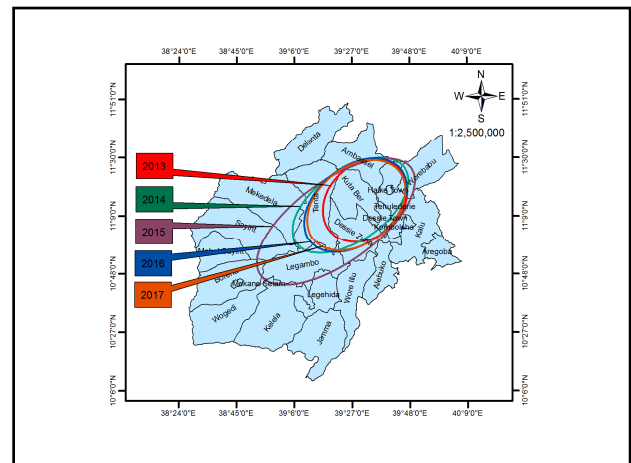
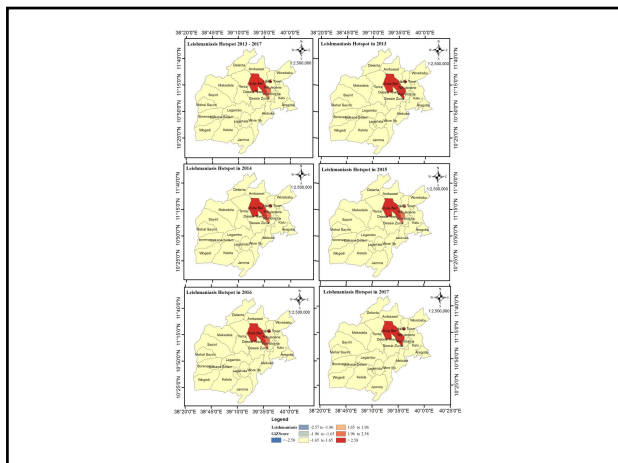
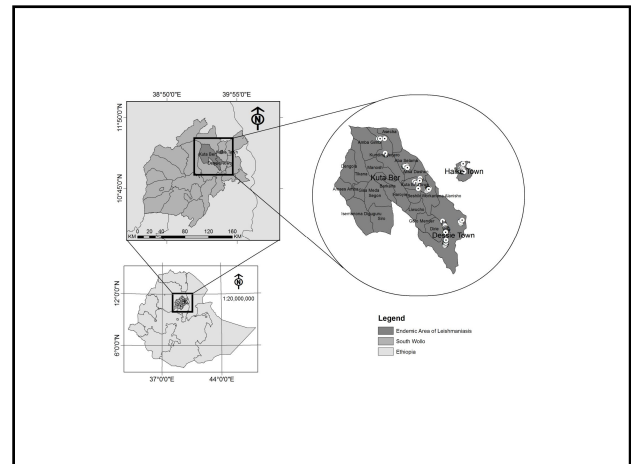
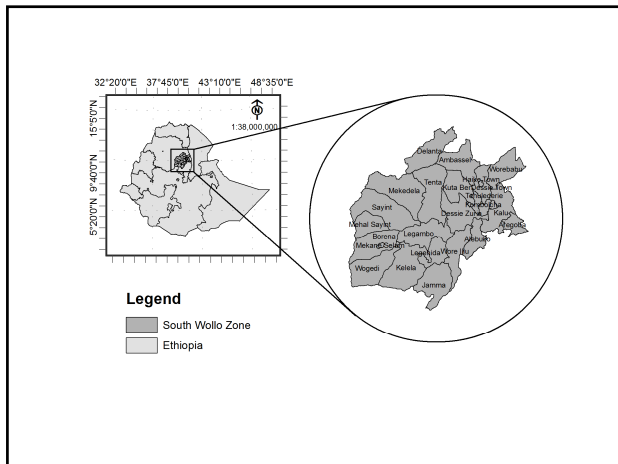
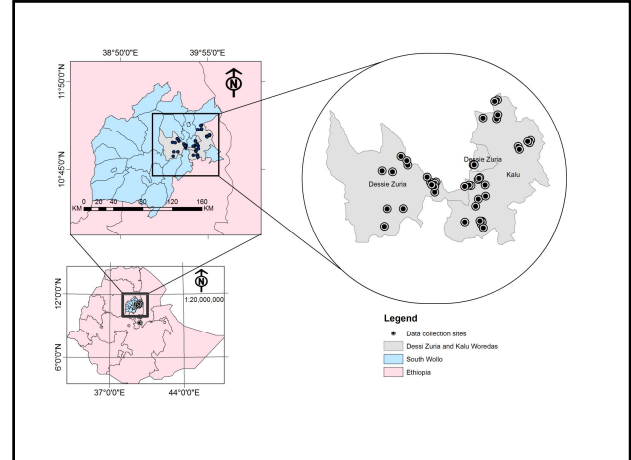




Geographic Information System

By
Dr. K. S. Goudar



INFORMATION

Information: Is nothing but data attached to the what, where and when. These data can be in the form of tables, attributes (features) or the characteristics (distinctiveness). These forms of data can be used to symbolize and provide further insight of a given experiment, objects and location for inference.



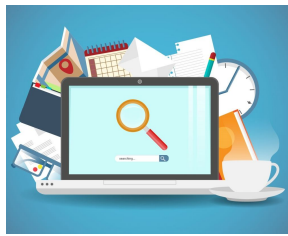
GEOGRAPHIC

Geographic: Is nothing but the data of related to where. Majority of collected data is associated with some location in a particular space.



SYSTEMS

Systems: Is nothing but many components working together to achieve a common goal. With reference to the geography, it is a seamless (without any fault) operation linking the information to the geography which requires hardware, networks, software, data and operational procedures to create map of your desire and need.



MAP

Map a diagrammatic representation of an area of land or sea showing physical features, cities, roads, etc.

Map is applicable for your house, city and forest area.



Definition of GIS

GIS is a computerized system designed for the storage, retrieval and analysis of geographically referenced data. GIS uses advanced analytical tools to explore at a scientific level the spatial relationships, patterns and processes of cultural, biological, demographic, economic, geographic and physical phenomena.



Definition of GIS

As per Environmental Systems Research Institute (ESRI), A geographic information system (GIS) lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends.



Definition of GIS

In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information (that is data identified according to their locations). (USGS)



Advantage of GIS

- Better decision made by experts of various disciplines
- Citizen engagement due to better system
- Help to identify communities that is under risk or lacking infrastructure
- Helps in identifying criminology matters



Advantage of GIS

- Better management of natural resources
- Better communication during emergency situation
- Finding different kinds of trends within the community
- Planning the demographic changes



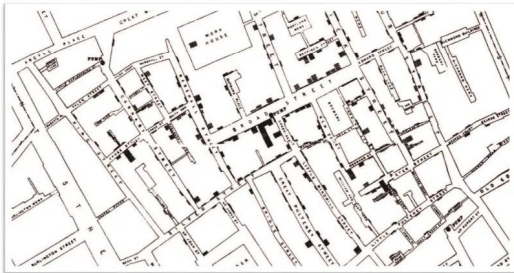
History of GIS

Modern GIS has seen series of development. GIS has evolved with the computer system. Here are the brief events that has happened for the development of the GIS system.



History of GIS

Year 1854 – The term GIS that used scientific method to create maps was used by John Snow in 1854. He used points on London residential map to plot outbreak of Cholera.

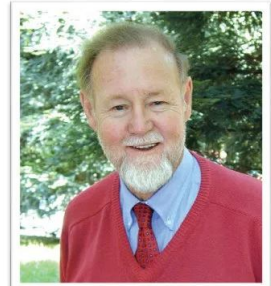


History of GIS

Year 1960 – Modern computerized GIS system began in year 1960.

Year 1962 – Dr. Roger Tomlinson created and developed Canadian Geographic Information System (CGIS) to store, analyze and manipulate data that was collected for the Canada Land Inventory (CLI).

This software had the capacity to overlay, measurement and digitizing (converting scan hardcopy map to digital data). It is never provided in commercial format but Dr. Tomlinson is the father of GIS.



History of GIS

Year 1980 – This period saw rise of commercial GIS software's like M&S Computing, Environmental Systems Research Institute (ESRI) and Computer Aided Resource Information System (CARIS). These all software were similar to CGIS with more functionality and user-friendliness. Among all the above the most popular today is ESRI products like ArcGIS, ArcView which hold almost 80 % of global market.

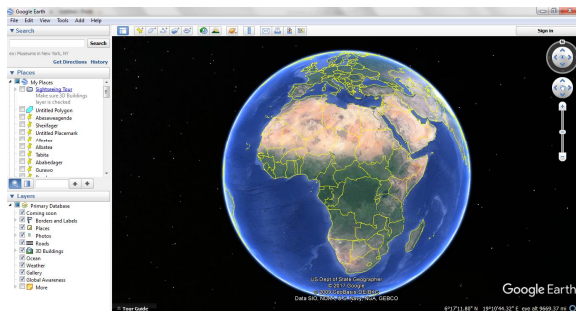


History of GIS



Google maps

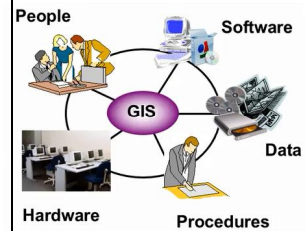
History of GIS



Components of GIS

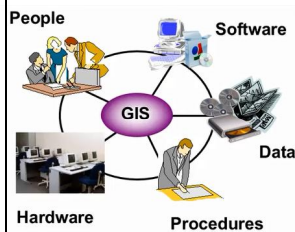
GIS constitutes of five key components:

- Hardware
- Software
- Data
- People
- Method



Components of GIS

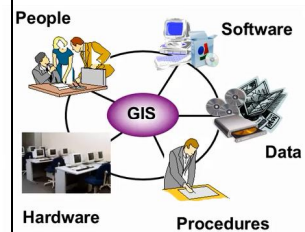
Hardware: Consists of the computer system on which the GIS software will run. The choice of hardware system range from 300MHz personal computers to super computers. The computer forms the backbone of the GIS hardware, which gets it's input through the Scanner or a digitizer board.



Components of GIS

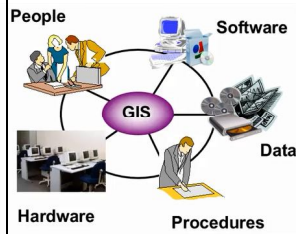
Scanner converts a picture into a digital image for further processing. The output of scanner can be stored in many formats e.g. TIFF and JPG etc.

A digitizer board is flat board used for vectorization of a given map objects. Printers and plotters are the most common output devices for a GIS hardware setup.



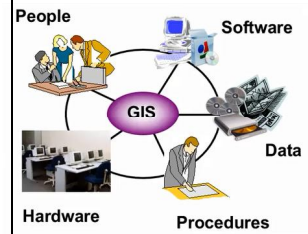
Components of GIS

Software: GIS software provides the functions and tools needed to store, analyze, and display geographic information. GIS software in use are MapInfo, ARC/Info, AutoCAD Map, etc. The software available can be said to be application specific



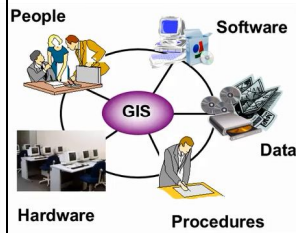
Components of GIS

When the **low cost GIS** work is to be carried out desktop **MapInfo** is the suitable option. It is easy to use and supports many GIS feature. If the user intends to carry out extensive analysis on GIS, ARC/Info is the preferred option. For the people using AutoCAD and willing to step into GIS, AutoCAD Map is a good option.



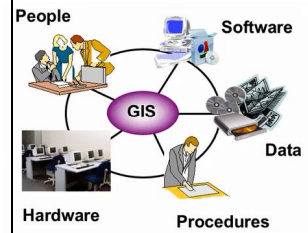
Components of GIS

Data: Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. The digital map forms the basic data input for GIS. Tabular data related to the map objects can also be attached to the digital data.



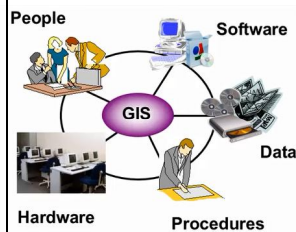
Components of GIS

A GIS will integrate spatial data with other data resources and can even use a Data Base Management System (DBMS), used by most organization to maintain their data, to manage spatial data.



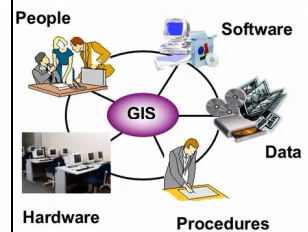
Components of GIS

People: GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work. The people who use GIS can be broadly classified into two classes.



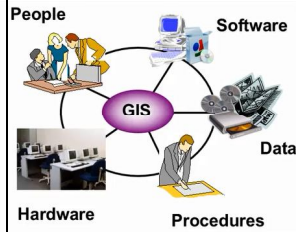
Components of GIS

The CAD/GIS operator, whose work is to vectorise the map objects. The use of this vectorised data to perform query, analysis or any other work is the responsibility of a GIS engineer/user.



Components of GIS

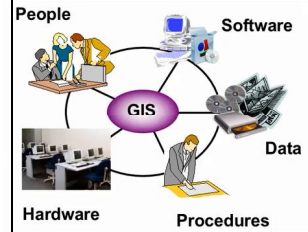
Data providers: data could be acquired through field observation, land survey, GPS, aerial photography, remote sensing technique, socio-economic surveys and so on. In Ethiopia, GIS data can be provided by Ethiopian mapping authority



Components of GIS

Method or Procedures:

There are various techniques used for map creation and further usage for any project. The map creation can either be automated raster to vector creator or it can be manually vectorised using the scanned images. The source of these digital maps can be either map prepared by any survey agency or satellite imagery.



Functions of GIS

- **Projection or co-ordinate system** is a key component of map making. A projection is a mathematical means of transferring information from a model of the earth, which represents a three-dimensional curved surface, to a two dimensional medium – paper or a computer screen



Functions of GIS

- **Geo-referencing** (also known as geo-rectification, geo-locating, geo-coding or registering) is the process of assigning spatial location identity to pieces of information.
- Or "Geo-referencing is the process of establishing a relation between the data displayed in your GIS software and its real world location."



Functions of GIS

- Geo-referencing enables us to know exactly where things are positioned on or in relation to the earth's surface.
- Geo-referencing is commonly achieved by using a coordinate system.



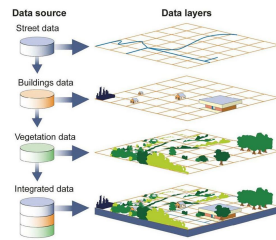
Features of GIS

- GIS is a computer-based tool that combines the visual appeal of conventional maps with database operations and statistical analysis.



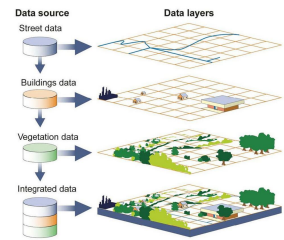
Features of GIS

- It is used for mapping and analyzing things that exist and happen on the surface of the Earth by classifying the information into "layers", making it easy for users to distinguish each element separately.



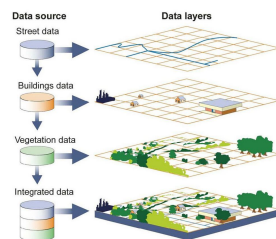
Features of GIS

- The speed and accuracy of a GIS provide an invaluable service to organizations, by explaining events, predicting outcomes and planning future strategies.



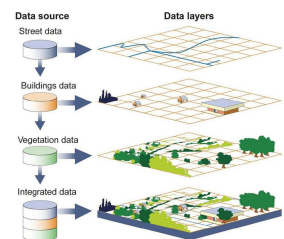
Features of GIS

- It must be realized that GIS is a peculiar technology with the essential features of spatial references and data analysis. Hence, the true power of GIS lies in its ability to integrate information and to help in making decisions.



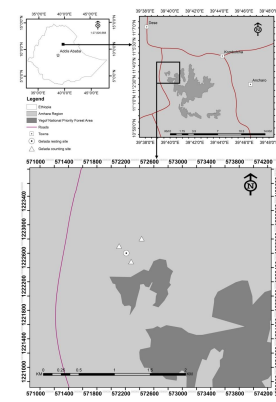
Features of GIS

- A GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.
- GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.



Questions GIS can Answer

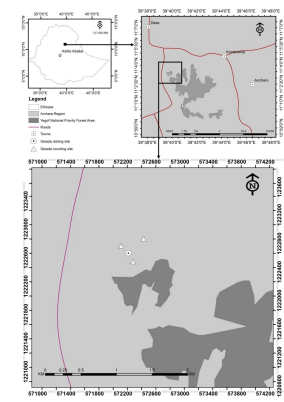
- GIS can be used to address concerns relating to location, condition, trends, patterns, modeling, spatial questions, as well as non-spatial questions. Basically, we can identify five broad types of questions that a sophisticated GIS can answer



Questions GIS can Answer

- Location: What is at.....?**

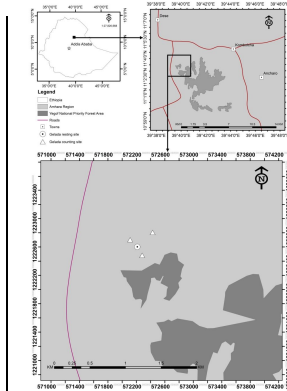
This question seeks to find out what exists at a particular location. A location can be described in many ways, using, for example, a place name, post code, or geographic reference such as longitude/latitude or x/y.



Questions GIS can Answer

- **Condition: Where is it.....?**

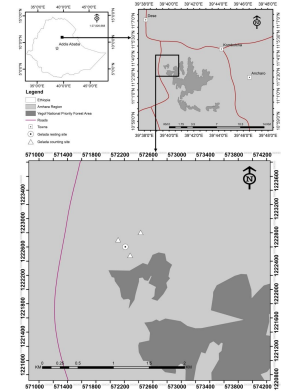
In this question, one may wish to find location(s) where certain conditions are satisfied (e.g. an forested section of at least 2000 square meters in size and with soils suitable for supporting buildings)



Questions GIS can Answer

- **Trends: What has changed since.....?**

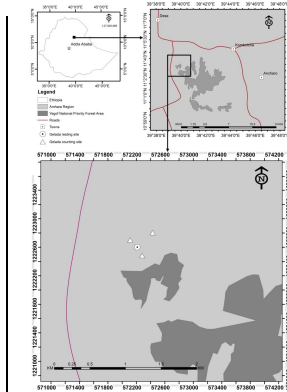
This question involves seeking to know what has changed over a given period of time, as well as the magnitude and spatial pattern of such a change (e.g. change in land use or elevation over time).



Questions GIS can Answer

- **Patterns: What spatial patterns exist.....?**

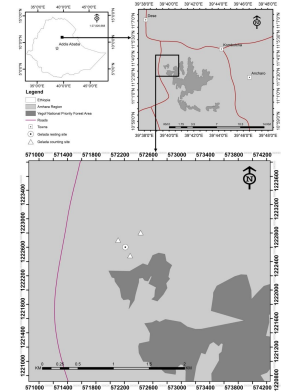
One might ask this question to determine whether, for instance, landslides are mostly occurring near streams.



Questions GIS can Answer

- **Modeling: What if.....?**

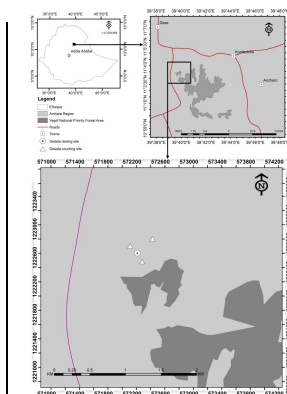
"What if..." questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local ground water supply. Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operations.



Questions GIS can Answer

- **Non-spatial Questions**

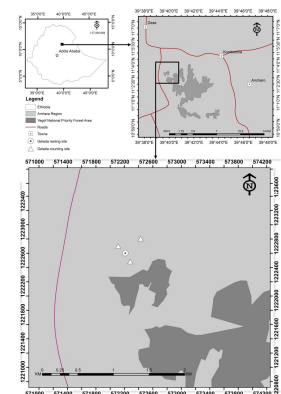
"What's the average number of people working as Estate Surveyors and Agents in each location?" is a non-spatial question - the answer to which does not require the stored value of latitude and longitude; nor does it describe where the places are in relation with each other.



Questions GIS can Answer

- **Spatial Questions**

"How many people work with estate firms in the major urban centers of Lagos metropolis?" OR "Which centre lie within 10 Km of each other?" OR "What is the shortest route passing through all these centers". These are spatial questions that can only be answered using latitude and longitude data and other information such as the radius of earth. Geographic Information Systems can answer such questions.



Coordinate system

A coordinate system is a reference system used to represent the locations of geographic features, and observations such as GPS locations within a common geographic framework.

Coordinate systems provide a framework for defining real-world locations.



Non-coordinate system

Any place or thing that do not gives the direction is called as non-coordinate system.

Examples are

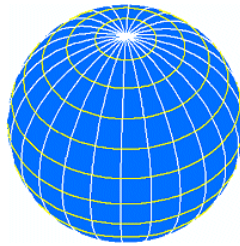
- Postal address
- Postal code
- Telephone codes
- House numbers
- Street address



Geographic coordinate system

A geographic coordinate system is a reference system for identifying locations and measuring features on the curved surface of the earth. It consists of a network of intersecting lines called a graticule.

These coordinates system can gives the direction

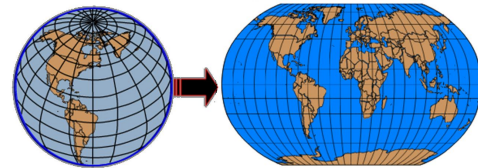


Types of coordinate system

There are two common types of coordinate systems used in GIS:

Angular or spherical coordinate system such as latitude–longitude. These are often referred to as geographic coordinate systems.

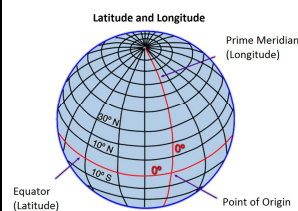
Projected or rectangular coordinate system based on a map projection such as universal transverse Mercator all of which provide various mechanisms to project maps of the earth's spherical surface onto a two dimensional rectangular coordinate system



Angular or Spherical Coordinate System

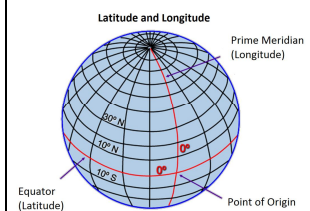
The graticule is made up of vertical lines, called lines of longitude, and horizontal lines, called lines of latitude. Because the earth is spherical, these lines form circles.

In a angular or spherical coordinate system, measurements are expressed in degrees, minutes, and seconds. A degree is 1/360th of a circle. Each degree can be divided into 60 minutes, and each minute can be divided into 60 seconds.



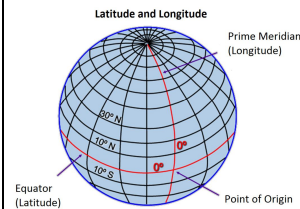
Angular or Spherical Coordinate System

Lines of longitude are called meridians. Measures of longitude begin at the prime meridian (which defines the zero value for longitude) and range from 0° to 180° going east and from 0° to -180° going west. Lines of latitude are called parallels. Measures of latitude begin at the equator and range from 0° to 90° from the equator to the north pole and from 0° to -90° from the equator to the south pole



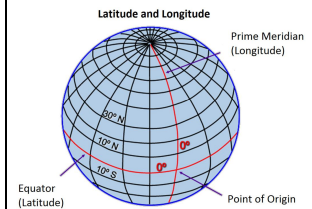
Angular or Spherical Coordinate System

The prime meridian (vertical red line) is the starting point for longitude and has a value of 0. The equator (horizontal red line) is the starting point for latitude and has a value of 0. It runs midway between the north and south poles, dividing the earth into northern and southern hemispheres.



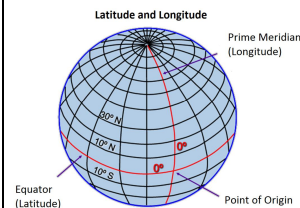
Angular or Spherical Coordinate System

- **Choosing which meridian** will be the prime meridian
- The Spanish have used a meridian passing through Madrid,
- The French a meridian passing through Paris, and during the
- American Revolution considered London or Philadelphia as the starting point.
- Later, the United states adopted Washington, D.C. as the prime meridian.
- Finally, in 1884, an International Meridian Conference was held in Washington, D.C., and the Observatory of Greenwich in Great Britain was adopted as the "official" prime meridian.



Angular or Spherical Coordinate System

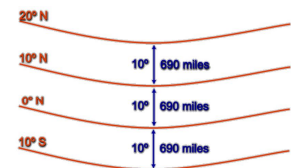
- Angular coordinate system perfectly suited to the ellipsoidal shape of the earth
- Position coordinates are based on an angular distance from known reference points
- The reference point is where the prime meridian and equator intersect
- This coordinate system is used for nautical (Ship navigation) and aeronautical navigation



Characteristics of Latitude

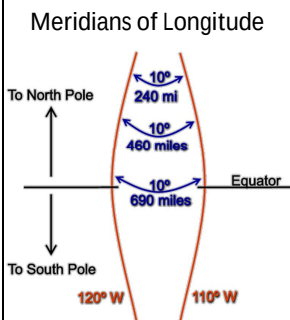
- Latitude is composed of parallels which are equally spaced circles around the earth paralleling to equator
- Parallels are designated by their angle north or south of the equator
- The equator is 0° latitude and north and south poles are at 90° angles from the equator
- The linear distance between parallel (Latitude) lines never changes regardless of their position on the earth

Parallels of Latitude



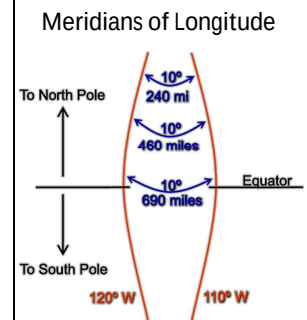
Characteristics of Longitude

- Longitude is comprised of meridians that form one-half or the circle or plane
- Meridians are designed by their angles west or east of the prime meridian
- The prime meridian is designated 0° and extends from the north pole to the south pole through greenwich, England.

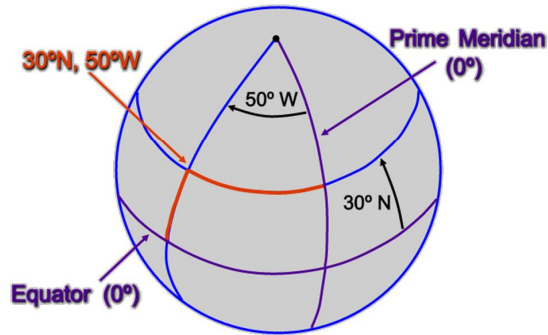


Characteristics of Longitude

- Meridians are angled and do not parallel each other
- The linear distance between one degree of longitude at the equator is approximately 690 statute miles
- The linear distance between one degree of longitude at the arctic circle is only about 26 statute miles



Determining Latitude and Longitude

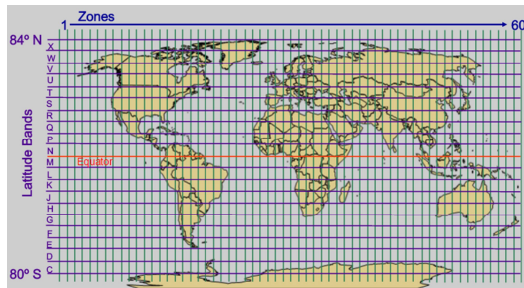


Determining Latitude and Longitude



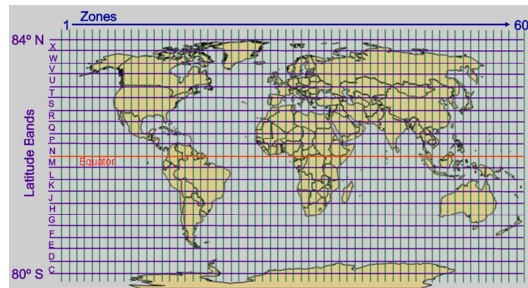
Universal Transverse Mercator

- Is a rectangular (Planar) coordinate system based on the latitude and longitude (Geographic) coordinate system.



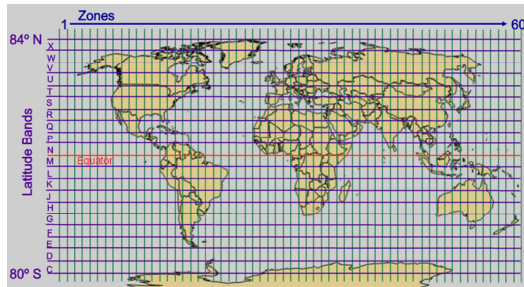
Universal Transverse Mercator

- The earth is divided onto 60 UTM zones, starting at the international date line, (each 6° of longitude in width) and 20 latitude bands between 80°S and 84°N latitude (Each latitude band is 8° high)



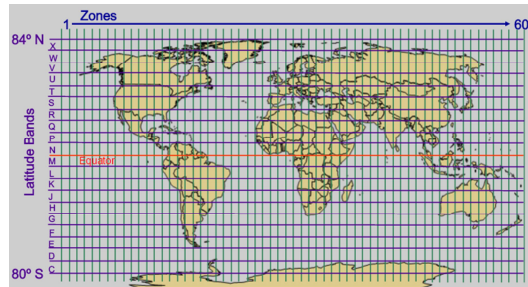
Universal Transverse Mercator

- In latitude band, letter "C" starts at 80°S increasing up until "X", omitting the letters "I" and "O" (because of their similarity to the numerals one and zero). The last latitude band, "X", is extended an extra 4 degrees, so it ends at 84°N latitude, thus covering the northernmost land on Earth.



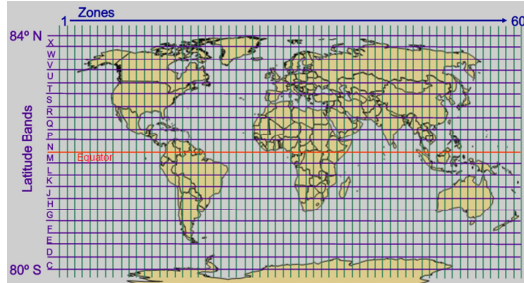
Universal Transverse Mercator

- Latitude bands "A" and "B" do exist, as do bands "Y" and "Z". They cover the western and eastern sides of the Antarctic and Arctic regions respectively. Note: The letter "N" is the first letter in "northern hemisphere", so any letter coming before "N" is in the southern hemisphere, and letter "N" and after is in the northern hemisphere.



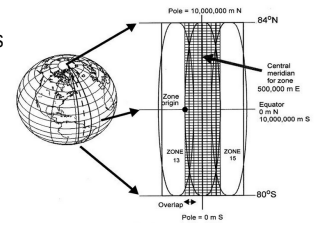
Universal Transverse Mercator

- Sixty zones allows the earth to be projected onto maps with minimal distortion
- Coordinates are expressed in meters
- The combination of a zone and a latitude band defines a grid zone. The zone is always written first, followed by the latitude band.



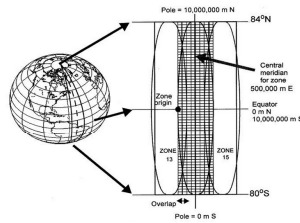
Universal Transverse Mercator

- The easting coordinate of a point is measured from the false origin 500000 meters as it is assigned arbitrarily at central meridian. Within a zone, easting values increase towards east.
- That is 8 meters east of central meridian has an easting of $500000 + 8 = 500008\text{mE}$. The easting of a point 350m towards west of central meridian would be $500000 - 350 = 499650\text{mE}$.



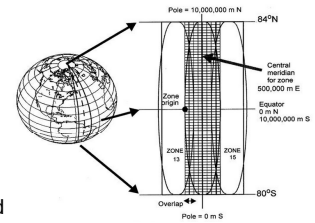
Universal Transverse Mercator

- The east-west distance between two points is obtained by the difference of their easting values. The distance between the above points is $500008 - 499650 = 358\text{m}$.
- Longitude lines are furthest apart at the equator, where latitude is zero.



Universal Transverse Mercator

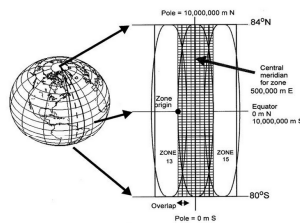
- Therefore the maximum width of a UTM zone occurs on the equator. **In general the easting values can not be larger than 834000m and smaller than 166000m.** As a result, an easting coordinate is always a six digit number. Sometimes in GPS systems and GIS software, the easting values are preceded with a 0 in order to represent them as 7 digit numbers.



11T 0541450
4789650

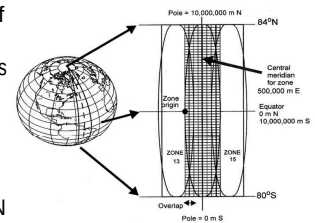
Universal Transverse Mercator

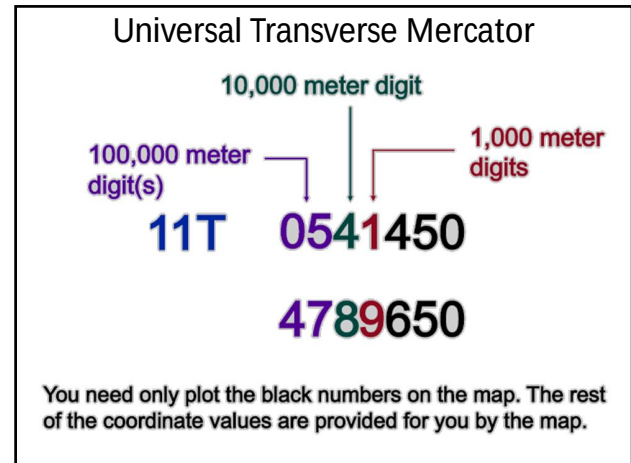
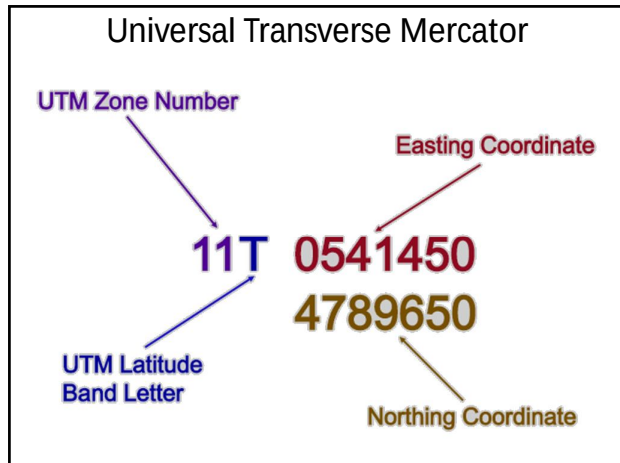
- A northing value in northern hemisphere specifies the number of meters a point is located north of the equator. The northing of a point south of the equator is equal to $10,000,000\text{m}$ minus its distance from the equator. In both northern and southern hemispheres, northing values increase from south to north.



Universal Transverse Mercator

- A point located 34m south of the equator has a northing of 9999966mN, while a point 34m north of the equator has a northing of 0000034mN.
- The north-south distance between two points north of equator with northings of 4867834mN and 4812382mN is $4867834 - 4812382 = 55452\text{m}$.





Universal Polar Stereographic coordinate system

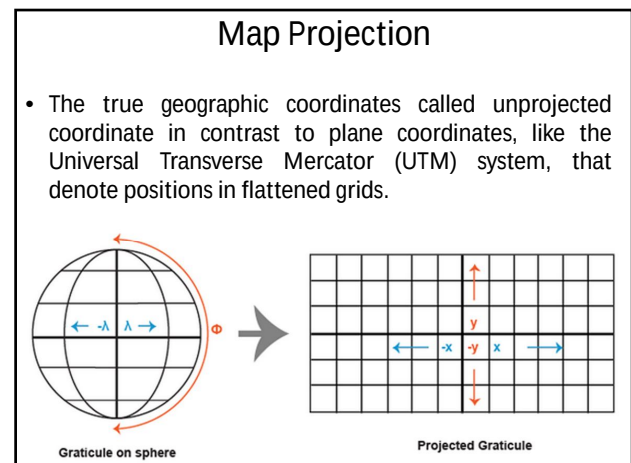
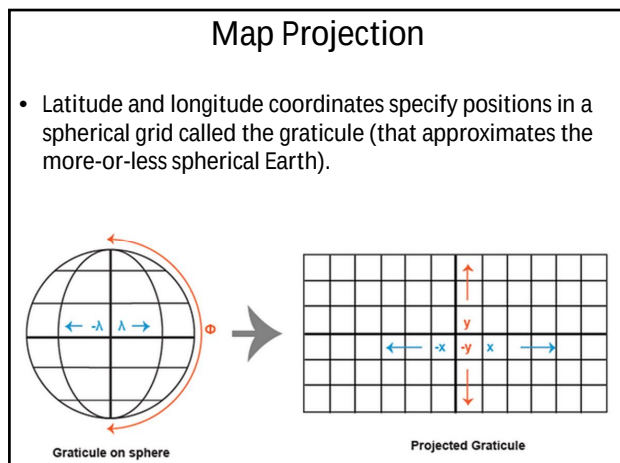
- According to this, the Northern Hemisphere's polar region extends from 84 degrees north latitude to the North Pole, which is located at 0 degrees north latitude. This region is split in half, with the Western Hemisphere creating Zone Y and the Eastern Hemisphere creating Zone Z.

The diagram shows a globe with the Northern Hemisphere shaded. Labels indicate the North Pole, 84° North Latitude, 0° Latitude (Equator), and South Pole. Red arrows point to the Northern Hemisphere's polar region, which is split into Zone Y (Western Hemisphere) and Zone Z (Eastern Hemisphere). The diagram also shows the Universal Transverse Mercator (UTM) coordinate system coverage of the Northern Polar Zone and the Universal Polar Stereographic (UPS) coordinate system coverage of the South Polar Zone.

Universal Polar Stereographic coordinate system

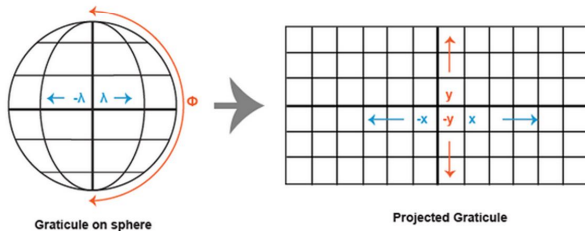
- The Southern Hemisphere's polar region extends from 80° south latitude to the South Pole, which is located at 0° south latitude. This region is split in half, with the Western Hemisphere creating Zone A and the Eastern Hemisphere creating Zone B.

The diagram shows a globe with the Southern Hemisphere shaded. Labels indicate the North Pole, 84° North Latitude, 0° Latitude (Equator), and South Pole. Red arrows point to the Southern Hemisphere's polar region, which is split into Zone A (Western Hemisphere) and Zone B (Eastern Hemisphere). The diagram also shows the Universal Transverse Mercator (UTM) coordinate system coverage of the Northern Polar Zone and the Universal Polar Stereographic (UPS) coordinate system coverage of the South Polar Zone.



Map Projection

- These georeferenced plane coordinates are referred to as projected. The mathematical equations used to project latitude and longitude coordinates to plane coordinates are called map projections.



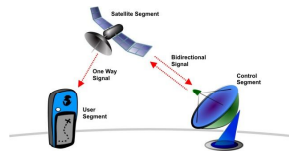
Global Positioning System

- GPS or Global Positioning System is a network of orbiting satellites that send precise details of their position in space back to earth.



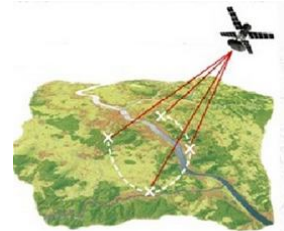
Global Positioning System

- GPS have three segments. They are space, control and user segments.
- A global network tracking system with a master control station is based at the Schriever Air Force Base in Colorado United States of America. This control unit tracks the position of the GPS satellite



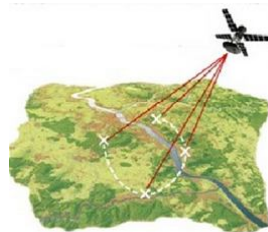
Global Positioning System

- GPS satellites circle the Earth twice a day in a precise orbit. Each satellite transmits a unique signal and orbital parameters that allow GPS devices to decode and compute the precise location of the satellite.



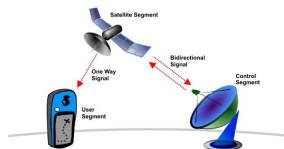
Global Positioning System

- Essentially, the GPS receiver are made to communicate with GPS satellites (Which have a much better view of the earth) to find out exactly where they are on the global scale of things



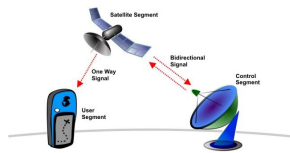
Global Positioning System

- The signals are obtained by user segment from space segment are used to calculate the exact position, speed and time at the particular location.
- GPS receivers use this information and trilateration to calculate a user's exact location.



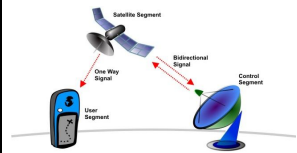
Global Positioning System

- Space segment emits two types of signals. They are
- L1 (1575.42 MHz) for civil use
- L2 (1227.60 MHz) for military use
- Minimum of 9 satellites signals are required for recording the position when we use German GPS user segment.



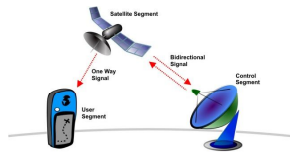
Global Positioning System

- The GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is
- $\text{Velocity} \times \text{Time} = \text{Distance}$
- Radio waves travel at the speed of light, roughly 186,000 miles per second (mps)



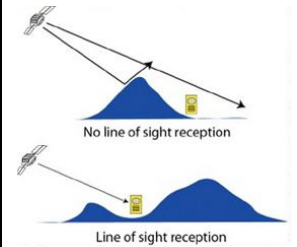
Global Positioning System

- If it takes 0.06 seconds to receive a signal transmitted by a satellite floating directly overhead, use this formula to find your distance from the satellite
- $186,000 \times 0.06 = 11,160$ miles



Global Positioning System

- Line of sight is the ability to draw a straight line between two objects without any other objects getting in the way. GPS transmissions are line of sight transmissions. It means obstructions such as trees, buildings, any natural formations may prevent clear line of sight.



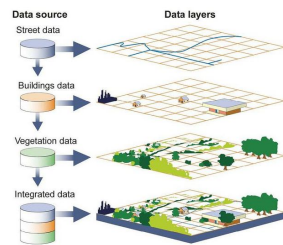
Applications

- Self-navigation for automated machines.
- Aircraft tracking
- Vehicle tracking systems
- Military units: for tracking a target
- Motion measurements of earthquakes and volcanoes

Database | Structure

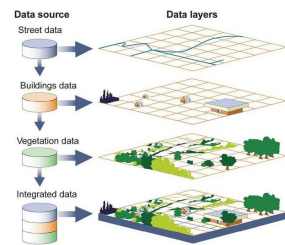
Database Structure

- As we all know, we need some information for GIS analysis. Any information needs to be fed in the form of data and they are organized in form of databases (collection of information about things and their relationship to one another).



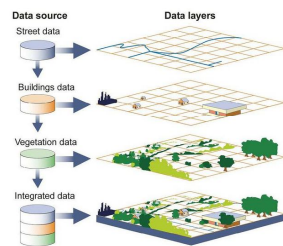
Database Structure

- A database, in turn, is typically organized according to general data structures (a theory of how a database is supposed to look like).
- So, understanding the nature of databases and database management systems is, therefore, crucial to understanding the creation and handling of data in a GIS environment.



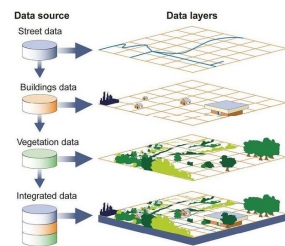
Database Structure

- Spatial Database:** Spatial databases are the store information related to objects of particular space. A spatial database is a database that is optimized to store and query data that is related to objects in space, including points, lines and polygons.



Database Structure

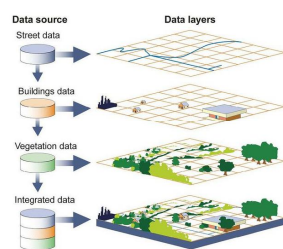
- The spatial database is also called as geometry or features. The content of a spatial database depends on its intended purpose, which in turn dependent on the organization using it.



Database Structure

Characteristics of spatial database

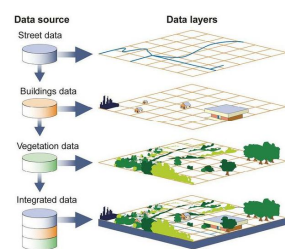
- Data should contain detailed information of the same time period for all its measured variables.
- Data should be accurate in terms of the geographical location or positions of features.
- Data should be exactly compatible with other information that may be overlain with it.
- Data should reveal the nature of phenomena without error
- Data can be easily updated on a regular schedule
- Data has to be accessible to whoever needs it and is authorized to use it



Database Structure

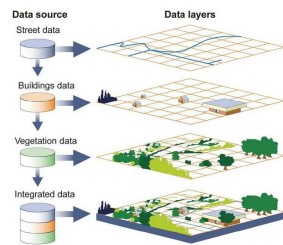
Functions of spatial database

- To perform its functions, spatial databases make use of spatial query types
- Spatial Measurements:** Find the distance between points, polygon area, etc.
- Spatial Functions:** Modify existing features to create new ones, for example by providing a buffer around them, intersecting features, etc.



Database Structure

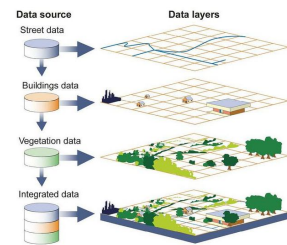
- Spatial Predicates: Allows true/false queries such as “is there a residence located within a mile of the area we are planning to build the landfill?”
- Constructor Functions: Creates new features.
- Observer Functions: specific information about a feature such as the location of the center of a circle.



Database Structure

Spatial Data Model :

- Real world features are represented in GIS using a spatial data model. GIS data represents real objects (such as roads, land use, elevation, trees, waterways, etc.). Real objects can be divided into two abstractions: discrete objects (e.g., a house, a roundabout, or a borehole) and continuous fields (such as rainfall amount, vegetation, or elevations).

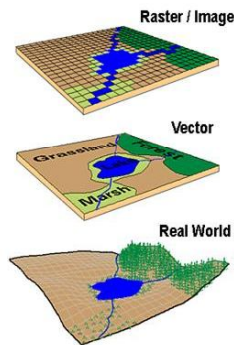


Database Structure

- Traditionally, there are two broad methods or models used to store spatial data in a GIS: *vector structures* and *raster structures* (Images).

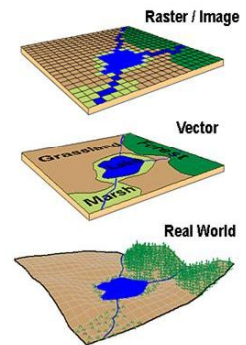
Vector Structure:

- In a GIS, geographical features are often expressed as vectors, by considering those features as geometrical shapes.



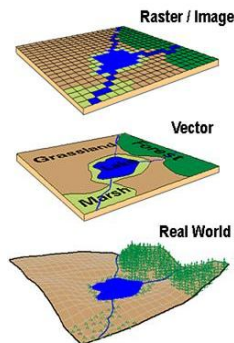
Database Structure

- Vector digital data have been captured as points (Zero-dimensional points are used for geographical features that can best be expressed by a single point reference), lines (a series of point coordinates line one-dimensional lines or polylines are used for linear features such as rivers, roads, railroads, trails, and topographic lines and line features can measure distance.),



Database Structure

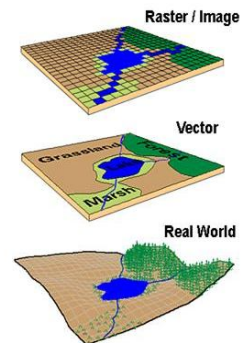
- Areas (shapes bounded by lines or two-dimensional polygons are used for geographical features that cover a particular area of the earth's surface). Polygon features can measure perimeter and area.



Database Structure

Raster Structure:

- A raster data type is, in essence, any type of digital image represented by reducible and enlargeable grids (also known as cells or pixels). Following figure illustrates the representation of point, linear and areal geographical features in a raster format.



Database Structure

- **Non-Spatial Database:** Non-spatial data (also called *attribute* or *characteristic* data) is that information which is independent of all geometric considerations. For example, a tree is a geographic feature, but the type, height, and age of the tree are non-spatial data because they are independent of the tree's location.
- In a GIS environment, attribute data are commonly stored in a tabular form. Presently, the Relational Database Management System (DBMS) is the most widely used commercial data management tool in GIS implementation and application.

Database Structure

Reason for use of RDBMS in GIS

- *Simplicity* in organisation and data modeling
- *Flexibility* - data can be manipulated in an ad hoc manner by joining tables
- *Efficiency* of storage – proper design of data tables can reduce redundancy
- *Queries* do not need to take into account the internal organization of data.

