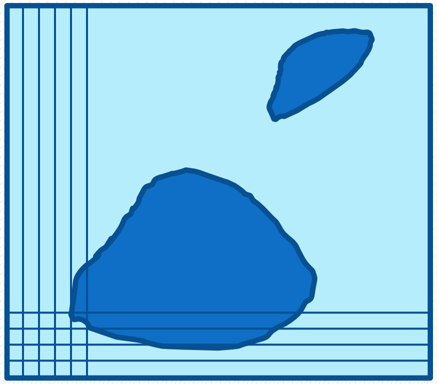
ORGANIZATIONAL ASPECTS OF GIS ...contd...

2. **Data entry – structure type**
3. **Derivation of information**
4. **Data retrival - query building**
5. **Management – data updation**

2. GIS DATA STRUCTURES

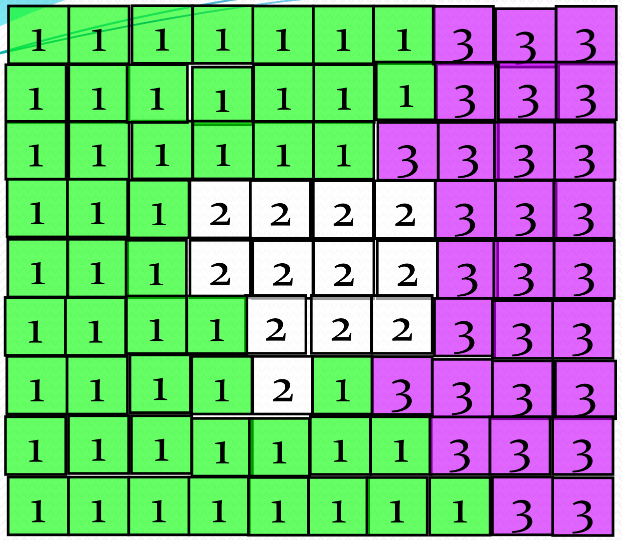
2.1 Definition

- Computer based data structure for the representation of real world entities
  - Two types
    - Vector data structure
    - Raster data structure



  - A data structure that uses
    - points, lines and polygons to describe world surface / spatial phenomena – VDS
    - Sets of regular shaped tessellated units to describe world surface / spatial phenomena – RDS
    - Tessellate - cover a surface by repeated use of a single shape **without gaps** or **overlapping**.

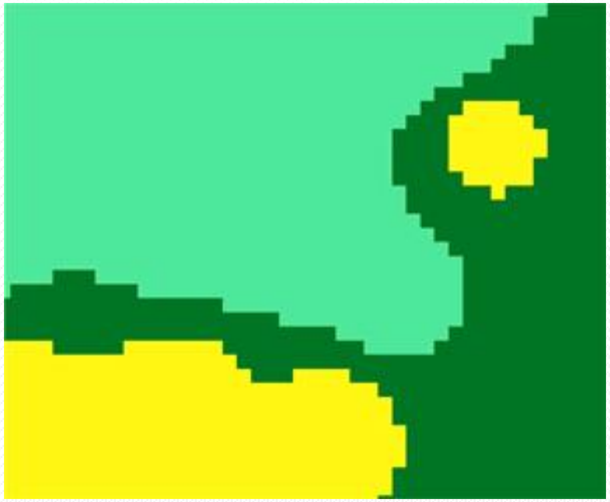
GIS Data Representation



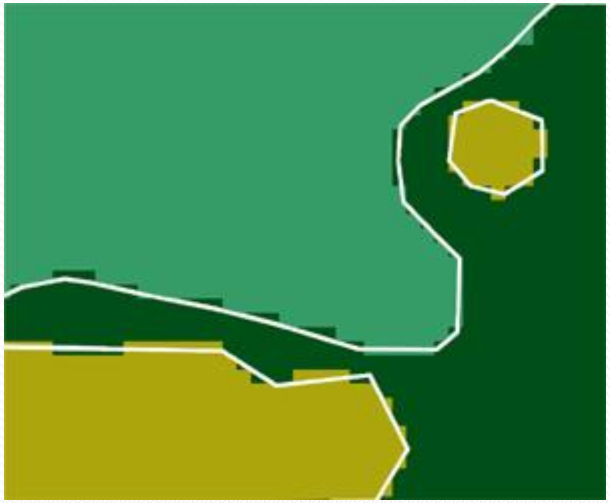
Rasterization

Consist arrays of cells in a grid pattern

Raster (Pixel size = 5mm x 5mm)



Vectorization



Go Back

Consist vector elements – points, lines & polygons

2.2 File and Data access

- Essential features of any **data storage system** are that they should allow data to be accessed and cross-referenced quickly.

1. Simple lists – Consider one second for checking a record or row (**n** no. of rows), the **Average Search Speed** in seconds can be calculated as, **T = (n+1)/2,** where, T = time, n=number of records in a file.

- For example, if there are **10,000 records** in a database, then it may take around a minimum of 5000.5 seconds, i.e., around **1 hour**
- **39 minutes.**
- Search event becomes a time taking one
- But easy to update the record, i.e., deletion and updation of record, and addition of new records at the end of the list in that file.

2.2 File and Data access ...contd...

2. Ordered sequential files – Nos. in Telephone directory

– Average Search Speed, T = $\log_2(n+1)$

- Binary Search
- For a search in a database containing 10,000 records,
- It takes 14 seconds only
- Searching becomes 50-100 times speedier
- Data updation becomes tedious
- By adding one row (i.e., a record), the entire database need to be arranged orderly – every time.

*n*n	$\log_2 n$
1	0
2	1
4	2
8	3
16	4
32	5
64	6
128	7
256	8
512	9
1024	10
2048	11
4096	12
8192	13
16384	14

2.2 File and Data access ...contd...

3. Indexed files – Word search in a dictionary

- Ordered and indexed for quick access
  - **Direct files** **(n1+1)/2 + (n2+1)/2**
  - **Indirect files** Where, n1 = No. of steps in the index
  - **Index inverted files** n2 = No. of items in the data block

  - Quick searching
  - Data updation is tedious – the entire database need to be ordered and indexed every time on deletion, editing or updating events.

Inverted files

Soil Profile No.	Series	pH	Depth	Drainage	Texture	Erosion
1	A	4	Deep	Good	Sandy	---
2	B	5	Shallow	Good	Clay	Yes
3	C	6	Shallow	Poor	Sandy	No
4	D	7	Deep	Good	Clay	Yes
5	E	4	Deep	Poor	Clay	No
6	F	5	Shallow	Poor	Clay	No

Index (Inverted file)

Topic	Soil Profiles (sequential numbers in original file)					
	1	2	3	4	5	6
Deep	1			4	5	
Shallow		2	3			6
Good Dr.	1	2		4		
Poor Dr.			3		5	6
Sandy	1		3			
Clay		2		4	5	6
Eroded		2		4		

2.3 Database structures and management

1. **Hierarchical** database structure
2. **Network** database structure
3. **Relational** database structure
4. **Object-oriented** database structure
5. **Full topological polygon network** db structure
6. **TIGER** (**T**opologically **I**ntegrated **G**eographic **E**ncoding and **R**eferencing)

- Other developments in database structures

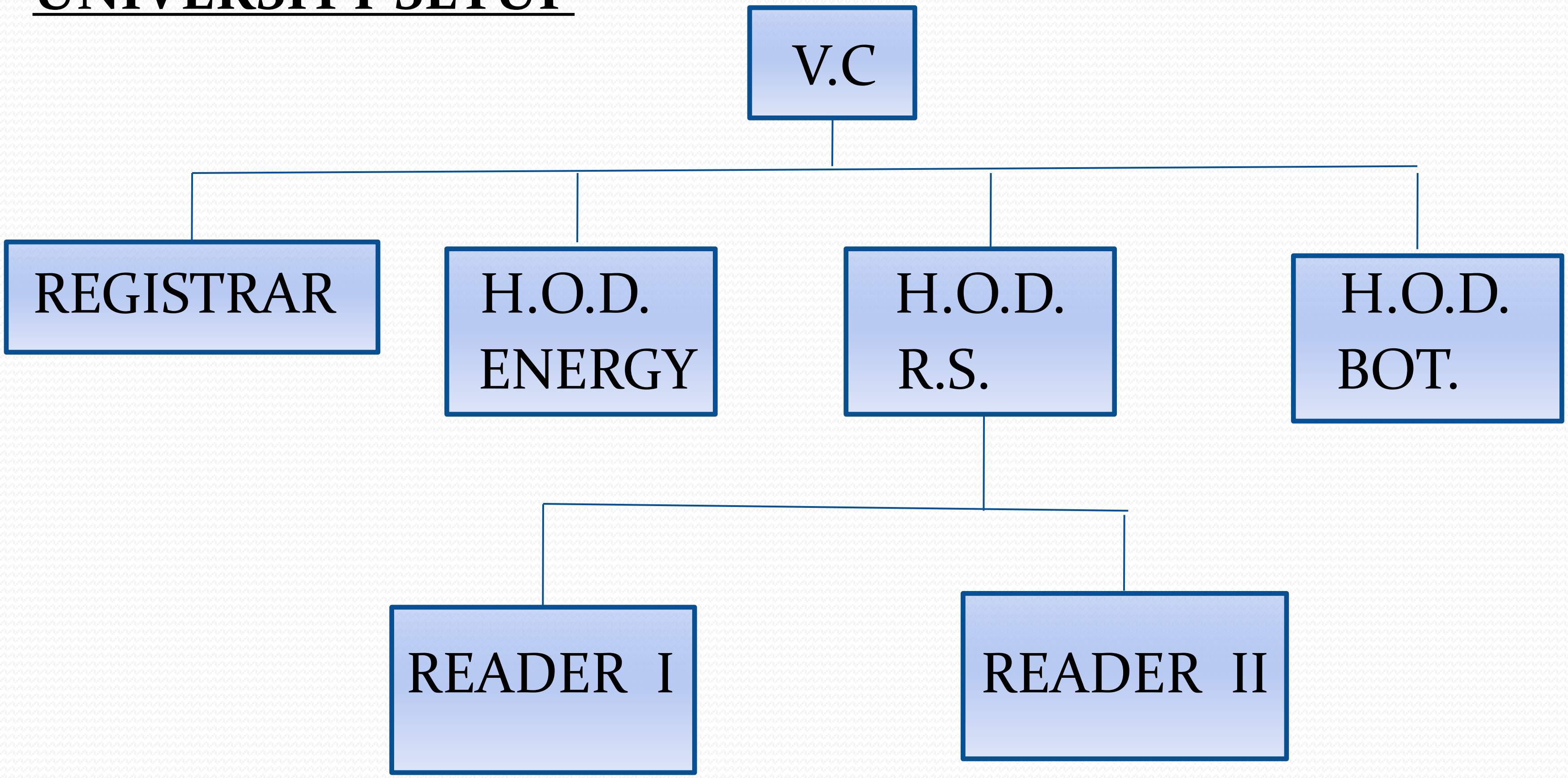
2.3 Database structures and management ...contd...

1. Hierarchical database structure

- Maintains a hierarchy as per their importance and level
- Vertical downward or upward connectivity amongst levels are possible
- Lateral connectivity amongst the database is not possible
- Data redundancy occurs
- Data updation is tedious

HIERARCHICAL DATA STRUCTURE

UNIVERSITY SETUP



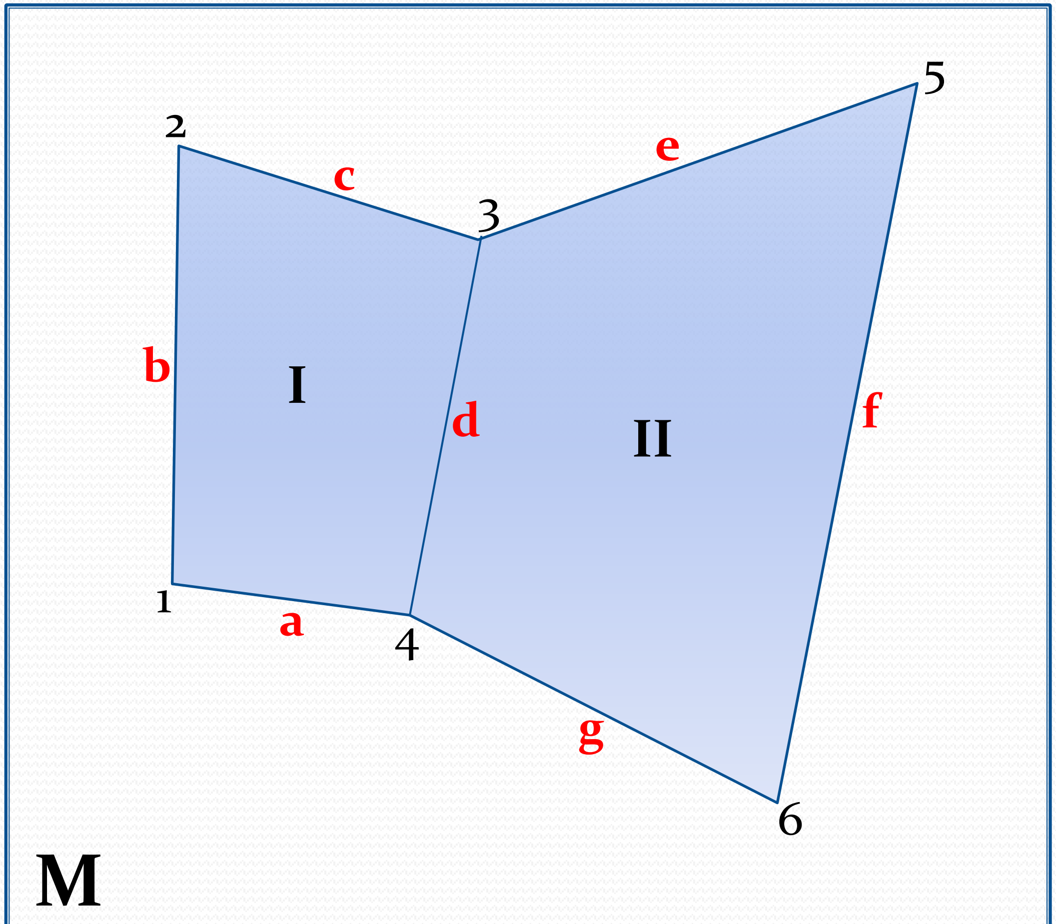
Go Back

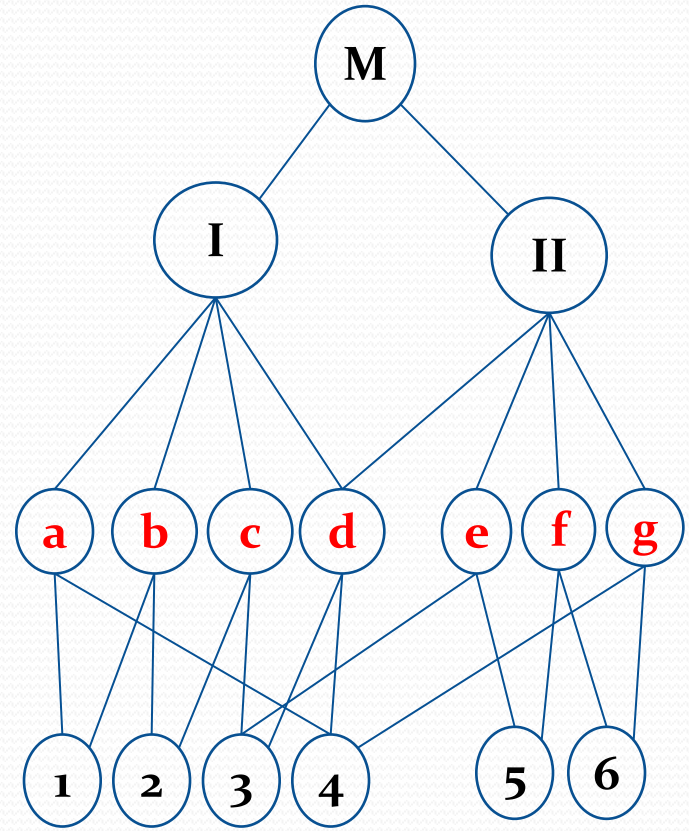
2.3 Database structures and management ...contd...

2. Network database structure

- Eliminates lateral connectivity amongst database – lateral linkage can be easily provided using networks and pointers
- Data repetivity – data redundancy is totally avoided
- Data updation is tedious.

NETWORK DATA STRUCTURE





Map M consists of 2 polygons, 7 lines (6+1 shared) and 6 nodes,

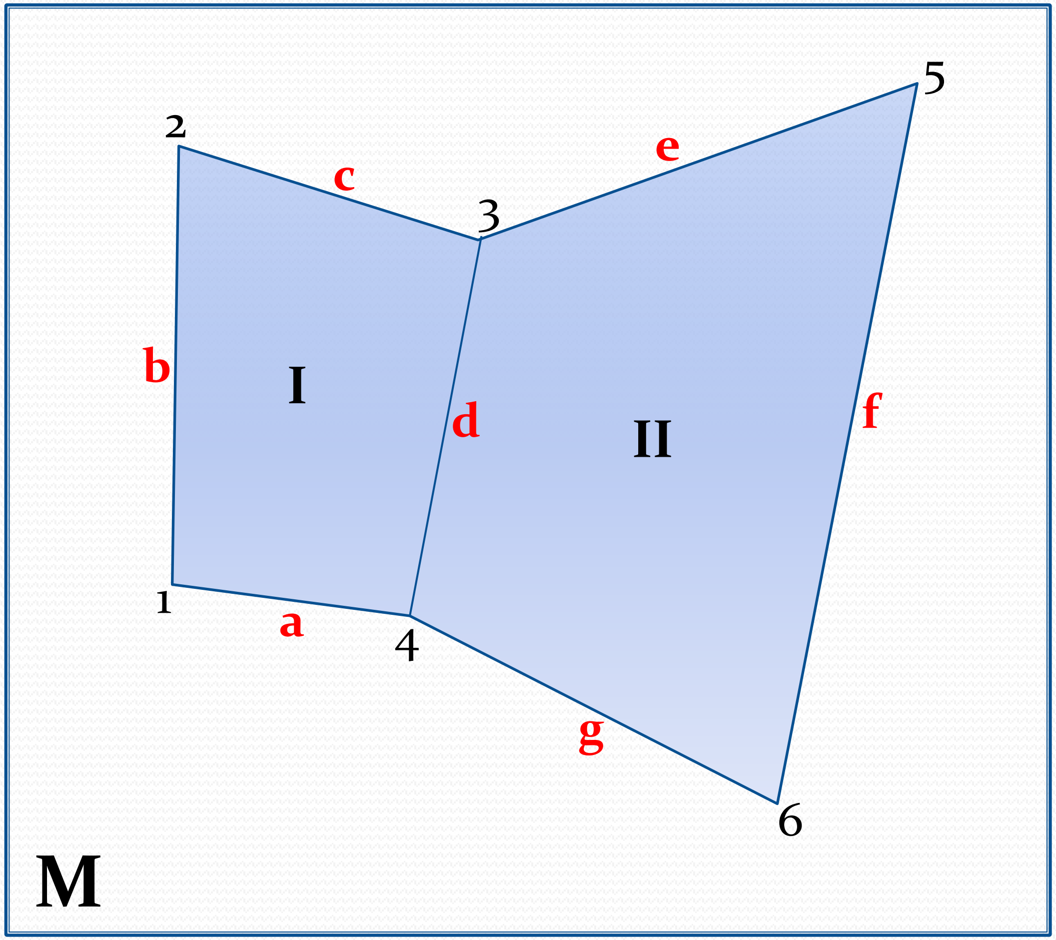
Go Back

2.3 Database structures and management ...contd...

3. Relational database structure

- Integrated database structure – a combination of Index, Hierarchy and Network structures
- Limited data redundancy is allowed
- Clarity in the database
- Every table is networked with Label Identifiers for the features
- Data updation is also easy
- Uses moderate storage space but effective searching is done.

RELATIONAL DATA STRUCTURE



Map:

M	I	II

Unique Identifiers / Label IDs / Feature IDs, attributesentities, variables, items, data elements-columns…

Polygons:

I	a	b	c	d
II	d	e	f	g

Tuples / rows / records, observations …

Lines:

I	a	4	1
I	b	1	2
I	c	2	3
I	d	3	4
II	e	3	5
II	f	5	6
II	g	6	4
II	d	3	4

Go Back

Co-ordinates:

4. OBJECT-ORIENTED GIS

Object-oriented data model is one application of object-oriented technology.

- It uses objects to organize spatial data.
- Unlike a geometric object of a point, line or area, an ***OBJECT*** is defined here as something that has a set of properties and can perform operations upon requests.
- That means, almost everything one uses in a GIS is an object.
- For e.g., a land use map is an object, which has properties, such as its coordinate system and feature type and can respond to requests such as zoom in, zoom out and a query.

There are aspects in Object oriented GIS and classified into two : 1) Structural aspects and 2) Behavioural aspects.

1) Structural aspects

Principles: To group objects : association, aggregation, generalization, instantiation and specialization aspects are required.

Association: Describes the relationships between objects of two types.

- If owner and land parcel represent two types of objects, the relationships between them can follow the rules that
  - ✓an owner can own one or more parcels and
  - ✓a parcel can be owned by one or more owners.

Aggregation: Asymmetric association in a whole-part relationship.

- For e.g., block groups are connected to form a census tract and census tracts are connected to form a county.

Generalization: Identifies the commonality among objects, and groups objects of similar types into a higher-order type.

- For e.g., parcel, zoning and census tract maps may be grouped into a higher-order class called boundary.
- Grouping of objects forms a hierarchical structure, which organizes objects into classes and classes into superclasses and subclasses.

Instantiation: An object of a class can be created from an object of another class.

- For e.g., a high-density residential area object may be created from a residential area object.

Specialization: Differentiates objects of a given class by a set of rules.

- For e.g., roads may be separated by average daily traffic volume.

Behavioural aspects of objects:

Inheritance: It is the basic principle in explaining the behaviours of objects:

- subclasses inherit properties and operations from a superclass, and
- objects inherit properties and operations from a subclass.
- For e.g., the residential area is a superclass and low-density area and high-density area are the subclasses.

- All properties of the class residential area are inherited by its own subclasses.
- Through inheritance, properties need only be defined once in the class hierarchy.

Encaptulation : Encaptulation refers to the mechanism to hide the properties and operations of an object so that the object can perform an operation by responding to a predefined message or request.

- For e.g., a polygon object can respond to a request called ReturnCenter (return the center of) by returning the physical center of the polygon.

Polymorphism: It allows the same operation to be implemented in different ways in different objects.

- For e.g., the same request called GetDimension (get the dimension of) can be sent to a point, a line, or a polygon but the result differs depending on the feature type.
- The number 0 is returned if the object is point,
  1 if the object is a line, and
  2 if the object is a polygon.

2.4 Data structures for Raster data

I. Simple raster database structure
II. Hierarchical database structure &
III. Compact data structures
   1. Chain encoding
   2. Run length encoding
   3. Block encoding
   4. Quadtree and binary tree encoding…

I. Simple Raster Data Structure

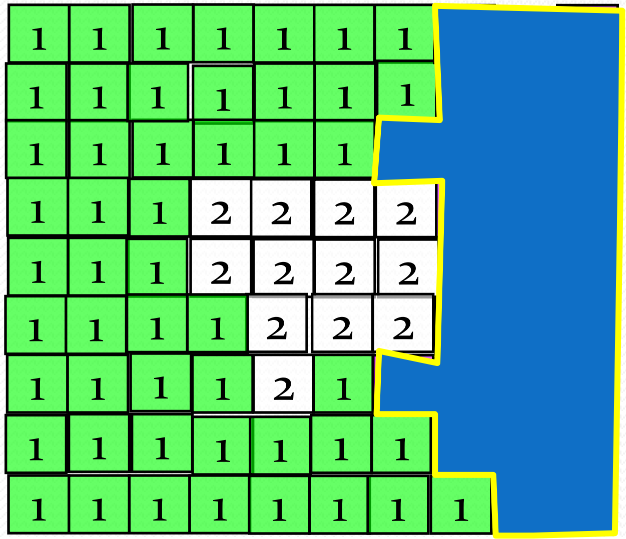
Consist arrays of cells in a grid pattern – a grid cell, i.e., pixel = picture element,

A Pixel is referenced by a row and column (x, y or Longitude, Latitude) and an attribute value (a number, alphabet or both to represent the real world object)

A point is represented by a single pixel / grid cell

A line by an array of pixels as a string along a direction continuously and

An area, i.e., polygon by an agglomeration of neighbouring cells.



This simple list raster database structure is easy to handle in computer.

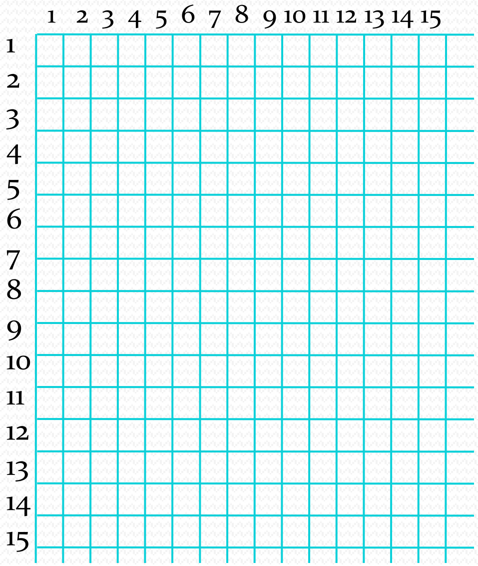
But, raster coding can affect accuracy of geometrical properties of objects – length / distance, area, perimeter, etc., due to cartesian effect of cells.

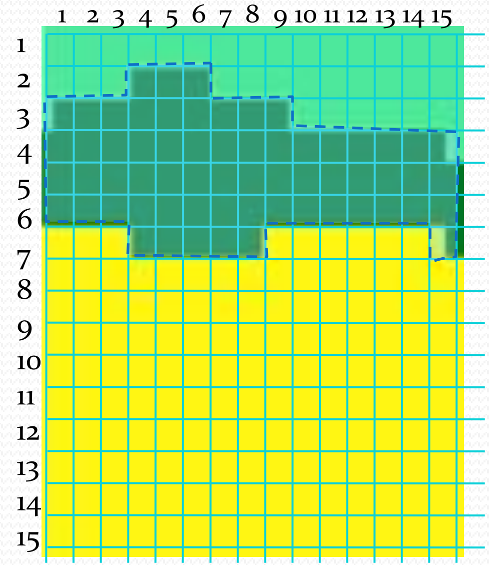
II. Hierarchical Raster Data Structure

- Based on the ascending or descending orderly arrangement, the spatial features / objects, i.e., each mapping units are referenced directly in this structure.
- Recoding a map requires one number per mapping unit which can consists of set of spatial features handled at a time – thus it has many advantages using many-to-one relationship.
- But, both are difficult when the database consists of too many objects and information covering a very large area.

III. Compressed Data structures

1. Chain encoding





$0^3, 1^1, 0^3, 3^1, 0^3, 3^1, 0^5, 3^1, 0^1, 3^3, 2^1, 1^1, 2^6, 3^1, 2^5, 1^1, 2^3, 1^4$

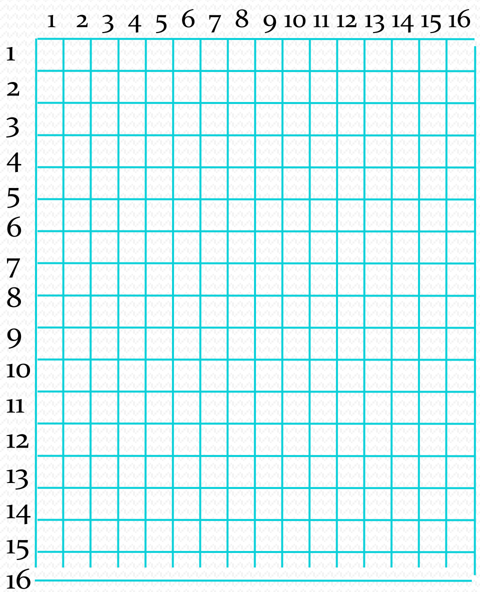
Conditions:

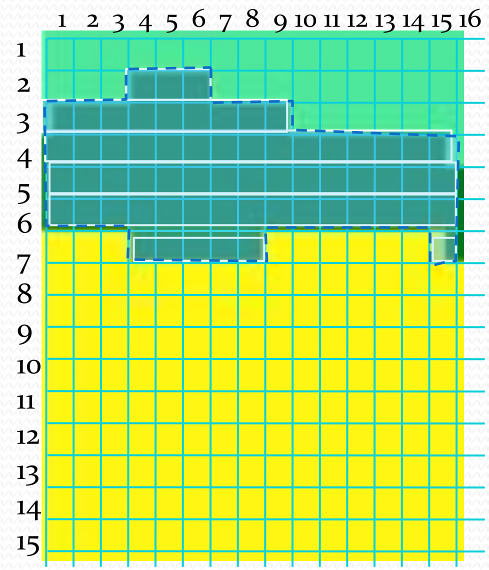
1. Define Origin: X & Y of starting cell
2. Sequence of unit vectors / cells along the outer boundary of the region in cardinal directions
3. Directions can be numbered (East = 0
   North = 1
   West = 2
   South = 3

4. Boundary of the region is coded clockwise.

Go Back

2.Run length encoding





Row wise from left to right – begin cell, end cell of a particular class

Row 1 ……

Row 2 4,6

Row 3 1,9

Row 4 1,15

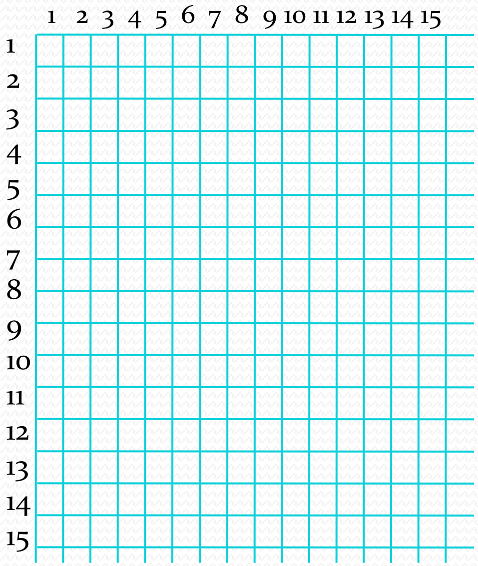
Row 5 1,15

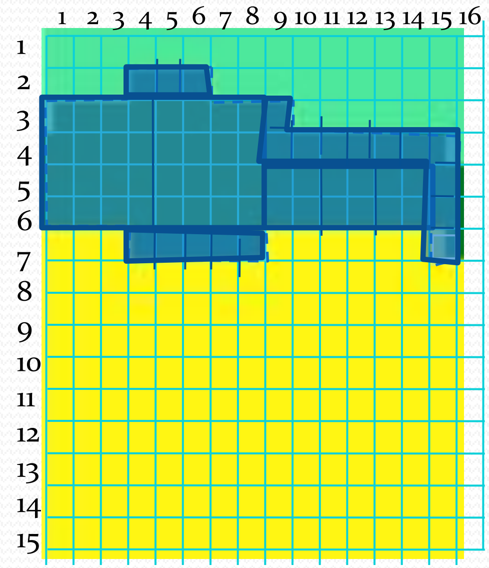
Row 6 1,15

Row 7 4,8 15,15

Go Back

3. Block encoding





lllr to RLE, but 2 dimensionally, using square blocks

Data structure consists of 3 nos.

1. The origin – X, Y(centre or bottom left)
2. Radius of each square – single unit squares, 4-square blocks, 16-square blocks, etc.

For Green Region 'B',

2 16-squares

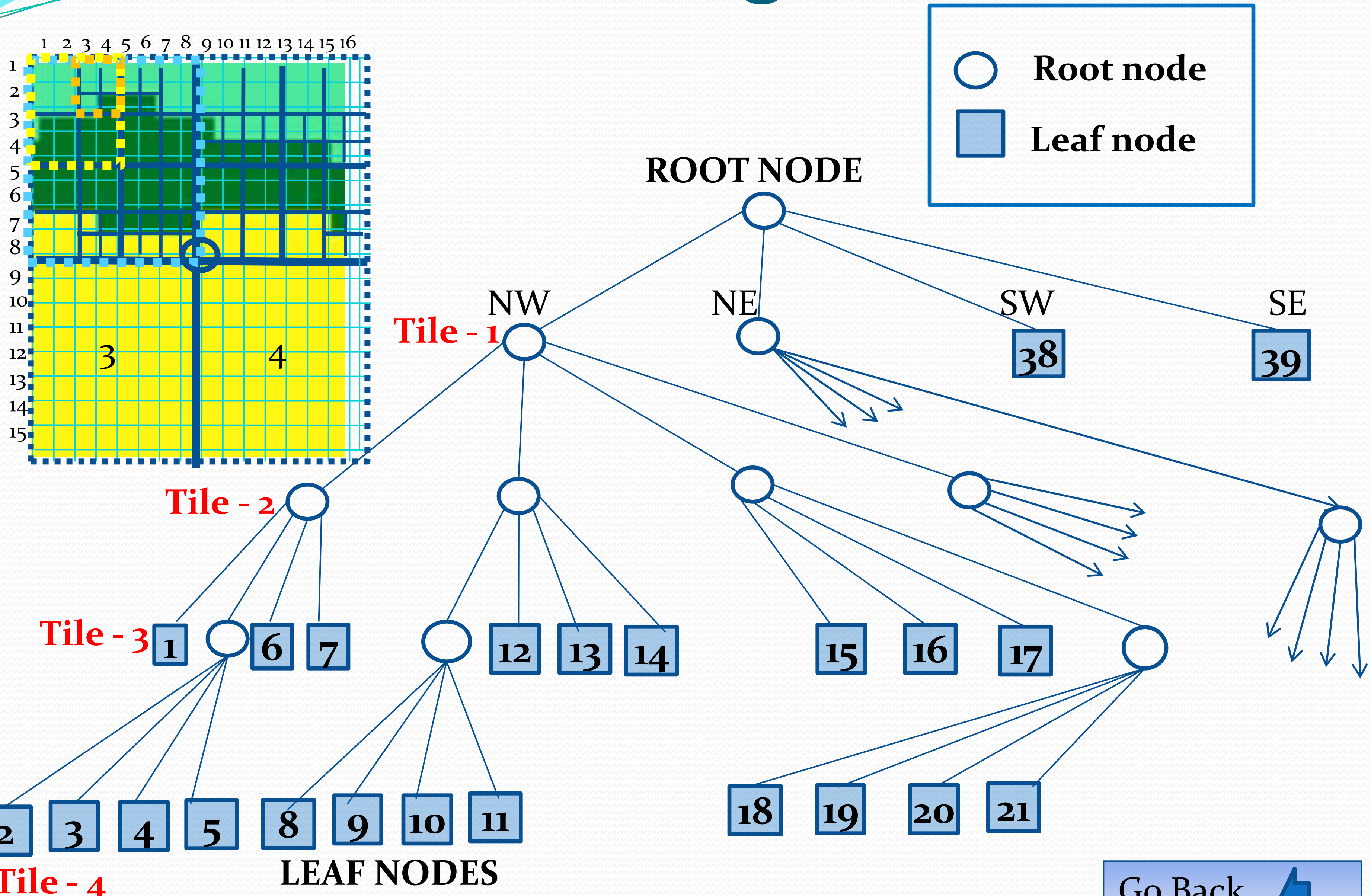
3 4-squares

16 unit squares

2 coordinates for each square (42)
3 for cell sizes,
Total=45 nos.

Go Back

Quadtree encoding…contd…



Go Back

2.5 Vector – Raster comparison

ADVANTAGES AND DISADVANTAGES OF RASTER DATABASE

ADVANTAGES	DISADVANTAGES
1. DATA STRUCTURE IS SIMPLE	1. IF THE PIXEL SIZE IS LARGER TO REDUCE THE VOLUME THEN DETAILS ARE LOST
2. OVERLAYING OF THEMATIC DATA WITH REMOTELY SENSED DATA IS EASY	2. NETWORK LINKAGE IS DIFFICULT
3. SPATIAL ANALYSIS IS EASY	3. PROJECTION & TRANSFORMATION IS TIME CONSUMING
4. SIMULATION IS EASY	4. OUTPUT LOOKS CLUMSY

2.5 Vector – Raster comparison ...CONTD...

ADVANTAGES AND DISADVANTAGES OF VECTOR DATA BASE

ADVANTAGES

1. COMPACT DATA STRUCTURE
2. TOPOLOGY WITH CLEAR NETWORK
3. ACCURATE GRAPHICS
4. RETRIVAL AND UPDATING IS POSSIBLE

DISADVANTAGES

1. COMPLEX DATA STRUCTURE
2. COMBINATION OF SEVERAL THEMES CREATE PROBLEMS
3. SIMULATION AND PROGNESTIGATION IS DIFFICULT
4. SPATIAL ANALYSIS IMPOSSIBLE.

Thank you

For your kind cooperation
Patient listening & Learning GIS

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