Unit - III

Geographic Information System

Syllabus: Introduction, key components, application areas of GIS, map projections. Data entry and preparation: spacial data input, raster data models, vector data models.

Introduction :-

The geographic(al) information System (GIS) consists of two distinct ~~dess~~ disciplines, namely Geography and information system.

Here the word 'Geographic' deals with spacial objects or features which can be reffered or related to specific location on the earth surface. The object may be physical / natural & may be cultural / man made.

Likewise the word 'Information' deals with the large volume of data about particular object on the earth surface. The data includes a set of qualitative and quantitative aspects which the real world objects acquire.

The term 'System' is used to represent systems approach where the complex environment is broken down into their components parts for easy understanding and handeling, but is considered to form an integrated whole for managing and decision making.

Now a days this is possible in a very short span of time with the development of sophisticated computer hardware and software.

Therefore, GIS is a computer based information system which attaches a variety of qualities and characteristics to geographical location and helps in planing and decession making.

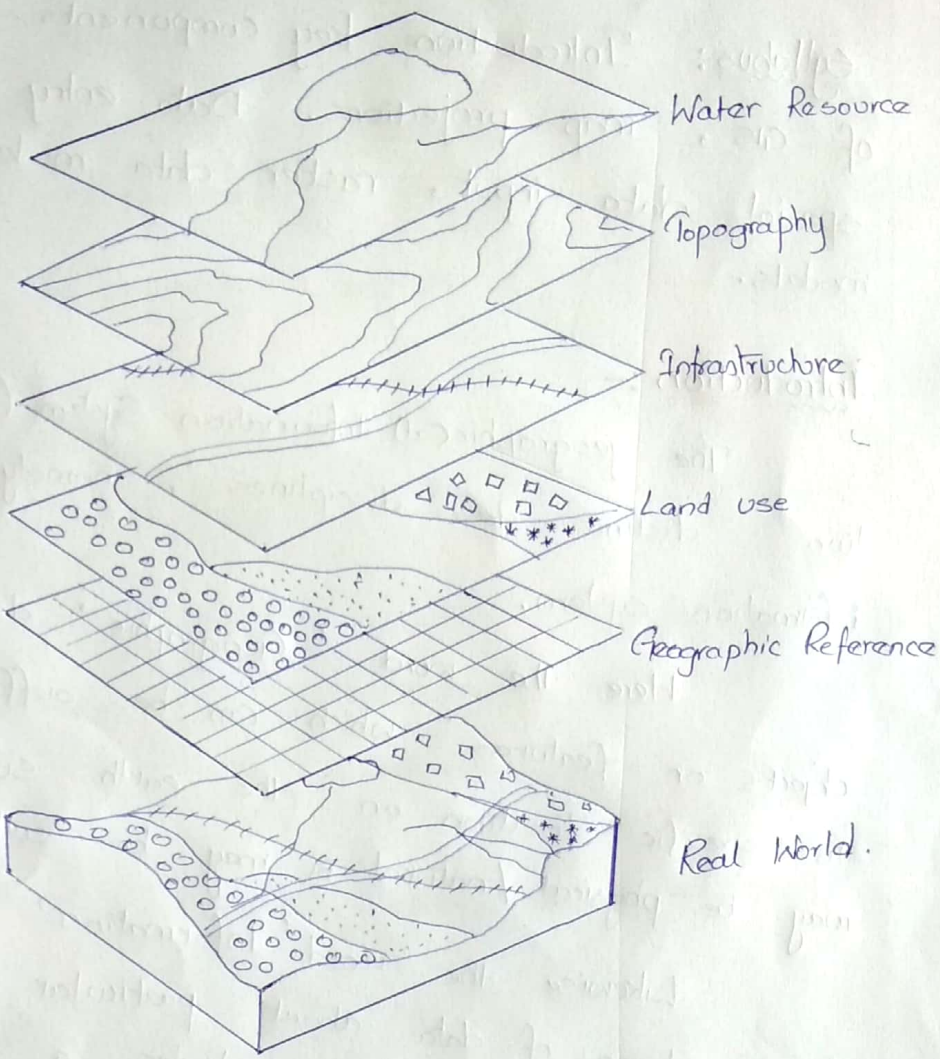


Fig. 1. Information stored on theme layers with each layer linked to common spacial feature referenced to a specific location.

'Every object present on the earth can be geo-referenced', is the fundamental key of associating any database to GIS. Here, the term 'database' is a collection of information about things and their relationship with each other, and 'georeferencing' refers to the location of a feature or coverage in space defined by the geographic coordinate referencing system.

A Geographic information System combine with hardware, Software components for capturing, managing analyzing and displaying all forms of geographically referenced information.

→ Two important aspects of GIS are

1) Defining absolute location of earth with reference to global coordinate Systems.

Ex: latitude / Longitude.

2). Ability to represent various georeferenced coordinate System and non-georeferenced coordinate System

Ex: Georeferenced Coordinate System = Northing, Easting elevation etc.,

Non-Georeferenced System = Image corrections.

Definitions of GIS:

GIS is an information system designed to work with data referenced by spacial geographical coordinates. In other words, GIS is both a data base system with specific capabilities for spatially referenced data aswell as a set of operations for working with the data.

The GIS has been defined in many ways by many people.

→ * Geographic Information System is a systematic integration of computer hardware, software, and spatial data, for capturing, storing, displaying, updating manipulating, and analysing, in order to solve complex management problems.

Another alternative definition :

* Geographic Information System (GIS) is defined as an Information System that is used to input, store, retrieve, manipulate, analyse, and output geographically referenced data or geospatial data, in order to support decission making for planning and management of landuse, natural resources, environment, transportation, urban facilities, and other administrative records.

* C. Dana Tomlin's definition (Tomlin 1990),

A geographic Information System is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth.

* Tomlin 1990:

In common parlance, a geographic Information System or GIS is a configuration of Computer hardware and software specifically designed for the acquisition, maintainance, and use of cartographic data.

* Jeffrey Star and John Estes. 1990:

GIS is an information system that designed to work with data referenced by spatial ~~and~~ or geographic coordinates. In other words, a GIS is both a data base system with specific ~~coordi~~ capabilities for spacially-reference data as well a set of operations for working with data.

* According to Environmental Systems Research Institute (ESRI 1990).

A GIS is an organized collection of Computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information.

GIS Terminology:-

Some of the terms used in GIS are briefly explained below:

* **Data Planes**, are discrete sets of data. For example, an imagery, a thematic map, a topographic sheet, a page of survey data each ~~constri~~ constitutes a data plane.

* **Themes**, are maps containing different types of Information.

Ex: A toposheet contains contours, roads, railways boundaries of forests etc., Each of these contributes a theme.

* **Registration**, the themes in a given data plane are spacially related to each other. We say that the data is registered. Data in different planes may not be so ~~readily~~ ~~readily~~ readily related. Scales may vary, there may be traditional and rotational errors. This process of correction and development of an invarient spacial relationship between different data planes is called Registration.

* **Database**;

This is the spacially registered set of data constitutes a spacial database. In addition, each spacial object has an associated attribute. This could be a name, a number, a range of values etc., For example, a ~~count~~ contour has a number, a road has a name. Such attributes also form a part of the data base. Further, there may be other data sets associated demographic data.

* Spacial objects :

All spacial objects can be represented by points, lines and polygons. A city is a point, a road is a line and a forest area is a polygon. The manner in which these fundamental units are represented are defined by the spacial data model.

For example, we can have a chain as a set of line segments, a closed chain forms a polygon, an open chain is a line, a line segment of zero length is a point.

* Scale :

This is the relationship between distances on the ground and difances on a map. Scale always apply to linear measures, never to area & elevations.

Resolutions :

This is the smallest element which can be distinguished in a data set. In case of imagery, this usually is the pixel size & a multiple to the pixel size.

However, in a map this term can be confusing.

This may be taken to mean the smallest mappable feature. However some features are mapped by symbols even if their size is small,

Elements ~~or Components~~ of GIS:

The GIS has been divided into four elements. They are

1. Hardware
2. Software
3. Data
4. Liveware.

S.No.	Elements of GIS	Details
1.	Hardware	Type of Computer Platforms Modest Personnel Computers. High performance Workstations. Mini Computers. ~~Main~~ Mainframe Computers. Input Devices: Scanners Digitisers Tape drivers CD Keyboard Graphic Monitor. Output Devices: Plotters Printers.
2.	Software	Input Modules Editing MRP manipulation/Analysis Modules Modeling Capability.
3.	Data	Attribute Data Spatial Data Remote Sensing Data Global Data-base.

4.	Live Ware	* People responsible for digitising, implementing using GIS * Trained.

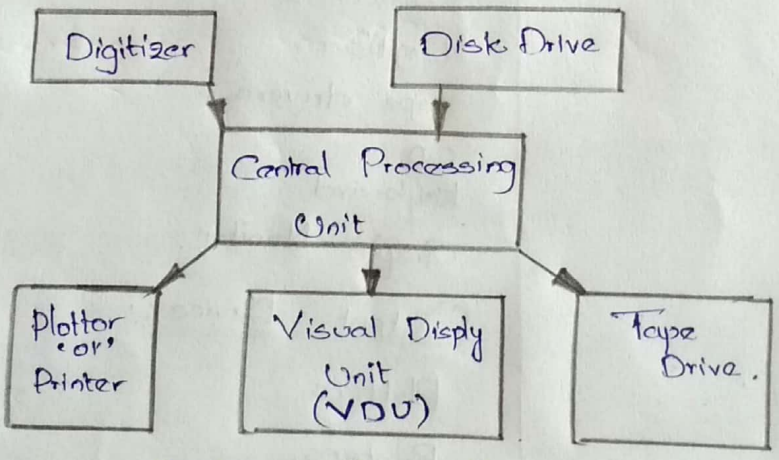
Components of GIS:-

Geographic Information System consists of three important components. They are:

1. Hardware Components of a Computer.
2. Software modules of Computer.
3. Organizational Setup.

GIS can function properly if these three Compon-ents are maintained ~~properly~~ in balance.

1. Hardware Components of GIS:



Hardware Components.

CPU- Central Processing Unit:-

Central Processing Unit is linked to disk drive, which provide space for storing data & programs.

Digitizer:-

It is a device used to convert data from ~~map~~ analog to digital form and stores into a Computer.

Printer or Plottor:

Plotter is a hardware device in which we provides the data to a plotter, then it processed and presents results on a paper.

Tape Drive:

It is used to store data (or) programs on magnetic tape for communicating with other systems.

VDU - Visual Display Unit:

It is used to control the computer and the other periphirals. It is otherwise known as terminal (or) workstation.

2. Software Components of GIS:

It consists of five basic Modules:

1. Data Input & Verification
2. Data storage and Data base management.
3. Data output & presentation.
4. Data Transformation.
5. Interaction with the user.

1. Data Input and Verification System:-

This is also called as data capture subsystem.

It deals with getting ~~intupt~~ inputs given by the use or input from global positioning system (GPS) or from scanning photographs from remote sensing & processing digital data received from satellites. The data is stored in computer in the digital form.

2. Data Base Management:

This is deals with the efficient storage, retrival and manipulation of data.

3. Data Transformation:

It deals with the transformation of data from one form to another.

It mainly works on two operations

1. Maintenance
2. Utalization.

4. User Interpretation:

GIS system should be proceed with eco-friendly language that the user can understand easily and it can proceed with command where it is used.

3. Organizational Context :-

Organizational context is nothing but the way the information flows & the way in which the analysis is done. The organizational context involves three sub components.

a) Data: It is nothing but information being used for the analysis.

b). People:

The people involved in the analysis and the creation of information system.

c). Methods:

The step procedures which are used for the analysis and in the making of the information system.

Application Areas of GIS

To understand the advantages and importance of GIS in a betterway, it is very important to know the applications and uses of GIS. A GIS enables us to better understand and evaluate our data by creating graphic displays using information stored in our database. The GIS can be applied in various distinct application areas.

Major areas of GIS applications:

1). Facilities Management:

* Locating Underground pipes and Cables.
* Planning facility maintenance
* Telecomunication network services.

2). Environmental and Natural Resources Management:-

* Suitable Study for agricultural cropping.
* Management of forests, agricultural lands, water resources, wetlands, etc.,
* Environmental Impact analysis.
* Disaster management and mitigation.
* Waste facility site location.

3). Street Network:

* Car Navigation
* Locating houses and streets
* Site location
* Transportation Planning.

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4). Planning and Engineering:-

* Urban Planning
* Regional Planning
* Route location of highways
* Development of public facilities.

Land Information System:-

* Cadastre administration.
* Taxation
* Zoning of land use
* Land acquisition.

Electric / Gas utilities:

The GIS is used on a daily basis by the cities and utilities to help them in mapping, in inventory systems, track ~~maintain~~ maintenance, monitor regulatory compliance, & model distribution analysis, transformer analysis, and load analysis.

Environment:

The GIS is used every day to help protect the environment. An environmental professional uses GIS to produce maps, inventory species, measure environmental impact, & trace pollutants. The environmental applications for GIS are almost endless.

Forestry:

Nowadays, managing forests is becoming a more complex and demanding challange. With GIS, foresters can easily see the forest as an ecosystem and manage it efficiently.

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Geology:

Geologists use GIS everyday in a wide variety of applications. The GIS can also be used to study geologic features, analyse soils and strata, assess seismic information, & create three-dimensional (3D) displays of geographic features.

Hydrology:-

The GIS can also be used to study drainage systems assess groundwater, and visualize water sheds, and in many other hydrologic applications.

Mapping:

Mapping is an essential function of a GIS. People in a variety of professions use GIS to help others understand geographic data. It is not necessary to be a skilled cartographer to make maps with a GIS.

Military:

Military analysts and cartographers use GIS in a variety of applications such as creating base-maps, assessing terrain, and aiding tactical decisions.

Risk Management:-

A GIS can help with risk management and analysis by showing us which areas are likely to be prone to natural & manmade disasters. When such forthcomming disasters are identified, preventive measures can be developed that deal with different scenarios.

Site Planning

~~Transpor~~ People around the world use GIS to help them locate sites for new facilities ~~like~~ & locate alternative

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sites for existing facilities.

Transportation:-

A GIS can be used to in managing transportation infrastructure & in managing logistical problems. They can help us in monitoring rail systems and road conditions & finding the best way (route) to deliver our goods or services.

Water / Waste Water Industry:

People in the water/ waste water industry use with the planning, engineering, operations, maintenance, finance and administration functions of their water/ waste water networks.

Limitations of GIS:

A GIS has many beneficial applications; ~~have~~ however, like other technological systems, there are also some limitations to its use. The following are some examples:

* Data for a specific area may lack spatial or temporal continuity.
* GIS data are relatively expansive than traditional data
* Collection of data can be very time consuming
* GIS often relies on the quality of available data which may introduce serious errors.
* GIS data may also be subject to misuse & misinterpr-tation.
* Learning time on GIS software and systems can be long, because it easily becomes the objective of the study rather than just a tool.

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Concept of Map :-

Map :

A map is the representation of the earth's surface / pattern as a whole or a part of it on the plane surface, with the conventional signs, drawn to a scale and projection so that each and every point on it corresponded to the actual position of the earth.

Maps are abstract representation of the physical features of a portion of the earth's surface, graphically displayed on a planar surface.

A map portrays (describe) three kinds of information about geographic features :

* Location and extent of the feature.
* Attributes (characteristics) of the feature.
* Relationship of the feature to other features.

Classification Of Maps :

According to purpose, maps may be classified as follows :

Cadastral Maps :

A cadastral map is a map showing boundaries and ownership of land. Some cadastral maps show ownership of landed property by demarcating boundaries, as well as boundaries and owenership details, such details as survey district names, block numbers, adjoining and adjacent street names, etc..

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Topographical Maps:

Topographic maps, also called contour maps, ~~by means~~ ~~of contour maps~~, topo maps, or topo sheets, are maps that show topography, or land contours, by means of contour lines. These maps usually show not only the contours, but also any significant streams or other bodies of water, forest cover, builtup areas, roads, and other features and points of interest.

These are multipurpose maps, and represents both physical and cultural details of an area.

Thematic Maps :-

A thematic map displays the spatial pattern of a theme or series of attributes. In contrast to general reference maps that show ~~many~~ many geographic features, thematic maps emphasize spacial variation of one or a small number of geographic distributions.

General referance maps show where something is in space, thematic maps tell a story about that place. These maps are prepared to serve some special purpose with reference to a specific theme or attribute.

Some examples are:-

- Relief maps - Shows elevation differences of the surface.
- Geological Maps - Shows rock features, earth crust. etc.,
- Weather maps - Shows Weather condition
- Vegitation Map -
- Political Map - Shows boundaries between different states.

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Map Projection:-

Map projection is a mathematical expression using which the three dimentional surface of the earth is represented in a two dimensional plane. The process of projection results in distortion of one or more map properties such as shape, size, area or direction.

A single projection system can never account for the correct representation of all map properties for all the regions of the world. Therefore hundreds of projected systems have been difined for accurate representation of a particular map element for a particular region of the world.

Classification of Map Projections:-

Map projections are classified on the following criteria:

Development surface used projection properties position of light source method of construction.

Map Projections based on Development Surface:

Projections transforms the coordinates of earth into a surface that can be flattened to a plane without distortion. Such a surface is called a developable surface. The three basic projections are based on the types of developable surface and are introduced below:

1) Cylindrical Projection
2) Conic Projection
3) Azimuthal / Zenithal Projection.

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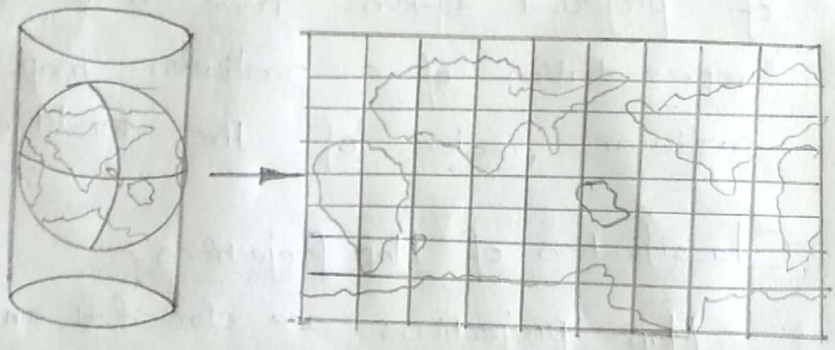
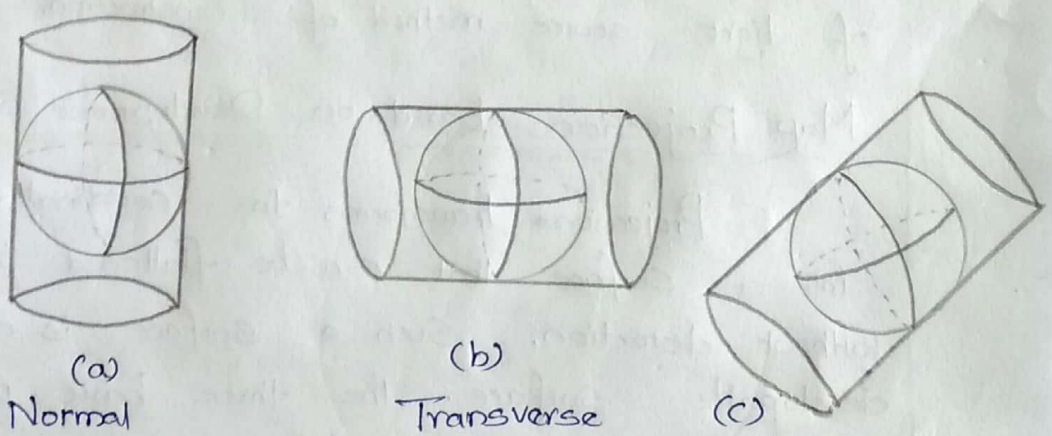
1. Cylindrical Projection:-

It can be visualised as a cylinder wrapped around the globe.

Once the graticule is projected into the cylinder, the cylinder is opened to get a grid like pattern of latitude and longitude. The longitude (meridians) and latitudes (parallels) appear as straight lines. The length of the equator on the cylinder is equal to the length of the equator, therefore, is suitable for showing ~~equa~~ equatorial regions.



Aspects of Cylindrical Projection:-



(a) Normal (b) Transverse (c) Oblique

a) Normal:

When the cylinder has a line of tangency to the equator. It includes equirectangular projection, the Mercat,

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or projection, Lambert's Cylindrical Equal Area, Gall's stereographic Cylindrical, and Miller Cylindrical Projection

(b). Transverse:

When the cylinder has the line of tangency to the meridian.

It includes the Cassini Projection, Transverse Mercator, Transverse cylindrical Equal Area Projection, and modified Transverse Mercator.

(c). Oblique:

When the cylinder has the line of tangency to another point on the globe.

It only consists of the oblique Mercator projection.

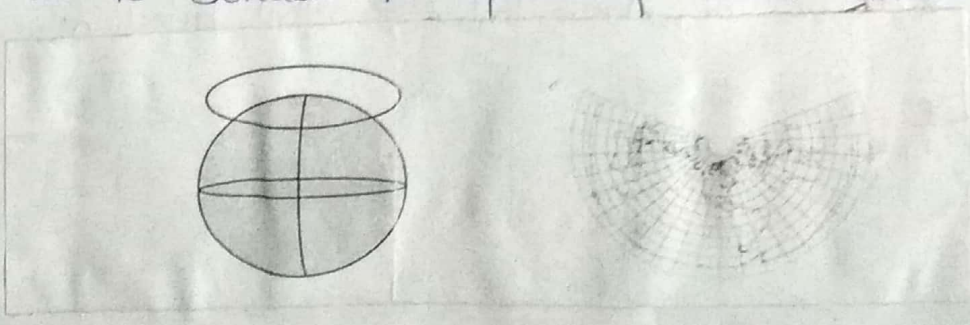
2. Conic Projection:-

It can be visualised as a cone placed on the globe, tangent to it at some parallel.

After projecting the graticule on to the cone, the cone is cut along one of the meridians and unfolded. parallels appar as arcs with a pole and meridians as straight lines that converge to the same point.

It can represent only one hemisphere, at a time, northern & southern,

It is suitable for representing middle altitudes.



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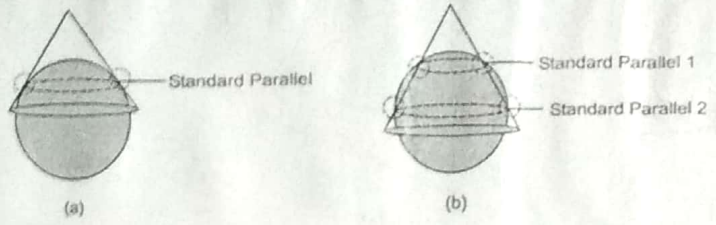
Aspects of conic projection:



a). Tangent :

When the cone is tangent to only one of the parallel.

b). Secant :

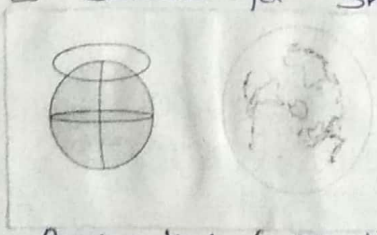
When the cone is not big enough to cover the curvature of the earth, it intersects the earth twice at two parallels.

3. Azimuthal / Zenithal Projection:-

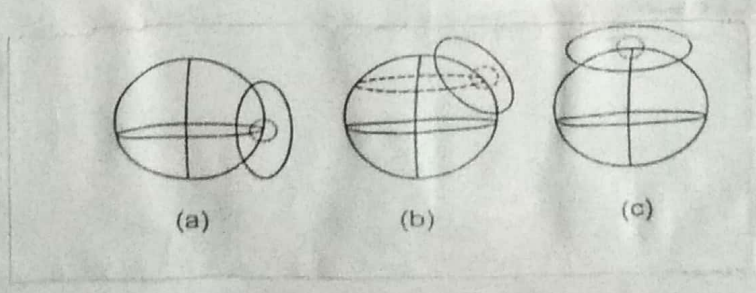
→ It can be visualised as a flat sheet of paper tangent to any point on the globe.

→ The sheet will have the tangent point on the centre of the circular map, where meridians passing through the centre are a straight line and the ~~para~~ parallels are seen as a concentric circle.

→ This is suitable for showing polar areas.



* Aspects of Azimuthal / Zenithal Projection:



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a). Equatorial Zenithal :

When the plane is tangent to a point on the equator.

b). Oblique Zenithal :

When the plane is tangent to a point ~~to~~ on a pole and the equator.

c). Polar Zenithal :

When the plane is tangent to one of the poles.

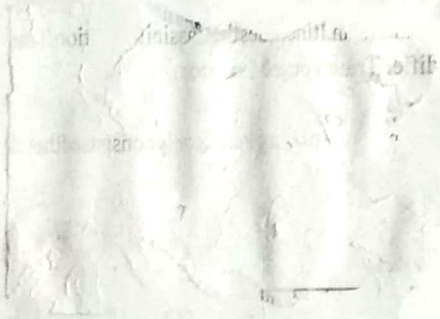

Fig: Polar Zenithal Equal Area Projection.

Properties of Map Projections :-

A major thing to be noticed in map projection is the way by which the properties of a map i.e., Shape, area, distance, and direction. getting affected.

Different projections take care of different properti-es.

1). Conformal Projections : (Shape Preserving)

* Conformal projections preserve local shape. To preserve individual angles describing spacial relationships, a conformal projection must also present ~~grati~~ gratiwle lines intersecting at 90° angles on the map.

* The drawback is the enclosed area may be greatly distorted.

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2. Equal Area Projections : (Area Preserving)

An equal-area map projection, which is also known as an equivalent map projection, correctly represents area of the sphere on the map.

In this projection, the meridians and parallels may not intersect at right angles.

3. Equidistant Projections : (Distance Preserving).

An equidistant map projection correctly represents distance between certain points. An equidistant map projection is possible only in a limited sense.

That is, if the scale on a map is correct along meridians the map is equidistant along the meridians.

If the scale on a map is correct along all parallels the map is equidistant along all the parallels.

No map is equidistant to and from all the points all the points on a map.

4. True-direction Projections : (Direction Preserving).

The shortest route between two points on a curved surface such as the earth is along the spherical equivalent of straight line on a flat surface

True-direction or azimuthal projects are used to rectify some of the great ~~circles~~ arcs, giving the directions or azimuths of all points on the map correctly with respect to the center.

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Data Entry and Preparation :-

GIS Data :

Geographical data deals primarily with two types of data:

Spatial and Non Spatial Data.

* Spatial data is that which has physical dimensions and geographic locations on the surface of earth.

Ex: River, state boundary, a lake, a state capital etc.

* Non-Spatial Data is that qualifies the data.

→ Attribute or Non Spatial data describes some aspects of spatial data, not specified by it geometry alone.

Representation of Spatial Information :-

Geographical features are described on map by

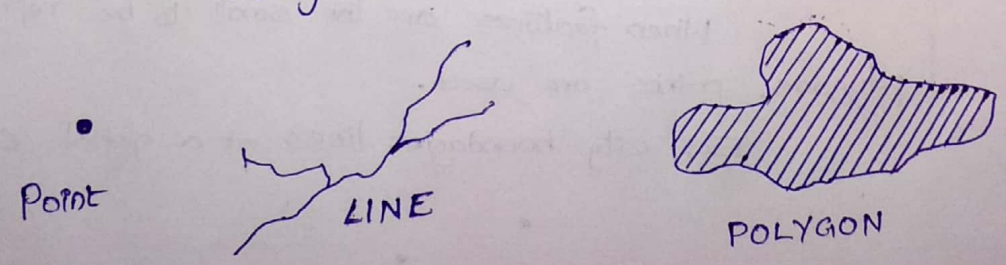
~~POA~~ POINT, LINE & POLYGON.

Point feature : A discrete location depicted (describe) by a spacial symbol or label.

A single x, y coordinates.

LINE feature : Represents a linear feature. A set of ordered x, y coordinates.

POLYGON feature : An area feature where boundary encloses a homogeneous area.



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→ Spatial data observations focus on locations.

Ex: Every house, every tree, every city has its own unique latitude and longitude coordinates.

Types of Spatial Data :-

In GIS, spatial data classified mainly into two types :

1) Vector Data, and
2) Raster Data.

1). Vector Data Model:

Vector data is not made up of grid of pixels. Insted, vector graphics are comprised of vertices and paths.

The three basic symbol types for vector data are points, lines and polygons (areas). Because cartographers use these symbols to represent real-world features in maps, they often have to decide based on the level of detail in the map.

→ **Points:** (x, y co-ordinates).

Vector points are simply x y coordinates.

Generally, they are a latitude and longitude with a spatial reference frame.

When features are too small to be represented as polygons, points are used.

Ex: city boundaries lines at a global scale.

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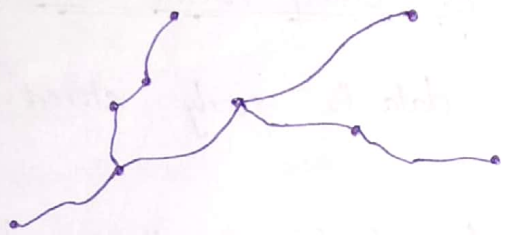
→ **LINES**: (Connect Vertices)

Vector lines connect each vertex with paths. Basically, you're connecting the dots in a set order and it becomes a vector line with each dot representing a vertex.

Lines usually represent features that are linear in nature.

Ex: Maps show rivers, roads, and pipelines as vector lines.



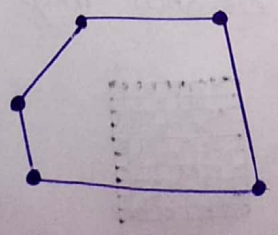
LINE

→ **POLYGONS**: (Connect vertices and closes the path.)

When you join a set of vertices in a particular order and close it, thus ~~to~~ is now a Vector Polygon ~~featu~~ feature. In order to create a polygon, the first and last coordinate pair are the same.

Cartographers use polygons to show boundaries and they all have an area.

Ex: building footprint has a square footage and ~~agri~~ agricultural fields have acreage.



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Advantages of Using Vector Data :-

Because vector data have vertices and paths, this means that the graphical output is generally more aesthetically - pleasing.

It gives higher geographic accuracy because data isn't dependent on grid size.

Network analysis and Proximity operations use vector data structures.

Disadvantages of Using Vector Data :-

*. Continuous data is poorly stored and displayed as vectors.

*. In order to display continuous data as a vector, it would require substantial generalization.

*. Vector manipulation algorithms are complex.

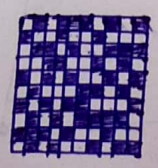
* Raster Data Models :

Raster data is made up of pixels. They are usually regularly - spaced and square but they don't have to be. Rasters often look pixelated, each pixel has its own value or class.

Ex:

* Each pixel value in a satellite image has red, green and blue value.
* Each value in an elevation map represents a specific height.

7	53	30
	68	
35		72



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Raster models are useful for storing data that varies continusly.

Ex: Elevation Surfaces, temparature & lead contamination.

→ Raster Models consist of two categories:

1) Discrete and
2) Continuous Rasters.

1. Discrete Raster Models:

Discrete rasters have distinct themes or categories.

Ex: One grid cell represents a land cover class or a soil type.

In a discrete raster land cover, you can distinguish each thematic class. Each class can be discretely defined where it begins and ends.

Discrete data usually consists of integers to represent classes.

2. Continuous Raster Data:

Continuous rasters are grid cells with gradual changing data such as elevation, temparature, or an aerial photograph.

A continuous raster surface can be derived from a fixed registration point.

Ex:-

* Digital elevation models use sea level as a registration point. Each cell represents a value above or below sea level.
* Representing of an oil spill, it can show how the fluid moves from high concentration to low concentration.

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Advantages of Raster Models :-

Raster grid format is data model for satellite data and other remote sensing data.

It is simple to understand cell size.

Map algebra with raster data is usually quick and easy to perform.

Quantitative analysis is easy to understand with discrete & continuous rasters.

Disadvantages of Raster Data :-

* Linear features and paths are difficult to display.
* Because cell size contributes to graphic quality, it can have a pixelated look and feel.
* You cannot create network datasets on rasters.
* It is difficult to flexibility with raster data attribute tables.
* It need more space to store data.

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