UG S1-02
(SEC)

FOUR YEAR BACHELOR'S DEGREE COURSE

(CBCS in Accordance with NEP 2020)

SEMESTER - I

INTRODUCTION TO GEOINFORMATICS

GPD School of Interdisciplinary and Vocational Studies

KRISHNA KANTA HANDIQUI STATE OPEN UNIVERSITY

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COURSE INTRODUCTION: INTRODUCTION TO GEOINFORMATICS

This course has been designed as Skill Enhancement Course (SEC) for undergraduate level learners of the first semester. It is a multidisciplinary course of 3 credits. The total duration of the course is six months. The main objective of the course is to provide the basic concepts and significance of Geoinformatics. This course will give an idea to understand the maps and familiarize the learners with the GIS (Global Information System) and its applications. It will also provide an idea of various GIS data types and the applications of geoinformatics in different areas. After the completion of this course, the learner will be able to acquire the knowledge and skills on geospatial technology and its applications. A small project report has to be submitted by the learners on a selected topic which will carry 1 credit of the course.

There are six units in the course. The **first unit** covers the definition of a map, properties of maps, various types of maps, present day significance of maps, map projection systems, map projections for hemispheres, world, continents and regions, Universal Transverse Mercator projection and International Terrestrial Reference Frame in GIS.

The **second unit** includes the basic concepts of Geographic Information System, components of a GIS, spatial data creation, Data Types, Data Editing and Analysis, Topological Relationships, Advantages of GIS, Social and Institutional Context of GIS, Contemporary Development of GIS and Web GIS

The **third unit** introduces to Global Navigation Satellite System (GNSS), Historical Development of GNSS, Segments of GPS, Basic working Principles of GNSS, GNSS Applications: Asset Mapping, Navigation Services, Location Based Services.

The **fourth unit** covers the introduction to remote sensing, remote sensing principles, types of remote sensing, Sensor and Platforms, Satellite Image Interpretation Elements, Indian Remote Sensing programmes.

The **fifth unit** covers the Open-Source Data, Open source Digital Elevation Model and Open Source Software i.e. QGIS.

The **sixth unit** covers the application of Geoinformatics in Natural Resource Management, Watershed Management, Disaster Management, Rural Development, Urban Planning, Monitoring and Evaluation of Projects.

While going through a unit, you will notice some boxes, containing such information as would help you to understand some of the difficult, unfamiliar terms. You will find an item called “ACTIVITY’

where you will apply your knowledge and thoughts in some questions pertaining to the relevant topic. Again, we have included some relevant concepts in “LET US KNOW” along with the text. And, at the end of each seection, you will get “CHECK YOUR PROGRESS” questions. These have been designed to self-check your progress of study. It will be better if you solve the problems put in these boxes immediately after you go through the sections of the units and then match your answers with “ANSWERS TO CHECK YOUR PROGRESS” given at the end of each unit.

UNIT 1: UNDERSTANDING MAPS

UNIT STRUCTURE

1.1 Learning Objectives

1.2 Introduction

1.3 Definition of Map

1.4 Properties of Map

1.5 Types of Map

1.6 Present day Significance of Maps

1.7 Map Projection Systems

1.8 Map Projections for Hemispheres and the World

1.9 Map Projections for Continents and Regions

1.10 Universal Transverse Mercator Projection

1.11 International Terrestrial Reference Frame in GIS

1.12 Let Us Sum Up

1.13 Further Readings

1.14 Answers to Check Your Progress

1.15 Model Questions

1.1 LEARNING OBJECTIVES

After going through this unit, you will be able to :

- explain the meaning of a map
- identify the map properties
- get an idea of different types of maps
- discuss the significance of maps in the present times
- elaborate the concept of map projection
- describe map projections for hemispheres, World, Continents and Regions
- enlighten the significance of Universal Transverse Mercator Projection
- explain the International Terrestrial Reference Frame in GIS

1.2 INTRODUCTION

In this unit, we are going to discuss the meaning of a map and how it differs from a sketch. This unit is also going to provide the different properties and types of maps. It also deals with the present day significance of maps. The basics of map projection systems and their types are also included in this unit. Some conceptual ideas about Universal Transverse Mercator Projection and International Terrestrial Reference Frame in GIS are also discussed at the end of this unit.

1.3 DEFINITION OF MAP

A map is the representation of the earth's surface or any part of it with a definite scale. It is the representation, usually on a flat surface, of a whole or part of an area. The job of a map is to describe spatial relationships of specific features that the map aims to represent. There are many different types of maps that attempt to represent specific things. Maps can display political boundaries, population, physical features, natural resources, roads, climates, elevation (topography), and economic activities. Maps are produced by cartographers. Cartography refers to both the study of maps and the process of map-making. It has evolved from basic drawings of maps to the use of computers and other technologies to assist in making and mass-producing maps. Map has distance, direction, shape and area. But all of these cannot be represented at a time. Maps are drawn on a planimetric surface.



Triangulation: Triangulation is a surveying technique to establish the absolute position (location) of a place and its elevation from the mean see level. Three specific places are selected to form a nearly equilateral triangle.

Maps have changed in many ways since maps were first used. The earliest maps that have withstood the test of time were made on clay tablets. Maps were produced on leather, stone, and wood. The most common medium for producing maps is paper. Today, however, maps are produced on computers, using software such as GIS or Geographic Information Systems.

Originally, maps were produced using land surveying, ***triangulation***, and observation. As technology advanced, maps were made using aerial photography, and then eventually remote sensing, which is the process

used today. The appearance of maps has evolved along with their accuracy. Maps have changed from basic expressions of locations to works of art, extremely accurate and mathematically produced maps.



CHECK YOUR PROGRESS

Q.1: Define a map.

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Q.2: What are the functions of a map?

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1.4 PROPERTIES OF MAP



Map Projection: Map projection is the way to represent three dimensional earth surface in two dimensional flat surface. In doing so only certain properties can be preserved

Map property refers to an alteration of area, shape, distance, and direction on a ***map projection***. These map properties exist because the conversion from a three-dimensional object, such as the earth, to a two-dimensional representation, such as a flat paper map, requires the deformation of the three-dimensional object to fit onto a flat map. The three-dimensional spherical surface is torn, sheared, or compressed to flatten it onto a flat developable surface. There are four basic properties of a map that are distorted to some degree, depending on the map projection used. These properties include Conformality or Orthomorphism (shape), Equivalence (area), True direction, and True distance.

Conformality or Orthomorphism:

Conformality orthomorphism means having the right shape. A conformal or orthomorphic map is a map in which shape mapped area of the earth's surface is identical to the corresponding area of the earth's surface. A conformal or orthomorphic map has two characteristics: the parallels and meridians are at right angles to one another and at any point, the scale remains the same in all directions. Conformal maps are useful for large-

scale mapping. Some map projections are developed on the basis of this property. One such map projection is conical orthomorphic projection.

Equivalence:

If the area of a certain zone on the globe is made proportionately equal to the area of the corresponding zones on the map projection, then the map is called an equal area map and hence it maintains the property of equivalence. An equal-area map, thus, preserves the ratio of the mapped area to the corresponding area on the earth. Equal-area maps are useful for general quantitative thematic maps when it is desirable to retain area properties. This is especially useful for choropleth maps when the attribute is normalized by area. The area is preserved on a map of the entire world or a hemisphere or a small part of the earth's surface.

True direction:

A true direction map preserves direction from one point to all other points in the map. Direction is only true when measured from the specific points chosen to any other point have true direction. Preservation of correct bearing or azimuths implies preservation of true direction which is particularly important in navigation. The correct direction can be maintained in a map when the map is constructed on a plane from one central point. When this central point coincides with the North or South Pole, the meridians will be lines of true bearing.

True distance:

If a map is constructed with scale, true to the globe, then the projection would be a true scale projection and it will show true direction. This means that a distance can be held true from one point to all other points, or from a few select points to others. It is also important to note the scale is uniform along these lines a true distance from the select points on the map.



CHECK YOUR PROGRESS

Q.3: Explain the concept of conformality.

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Q.4: What do you mean by equivalence?

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Q.5: What are the applications of an equal area map?

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1.5 TYPES OF MAP

Maps can be used in a variety of different ways, from navigation to establishing ownership, to presenting information. According to the ICSM (Intergovernmental Committee on Surveying and Mapping), there are five different types of maps: Cadastral Maps and Plans, Topographical maps, Thematic maps, General Reference maps, and Navigation Charts.

Cadastral Map:

"Cadastral" comes from the word cadastre, meaning a public record, survey, or map of the value, degree, and ownership of land for purposes of taxation. Cadastral maps are much more detailed. The plans map out individual properties providing details, such as boundary information when houses or land are surveyed, and could be combined to build bigger cadastral maps. Cadastral mapping was among the earliest types of mapping where the ancient Egyptians created cadastral records to establish ownership of land just after flooding from the Nile River.

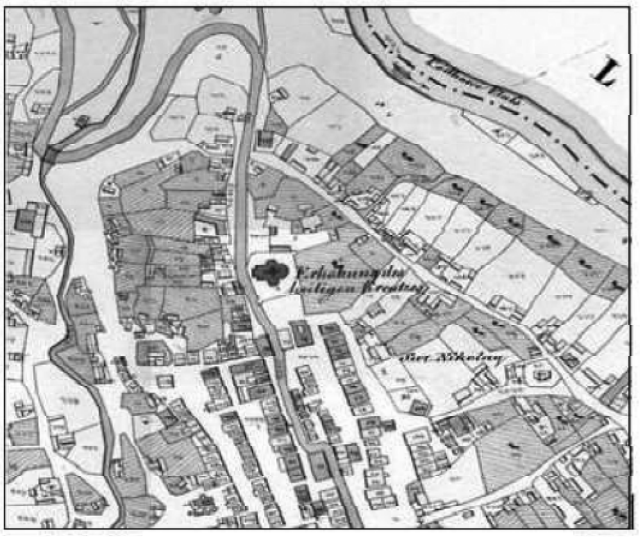


Fig. 1.1: A cadastral map

Topographic Map:

A topographic map indicates different physical landscape features on the earth's surface. These maps are different on the other hand because they use contour lines rather than colors showing changes in the Topography. Contour lines on topographic maps are usually spaced at regular intervals showing elevation changes and the closer the lines are together, the steeper the terrain.

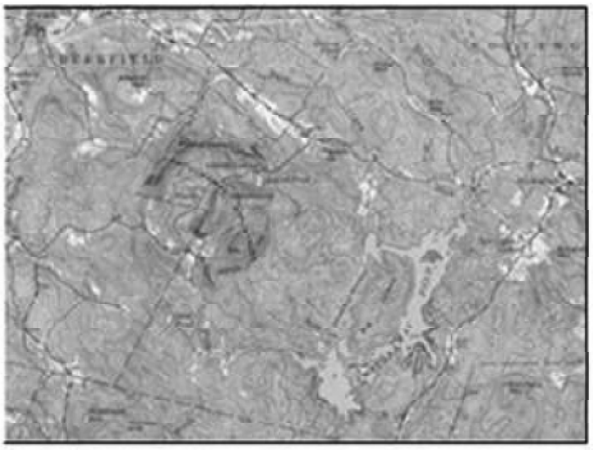


Fig. 1.2: A topological Map

These maps can be used for a variety of reasons, from camping, hunting, fishing, and hiking to urban planning, resource managing, and surveying. The biggest advantage of relief or topographical maps is that they show the true lay of the land which includes streams, valleys, rivers, mountains, hills, and more. They also display important landmarks and roads. Every country in the world prepares topographic maps.

Thematic Map:

Thematic maps are data maps of a unique topic or for a specific purpose. A thematic map is not the same as a general reference map since these maps don't just show natural features like rivers, cities, political subdivisions, elevation, and highways. If these things are on a thematic map, they are background details and they

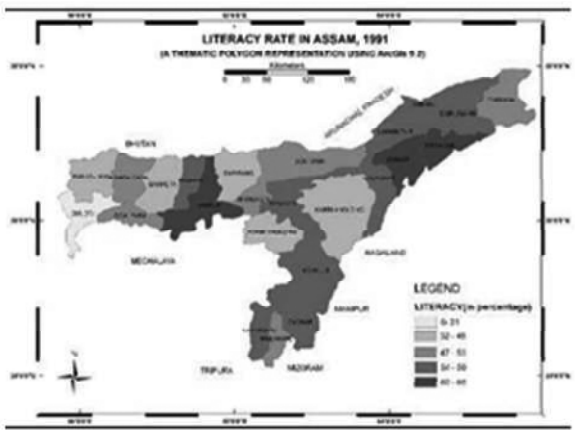


Fig. 1.3: A thematic Map of literacy distribution

are used as reference points to improve the map' s design. The different forms of thematic maps are: Dot map, Isopleth map, Choropleth map, and Choro- chromatic map.

Political Map:

Political maps are made to show administrative boundaries of nations, states, counties, cities, and towns, and might have some physical features such as rivers, streams, and lakes. The characteristic of a political map is a simple-to-use detailed index. Political maps will not indicate any topographic features. It instead focuses just on the national and state borders of a region. They will also add the location of key cities, plus they usually include significant bodies of water, according to the details on the map. Although some physical features show up on political maps, including major mountain ranges, the use of this is to provide g e o g r a p h i c a l reference indicating any physical features. These boundaries and locations are usually based on people instead of the natural world.



Fig. 1.4: A Political Map

Physical Map:

A physical map displays the natural landscape characteristics of an area. The definition of a physical map is a description of the geographical features of a location. Physical maps can include a lot of identical information available on a political map, however, their main function is to indicate landforms like deserts, mountains, lakes, and plains. Their topography style provides a complete picture of the local terrain.

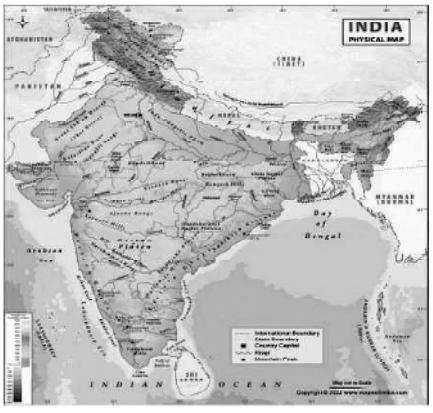


Fig. 1.5: A Physical Map

Climate Map:

A climate map shows knowledge about the climate of a region. It displays things like the precise climatic zones of an area using the temperature, such as, how much snow an area gets or the average amount of cloudy days. These maps normally use colors to point out different climatic areas.

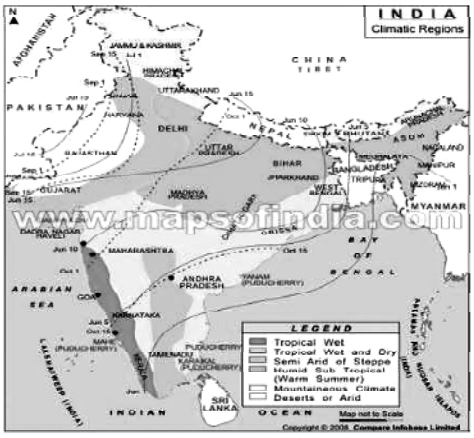


Fig. 1.6: A Climate Map

Road Map:

A road map or route map is a form of navigational map that primarily displays roads and transport links instead of natural geographical information. A road map is one of the more popular types of maps. These maps show minor and major highways and roads (based on detail) along with things like airports, city locations, and interesting attractions, such as parks, campgrounds, and monuments. Major highways with a road map are usually red and bigger than other roads, while minor roads can be a lighter color and have a smaller line thickness.



Fig. 1.7: A Map Displaying Road Network

General Reference Map:

These are the basic maps that are perfect for helping you get to your destination. They are easily read and include street and tourist maps. A general reference map is a regular map in which towns and cities are named, major transportation routes are included together with natural features like lakes



Fig. 1.8: A Reference Map

and rivers. The maps display the boundaries, names, and different identifiers of ordinary regional areas, along with major cultural and physical features, for example, roads, railroads, coastlines, rivers, and lakes.

Navigational Chart Map:

It is a map that shows the layout of the shoreline and seafloor. Navigational charts are important tools that help navigators make their way around, no matter whether they are on the ocean or in the air. Maps for the ocean are usually known as charts, and the same is true for air navigation mapping. These charts often include information which is essential to avoid accidents in and around the water like submerged rocks, as well as, providing additional navigational aids.



Fig. 1.9: A Navigation Chart



CHECK YOUR PROGRESS

Q.6: What are the different types of maps?

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Q.7: Differentiate between a cadastral map and a topographical map.

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Q.8: What is a thematic map?

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1.6 PRESENT DAY SIGNIFICANCE OF MAPS

From the dawn of humankind, man has sketched crude abstractions of geography on cave walls and rocks. These early maps documented and

communicated important geographic knowledge our ancestors needed to survive. Fast-forward to present times, the world has become significantly more complex than it was for our early ancestors. But luckily, we now have information technologies at our disposal to help us in solving complex problems. It is a natural fit to apply these powerful information technologies to the serious environmental, geographic, and social problems we face. And thus, the modern maps come into existence. Modern maps can be used to tell stories, and apps provide the user experience through which we work with maps and share them. The present day significance of maps can be understood from the following things that modern maps do to help us address the complex problems we face today.

1. Maps communicate and foster understanding. GIS maps provide windows into useful information. Many kinds of descriptive information can be stored with the map and accessed on demand for individual features in your map.
2. Maps provide a powerful way to tell many kinds of stories. Story maps make it easy to tell rich, map-based stories in the form of self-contained web apps. These web apps combine intelligent web maps with text, photos, video, and sound to elucidate interesting topics.
3. Maps can display dynamic information that changes over time. In GIS, many maps can dynamically display time frames, much like a weather map. The following map displays snow cover from NASA's next-generation Blue Marble imagery.

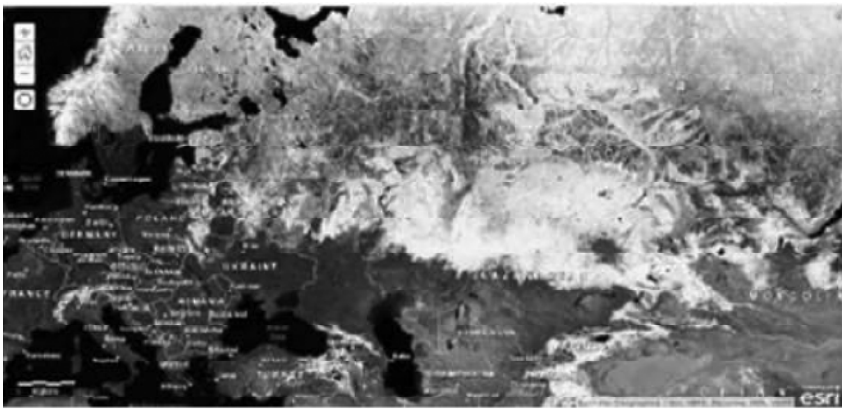


Fig. 1.10: Blue Marble Imagery

4. Maps help in finding patterns from a huge volume of data. Although it may seem counter-intuitive, sometimes adding thousands or millions of individual features or events helps a more coherent picture to emerge, one that simply couldn't be seen any other way. There can be value in adding mapping detail in order to give clarity to an overall view of your data, and sometimes this is referred to as "data art."



Fig. 1.11: Digital Network Flow Map

5. Maps help us to perform analysis. Maps can be used to enable geographic analysis. GIS maps combine powerful visualization with a strong analytic and modeling framework. Just as we can use each map layer as a window into information about features, we can use the map as a window into sophisticated analytical tools and results.



Fig. 1.12: Crime Web-Map

6. Maps can be used to compile data. Sometimes a map is a container or capturing device.

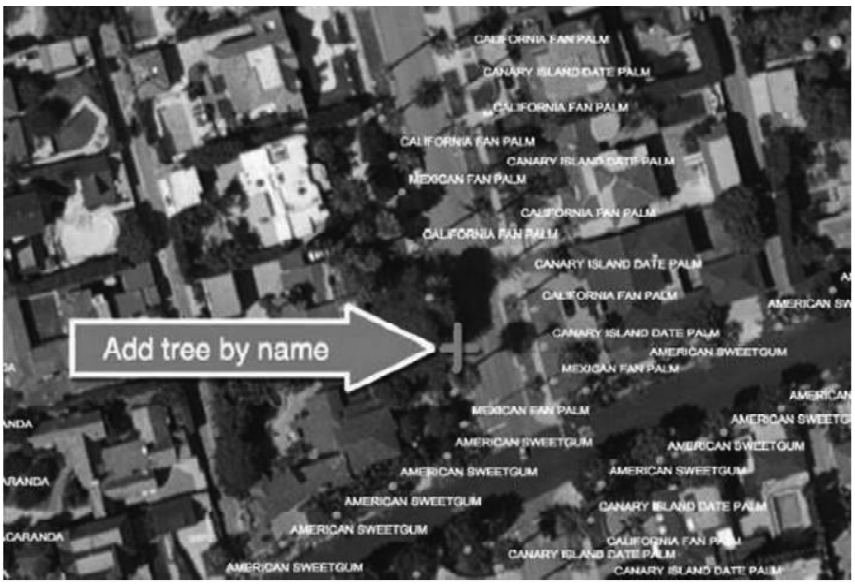


Fig. 1.13: Digital Satellite Map

(This simple map runs on an iPad. A team of arborists in Beverly Hills, California, uses it to add to and update a database of every tree in the city.)



CHECK YOUR PROGRESS

Q.9: Explain the significance of maps?

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1.7 MAP PROJECTION SYSTEMS

Map is an important cartographic tool. Map has different elements like location, scale, symbols, standardization and generalization, map projection. Each of these map elements is necessary to prepare a map of any place. Map projection is also a necessary element for map making in cartography and GIS. Map projection can be defined as a technique to transform and represent the 3-dimension earth surface on a flat or plane surface using graticules. Graticules refer to the networks of parallels of latitude and meridians of longitude drawn on a plane surface using

mathematical derivation formulas. Map projection includes 2 step processes. Firstly, the earth is reduced to a generating globe, and then this generating globe is drawn on a flat surface. A map projection uses mathematical formulas to relate spherical coordinates on the globe to flat and planar coordinates. Representing the earth's surface (3-D) in two dimensions (2-D) causes distortion in the shape, area, distance, or direction of the data (ESRI, 2014).

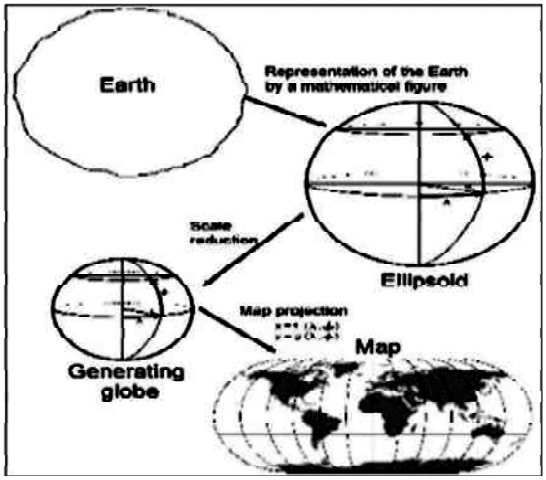


Fig. 1.14: Map Projection Process (After Canters)

In order to choose a projection system in GIS, one needs to concern about location, scale, shape, size of the area, purpose, theme of map, and requirements of the end users of map. There are different types of map projections. Every projection has some properties, uses and limitations. Based on the developable surface (onto which graticules are projected) *Zenithal projection*, *Conical projection* and *Cylindrical Projection* are used. Based on area, shape, direction and scale there are *Equal-area projection*, *True-shape projection*, *True-bearing projection* and *True-scale projection.*

(i) **Zenithal map projection:** Zenithal map projection is also known as Planar projection or Azimuthal projection. In Zenithal projection a plane or flat surface is used to project the graticules and this plane surface can be placed at any point on the globe. For example, if the plane is placed at the poles then this is called Polar Zenithal Projection. Some important Zenithal projections include- *Polar Zenithal Gnomonic Projection, Polar Zenithal Stereographic Projection, Lambert's Azimuthal equal-area Projection, Zenithal Stereographic Equatorial Projection* etc.

(ii) **Conical map projection:** Conical projection is also known as Conic projection. Here, the developable surface is a cone surface. The globe is wrapped inside a cone surface and the shadow of the

graticules of the globe is projected on the cone surface. The latitude of the globe where the cone surface is tangent, is known as standard parallel in conical map projection. Scale is correct along the standard parallel of Conical projection. Some examples of Conical map projections include *Simple Conic Projection with one standard parallel, Bonne's Conical Projection, Polyconic projection, Alber's Conic projection, Lambert Conformal Conic projection* etc.

(iii) Cylindrical map projection: In Cylindrical map projection the developable surface is a cylindrical sheet of paper. The graticules of the globe are projected on this cylindrical surface, and later the cylindrical sheet of paper is cut open to create the map projection with parallels and meridians. In cylindrical map projection, the parallels and meridians are straight-lines and intersect each other at right angles. *Mercator's projection, Gall's Cylindrical projection, Simple Cylindrical projection, Cylindrical Equal Area projection* etc. are the examples of Cylindrical map projection.

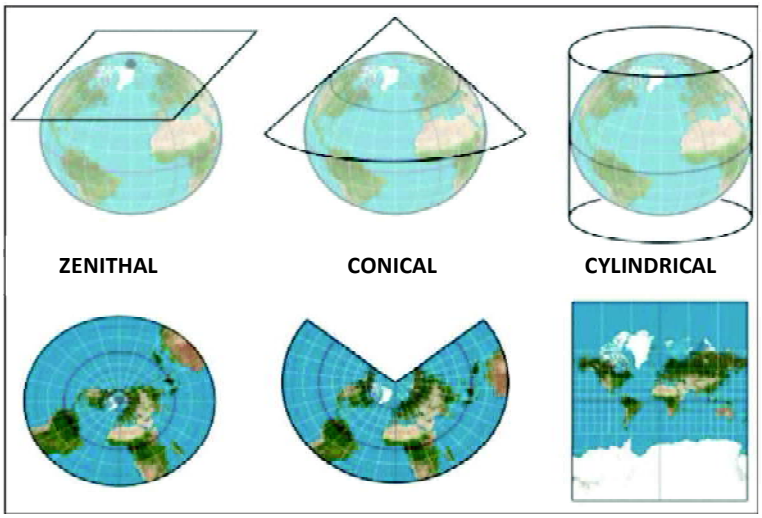


Fig. 1.15: Types of Map Projection based on developable surface
(https://gistbok.ucgis.org/)

(a) Equal-area map projection: Equal-area projection is also known as Homolographic map projection. In Equal-area map projection, the area of the earth's surface represented on the map is correctly preserved. In equal area projection, the directions and shape of the area cannot be correctly preserved.

Lambert's Azimuthal equal-area Projection is an example of an Equal-area map projection.

(b) True-bearing map projection: This map projection preserves correct directions from any point on the map. This projection is also called as True-directional map projection. *Lambert Conical projection* is an example of True-directional map projection.

(c) True-shape map projection: This map projection is also known as Conformal or Orthomorphic map projection. This projection preserves correct shape of the map area; hence, Conformal projections are not having equal-area properties. *Mercator's* map projection is an example of True-shape map projection.

(d) True-scale map projection: This map projection is also known as Equidistant map projection. Equidistant or True-scale map projections maintain correct distances between certain points on a map. Scale is also correctly preserved along certain parallels on Equidistant map projections. *Sinusoidal* map projection is an example of True-scale map projection.

This is rare to exactly find a suitable map projection that preserves all map projection properties like scale, shape, area, distance and directions. Hence, the choice of map projection is dependent on the purpose, requirements and needs of the users. Besides, every map projection has some specific applications. Some commonly used map projections in GIS include-

- Mercator's projection.
- Universal Transverse Mercator's projection.
- Polyconic Projection.
- Lambert conformal conical.
- Zenithal Stereographic projection.
- Equatorial Zenithal projection.
- Alber's Equal Area projection.
- Robinson projection.
- Mollweide projection.
- Lambert Azimuthal Equal Area projection.

- Gall's Stereographic projection.
- Bonne's projection.



CHECK YOUR PROGRESS

Q.10: Define map projection.

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Q.11: What is Zenithal map projection?

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1.8 MAP PROJECTIONS FOR HEMISPHERES AND THE WORLD

Every map projection has certain properties and uses. Some map projections are meant for some specific places, whereas, some other projections are suitable for regional, global mapping. Based on the map projection properties and user's requirements, various map projections are used for depicting hemispheres and the world in GIS. Some map projections used in GIS for Hemispheres and the World are briefly mentioned below:

Table 1.1: Map projections for Hemispheres

Map projection	***Properties***	***Limitations***
Zenithal Equal Area	Parallels are concentric circles. Preserves equalarea properties.	Cannot be used for showing true-shape and true-directions.
Zenithal Equidistant	Parallels are concentric circles. Preserve correct distances from the centre point.	Does not have equal-area properties.
Zenithal Gnomonic Projection	Parallels are circles & meridians are straight lines.	Not suitable for world map.
Zenithal Stereographic	Parallels are circles & meridians are straight lines.	Neither preserves area nor preserves distances.
Apian	Parallels are straight lines. Suitablefortwo-hemispheremap.	Does not have equal area properties.

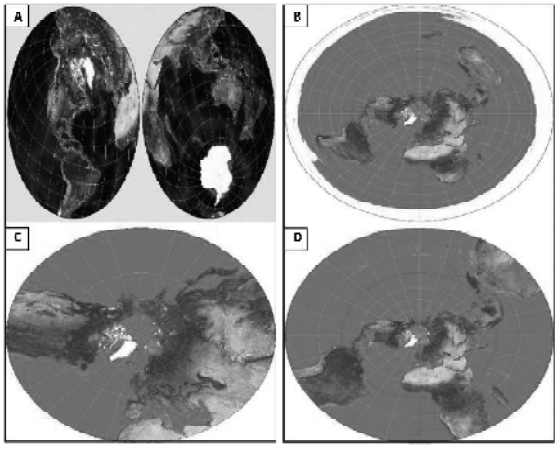


Fig. 1.16: A=Zenithal Equal-Area Projection, B=Zenithal Equidistant Projection, C=Zenithal Gnomonic Projection, D=Zenithal Stereographic Projection

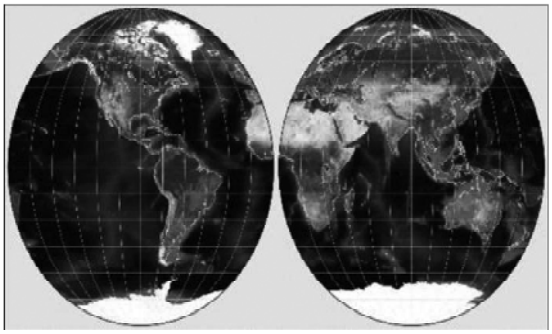


Fig. 1.17: Apian Map Projection Showing Two-hemispheres.

Table 1.2: Map projections for World

Map projection	***Properties***	***Limitations***
Mercator's	Parallels & meridians are straight lines.Preserves true-bearing.Rhumb line can be drawn as straight line showing constant direction.Cylindrical projection.	Does not have equal-area properties.
Gall's Stereographic	Parallels & meridians are straight lines.Up to 90^0 parallels can be drawn. Cylindrical projection.	Neither preserves area nor preserves shape.
Lambert Azimuthal Equal Area	Equal area projection. 0^0 parallel & 0^0 meridian are straight lines.	Does not preserve shape.
Sinusoidal	Parallels are straight lines & equidistance.Preserves area & distances.	Does not preserve shape.Not suitable for smaller areas.

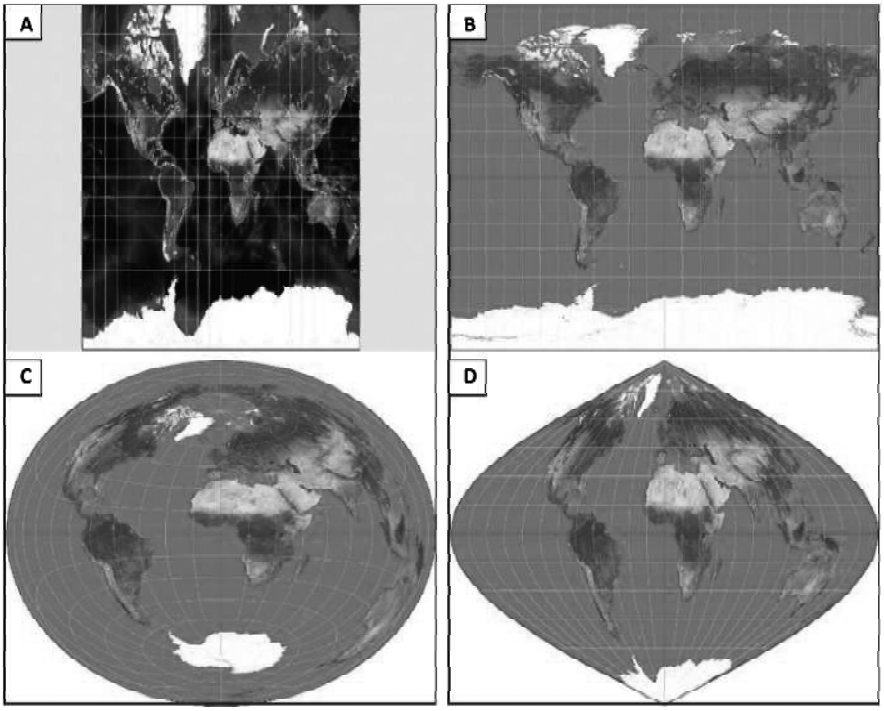


Fig. 1.18: A=Mercator's Projection, B=Gall's Stereographic Projection, C=Lambert Azimuthal Equal Area Projection, D=Sinusoidal Projection.



CHECK YOUR PROGRESS

Q.12: Mention two properties of Zenithal Equal-Area map projection.

.....

Q.13: Mention two properties of Mercator's projection.

.....

.....

1.9 MAP PROJECTIONS FOR CONTINENTS AND REGIONS

There are map projections suitable for representing continents, regions and countries. The map projections representing world and hemispheres may not be suitable for representing smaller regions and areas. Therefore, there are various location-specific, country and continent specific, and region-specific suitable map projections in GIS. Some of these map projections are briefly mentioned below:

Table 1.3: Map projections for continents, regions & countries

Map projection	***Properties***	***Limitations***
Polar Zenithal Stereographic	Suitable for showing North pole or South pole.Meridians are straight lines.Parallels are circles.Local shapes & directions are accurate.	Does not have equal area properties.Not suitable for areas other than poles.
Conical Equidistant with one or two standard parallels	Meridians are radiating straight lines.Parallels are arcs. Preserve distances.Scale is correct along standard parallel(s). Suitable for Australia, China, Mid-latitudinal regions.	Does not have equal area properties.Does not preserve true-shape.
Alber's Conical Equal Area	Meridians are radiating straight lines.Parallels are arcs. Scale is correct along standard parallel(s).Suitable for small regions and countries.	Does not preserve true-shape.Not suitable for continent mapping.
Lambert's conformal Conical	Meridians are radiating straight lines.Parallels are arcs. Scale is correct along standard parallel(s).Suitable for continent mapping.Suitable for larger areas. Preserves true-shape.	Does not have equal area properties.
Bonne's Conical with one standard parallel	Central meridian is a straight line. Scale is correct along standard parallel. An equal area projection. Suitable for India and Indian sub-continent.Suitable for compact countries and regions.	Neither preserves true-directions nor preserves shape.Not suitable for continent mapping.
Universal Transverse Mercator	Transverse cylindrical projection. Parallels and meridians are straight lines.Very much suitable for large scale mapping of smaller areas and zones.Preserves true-shape and directions.	Not suitable for World mapping.Cannot represent polar regions.

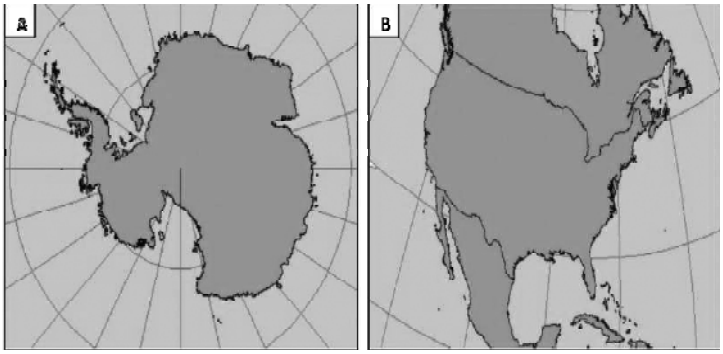


Fig. 1.19: A=Polar Zenithal Stereographic Projection, B=Conical Equidistant Projection.

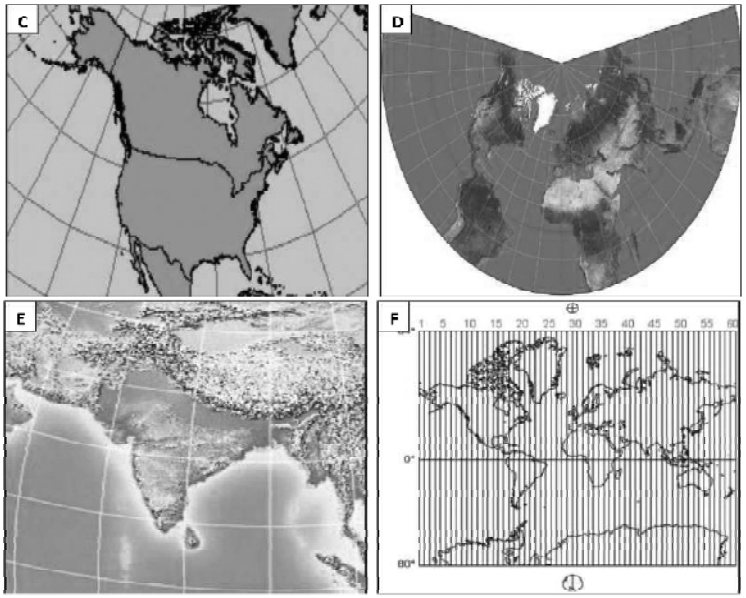
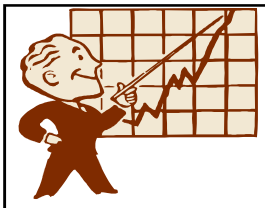


Fig. 1.20: C=Alber's Conical Equal Area Projection, D=Lambert's Confor-mal Conical Projection, E-Bonne's Conical Projection, F=Universal Transverse Mercator Projection.



CHECK YOUR PROGRESS

Q.14: Mention two properties of Bonne's conical projection?

.....

.....

1.10 UNIVERSAL TRANSVERSE MERCATOR PROJECTION

Universal Transverse Mercator also known as UTM, is a popular and one of the most widely projection systems in GIS. Universal Transverse

Mercator uses a transverse cylinder, secant to the horizontal reference. UTM is a derivation from Transverse Mercator projection (ITC, 2001). In UTM projection the globe is divided into 60 north and south zones, each spanning 6 degrees of longitude. Each zone has its own central meridian. Zones 1N and 1S start at -180° W. The limits of each zone are 84° N and 80° S, with the division between north and south zones occurring at the equator (ESRI, 2004). The origin for each zone is its central meridian and the equator. To eliminate negative coordinates, the coordinate system alters the coordinate values at the origin. The value given to the central meridian is the false easting and the value assigned to the equator is the false northing. A false easting of 500,000 meters is applied. A north zone has a false northing of zero, while a south zone has a false northing of 10,000,000 meters. The main property of UTM projection is that UTM preserves correct shapes of the smaller areas with correct representation of angles and true-directions. UTM is one of the best projections for large-scale thematic as well as topographical mapping of small areas. UTM provides high accuracy in mapping within a specified zone. UTM 46 north zone represents Assam in GIS grid systems with 93Ú meridian as the central meridian. The shape of each zone is like a boat bulging in the middle and tapering to a point on the poles. A rectangular representation is shown in figure 1.21.

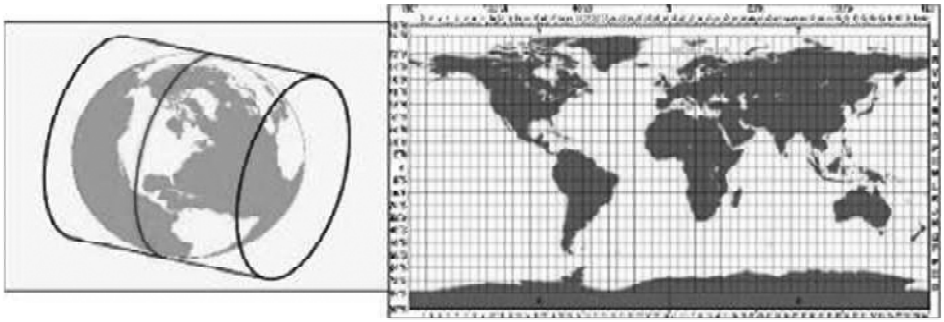


Fig. 1.21: UTM Projection System



CHECK YOUR PROGRESS

Q.15: Which is the UTM zone for Assam?

.....

1.11 INTERNATIONAL TERRESTRIAL REFERENCE FRAME IN GIS

The International Terrestrial Reference Frame (ITRF) is a standard and ideal co-ordinate reference system in GIS. ITRF is a 3-dimensional Cartesian coordinate system used in GIS and other ground surveying systems. ITRF is based on International Terrestrial Reference System (ITRS) that is geocentric and co-rotation spatial reference system. The IRTS was adopted in 1991 in Vienna based on the International Union of Geodesy and Geophysics resolution. The ITRF is maintained through an international network of space geodetic observatories and an international network of GNSS tracking stations. The ITRF is the most accurate terrestrial reference frame to date. Therefore, it is frequently used as the basis for other reference frames, or, as an intermediate to describe relations between coordinate systems. For instance, the well-known WGS84, used by GPS, is directly linked to the ITRF (Marel, 2014). In GIS, there are different types of ITRF like ITRF92, ITRF93, ITRF94, ITRF2000, IRTF2014 etc.



CHECK YOUR PROGRESS

Q.16: What is the full form of ITRF?

.....



1.12 LET US SUM UP

- A map is the representation of the earth's surface or any part of it with a definite scale by maintaining distance, direction and relative locations.
- Maps can display political boundaries, population, physical features, natural resources, roads, climates, elevation (topography), and economic activities.
- There are four basic properties of a map: Conformality or Orthomorphism (shape), Equivalence (area), True direction, and True distance.

- According to the ICSM (Intergovernmental Committee on Surveying and Mapping), there are five different types of maps: Cadastral Maps and Plans, Topographical maps, Thematic maps, General Reference maps and Navigation Charts.
- Maps can display dynamic information that changes over time and it helps in finding patterns from a huge volume of data and also to perform analysis.
- Map projection can be defined as a technique to transform and represent the 3-dimension earth's surface on a flat or plane surface using graticules.
- Based on the developable surface there are three map projections namely Zenithal projection, Conical projection and Cylindrical projection.



1.13 FURTHER READING

1. Fundamentals of Cartography by R. P. Misra, Concept Publishing Company, New Delhi, 2014.
2. https://en.wikipedia.org/wiki/List_of_map_projections
3. http://egyankosh.ac.in/
4. Kang-Tsung Chang, *Introduction to Geographic Information System,* Published by McGraw-Hill, 2002.
5. Principals of Geographic Information Systems from ITC, Netherlands, 2001.
6. Reference Systems for Surveying and Mapping by H. Vander Marel, Delft University of Technology, Netherlands, 2014.
7. SLM, Course 1 of PGCPG, *Fundamentals of GIS*, published by KKHSOU, 2020
8. Suren Talukder, *Introduction to Map Projections*, published by EBH Publishers (India), 2008.
9. Understanding Map Projections by ESRI, 2004.



1.14 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: A map is the representation of the earth's surface or any part of it with a definite scale. It is the representation, usually on a flat surface, of a whole or part of an area.

Ans. to Q. No. 2: A map describes the spatial relationships of specific features on the earth's surface. Map displays political boundaries, population, physical features, natural resources, roads, climates, elevation (topography), and economic activities.

Ans. to Q. No. 3: Conformality means having the same shape. A conformal map is a map in which shape of the map surface at any given point is identical to the corresponding point on the earth's surface.

Ans. to Q. No. 4: Equivalence is a map property in which the area of a certain zone on the globe is made proportionately equal to the area of the corresponding zones on the map projection. An equal area map, thus, preserves the ratio of the mapped area to the corresponding area on the earth.

Ans. to Q. No. 5: Equal area maps are useful for general quantitative thematic maps. This is especially useful for choropleth maps to show the spatial distribution of events or phenomena.

Ans. to Q. No. 6: According to the ICSM (Intergovernmental Committee on Surveying and Mapping), there are five different types of maps: Cadastral Maps and Plans, Topographical maps, Thematic maps, General Reference maps and Navigation Charts.

Ans. to Q. No. 7: The map which displays public records is called cadastral map. It is a map that shows the value, degree, and ownership of land for purposes of taxation. Cadastral maps are much more detailed. The plans map out individual properties providing details, such as, boundary information when houses or land are surveyed, and could be combined to build bigger cadastral maps, whereas, a topographic map is like a physical map because

it indicates different physical landscape features. Topographical maps show the true lay of the land which includes streams, valleys, rivers, mountains, hills, and more. They also display important landmarks and roads.

Ans. to Q. No. 8: Thematic maps are data maps of a unique topic or for a specific purpose or theme. The different forms of thematic maps include Dot map, Isopleth map, Choropleth map and Choro-chromatic map.

Ans. to Q. No. 9: Maps communicate and foster understanding. GIS maps provide windows into useful information. Maps can display dynamic information that changes over time. Maps help in finding patterns from a huge volume of data. Maps help us to perform analysis. Maps can be used to enable geographic analysis. GIS maps combine powerful visualization with a strong analytic and modeling framework. Maps can be used to compile data.

Ans. to Q. No. 10: Map projection can be defned as a technique to transform and represent the 3-dimensional earth surface on a flat or plane surface using graticules.

Ans. to Q. No. 11: In Zenithal projection a plane or flat surface is used to project the graticules and this plane surface can be placed at any point on the globe.

Ans. to Q. No. 12: Two properties of Zenithal Equal Area projection includes: Parallels are concentric circles; Preserves equal area properties.

Ans. to Q. No. 13: Two properties of Mercator's projection includes: Preserves true-bearing and Rhumb line can be drawn as straight line showing constant direction.

Ans. to Q. No. 14: Two properties of Bonne's projection includes: Central meridian is a straight line; An equal area projection.

Ans. to Q. No. 15: UTM 46 north zone represents Assam in GIS grid systems with 93Ú meridian as central meridian.

Ans. to Q. No. 16: International Terrestrial Reference Frame (ITRF).



1.15 MODEL QUESTIONS

Q. 1: What is cartography?

Q. 2: Explain the evolution of map making.

Q. 3: Define orthomorphism.

Q. 4: What are the different properties of a map?

Q. 5: What is a general reference map?

Q. 6: Explain the significance of map- making.

*** ***** ***

UNIT 2: INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS (GIS)

UNIT STRUCTURE

2.1 Learning Objectives

2.2 Introduction

2.3 Basic Concepts of GIS

2.4 Components of GIS

2.5 Spatial Data Creation

2.6 Data Types

- 2.6.1 Spatial Data
- 2.6.2 Non-Spatial Data
- 2.6.3 Raster Data
- 2.6.4 Vector Data
- 2.6.5 TIN

2.7 Data Editing and Analysis

2.8 Topological Relationships

2.9 Advantages of GIS

2.10 Social and Institutional Context of GIS

2.11 Contemporary Development of GIS

2.12 Web GIS

2.13 Let Us Sum Up

2.14 Further Readings

2.15 Answers to Check Your Progress

2.16 Model Questions

2.1 LEARNING OBJECTIVES

After going through this unit, you will be able to :

- explain the Geographic Information Systems (GIS)
- identify the components of GIS

- describe the GIS data types
- discuss the editing and analyzing GIS data
- enlighten the topological relationships
- list out the advantages of GIS
- describe the social and institutional context of GIS
- discuss the contemporary development of GIS
- elaborate on the use of web GIS

2.2 INTRODUCTION

In the previous unit, you have learnt about basics of map and map projections. In this unit, we are going to provide you an introductory knowledge of Geographic Information System (GIS). GIS can be considered both as science and technology, a discipline, and an applied problem solving methodology. This unit also provides the basic components and the benefits of GIS. It will also provide you the basics of GIS data types. Data verification, correction, storage and data conversion methods in GIS are also a part of discussion in this unit. Social and institutional context of GIS and contemporary development of GIS are also discussed in this unit. It will also help you to discuss the web GIS and its applications.

2.3 BASIC CONCEPTS OF GIS

Since the late 1960's computers have been used to store and process the geospatial data. The ability of GIS to manage Geospatial data establishes GIS as an important tool for a wide variety of applications. Since the 1970s, GIS has played an important role in the management of natural resources. More recently, GIS has been used for crime analysis, emergency planning, land records management and updates, marketing analysis, and transportation planning. Now-a-days, many of us use GIS technology on a daily basis even though we may not be aware of it. For instance, we go online to search the name of a restaurant and download a map and directions to get there, we use in vehicle navigation system to get

the shortest route and driving directions to reach our destination. All of these activities involve GIS technology, a technology that can handle a location and attribute data of spatial features. Therefore, now-a-days GIS is no longer for specialists. But the popularity of GIS has also created situations in which misuse or misinterpretation of data and results can easily take place. Therefore, to use GIS properly, we must be familiar with the technology, as well as, the basic concepts that drive the technology.

The Geographic Information System consist of two distinct disciplines, namely, geography and information system. Geography is the scientific study of spatial pattern and process. It seeks to identify and account for the location and distribution of human and physical phenomena on the earth's surface. On the other hand, an information system most often refers to a system containing electronic records, which involves input from the source documents, recording on electronic media, and output of records, along with related documentation and any indexes. A **Geographic Information System** is a computer system for capturing, storing, querying, analyzing and displaying ***geospatial data***. The geospatial data is also referred to as geographically referenced data. The geospatial data are data that describe both the locations and characteristics of spatial features such as roads, land parcels and vegetation stands on the earth's surface.



Spatial data or Geographical data or Geospatial data: It refers to graphic objects in GIS and they are georeferenced with respect to a coordinate system or geocoded (with respect to street number / important landmark)

CHECK YOUR PROGRESS

Q.1: What is GIS?

.....

.....

Q.2: What do you mean by geospatial data?

.....

.....

2.4 COMPONENTS OF GIS

Like any other information technology, GIS requires mainly five components to work with geospatial data.

These components are discussed below:-

Computer Hardware:

The computer system includes the computer (the personnel computer PC) and the operating system (windows or UNIX or Linux) to run GIS. Some additional equipment e.g.; digitizer or scanner for spatial data input, GPS receivers for field work, printers-plotters for hard copy data display may also require.



Fig. 2.1: Components of GIS

GIS Software:

The GIS software provides the functions and tools that are necessary to store, analyze and display geospatial data. Some popular professional GIS software are ArcGIS, MapInfo, Geomatica, TNTmips, and Autodesk Map etc. The open source software are - ILWIS, QGIS and there are many such software.

User:

People refer to GIS professionals and users who define the purpose and objectives and provide the reason and justification for using GIS.

Data:

Data consist of various kinds of inputs that the system takes to produce information.

Methods or Infrastructure or Procedure:

Besides the technical components, institutional framework and policies are also important to support GIS operations.



CHECK YOUR PROGRESS

Q.3: What are the main components of GIS?

.....

.....

Q.4: Name a few common GIS software.

.....

2.5 SPATIAL DATA CREATION

Maps, Topographical sheets, Aerial photographs, Satellite imagery, GPS survey data etc. are the main sources of spatial data in GIS. In GIS, the spatial data are created using the process of on-screen digitization for extracting earth features from base map data using three preliminary forms of geometries such as point, line and polygon. A point geometrical entity (a point has zero dimension) is used to represent the location and occurrence of the digitized features on the map, e.g., location of places, location of hospitals, location of schools, etc. A line geometrical entity (a line has one-dimension, i.e., length) is used to represent the location, existence and extent of the digitized features on the map, e.g., roads, rivers, railway networks etc. A polygon geometrical entity (a polygon has two-dimension, i.e., area) is used to represent the location, existence, extent and area of the digitized features on the map, e.g., a lake, a district, an agricultural field, etc. In the process of spatial data creation, a vector database in the forms of shapefile, geodatabase etc. is used to extract features from the base maps.

2.6 DATA TYPES

The GIS is a computer-based system that offers capturing, storing, analyzing and displaying geo-spatial data. To understand the term 'Geo-spatial Data' we first have to be aware of what exactly the term 'data' means. In simple term, data are raw form of information which is entered into the computer for processing. The GIS Data is the key component of a GIS. In the GIS, we basically use two types of data. One is the spatial data and the other is Non-spatial data or attribute data.

2.6.1 Spatial Data

Spatial Data is the data that describes the geometry of spatial features. It represents information about the location, size and shape of an object located on the Earth’s surface such as a building, a



2-D Plane: It is also called Euclidean plane or surface with length and breadth of the space.



Discrete or continuous: An individual building is a discrete object. The slope of an area is continuous.

lake, a mountain or a township etc. by numerical values in a geographic coordinate system. In other words, these data are location-based and they have geometric attributes like length, area, perimeter etc. The Spatial data can be obtained from satellite images or scanned maps and similar resources.

Spatial Data is the graphic data on the space that describes the geometry of the spatial features. The important characteristics of spatial data are:

- Spatial data describe the location based (x, y) on a ***2-D plane***
- Spatial data represents the shape and size of Earth's surface features.
- Spatial data can either be ***discrete or continuous***.
- Spatial data can be represented graphically by using various colours, symbols or signs.
- Spatial data can be linked to a desired attribute. The attribute may text, number, colour or symbols/ graphic objects.

2.6.2 Non-Spatial Data

Non-spatial data is the data that describes the characteristics of spatial features. In the GIS, the non-spatial data (often termed as thematic data or attribute data) are linked with the spatial data or the Geometric data. The Attribute data is information appended in tabular format to spatial features. Some popular sources to gather attribute data are the town planning and management departments, fire departments, etc. Thus, in short, the spatial data describes the location (where) and the non-spatial data specifies characteristics at that location (what, how much and when).

Consider the example of the National Highways shown on the Google Earth map. In order to describe the NH-31 or NH-37 or NH-40, we will refer to its location i.e. where it is and its characteristics (e.g. length, name, speed limit and direction) as shown on the image. The location also called geometry or shape

represents the **spatial data**, whereas the characteristics are the **attribute or non-spatial data**. Thus, geo-spatial data describes both the locations and characteristics of spatial features on the Earth's surface.



Fig. 2.2: Example of Google Earth Map

2.6.3 Raster Data

There are two methods namely **raster** and **vector** used to reduce geographic phenomena to forms that can be coded in computer databases. In principle, both can be used to code both fields and discrete objects, but in practice there is a strong association between raster and fields, and between vector and discrete objects. Raster and vector are two methods of representing geographic data in digital computers. The two data structures of the GIS are given below.

Raster Data:

In a raster representation, space is divided into an array of rectangular (usually square) cells. All geographic variations are then expressed by assigning properties or attributes to these cells.

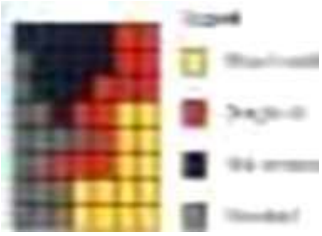


Fig. 2.3: Raster Data

The cells are also called as pixels (short for picture elements). Raster representations divide the world into arrays of cells and assign attributes to the cells.

Raster data is very useful as they are:

- Simple data structure.
- Easy and efficient overlying
- Compatible with remote sensing imagery.
- High spatial variability is efficiently represented.
- Efficient to represent continuous data.

2.6.4 Vector Data

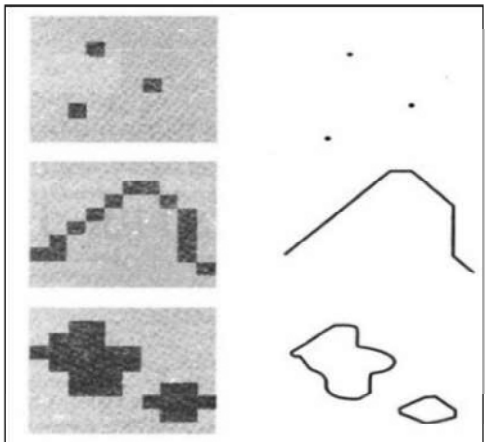


Fig. 2.4: Representation of point, line and area features: raster format on the left and vector format on the eight

The vector representation of an object is an attempt to represent the object as exactly as possible. The coordinate space is assumed to be continuous, not quantized as with the raster space, allowing all positions, lengths and dimensions to be defined precisely. Vectors are graphical objects that have geometrical primitives such as points, line and polygons to represent geographical entities in computer graphics. Vector data has well defined geometry and these are geometric objects of space. Vector data have a precise direction, length and shape and can be defined by co- ordinate geometry. As shown in the figure, a point is described by a single x-y coordinate pair and by its name or label. A line is described by an infinite number of points. An area, also called a polygon, is described by a set of coordinate pairs and by its name or label. Vector data is very useful as they are:

- Smaller file size
- Individual identity for discrete objects like line, polygon etc.
- Efficient to show topological relationship
- Efficient for projection transformation
- Accurate map output provider
- Easy to edit.

In short, the raster data structure represents geography via grid cells and the vector data structure represents geography via coordinates.

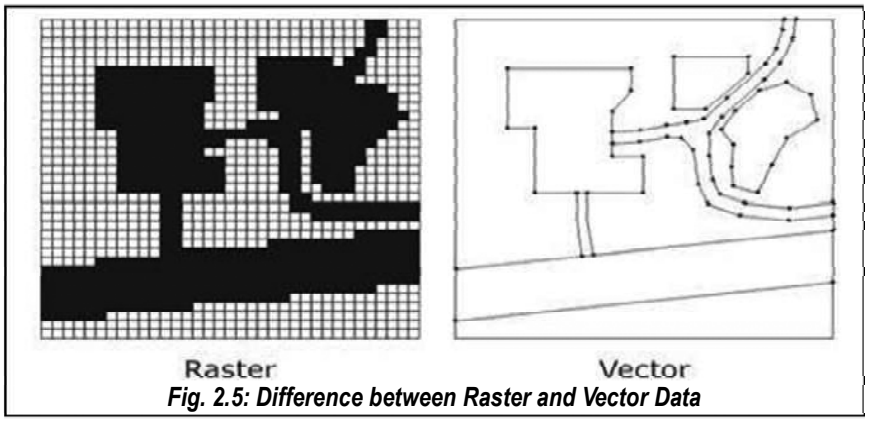


Fig. 2.5: Difference between Raster and Vector Data

2.6.5 TIN

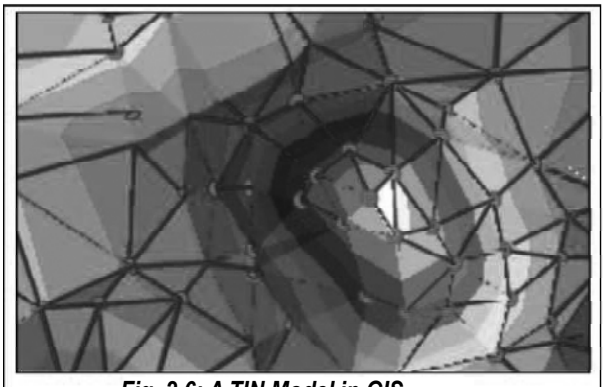


Fig. 2.6: A TIN Model in GIS

The TIN refers to the *Triangulated Irregular Network*. The TIN is a GIS data model and it belongs to the category of vector data. The TIN is a 3-dimensional data representation model in a GIS that depicts elevation, surface morphology etc. with *x, y* and *z* coordinates where *z* shows height of the ground. The TIN visualizes the 3-dimensional surface with a network of irregular triangles with vertices, edges and faces. Vertices

are mass points of the triangles with angular values. Edges are the sides or lines of the triangles and faces represent the area of the triangles. The TIN is a vector- based model for terrain representation, and from a TIN other terrain models like DEM, DSM, DTM can be generated. Each node of a TIN contains the elevation (i.e. z-coordinate).



CHECK YOUR PROGRESS

Q.5: What is raster data?

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Q.6: What is vector data?

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Q.7: What is a TIN?

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2.7 DATA EDITING AND ANALYSIS

Data Editing or Spatial Data Editing in GIS refers to the process of adding, deleting and modifying features in digital layers. A major part of spatial data editing is removing digitizing errors. Newly digitized maps, no matter how carefully prepared, always have some errors. There are basically two types of digitizing errors:

- **Location Error:** It refers to the geometric inaccuracies of digitized features. We can examine location errors by referring to the data source used for digitizing.
- **Topological Error:** To correct topological errors, we must first learn about the topological relationships and then use a topology-based

GIS package to help us to make corrections. However, many GIS software allows us to identify and remove the errors automatically. This process includes the major actions shown in the table.

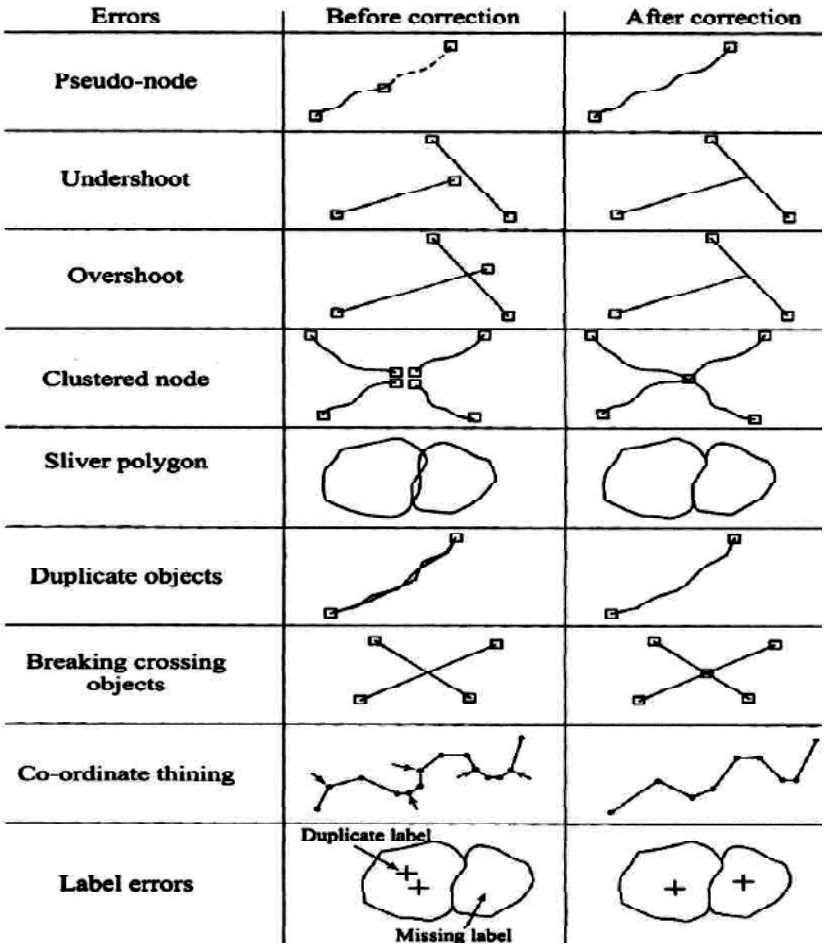


Fig. 2.7: Data Enditing Errors in GIS

2.8 TOPOLOGICAL RELATIONSHIPS

Topology is the study of those properties of geometric objects that remain invariant under certain transformations such as, bending or stretching (Massey 1967). Topology-based data sets require additional data files to store the spatial relationship between features. The topology has two main advantages–

- The first advantage is the assurance of data quality. The Topological relationships enable us to detect errors such as lines that do not meet correctly or polygons that are not closed properly.

- Secondly, the topology can enhance a GIS analysis.

  Only topological data will allow various operations and functions like union, intersections, network analysis etc.

  The coverage model enforces three topological relationships with its data structure. Rules that apply to features within a feature class are functionally similar to the build-up in topology for the coverage model. Some topology rules applied in data model are:

- **Polygon:** Polygon must not be overlapped, must not have any gaps, must be covered by feature class of, must cover each other, must be covered by, boundary must be covered by, area boundary must be covered by boundary of, and contains points.

- **Line:** Line must not overlap, must not intersect, must not have pseudo-nodes, must not intersect or touch interior, must not overlap with, must be covered by feature class of, must be covered by boundary of, end point must be covered by, must not self-overlap, must not self-intersect, and must be single part.

- **Point:** Point must be covered by boundary of, must properly be inside polygons, must be covered by end point of, and must be covered by line.

  There are mainly three types of topological relationships (ESRI, Inc. 1998):

- **Connectivity:** Arcs connect to each other at nodes.

- **Area definition:** An area is defined by a series of connected arcs.

- **Contiguity:** Arcs have directions as well as, left and right polygons.

Apart from the types, name of some data models used in the GIS are–

DATA MODEL	TYPE	EXAMPLES IN APPLICATIONS
CAD	Vector	Engineering design and drafting
Graphical	Vector	Simple mapping
Image	Raster	Image processing and grid analysis
Raster/Grid	Raster	Spatial analysis and modelling
Network	Vector	Network analysis
Geo-relational	Vector	Geoprocessing geometric features
TIN	Vector	Surface / terrain analysis / modelling
Object	Vector	Features with behaviour



CHECK YOUR PROGRESS

Q.8: What is topology?

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2.9 ADVANTAGES OF GIS

There are various advantages of GIS, some of which are interrelated. The following sections describe the advantages of GIS in considering different issues.

Advantage over Traditional Map:

- GIS can take maps from different sources and register them easily and is consistent in its analysis of multiple layers of map data.
- GIS is faster than manual methods of analysis, allowing the flexibility to try alternate variables in analysis.
- A common problem with traditional paper map is the loss of paper, misplacement or being misfiled. But, GIS is a central computer database of all map data stored in different data layers and can be accessed by any number of users within the network.
- In GIS, the map products can then be created centered on any location, at any scale, and showing selected information symbolized effectively to highlight specific characteristics such as a river or a hill.
- Revision of traditional maps requires extensive work and time, where digital maps in GIS can be manipulated and revised easily in less time.

Advantage over mapping software:

- Apart from GIS, several software also being used for a long time to generate digital maps. But, GIS is much more than conventional mapping software, in fact it is a combination of maps and database.



Computer Aided Drawing: It is software used in art, architecture, engineering and manufacturing to assist in precision drawing.



Topological data model: Set of objects and object data that defines the linkage and relationship between the objects.



Attribute Data: It is the type of data that represents the descriptive information of spatial objects.

Advantage over Computer Aided Drawing(CAD):

- For a long period of time, ***Computer Aided Drawing*** was used to produce maps. It is an effective replacement for the traditional manual. Some CAD software can create, display, and print georeferenced data just like a GIS software package, but due to the lack of ***topological data model***, spatial analyses cannot be performed. GIS is intended not only as a drawing tool. GIS allows the user to take information and associate it with a representation of a geographic object which exists in a commonly recognised co-ordinate system and projection and place it exactly upon a map of the earth in a universally-recognised way. People who draw maps with CAD without the benefit of GIS knowledge tend not to go beyond the simple act of line drawing.

Advantage over Conventional Database Management System(DBMS):

- GIS can be used more efficiently with the help of spatial and textual data rather than a traditional information system. GIS software is designed to permit the querying of both spatial and ***attribute data*** in a common denominator.

Advantage over Analysis,Modeling,Presentation and Decision Making:

- The GIS integrates spatial and other kinds of information within a single system. It offers a consistent framework for analyzing geographical data by placing maps and other kinds of spatial information into digital form.
- GIS allows the overlaying of data layers from different sources to produce user-defined maps that contain features desired by the user.
- Rather than other traditional methods, GIS can be use in simulation modelling.

  GIS can be very important tool in decision making for sustainable development.



CHECK YOUR PROGRESS

Q.9: State whether true or false :

i) GIS is faster than manual methods of analysis.

ii) GIS can be accessed by limited number of users.

iii) GIS is a combination of maps and database.

iv) GIS can be used more efficiently with the help of spatial and textual data rather than a traditional information system.

v) GIS allows the overlaying of data layers from the same source to produce user-defined maps..

2.10 SOCIAL AND INSTITUTIONAL CONTEXT OF GIS

GIS is a system of integrated computer-based tools for end-to-end processing (capture, storage, retrieval, analysis, display) of data using location on the earth's surface for interrelation in support of operations management, decision making, and science. GIS make possible the automation of activities involving geospatial data.

It allows for the integration of data update confined to independent domains. By tying up data with maps, GIS permits the succinct communication of complex spatial patterns**.** Apart from that, GIS provides answers to spatial queries and perform complex spatial modelling**.** GIS even plays an important role in social and institutional aspects that it allows.

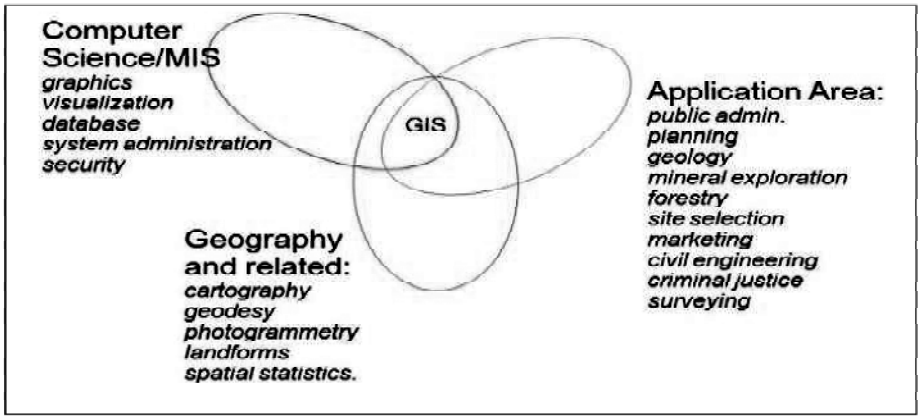


Fig. 2.7: Example of applications of GIS

The GIS applications are uses by all levels users such as indigenous people, communities, research institutions, environmental scientists, health organizations, land use planners, businesses, and government agencies etc. The major categories of application of GIS and the examples are provided below.

1. Local Government use the GIS for the following purposes:
   a. Public or infrastructure management for roads, water, sewer etc.
   b. Utilities and communications such as Electric, Gas, Location-Based Services, Telecommunications, Water / Wastewater.
   c. Urban Planning, Management and Policy. Example: Zoning, subdivision planning, Land acquisition, Economic development, Code enforcement, Housing renovation programs, Emergency response, Crime analysis, Tax assessment.
   d. Education. Example- Geography, Geology, Forestry, Meteorology, Oceanography, History, Civil Engineering, Environmental studies etc.
   e. Agriculture: Example-crop type classification, condition assessment, crop yield estimation, compliance monitoring, Irrigation etc.
   f. Business. Example: demographic analysis, market penetration / Share analysis, etc.
2. Real Estate and marketing user uses GIS for site selection, site evaluation, Traffic Impact Analysis, etc.
3. Public safety and defense user uses GIS for crime analysis, fire prevention, emergency management, military/defense etc.
4. Natural resource and Environmental monitoring user use for exploration / extraction of Petroleum, minerals, protection of wildlife habitat, urban expansion / encroachment, identification of landing

strips, roads, clearings, bridges, and land / water interface, and in natural hazard management such as earthquake, drought, fire, flood and cyclones, landslide and soil erosion, volcano etc.

5. The user in transportation department uses airline route planning, transportation planning / modelling etc.

6. The user in Health Management uses GIS for management of health systems, health centers, beds in hospitals, epidemiology, needs analysis, Service Inventory etc.

7. The user in the Geospatial Industry uses GIS for Data development, application development, programming etc.



CHECK YOUR PROGRESS

Q.10: State True or False:

I. GIS can take maps from different sources and register them.

II. GIS can't provide answers to spatial queries and perform complex spatial modeling.

III. GIS is very useful for Bedrock mapping and Lithological mapping.

IV. CAD stands for Computer Aided Diagram.

V. GIS can be very important tool in decision making for sustainable development.

VI. Revision of traditional map requires less work and time.

2.11 CONTEMPORARY DEVELOPMENT OF GIS

The contemporary development of GIS as a popular geospatial tool mainly started after 1960's when Roger Tomlinson developed Canadian Geographical Information System for Canadian Land inventory mapping. During the same period GIS developed as a modern tool rooted in Computer Assisted Cartography (CAC), Computer Assisted Mapping (CAM) that were taught in different Universities in North America and Europe. In the year 1969 the Environmental System Research Institute (ESRI) was founded in California, USA that introduced ArcGIS software for GIS mapping and

applications. This contribution of ESRI triggered sound popularization of GIS among the users community. Currently, ESRI's ArcGIS has a share of around 50 percent in global GIS market. The Integrated Land and Water Information System (ILWIS) GIS software was developed by International Institute for Geo-Information Science and Earth Observation (ITC) located in the Netherlands in the year 2002. In the same year another popular GIS software, i. e. Quantum GIS was initially released as the first free and open-source GIS software under an open-source license agreement. Now, QGIS evolved as a most widely used open-source GIS software for various GIS applications by the GIS community, and QGIS is available in about 48 languages worldwide. Presently in the earlier part of the 21st century, GIS has been developing as an integrated tool for geospatial analysis in different fields of applications. Introduction of Google Earth software also added a foundation growth in GIS. With the progress of global geo-spatial infrastructure, GIS is evolving day by day right from the Desktop GIS to Web GIS, Cloud GIS and Mobile GIS. Very recently, the relevant concepts of Machine Learning & Artificial Intelligence are also being applied in GIS

Fundamentals of GIS 73 applications. In India, Indian Space Research Organization (ISRO) of Government of India is the key agency that is developing and popularizing GIS and its applications through Indian Institute of Remote Sensing (IIRS) located in Dehradun, National Remote Sensing Centre located in Hyderabad, North East Space Application Centre (NESAC) located in Umium. The Space Application Centre (SAC under ISRO), Ahmadabad during 2009 developed a commercial Indian made GIS software called Integrated Geographic Information System (IGIS) through Government-Private partnership. Every year the ESRI is organizing ESRI User Conference worldwide for popularizing their commercial ArcGIS software and also for demonstration, discussion for current and future progress of GIS. Similarly, The Open Source Geospatial Foundation (OSGeo) is organizing OSGeo conference every year worldwide for diverse discussions on GIS applications based on open source GIS software as well as for detail framework discussions on the progress, challenges and future of GIS.



CHECK YOUR PROGRESS

Q.11: What is the full form of ILWIS?

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.....

2.12 WEB GIS

Web-GIS is a web-based platform that offers the ability to access, analyze, and share geospatial data in real-time over the internet. This platform integrates web-based technologies with GIS functionalities to create a user-friendly interface for creating, analyzing, and sharing geospatial information. It has become increasingly popular across various sectors including urban planning, transportation, disaster management, public health, and environmental management. A typical Web-GIS application comprises a client-side application that operates within a web browser, and a server-side application that manages data and provides GIS services. The client-side application allows users to interact with the data and perform GIS functions such as data visualization, query, and analysis. The server-side application provides data and performs GIS functions on the server. Developers can use a range of programming languages and GIS software platforms to develop Web-GIS applications, such as JavaScript, HTML, CSS, ArcGIS Online, OpenLayers, and Google Maps API. Web-GIS is highly accessible, enabling users to access geospatial data from anywhere in the world as long as they have an internet connection. It provides a real-time view of data, which is especially useful in emergency management situations. Web-GIS platforms are varied, and examples include ArcGIS Online, MangoMap, ISRO's Bhuvan portal, John Hopkins University's Covid portal, MapmyIndia, among others. Overall, Web-GIS is an effective tool for managing, analyzing, and sharing geospatial information across different industries.



2.13 LET US SUM UP

- A Geographic Information System is a computer system for capturing, storing, querying, analyzing and displaying geospatial data.
- To use GIS properly, we must be familiar with the technology, as well as, the basic concepts that drive the technology.
- GIS requires four components namely; Computer System, Software, User Data and procedure to work with geospatial data.
- GIS is faster than manual methods of analysis, allowing the flexibility of trying alternate variables in analysis.
- Raster and vector data are two main GIS data types for representing geographic data.
- The GIS integrates spatial and other kinds of information within a single system.
- GIS even play a very important role in both social and institutional aspects.
- The current development of GIS goes through web-based and mobile-based GIS.



2.14 FURTHER READING

1. *Geographic Information Systems and Science* by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind.
2. *Introduction to Geographic Information System* by Kang- Tsung Chang.
3. *Remote Sensing and GIS* by Basudeb Bhatta.
4. *Remote Sensing and Geographical System* by Anil K. Jamwal.
5. Related reading material of the National Programme on Technology Enhanced Learning (NPTEL). Example http:// nptel.ac.in/courses/ 105102015/http://nptel.ac.in/courses/105102015/39



2.15 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: A Geographic Information System is a computer system for capturing, storing, querying, analyzing and displaying geospatial data.

Ans. to Q. No. 2: The geospatial data are data that describes both the locations and characteristics of spatial features such as; roads, land parcels and vegetation stands on the earth surface.

Ans. to Q. No. 3: The main components of GIS are computer system, GIS software, user and data.

Ans. to Q. No. 4: Some common GIS software's are Arc GIS, MapInfo, QGIS, Geomatica, TNTmips, and Autodesk Map.

Ans. to Q. No. 5: In a raster representation space is divided into an array of rectangular (usually square) cells. All geographic variation is then expressed by assigning properties or attributes to these cells.

Ans. to Q. No. 6: Vector data has a precise direction, length and shape and can be defined by co-ordinate geometry.

Ans. to Q. No. 7: TIN is a 3-dimensional data representation model in a GIS that depicts elevation, surface morphology etc. In a GIS it is with x, y & z co-ordinates where z shows height of the ground.

Ans. to Q. No. 8: Topology is the study of those properties of geometric objects that remain invariant under certain transformations such as, bending or stretching.

Ans. to Q. No. 9:

i. True

ii. False

iii. True

iv. True

v. False

Ans. to Q. No. 10:

i. True

ii. False

iii. True

iv. False

v. True

vi. False

Ans. to Q. No. 11: The full form of ILWIS is Integrated Land and Water Information System.



2.16 MODEL QUESTIONS

Q. 1: Write a brief note on GIS in your own words.

Q. 2: How the components of GIS are interrelated to each other. Explain with a suitable diagram.

Q. 3: Mention useful properties of raster data and vector data?

Q. 4: Give a brief description about the advantages of GIS in different sections.

Q. 5: How is GIS useful in social and infrastructural context? Explain.

Q. 6: Write about the contemporary development of GIS.

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UNIT 3: INTRODUCTION TO GLOBAL NAVIGATION SATELLITE SYSTEM

UNIT STRUCTURE

3.1 Learning Objectives

3.2 Introduction

3.3 Basic Concept of GNSS

3.4 Historical development of GNSS

3.5 Segments of GPS

3.6 Basic Working Principles of GNSS

- 3.6.1. Time and Ranging
- 3.6.2. Calculating Location

3.7 GNSS Applications

- 3.7.1 Asset Mapping
- 3.7.2 Navigation Services
- 3.7.3 Location Based Services

3.8 Let Us Sum Up

3.9 Further Reading

3.10 Answers to Check Your Progress

3.11 Model Questions

3.1 LEARNING OBJECTIVES

After going through this unit, you will be able to :

- explain the basic concept of GNSS
- describe the historical development of GNSS
- identify the segments of GPS
- discuss the working principles of GNSS
- explain the various applications of GNSS

3.2 INTRODUCTION

In this unit, we are going to discuss the basics of GNSS, historical development of GNSS, different segments of GPS and basic working principles of GNSS. In this unit also we are going to discuss applications of

GNSS in assets mapping , Navigation services including location based services.

3.3 BASIC CONCEPT OF GNSS

The global navigation satellite system (GNSS) is the standard generic term for satellite-based navigation systems that provide autonomous geospatial positioning with global coverage. The GNSS is a network of satellites that continuously transmits coded information, which makes it possible to precisely identify locations on the earth by measuring the distance from the satellite. Among currently used GNSSs, the USA-invented Global Positioning System (GPS) is the best known. The Global Positioning System (GPS) is a satellite-based radio-navigation system established by the U.S. Department of Defence for military positioning applications and has been made available to the civilian community as well as a by-product. Navigation, surveying and integration with Geographic Information System (GIS) are a few of the fields which have seen the successful application of GPS technology.

Using the GPS following two values can be determined anywhere on the earth.

- One's exact location (longitude, latitude and height co-ordinates) accurate within a range of 20m to approx. to 1mm.
- The precise time also referred to as Universal Time Coordinated, (UTC) accurate within a range of 60ns to approx. 5ns (1ns = 1 nano-seconds = 10-9 second, that one billionth of a second). The speed and direction of travel (course) can be derived from the coordinates, as well as, the time. The co-ordinates and time values are determined by these 28 satellites orbiting the earth.

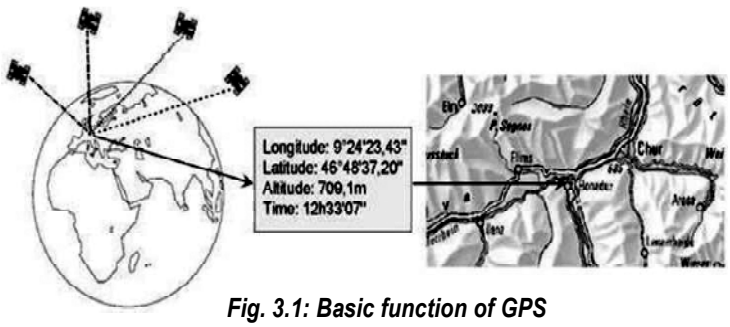


Fig. 3.1: Basic function of GPS



CHECK YOUR PROGRESS

Q.1: State True or False

a) The GPS is an active system.

b) Initially, the GPS was developed to fulfil military needs.

c) UTC stands for Universal Time Co-ordinates.

d) The co-ordinates and time values are determined by 20 satellites orbiting the earth.

e) Using the GPS, time and location can be determined anywhere on the earth.

3.4 HISTORICAL DEVELOPMENT OF GNSS

Global Navigation Satellite System (GNSS) which was developed for the first time by US Department of Defense. It is called Navigation Satellite with Time and Ranging (NAVSTAR) Global Positioning System. In brief, it is also called 'NAVSTAR GPS'. This satellite-based navigation system uses a constellation between 24 and 32 orbiting satellites. This satellite are circulating at a distance between 14,000 and 20,000 kms from the earth's surface moving in six orbital paths. These are constantly moving and make two complete orbits around the Earth in only 24 hours which means that the satellites are moving at a speed of 2.6 kilometers per second. The signal being sent to the earth at the speed of light is picked up by any GPS receiver anywhere at any time in the world.

The credit for sowing the seeds of global positioning goes to Ptolemy, an Egyptian in the first century AD. He simply expanded the earlier works of Greeks. But Ptolemy's earliest recorded work on geographical position. Later the Byzantines (belonging to the Eastern Roman Empire) and Arabs did commendable works to carry this knowledge to the modern era. Chinese have also contributed significantly to add to this knowledge.

Ptolemy was the first to describe the position with the help of latitude and longitude. This he did while describing the sphere. Much later in the late 1600's English Mathematician, Sir Isaac Newton speculated that the

earth was not a true sphere as the distance from pole to pole was less than the distance across the equator. This estimation was proved right with further observation. Now it has become a fact and forms the basis for a true global positioning system. Apart from this important finding Newton also created the theory of gravity by simply observing the apple falling from a tree. This theory of gravity became the basis of a number of inventions. In GPS, too, the movement of the orbiting satellites is based on the theory of gravity. Launching of the first Sputnik and subsequent satellites proved to be an important step forward in the historical development of global positioning system. Scientists noticed that the path of each satellite varied due to the effects of gravity. From these observations, the centre of the mass of the earth was determined reasonably and is accepted worldwide in the definition described as the World Geodetic System, 1984 or WGS84. Now this along with a radius and the flattening factor for the squashed polar axis is the datum of our modern global positioning system.

The contribution of Marconi who did commendable work in understanding the radio waves of electromagnetic energy cannot be ignored. Using Marconi's findings regarding radio energy, radio stations were established in 1920's. Significant advancement were made in radio technology during and after the second World War. As the need for communication increased with the launching of early satellites and rockets, it resulted in even more advanced system of radio technology. To receive the radio signals, the receivers were required. These receivers are called radio sets. The same technology is applied for the GPS in which we need a rather special radio receiver. It is really quite surprising to receive radio signals in a small hand-held radio receiver sets from about 20,000 kms away.

Prior to the launching of the series of NAVSTAR satellites, the first navigation satellite used by US Navy was successfully tested in the year 1960. Thereafter the launching of the series of NAVSTAR satellite began. The first GPS satellite NAVSTAR-1 was launched on February 22, 1978. It was operated by the 50th Space wing of the United States Air Force. It was launched chiefly for the purpose of meeting the U.S. defense needs.

Many countries of the world have now started developing their own GPS system. This is because of the US Govt. Policy according to which the access to the GPS system of the country may be given or denied selectively. Later the first country which joined this field after U.S. was Russia. The Russian Global Navigation Satellite System (GLONASS) came into existence but it could not provide complete coverage of the globe till mid-2000s. After Russia, China has also joined this field under the name BeiDou Navigation Satellite System (BNSS) and is most likely to achieve global coverage in 2020. In Europe, the GPS system has been developed bearing the name European Union Galileo Positioning System (EUGPS). India joined this field in the year 2013 and is also known as NAVIC (Navigation with Indian Constellation). In Japan, Quasi-Zenith Satellite System (QZSS) commenced in November 2018. Many more countries are planning to develop their own GPS facilities in the years to come.



CHECK YOUR PROGRESS

Q.2: What is the full form of GNSS?

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Q.3: Define Selective Availability.

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Q.3: What is NAVIC?

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Q.4: Define GLONASS.

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3.5 SEGMENTS OF GPS

The GPS uses radio transmissions and its signals are sent to the receiver. The satellites transmit timing information and satellite location

information. As given in Figure 3.2 a typical GPS is a satellite-based navigation system that consists of three segments:

(1) Space segment, (2) Control segment and (3) User segment.

1. Space segment:

The space segment consists of the 24-satellite constellation at an altitude of 20,200 km and with a period of 12 hours. They are about the size of a car. Each GPS satellite transmits a signal, which has a number of components namely two sine waves (carrier frequencies), two digital codes, and a navigation message. The codes and the navigation message are added to the carriers as binary bi-phase modulations. The main uses of the carriers and the codes are to determine the distance from the user's receiver to the GPS satellites.

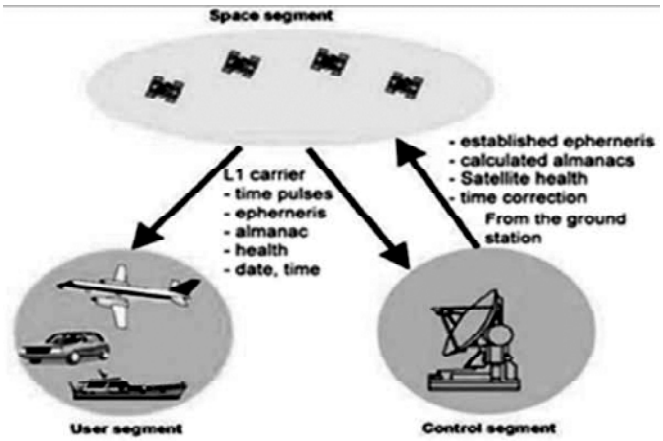


Fig. 3.2: Segment of GPS

2. Control Segment:

The control segment consists of a worldwide network of tracking stations. Its Master Control Station (MCS) is located in Springs, Colorado, USA. The task of the control segment is to track the GPS satellites in order to determine and predict satellite locations, system integrity and behaviour of the satellite atomic clocks, atmospheric data, the satellite almanac, and other considerations. Such information is then packed and uploaded into the GPS satellites through the S-band link.

Master Station

- Colorado Springs

Monitor Stations

- Diego Garcia
- Ascension Island
- Kwajalein
- Hawaii
- Colorado Springs



Fig. 3.3: Controll Segment Locations

3. User Segment:

The user segment includes users from military and civilian communities. With a GPS receiver connected to a GPS antenna, a user can receive GPS signals, which can be used to determine his or her position anywhere in the world. The receiver is usually used in conjunction with computer software to output the information to the user in the form of a map. The GPS is available to all users worldwide without any direct charge. The user can download locational information for events and later they can add the attributes for the events to do the spatial analysis of various attributed data.



CHECK YOUR PROGRESS

Q.6: State True or False:

i. A GPS consists of four segments.

ii. The space segment consists of the 24-satellite constellation at an altitude of 20,200 m.

iii. The control segment packed and upload information into the GPS satellites through the S-band link.

iv. Colorado Springs is a Monitor Station.

v. The user segment includes all military and civilian users.

3.6 BASIC WORKING PRINCIPLES OF GNSS

When the GPS receiver starts its job, it should have information about where the satellites are and how far away, they are. The GPS receiver knows where the satellites are located in space. The GPS receiver picks up two kinds of coded information from the satellites, **almanac** and **ephemeris**. *Almanac* data is a course orbital model (approximate positions for a given time) for all satellites. Each satellite broadcasts almanac data for all satellites. This almanac data is not very precise and is considered as valid for up to several hours. This data is continuously transmitted and stored in the memory of the GPS receiver so that it knows the orbits of the satellites and where each satellite is supposed to be. The almanac data is periodically updated with new information as the satellites move around.

Ephemeris is a very precise orbital and clock correction for each satellite and is necessary for precise positioning. Any satellite can travel slightly out of orbit, so the ground monitor stations keep track of the satellite orbits, altitude, location and speed. The ground stations send the monitored orbital data to the master control station, which in turn sends corrected orbital data and clock corrections up to the satellites. This corrected and exact position data is called the 'ephemeris' data, which is transmitted as coded information to the GPS receiver. Each satellite broadcasts only its own ephemeris data. Subsets of ephemeris data are broadcast by each satellite continuously, which remain valid for the orbit for a few minutes.

The unit stores data about where the satellites are located at any given time. This data is called the almanac. On the ground, all GPS receivers have an almanac programmed into their computers that tells them where in the sky each satellite is moment by moment. This data helps the receiver

to track the satellites faster. Ephemeris data is required to know the exact positions of each visible satellite and clock errors for precise calculation of the receiver's location.

Therefore, having received the almanac and ephemeris data, the GPS receiver knows the precise positions of the satellites at all times.

3.6.1 Time and Ranging

The GPS receiver knows the precise location of the satellites in space, it still needs to know how far away the satellites are, so it can be determined its position on the earth. There is a simple formula that tells the receiver how far it is from each satellite:

The distance from a given satellite object equals the velocity of the transmitted signal multiplied by the time taken by the signal to reach us (velocity x travel time = distance).

GPS works on the principle called the *time of arrival*. We noticed that during a thunderstorm, we heard the sound sometime after we saw the light. The reason is that sound waves travel much slower than light waves. We can estimate our distance to the storm by measuring the delay between the time that we see the thunder and the time that we hear it. Multiplying this time delay by the speed of sound gives us our distance from the storm. Sound travels about 344m per second in air. So if it takes 2s between the time that we see the lightning and the time we hear it, our distance to the storm is 2 x 344 = 688m. We can calculate the distance to an object by measuring the time that it takes for its signal to reach us.

Using the same basic formula to determine distance, the receiver already knows the velocity. It is the speed of a radio wave-186,000 miles (3×10^8 m) per second (the speed of light), less any delay as the signal travels through the earth's atmosphere.

Now the GPS receiver needs to determine the time part of the formula. The answer lies in the coded signals the satellites transmit. The transmitted code is called 'pseudorandom code' (PRC) because it looks like a noise signal. The PRC is a fundamental part of GPS.

Physically, it is just a very complicated digital code. The signal is so complicated that it almost looks like random electrical noise and hence the name is 'pseudo-random'. When the satellite generates the PRC, the GPS receiver simultaneously generates the same code and tries to match it up to the satellite's code. The receiver then compares the two codes to determine how much it needs to delay its code to match the satellite code. This delay time is multiplied by the speed of light to get the distances.

Our GPS receiver clock does not keep the time precisely as the satellite clocks. Putting an atomic clock in our GPS receiver would make it much larger and far more expensive. Therefore, each distance measurement needs to be corrected to account for the GPS receiver's internal clock error. For this reason, the range measurement is referred to as a 'pseudo-range'. To determine position using pseudo-range data, a minimum of four satellites must be tracked and the four fixes must be recomputed until the clock error disappears.

3.6.2 Calculating Location

The basis of GPS is 'triangulation' from satellites. To 'triangulate', a GPS receiver measures distance using the travel time of radio signals. To measure travel time, GPS needs very accurate timing, which is achieved through some tricks. Along with distance, we need to know exactly where the satellites are in space.

Suppose we measure our distance from a satellite and find it to be 20,000 km. Knowing that we are 20,000 km from a particular satellite narrows down all the possible locations we could be in the whole universe to the surface of a sphere that is centred on this satellite and has a radius of 20,000 km. Next, we measure our distance to a second satellite and find out that it is 21,000 km away. This conveys that we are not only on the first sphere but we are also on a sphere that is 21,000 km from the second satellite. If we then make a measurement from a third satellite and find that we are 22,000 km from that one, which narrows our position down even further, to the

two points where the 22,000 km sphere cuts through the circle that is the intersection of the first two spheres. So by ranging from three satellites we can narrow our position to just two points in space.

Even though there are two possible positions, they differ greatly in latitude and longitude position and altitude. By adding a fourth satellite, the receiver can determine our three-dimensional position (latitude, longitude, altitude). Let us say our distance from a fourth satellite is 21,000 km. We now have a fourth sphere intersecting the first three spheres at one common point. But usually one of the two points is a ridiculous answer and can be rejected without a measurement, though, a fourth satellite gives us more accurate positional information.



CHECK YOUR PROGRESS

Q.7: What do you mean by almanac and ephemeris data?.

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Q.8: What is pseudorandom code.

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3.7 GNSS APPLICATIONS

The GNSS has a variety of applications on land, sea and in the air. Basically, GNSS allows us to record or create locations from places on the earth and helps us navigate to and from those spots. GNSS can be used everywhere except where it is impossible to receive the signal such as inside buildings, in caves, parking garages and other subterranean locations and underwater. A vital role of GNSS is to help in navigation and positioning of remote sensing satellite. The original motivation for satellite navigation was for military applications. Currently, GNSS guided missiles are being used in wars.

The GNSS technology has matured into a resource that goes far beyond its original design goals. Nowadays scientists, sportsmen, farmers, soldiers, pilots, surveyors, hikers, delivery drivers, sailors, dispatchers, lumberjacks, fire-fighters and people from many other walks of life are using GNSS in ways that make their work more productive, safer and sometimes even easier. Experts say that within 10-15 years all cellular phones, watches and car stereos will have receivers for GNSS satellite signals.

There are several real-world applications of GNSS, these applications are:

3.7.1 Asset Mapping

GNSS helps us to determine the precise locations of every important assets on the earth surface starts from location of tube well, well and other water sources. Helps in identifying the exact location of petrol pump, ATM, location of transformers and many more. Accuracy assessment of land use land cover map can be done properly with GPS. Identification of proper location of medical centres, tourism spots and their distances can be easily determine with the help of GPS. For agicultural sector also identification of water source, crop damage locations, location of bore well GPS technology is very useful.

3.7.2 Navigation Services

GNSS helps us to determine exactly where we are, but sometimes it is important to know how to get elsewhere. GNSS was originally designed to provide navigation information for ships and planes. Therefore, this technology is appropriate for navigation on water and also very useful in the air and on the land.

One of the most difficult tasks for soldiers in the unknown enemy territory is to navigate the unfamiliar areas. It becomes really challenging when they have to navigate in the dark. The GPS plays an important role in giving the soldiers their precise location with respect to the surroundings. Advanced GPS receivers are used by

specialized forces with crack teams to achieve goals and diffuse enemy installations. Navigation supports major application for military peoples.

3.7.3 Location Based Services

The first and most obvious application of GNSS is the simple determination of a position or location. GNSS is the first positioning system to offer highly precise location data for any point on the planet, in any weather. This alone would be sufficient to qualify it as a major utility. In a military usage before declaring a target hostile and engaged by various weapon systems, it needs to be tracked for suspicious activities. These modern weapon systems of missiles and smart bombs are fed with the tracking data as input. The GPS based tracking system on mobile that provides up-to-date data with radio link & high computer technology enabling highly accurate and real time position information system on the basis of various objects. The GPS always proves very worth in case of rescue and emergency response services. Emergency response team members can make the benefits of the GPS for reducing response time, by determining the location of a casualty during operations.



CHECK YOUR PROGRESS

Q.9: Mention some applications of GNSS.

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3.8 LET US SUM UP

- The Global Positioning System (GPS) is a space-based navigation system developed by the US military in the early 90s.
- A GPS provides longitude, latitude, altitude and time information to the user.

- A control segment of the GPS consists of a worldwide network of tracking stations, having a master control station (MCS) located in Colorado Springs, the USA.
- Global Navigation Satellite System (GNSS) which was developed for the first time by US Department of Defense. It is called Navigation Satellite with Time and Ranging (NAVSTAR) Global Positioning System.
- In absolute positioning GPS involves one GPS receiver and at least four satellites visible at the receiver.
- The GPS receiver is kept at the point for which the coordinates are to be found. These coordinates are calculated with the help of signals received from the satellites.
- GNSS applications are widely in aviation, marine, farming, science, surveying, military, security, search and rescue, cellular telephones and geofencing.



3.9 FURTHER READING

1. Concepts of Cartography Remote Sensing and GIS - K.K. Maltiar and S.R.Maltiar.
2. GAGAN - The Indian Satellite-based augmentation system - K N Suryanarayana Rao.
3. INTRODUCTION TO GPS THE GLOBAL POSITIONING SYSTEM - Ahmed EL-Robbery.
4. Remote sensing and GIS - B.Bhatta



3.10 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: a) False b) True c) True d) False e) True

Ans. to Q. No. 2: GNSS stands for Global Navigation Satellite Systems.

Ans. to Q. No. 3: Selective Availability (SA) was an intentional degradation of public GPS signals implemented for national security reasons.

Ans. to Q. No. 4: To fulfill the positioning, navigation and timing requirements of the India, ISRO has established a regional navigation satellite system called Navigation with Indian Constellation (NavIC). NavIC was erstwhile known as Indian Regional Navigation Satellite System (IRNSS).

Ans. to Q. No. 5: GLONASS is a Russian satellite navigation system operating as part of a radionavigation-satellite service. It provides an alternative to Global Positioning System and is the second navigational system in operation with global coverage and of comparable precision.

Ans. to Q. No. 6: i. False ii. False iii. True iv. False, v. True

Ans. to Q. No. 7: Almanac data is data that describes the orbital courses of the satellites. Every satellite will broadcast almanac data for each satellite.

GPS satellites transmit information about their location (current and predicted), timing and "health" via what is known as ephemeris data. This data is used by the GPS receivers to estimate location relative to the satellites and thus position on earth.

Ans. to Q. No. 8: Pseudorandom code is a transmitted code generated by the GPS receiver. This code plays a significant role in the position determining technique.

Ans. to Q. No. 9: Some real world applications of GNSS are asset mapping, navigation services, location based services etc.



3.11 MODEL QUESTIONS

Q. 1: What are the errors introduced in GNSS? Explain in brief.

Q. 2: Explain the basic principle of calculating location by a GPS receiver.

Q. 3: Explain the parameters of Ground truthing.

Q. 4: Explain the intentional degradation of GPS satellite signal.

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UNIT 4: BASICS OF REMOTE SENSING

UNIT STRUCTURE

4.1 Learning Objectives

4.2 Introduction

4.3 Introduction to Remote Sensing

4.4 Remote Sensing Principles

4.5 Types of Remote Sensing

4.6 Sensor and Platforms

4.7 Satellite Image Interpretation Elements

4.8 Indian Remote Sensing Programmes

4.9 Let Us Sum Up

4.10 Further Reading

4.11 Answers to Check Your Progress

4.12 Model Questions

4.1 LEARNING OBJECTIVES

- describe the basic concept of remote sensing
- explain the working principle of remote sensing
- get an idea of types of remote sensing
- explain the remote sensing sensor and platforms
- discuss the satellite image interpretation elements
- explain the development of remote sensing in India

4.2 INTRODUCTION

In the previous unit, we have focused on the basics of global navigation satellite system (GNSS). In this unit, we will discuss the concept of remote sensing. In addition, the working principles and types of remote sensing will also be highlighted. Remote sensing sensors and platforms are also provided in this unit. Apart from this, the unit will also cover the

overview of satellite image interpretation elements and the development of remote sensing in India.

4.3 INTRODUCTION TO REMOTE SENSING

Remote sensing is comparatively a new branch of science. The term remote sensing is used by a number of scientific disciplines. The term remote sensing was first used in the early 1960s. It is currently used more commonly to denote the identification of earth features by detecting the characteristic electromagnetic radiation that is reflected, emitted or scattered by the earth's surface. To know about remote sensing, one must know and understand the meaning and principles of remote sensing and its essential components of remote sensing. The components are- (1) The signal, which is the carrier of information from the object or phenomenon, (2) The sensor or detector, which transforms the energy of the incoming radiation into a form of recordable information, and (3) The sensing, i.e., the acquiring knowledge about the object analysing of the signals at the user's laboratory. The processes involved in collection of information in remote sensing are: (a) Source of energy (sun/ self-emission) (b) Transmission of energy from the source to the surface of the earth (c) Interaction of energy with the earth's surface features (d) Propagation of reflected/emitted energy through atmosphere (e) Detection of the reflected/emitted energy by the sensor (f) Conversion of energy received into photographic/digital form of data, and (g) Conversion of information into Map/tabular forms.

Remote sensing makes it possible to collect data from remote or inaccessible areas. Remote sensing applications made it possible to monitor deforestation, a forest fire in the midst of vast deep forests, glacial features and their changes with time in inaccessible Arctic and Antarctic regions, measurement of ocean depths and many more. It also replaces costly and slow data collection on the ground and changes in land use and land cover on the surface of the earth.



CHECK YOUR PROGRESS

Q.1: Since which decade the Remote Sensing in map-making was started?

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Q.2: What are the essential components of Remote Sensing?

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Q.3: Write the processes involves in collection of information in Remote Sensing?

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4.4 REMOTE SENSING PRINCIPLES

The principle of remote sensing is same with that of human eye vision, where the reflected sun rays are sensed by the eye sensor and send the information to brain for identification of the feature. In the same way, the science/technology of remote sensing is making inferences about material objects from measurements made at a distance without coming into physical contact with the objects under study. However, the term 'remote' is considered as highly relative and depends on the characters of the signals and the sensors. In remote sensing, though there is no physical contact between the sensor and the object, in all conditions the objects to be sensed and the sensors are always covered in an interacting fields like gravitational field, electromagnetic field etc.

The following principles are considered in an ideal Remote Sensing process, and each of them is equally important for the successful operation of remote sensing.

I. Source of energy or source of illumination (A).

II. Solar radiation and interaction within the atmospheric (B).

III. Interactions with the target over Earth surface(C).

IV. Recording of the reflected energy by sensor (D).

V. Transmission, reception and processing of Data (E).

VI. Processing and analysis of data (F).

VII. Application (G)

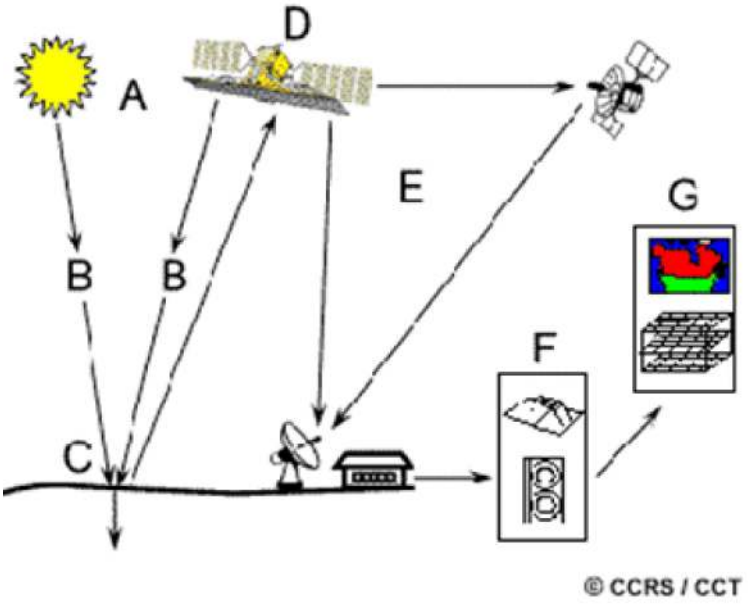


Figure 4.1: Process of remote sensing

I. Source of energy or source of illumination (A):

The first requirement of any remote sensing process is to have an energy source to illuminate the target under investigation. The energy mentioned here is the form of electromagnetic radiation (EMR). Two components are there in EMR, namely Electric field (E) and Magnetic field (M), both are perpendicular to the direction of propagation.

II. Solar radiation and interaction within the atmospheric (B):

Electro Magnetic Radiation interacts with theatmosphere when it travels from the source to earth's surface and from earth's surface to the sensor. During this whole process, the EMR changes its properties due to loss of energy and alteration and change of direction of propagation in wavelength, which ultimately impacts the sensing of the EMR by the sensor.

III. Interactions with the target over Earth surface (C):

Interaction with the Target (III) - after the energy makes its approach to the target through the atmosphere, it interacts with the target depending on the characteristics of both the target and the type of radiation. Three types of interaction can take place when energy or EMR strikes upon the surface of the earth. These are absorption, transmission and reflection. Absorption occurs when energy is absorbed by the elements of the earth's surface. Transmission happens when radiation passes through a target. Reflection takes place when radiation "bounces" of the target and is redirected.

IV. Recording of the reflected energy by sensor (D):

After the interaction with the target, energy is scattered by or, emitted back from the target. In that stage, there are requirements for remote sensing devices called sensors with detection and capturing abilities. Different kinds of EMR can be sensed by the device depending upon the amount of EMR and the sensor's capabilities to resolve.

V. Transmission, reception and processing of Data (E):

Once the EMR transmitted from earth's surface are recorded by the different remote sensing device (sensor), those are sent back to Earth receiving and data processing stations. Here the recorded EMR energy is transformed into an interpretable and recognizable output- digital or analogue images. these images are finally further processed based on different purposes.

VI. Processing and analysis of data (F):

The digital satellite images which are captured by the sensors are further processed using specialized software designed for satellite digital image processing, for example, widely used and popular software are ArcGIS, ENVI, EDRAS imagine software, etc. Image processing and analysis of satellite data leads to different types of information extraction, which is required by the end users. For example- extraction of, vegetation, cultivation, built-up water body land, etc. Methods of processing, analysis and use of different types of data depend on the requirements of the users.

VII. Application (G):

The final element of the remote sensing process is its application part. It is achieved through the use of extracted information from the imagery. Some new information can be figured out which can ultimately assist in solving different types of problems in real life world. The following fields can be considered as examples:

1. Mapping: Topological, geological mapping and weather mapping.
2. Hydrology: River analysis, monitoring wetlands and snow cover.
3. Forestry: Forest type monitoring and mapping, biomass estimation.
4. Soils and Land degradation: Soil mapping, land degradation status analysis, land degradation hotspots etc.
5. Agriculture: Crop health identification, crop condition monitoring, soil moisture measurement, etc.
6. Land use land cover change. etc.



CHECK YOUR PROGRESS

Q.4: State True or False:

a) In remote sensing there is physical contact between the sensor and the object.

b) The principle of remote sensing is the same as that of human eye vision.

Q.5: What are the different applications of remote sensing?

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4.5 TYPES OF REMOTE SENSING

Based on the illuminating source of energy used by the sensors, the remote sensing process can be classified into two different types – Active Remote Sensing and Passive Remote Sensing.

Active Remote Sensing:

In Active Remote sensing, sensors use their own source of energy and the target on the earth's surface is illuminated by this energy transmitted by the sensor itself. A part of energy, after hitting the target is reflected back to the sensor. This reflected energy contains information about the earth's surface. The easy way to understand an active sensor is when a photographic camera uses its flash, it acts as an active sensor. RADAR, LiDAR, SONAR and LASER altimeters are active sensors. A radar is a system having a transmitter and a receiver. The transmitter emits waves in all directions, these waves strike objects of its target and are then reflected back to the receiver and thus calculate the distance and velocity of the target object. The active sensors can be utilized in any type of weather condition but the mechanism and technology are equally complex and expensive.

Passive Remote Sensing:

Contrary to active remote sensing, passive remote sensing does not have its own source of energy. They depend on other sources of energy. The most common source of energy in passive remote sensing is solar energy. The surface of the earth is illuminated by the sun or solar energy. Reflected solar energy from the earth's surface or the emitted electromagnetic energy is received by the sensor's photographic camera and it detects the signals. We may say that a passive sensor's camera is used in sunlight, without using the flashlight. The passive sensors are comparatively simple both mechanically and electrically and it does not have high power requirement. But the problem is, it depends upon good weather conditions.



CHECK YOUR PROGRESS

Q.6: What is the basic difference between active remote sensing and passive remote sensing?

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4.6 SENSORS AND PLATFORMS

Remote Sensing Sensors:

Remote sensing sensors are employed on earth observation platforms and designed to record radiations in one or more parts of the electromagnetic spectrum. Sensors are electronic instruments that receive electromagnetic radiation and generate an electric signal that corresponds to the energy variation of different earth's surface features. The signal can be recorded and displayed as numerical data or an image.

There are basically two kinds of sensors- (i) image forming and (ii) non-image forming. Within the image forming sensors, there are two types- active sensor and passive sensor. Passive sensors gather radiation that is emitted or reflected by the object or surrounding areas. Reflected sunlight is the most common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, charge-coupled devices and radiometers. Active sensors create their own radiation to illuminate the target whereas passive sensors rely on naturally occurring radiation. When remote sensing is done using sensors that have their own source of electromagnetic radiation of specific wavelengths to illuminate the terrain, it is called active remote sensing sensors. Examples of such sensors are RADAR (Radio Detecting and Ranging) or LiDAR (Light Detection and Ranging).

The sensors mounted on a platform receive spectral signatures from the earth's surface features, pixel-wise, in a number of spectral bands. These data are stored as latent image on photographic films or stored on magnetic tape in digitized form. After completion of the mission, these data are physically brought to the laboratory where images are processed. This method of data transmission is not possible from an unmanned space-borne platform i.e., from the satellites, which are continuously remaining in space for many years. In such case, radio/microwave communication provides a link between the sensors on satellites and the data-receiving stations on the ground.

However, the radio or microwave transmission of data may be made in real-time or it may be delayed until the ground receiving station come within the data transmission and reception range of the revolving satellites. For such a delay in the transmission of data, an onboard data storage facility is required. Before transmitting, in the satellite platform itself, the imagery is scanned by various processes to organize the information in a series of similar or equivalent digital forms.

When the remote sensing data are conveyed by radio link to the ground receiving station, the reception begins with a large high-gain antenna, thereby maximizing the signal power level from the remote satellite.

At present, there is a limited number of ground-receiving stations. These are found to be inadequate to handle the high volume of image data transmitted from a large number of satellites launched by the countries like USA, Russia, France, India, Canada, China, Japan and many other countries. To avoid large volume of on-board data storage facilities, the USA has launched the Tracking and Data Relay Satellites (TDRS). These satellites are placed in geo-stationary orbits to receive data directly from remote sensing satellites and transmit them to the TDRS ground receiving stations. These TDRS relay the image data via a Domestic Communication Satellite (DOMSAT) to different centres where satellite data convert into master film negatives, computer compatible tapes or other data products for distribution to users. Although at present the requisite number of TDRS platforms is not there, efforts have been made to increase the number of TDRS so that all remote sensing satellite data could be acquired on a worldwide basis.

Remote Sensing Platforms:

For the collection of remotely sensed data, the first requirements are the platform and a sensor. Remote Sensing platform means the base where sensors are mounted, it may be moving or stationary. It may range from a simple tripod to balloons, rockets, helicopters, drones, aircraft and spacecraft. The choice of a particular platform is guided by the choice of sensor.

There are three main types of platforms used in remote sensing wherefrom information on the earth's surface features is recorded or transmitted to the earth's receiving stations for their analysis and interpretation. These platforms are-

(1) Ground-borne

(2) Air-borne and

(3) Space-borne

(1) Ground-borne platform:

Ground-borne platforms are necessary to develop the scientific understanding of the single object and signal-sensor interactions. Important ground observation platforms include- handheld platform, cherry picker, towers and portable masts. Portable handheld photographic cameras and spectro-radiometers are used for laboratory and field experiments to collect the ground truth. In cherry pickers, automatic recording sensors can be placed at a height of about 15 m from the ground. Towers can be raised by placing sensors at a great height for observation. Portable masts mounted on vehicles can be used to support cameras and other sensors.

(2) Air-borne platform:

When observation platforms are placed on balloons, aircraft or high-altitude sounding rockets, such platforms are called air-borne platform. Drone is also used as an air-borne platform which is a remotely piloted vehicle that looks like a miniature aircraft. Balloons and aircraft used for remote sensing purposes are of different types. Different aircraft have different ceiling heights, speeds and area coverage. High-altitude sounding rockets can provide synoptic imageries for areas of some 500,000 sq. km per frame. Such a high-altitude sounding rocket is fired from a mobile launcher. During the flight, its sensors are held at a stable altitude by an automatic control system. The Skylark Earth Resource Rocket is an example of this type of platform.

(3) Space-borne platform:

It is the platform where the sensor is placed on an artificial satellite. Platforms in space are not affected by atmosphere and hence the orbits

can be defined. It provides a synoptic view i.e., observation of large area in a single image, and systematic and repetitive coverage. The ceiling heights of the space-borne platforms of different series of satellites are between 220 km in the case of a shuttle to 30,000 km for geostationary. There are two types of satellite platforms namely (i) Manned satellite platform and (ii) Unmanned satellite platform. In the manned satellites, crew operates the sensors as per the programme schedules. Some manned satellite programmes by NASA are Mercury, Gemini, Apollo, Skylab, International Space Station etc. On the other hand, unmanned satellite includes LANDSAT series, SPOT series, IRS series, NOAA series, INSAT series and an entire constellation of GPS satellites.



CHECK YOUR PROGRESS

Q.7: Define a sensor.

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Q.8: What are the two types of remote sensing sensors?

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Q.9: What are the types of Remote Sensing Platforms?

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Q.10: What is the use of Drone in remote sensing?

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4.7 SATELLITE IMAGE INTERPRETATION ELEMENTS

Satellite image interpretation is a key component of the remote sensing process. True interpretation can only give us better output and better output leads toward the best applicability of the technology. The human eye can only see the visible range of the electromagnetic radiation. The visual perception is the capability to interpret information about any

phenomena of surroundings from the effects of visible light that reaches the human eye. The interpretation process is the extraction of qualitative and also quantitative information of the phenomena under investigation from aerial photograph or a satellite image.

There are several satellite image interpretation keys that are used in interpreting the phenomena over the earth's surface. those are as follows:

a. **Tone:** The ton can be defined as a particular quality of brightness or profundity or hue of a shade of a colour or multiple colours. Therefore, tone can be referred to as the relative brightness or colour of a feature on a satellite image. Variations in terms of tone make it easier to differentiate between features on any image. Patterns Shapes, and textures on an image are identifiable mainly due the tonal variations.

b. **Shape:** Most of the earth's features and functions can solely be recognized using the shape element of visual interpretation. Outline, structure, or the external form of a particular feature can be considered as shape. In some instances, the height also helps in determining its shape. The anthropogenic features or manmade features are mostly symmetric, regular, or have some sharpness in shape while most of the natural features like rivers, and forest cover is irregular in shape and asymmetrical in nature.

c. **Size:** Size can give us a quick understanding of the feature. Especially when we compare two or more features. Comparing the size of features in perspective with others in an image helps in better interpretation and understanding of the features in an image. A quick estimation of the size of a feature makes the image interpretation process faster and easy.

d. **Pattern:** Pattern means the spatial arrangement of features over the earth's surface. Certain objects can be easily identified because of their spatial pattern of arrangement. Some particular patterns have an inherited relation with several factors of its origin. e.g., urban and rural settlement areas can be easily recognized on the basis of patterns created by the rows of houses or buildings or housing patterns.

e. **Texture:** texture is an accumulation of shape, size, tone, shadow and pattern of a particular object. It is based on the visual roughness or smoothness of a satellite image. Abrupt changes result in rough texture while very minor tonal variations are examples of smooth textures.

f. **Shadow:** When other image interpretation keys cannot decide some features, shadow helps in establishing the truth. Shadow is the dark area produced by the features coming between light rays and earth surface. Shadows have both advantages and disadvantages at the same time. The advantage of shadow is that it can provide the height information of the feature or elements. But the major disadvantage is, the features under shadows cannot be identified. So, there is the importance of giving consideration to shadow while interpreting an image.

g. **Association:** Association means the occurrence of two or multiple features in relation to each other. Certain features cannot be directly identified by their actual form. But this problem can be shorted out and interpreted easily according to its relationship with the surrounding elements. For example, an association of a bridge with a river, Buildings with gardens, a playground with a school etc.



CHECK YOUR PROGRESS

Q.11: How the element size helps us in interpreting any satellite image?

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Q.12: What is the role of association in the interpretation of satellite imagery?

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4.8 INDIAN REMOTE SENSING PROGRAMMES

India launched two satellites namely Bhaskara 1 and Bhaskara 2 in 1979 and 1981 respectively to support the national economy in the areas of agriculture, water resources, forestry and ecology, geology, watersheds, marine fisheries and coastal management. A moderate resolution satellite system, the IRS (Indian Remote Sensing) programme began with the launch of IRS-1A in the year 1988. It was followed by IRS-1B in 1991, IRS-1C in 1995 and IRS-1D in 1997. The Indian Remote Sensing Satellites are the main-stay of National Natural Resources Management System (NNRMS), for which the Department of Space (DOS) is the nodal agency. Data from IRS satellites is received and distributed to several countries all over the world.

Remote sensing applications in the country, under the umbrella of NNRMS, now cover diverse fields such as crop acreage and yield estimation, draught warning and assessment, water resource management, under-ground water exploration, prediction of snow-melt run-off, management of watersheds and command areas, fisheries development, under development, mineral perspective, and forest resource survey. Besides, IRS-P1 in 1993, IRS-P2 in 1994, IRS-P3 in 1996, IRS-P4 (Oceansat) in 1999, IRS - P6 (Resourcesat) in 2003 were launched by India. At present the Indian Remote Sensing satellite system becomes one of the largest constellations of remote sensing satellites in operation in the world. Resourcesat - 2, Cartosat - 2B, Oceansat - 2, Risat - 2, Cartosat - 2A, IMS - 1, Cartosat - 2, Cartosat - 1, Resourcesat-1 and TES satellites of India are currently in operation state in addition to the IRS satellites. INSAT-3A and SARAL, are some of the recent additions of successful satellite missions of the country. With these, it is expected that the thematic series of satellites in the coming years, such as Cartosat-3, MeghaTropiques, and Insat-3D will continue to provide enormous data in several areas spanning from cartography to climate-related issues.
India's Remote Sensing Satellites-

Satellites of the past are–

- Aryabhata, 1975
- Bhaskara I, 1979
- Bhaskara II, 1981
- Rohini Series, 1980-83
- SROSS Series, 1985-92
- IRS-1A, 1988
- IRS-P1, 1993

Presently working Satellites–

- IRS-1B, 1991
- IRS-P2, 1994
- IRS-1C, 1995
- IRS-P3, 1996
- IRS-1D, 1997
- IRS-P4, 1999 (Oceansat)
- IRS-P6, 2003 (Resourcesat-1)
- IRS-P5, 2005 (Cartosat-1)
- IRS-P7, 2007 (Cartosat-2)
- IRS-P6, 2011 (Resourcesat-2)
- RISAT-1, 2012 (RISAT-1)



CHECK YOUR PROGRESS

Q.13: What is the full form of NNRMS?

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Q.14: What is the full form of IRNSS?

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4.9 LET US SUM UP

- Remote sensing is mainly used to identify the earth's features by detecting the characteristic of electromagnetic radiation that reflected, emitted or scattered by the earth's surface.

- The process of remote sensing involves a source of energy, transmission of energy, interaction of energy with the earth's surface features, detection of the reflected or emitted energy by the sensor, conversion of energy received into a photographic or digital form of data and conversion of information into map or tabular forms.
- The two kinds of sensors are image forming and non-image forming.
- The three types of remote sensing platforms are ground-borne, air-borne and space-borne.



4.10 FURTHER READING

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5. Konecny, G. 2003, Geoinformation- Remote Sensing, Photogrammetry and GIS, Taylor and Francis, London



4.11 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: Since 1960s.

Ans. to Q. No. 2: Signal, Sensor and Sensing.

Ans. to Q. No. 3: The processes involve (a) Source of energy (sun/ self-emission) (b) Transmission of energy (c) Interaction of energy with the earth's surface features (d) Propagation of reflected/emitted energy through atmosphere (e) Detection of the reflected/emitted energy by the sensor (f) Conversion of energy received into

photographic/digital form of data, and (g) Conversion of information into Map/tabular forms.

Ans. to Q. No. 4: a) False b) True.

Ans. to Q. No. 5: * Mapping: topological, geological mapping weather mapping.

* Hydrology: river analysis, monitoring wetlands and snow cover.

* Forestry: Forest type monitoring and mapping, biomass estimation.

* Soils and Land degradation: soil mapping, land degradation status analysis, land degradation hotspots etc.

* Agriculture: crop health identification, crop condition monitoring, soil moisture measurement, etc.

* Land use land cover change. etc.

Ans. to Q. No. 6: Active remote sensing depends on its own source of energy, while passive remote sensing depends on another energy source i.e., solar energy.

Ans. to Q. No. 7: Sensors are electronic instruments that receive electromagnetic radiation and generate an electric signal that corresponds to the energy variation of different earth's surface features.

Ans. to Q. No. 8: Two types of remote sensing sensors are image forming sensors and non-image forming sensors.

Ans. to Q. No. 9: Remote sensing platforms are:

(1) Ground-borne

(2) Air-borne and

(3) Space-borne

Ans. to Q. No. 10: Drone is an air-borne platform used for remote sensing purposes. It is a remotely piloted vehicle that looks like a miniature aircraft.

Ans. to Q. No. 11: Size can give us a quick understanding of the feature. Especially when we compare two or more features. Comparing the size of features in perspective with others in an image helps in better interpretation and understanding of the features in an image. A quick estimation of the size of a feature makes the image interpretation process faster and easy.

Ans. to Q. No. 12: Association means the occurrence of two or multiple features in relation to each other. Certain features cannot be directly identified by its actual form. But this problem can be shorted out and interpreted easily according to its relationship with the surrounding elements. For example, an association of a bridge with a river, buildings with gardens, a playground with a school etc.

Ans. to Q. No. 13: National Natural Resources Management System.

Ans. to Q. No. 14: Indian Regional Navigation Satellite System.



4.12 MODEL QUESTIONS

Q. 1: What are the main advantages of remote sensing over conventional surveys?

Q. 2: Write a note on the development of remote sensing in India.

Q. 3: Write briefly on the difference between air-borne and space-borne.

Q. 4: Discuss the characteristics of different platforms used in collecting the remotely sensed data.

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UNIT 5: OPEN DATA SOURCES AND SOFTWARE FOR GEOINFORMATICS

UNIT STRUCTURE

5.1 Learning Objectives

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5.1 LEARNING OBJECTIVES

After going through this unit, you will be able to-

- explain different types of open sources used in GIS
- describe the open-source digital elevation model
- illustrate the open-source software used in GIS

5.2 INTRODUCTION

In the previous unit, we have focused on the basics of remote sensing. In this unit, we are going to discuss open data sources and software. This unit provides a discussion on the basic idea of software engineering. The unit will also deal with the different types of software development life cycle models. Also, you will also learn different approaches to software design. Apart from this, the unit will also focus on the different types of tests to develop software and the concept of an object-oriented design approach.

5.3 OPEN-SOURCE DATA

The possibilities for combined use of open-source data, predominantly remote sensing data, and freely available and Open-source Software in studying earth phenomena and other applications are very high but it has some issues and certain challenges. In today's world, the satellite remote sensing industry is highly developed and offers millions of datasets, various state-of-the-art software tools, meaningful algorithms, and methodologies, including the public domain, which cover thousands of topics and these, are helping academicians and researchers to find new insights of a variety of complex phenomena.

5.3.1 Relevance and Use

This is the era of booming new technology. In this era of new satellite constellations, the resolving capability of satellite sensors has been significantly advanced which shows a great potential to support precise and judicious monitoring of changes across the Earth's surface and atmosphere. In addition, various data products using Earth observations satellites are key inputs for various interdisciplinary studies. Open-source remotely sensed products derived from various remote sensing constellations are highly required in various communities, such as natural resource management urban planning and design environmental modeling

etc. There is an increasing need for unique, useful, compatible, and complete open data sources to support environmental, social, and economic advancements and holistic societal benefits.

5.3.2 ISRO Bhuvan

Bhuvan can be considered the Indian version of Google Earth. Bhuvan focuses entirely on providing freely accessible high-resolution satellite imagery of the Indian region specific. With some add-on features and capabilities Bhuvan is designed as a software application as a part of the Indian geospatial data services. Users are allowed to explore a near-perfect 2D/3D representation of the Earth's surface. The browser is specifically customized to view the Indian region, with few local languages.

Bhuvan was introduced as a Geo-portal in India on 12th August 2009, containing multi-resolution images from multiple sensors of IRS (Indian Remote Sensing) satellites. Free-of-cost data sets, services, and applications in various spectral, radiometric spatial, and temporal resolutions are available in the domain. It also has a web-based mapping service that offers navigation in a 3D viewing environment, with a resolution range of 5.8 meters to 1 meter, and various geo-processing functionalities. With all browsers' compatibility, Bhuvan provides a very user-friendly interface. The users only need to register when downloading satellite data of various resolution products like LISS-III, Cartosat DEM, Ocean Color Monitor data, etc. there are some high-quality readily available thematic map products that are also preloaded for utilization in various purposes. We also have mobile and Android apps for Bhuvan which make it possible to access data on the fly.

5.3.3 USGS: Earth Explorer

On March 3, 1879, the United States Geological Survey was established aiming to provide knowledge to the advancement of science and technology. The prime motive of the USGS's mission is

to analyze, monitor, and predict the current status and dynamics of complex human and natural Earth systems. The access to USGS data began in 1991 through the Global land information system. The Global land information system (GLIS) was replaced by a modified Earth Explorer in the year 2000.

USGS EarthExplorer is developed to provide easy to use, fast, highly responsive search engine to allow researchers and general users the ability to search and download required datasets over their area of interest. This data portal is one stop superstore for gathering geo-spatial datasets. It has extensive collections of various up to date datasets. Users have the freedom to navigate via interactive map or text search to obtain a range of up to date Landsat satellite imagery, Radar data, digital graphs, digital elevation model (DEM) data, aerial photos, Sentinel satellite data, some of the commercial satellite imagery including IKONOS and OrbView3, land cover data, digital map data from the National Map, Indian Remote Sensing data and many other datasets. One searches by exact location, coordinates, and extension via an interactive map to view what data types are available.

5.3.4 Sentinel Data

On 3 October 2014, European Space Agency (ESA) started disseminating data products from the Copernicus Sentinel-1A satellite mission through the Sentinel Data Access System. Since then the Data Access System has been continually developing, to keep tempo with the rapid growth both in the amount of Copernicus Sentinel data availability and growing user demand for that data. Copernicus Open Access Hub which was previously known as Sentinels Scientific Data Hub provides open access, free and complete dataset of Sentinel-1, Sentinel-2, Sentinel-3, and Sentinel-5P user products. The Data Access System automatically receives products from ESA's Sentinel ground segments (PDGSs) and publishes them through online platform hubs. Users can

explore the data collections and download products accessing these hubs, through an interactive graphical web interface.

From 24 January 2023, a new Copernicus Data Space Ecosystem is launched to provide access to all Sentinel data with new updated features for visualization and data acquisition. The Copernicus Data Hub distribution service will continue its full operations until the end of June 2023 to allow a smooth migration to the new Copernicus Data Space Ecosystem by all user communities. Sentinel Data are also available via the Copernicus Data and Information Access Services (DIAS) through several platforms.

5.3.5 Google Earth

Primarily based on satellite images, Google Earth renders a 3D representation of Earth. The venture of Google Earth started in the early 90s with a company named Intrinsic Graphics. In October 2004, Google acquired this technology and further developed it as one of the most popular Earth representation tools ever existed. Through a Digital Globe, Google Earth's imagery is displayed; which displays the earth's surface using a single composited image. Google confirms that Google Earth covers more than 97 percent of the Earth's surface, and has already captured more than 10 million miles of Street View imagery.

An ambitious geospatial processing service is also provided through Google Earth Engine. With the help of Earth Engine, one can perform geospatial processing at scale, powered by the Google Cloud Platform. The purpose of Earth Engine is to provide an interactive platform for geospatial algorithm development. and also to enable and endorse high-impact, data-driven science. Google Earth Engine (GEE) also tries to make substantive development on different global challenges that involve large amounts of geospatial datasets. Google Earth Engine allows users to run algorithms on geographically referenced satellite imagery. Google Earth Engine also provides a digital

library of functions that is applied to data for display and analysis. Earth Engine's Public Data Catalog contains a huge amount of publicly and freely available imagery and vector (point, line and polygon) datasets.

5.3.6 Gram Manchitra

In 2019, Shri Narendra Singh Tomar, Union Minister for Panchayati Raj, Rural Development launched 'Gram Manchitra'. Gram Manchitra is a specially designed Spatial Planning Application which is developed by the National Informatics Centre (NIC). The application is based on National Information Center's multiple-layer GIS platform Bharatmaps. It is a Geo-Spatial based decision support system for the smooth functioning of Panchayats. The Panchayats can make use of this application for planning, developing and monitoring developmental activities and schemes on real-time basis very efficiently. The followings are the objectives of Gram Manchitra:

a. A Single Window Geo-Spatial platform for users to better visualize developmental works across different sectors.

b. Independence in the process of planning as a Decision support system tool for GPDP.

c. Integration of the inter-ministerial spatial and non-spatial data spanning.

d. Enabling prioritization of activities based on existing resources.

e. 'Real time' monitoring of activities/ development work carried under different schemes of Panchayats.

f. De-duplication of asset-based activities across central and state-run schemes and development programmes.



CHECK YOUR PROGRESS

Q.1: what are the objectives of GramManchitra?

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5.4 OPEN-SOURCE DIGITAL ELEVATION MODEL

The height above some certain specified level is generally considered as elevation. With the help of technology and skills, elevation and elevated surface of any terrain can be brought into a digital environment, which is in general considered as Digital Elevation Model (DEM). Digital Elevation Model or popularly known as DEM is a/ representation of the exposed ground topographic surface of the Earth or other celestial bodies/ excluding trees, buildings, and any other surface objects through a series of cells. Each cell represents the elevation of any feature at its specific location./ A variety of sources is considered while preparing DEMs. The primary data source is the topographic maps. Some other techniques of DEM generations are photogrammetry, aerial stereo photograph, interpolation of contour maps, interferometry, ground and laser and lidar, surveying, and other techniques. Digital Elevation Model (DEM) is actually a quantitative representation of the terrain. It works as a very important tool for earth science studies, terrain visualization and mapping, hydrological parameters analysis, modeling of water flow, runoff estimation, flood susceptibility, simulation and management mapping, mass movement hazard analysis, etc. There are So many freely available DEMs there as ASTER, CARTOSAT-DEM, SRTM, GTOPO 30, etc.

Following are some of the highly used free global DEM data sources:

1. Shuttle Radar Topography Mission (SRTM):

Back in February 2000, NASA created 30-meter digital elevation model through the adventure named Shuttle Radar Topography Mission (SRTM) with the help of Space Shuttle Endeavour. This mission collected sufficient data to generate a precise digital elevation model using a method known as interferometric synthetic aperture radar (InSAR). It could penetrate the canopy cover to the ground. In l2014, the United States government released the highest resolution SRTM DEM to the public for free. This 1-arc second global digital elevation model comes with a spatial resolution of about 30 meters with worldwide coverage. But the accuracy of SRTM-DEM is about 16m.

2. CARTOSAT DEM:

CARTOSAT -1 satellite was launched in 2005. it had the payload of pairs of Panchromatic cameras having an along-track scanning stereoscopic capability. -derived 10 m spatial resolution digital elevation model (DEM) for the entire India was compiled for several applications. The advantage of Cartosat-1 satellite is that it provides very good resolution near-instantaneous stereo data with a spatial resolution of 2.5 meters. Cartosat-1 is the lone satellite with global stereo capability. Numerous scientific studies have been carried out so far using this data for various applications. Cartosat-1 Scientific Assessment Programme (C-SAP) brought out many interesting and meaningful results using Cartosat-1 stereo data for various terrain conditions worldwide. CartoDEM products are very functional in drainage network and system analysis, watershed planning, generation of contour, quantitative analysis of run-off estimation and monitoring soil erosion, infrastructural use like the design of new road, rail, and pipeline alignments, landslide zonation; and flood hazard analysis and many more. India's more than 80% of the area is covered by CartoDEM. ISRO is still working to complete the remaining parts of the country.

3. ASTER Global Digital Elevation Model:

The first version of the ASTER GDEM, released in June 2009. ASTER has onboarded the Terra satellite to produce 30-meter spatial resolution digital elevation data. It covers 99% of the earth's surface from 83° north latitude to 83° south latitude. the modified Version 2 of these data was released in October 2011 and is a significant improvement over the initial datasets. On August 5, 2019, the government of Japan and the United States National Aeronautics and Space Administration (NASA) jointly released the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), and the ASTER Water Body Dataset (ASTWBD). ASTER GDEM can be downloaded from the USGS Earth Explorer portal freely.

4. JAXA's Global ALOS 3D World:

On January 24, 2006, Advanced Land Observing Satellite "ALOS" was launched by apan Aerospace Exploration Agency (JAXA). The ALOS has the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping. ALOS products can be used for cartography, disaster monitoring and management regional observation, and resource surveying. This data set is a global digital surface model (DSM) with a horizontal resolution of approximately 30 meters (basically 1 arcsecond). The latest version is 3.2 and 3.1. Any of the commercial and non-commercial purposes can be utilized free of cost. Datasets have a high potential to be widely used in education, scientific research, and new services that use geospatial information widely. The significant thing about ALOS is that it is one of the most precise world-scale elevation database.



CHECK YOUR PROGRESS

Q.2: When the Cartosat-1 satellite mission was launched?

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Q.3: what is the spatial resolution of ASTER Global Digital Elevation Model ?

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Q.4: What is the name of the instrument there in JAXA's Global ALOS?

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5.5 OPEN-SOURCE SOFTWARE

Open-source software (OSS) is one type of computer software with the purpose of a license in which the developer grants users the rights to

use, change, and distribute the software. Open-source software may be developed in a collaborative, public manner multi-dimensional developer of the application. Open-source software is generally much cheaper, has flexibility, and has more permanence because it is developed by a large community rather than a single author or company. According to the need and requirements, the users can contribute to the software. The preference for open-source GIS software use is increasing rapidly, and now is becomes an increasingly integral part of the geospatial industry for cartography, GIS data handling, spatial analysis, and visualizations purposes.

The followings are some of the major open-source GIS software available in the public domain:

5.5.1 QGIS (Quantum Geographic Information System)

QGIS is a widely used professional GIS application that is Free and Open-source Software (FOSS). Gary Sherman started working on the development of the Quantum GIS project in early 2002. It became a game-changing project of the Open-source Geospatial Foundation in 2007. The very first Version 1.0 was released in January 2009. With the release of version 2.0 in 2013, the name was officially changed from *Quantum GIS* to *QGIS*. The software itself offers a good amount of free and open online resources and maps accessible to download. QGIS accepts several file formats including vector file formats. There are varieties of plug-ins for use, and there is always the creation of new plug-ins being by many developers worldwide. Plug-in is the extra application that can be downloaded to complete a specified responsibility that is not easily accomplished otherwise. QGIS can also be utilized as a graphical user interface to GRASS GIS software. GRASS is also free and open-source software. QGIS has a small install footprint on the host computer file system compared to commercial GIS software and generally requires less RAM and hence consumes less power while processing; so, it can be used on older version computer software and hardware systems.

5.5.2 GRASS GIS (Geographic Resources Analysis Support System)

As a tool for land management and environmental planning, GRASS GIS was developed by the US Army Corps of Engineers. Since 1982, GRASS GIS has been under continuous development. U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (USA/CERL) started exploring the use of GIS tools for research, monitoring, and management of military lands. GRASS GIS can process multispectral image data and create, manage, and store a variety of spatial data. It also contains over 350 ready-to-user maps and images. The software can also manipulate different raster file formats and vector data including complex vector networks. Any application developers can very easily contribute to the further development of tools of GRASS GIS.

5.5.3 SAGA GIS: System for Automated Geoscientific Analyses

SAGA GIS is one of the oldest application software in the world of free GIS software. Initially, it was developed by a very small team from the Department of Physical Geography, University of Gottingen, located in Germany. But now SAGA GIS is being maintained and extended support by a huge international developer community. Starting of SAGA GIS was primarily initiated for terrain analysis such as hill shading, and watershed delineation. But Now, SAGA GIS is a powerhouse of so many other sophisticated tools because it has been delivering a fast-growing set of geoscientific methods to the geoscientific community for geospatial analysis. The overall impression of SAGA GIS is that it's very quick, much reliable, and highly accurate. That is why SAGA GIS is a prime choice for environmental modeling and other applications for researchers. SAGA GIS can be used together with other GIS software like Q GIS to get improved detail in vector datasets as well as higher-resolution raster map-production capabilities.

5.5.4 ILWIS (Integrated Land and Water Information Management)

Initially, LWIS was developed by International Institute for Geo-Information Science and Earth Observation, Enschede, in the Netherlands for use by its research scholars and other students. On 1st July 2007, it was released as free and open software. ILWIS is excellent at doing the basics like editing, digitizing, and displaying geographic data. It's also useful for remote sensing with various tools for image enhancements, classification, and spectral band manipulation. ILWIS can perform some very powerful raster analysis tasks with high precision and have flexibility in the vector digitizing module.

As we have discussed there is a bucket load of free GIS software that can perform hundreds of advanced Geographic Information System processing jobs, and generate astonishing cartographic and mapping outputs. Some of the worth mentioning are, Open Jump, GeoDA, gVISG, DIVA GIS etc.



CHECK YOUR PROGRESS

Q.5: . Who developed the ILWIS open-source software?

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5.6 LET US SUM UP

- Geoinformatics is a combination of a variety of elements but data, and software has a very crucial role to play. The availability of open free and reliable data and software can make a huge difference in acquiring clear insights about the earth and its phenomena.

- Some new opportunities can be provided to researchers and academicians with the help of easily available data and software to tackle the challenges in research and findings.
- With the open knowledge hub inclusive development in earth research can be achieved.



5.7 FURTHER READING

1. Jakovljević, G., Govedarica, M., & Álvarez-Taboada, F. (2019). Waterbody mapping: A comparison of remotely sensed and GIS open data sources. *International Journal of Remote Sensing*, *40*(8), 2936-2964.
2. Mobasheri, A., Pirotti, F. & Agugiaro, G. Open-source geospatial tools and technologies for urban and environmental studies. *Open geospatial data, softw. stand.* **5**, 5 (2020).
3. Steiniger, S., & Hunter, A. J. (2009). Free and open-source GIS software for building a spatial data infrastructure. In *OGRS* (pp. 247-261).



5.8 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: The followings are the objectives of Gram Manchitra:

a. A Single Window Geo-Spatial platform for users to better visualize developmental works across different sectors.

b. Independence in the process of planning as a Decision support system tool for GPDP.

c. Integration of the inter-ministerial spatial and non-spatial data spanning.

d. Enabling prioritization of activities based on existing resources.

e. 'Real time' monitoring of activities/ development work carried under different schemes of Panchayats.

f. De-duplication of asset-based activities across central and state-run schemes and development programmes.

Ans. to Q. No. 2: CARTOSAT -1 satellite was launched in 2005.

Ans. to Q. No. 3: ASTER DEM has a 30-meter spatial resolution.

Ans. to Q. No. 4: The JAXA- ALOS has the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping.

Ans. to Q. No. 5: LWIS was developed by International Institute for Geo-Information Science and Earth Observation, Enschede, in the Netherlands



5.9 MODEL QUESTIONS

Q. 1: Discuss ISRO's Bhuvan web portal as a source open of data.

Q. 2: What do you mean by Open-source Software? Discuss a few open-source software and their capability in brief.

Q. 3: Discuss a few fields of application of the Digital Elevation Model. also mention some open data sources or DEM.

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UNIT 6: APPLICATIONS OF GEOINFORMATICS

UNIT STRUCTURE

6.1 Learning objective

6.2 Introduction

6.3 Application of Geoinformatics in Natural Resource Management

6.4 Watershed Management

6.5 Disaster Management

6.6 Rural Development

6.7 Urban Planning

6.8 Monitoring and Evaluation of Projects

6.9 Let Us Sum Up

6.10 Further Reading

6.11 Answer to Check Your Progress

6.12 Model Question

6.1 LEARNING OBJECTIVES

After going through this unit, you will be able to-

- explain the applications of geoinformatics in Natural Resource Management
- discuss the applications of geoinformatics in watershed management
- describe the use of geoinformatics in the disaster management
- discuss the applications of geoinformatics in rural development
- describe the applications of geoinformatics in urban planning.

6.2 INTRODUCTION

In the previous unit, we have discussed the open data sources and software used in geoinformatics. In this unit, we will provide the applications of geoinformatics in different areas. This unit provides you the knowledge

of geoinformatics applications for natural resource management. Application of geo-informatics in watershed management and in early warning systems for disasters and hazards, rural and urban infrastructures surveys are also discussed in this unit. Mapping and planning are also a part of the discussion in this unit.

6.3 APPLICATION OF GEOINFORMATICS IN NATURAL RESOURCE MANAGEMENT

The earth is constantly under observation from dozens of satellites orbiting the planet and collecting image data of the earth's surface and its environment. The term 'land cover' and 'land use' (LULC) are often used interchangeably, their actual meanings are quite distinct. Land cover mapping is one of the foremost important and typical applications of remote sensing data. Land cover corresponds to the ground surface, for instance, forest, grassland, open water etc., while land use reflects human activities like the use of the land for industrial zones, residential zones, agriculture fields, etc.

In more detail, land use refers to the purpose the land serves such as recreation, wildlife habitat, or agriculture. It does not describe the surface cover on the ground. For example, recreational land use could occur in a forest, shrubland, grasslands, or on manicured lawns. Whereas land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil, or other. It does not describe the use of land. The use of land may be different for lands with the same cover type. For example, a land cover type of forest may be used for timber production, wildlife management, or recreation; it might be private land, a protected watershed, or a popular state park.

High-resolution images have often been employed in transportation studies and might be able to identify vehicle types, estimate traffic flows, identify parking problems on city streets, estimate car parking zone usage, and even measure the speed of vehicles on a highway. New construction can be identified on an aerial photograph or on a very high-resolution satellite image and permit records can be checked to verify that a building permit was issued for the project. This type of application requires large-scale imagery like 1:5,000.

Remote sensing images have been used to aid in locating businesses or public facilities such as schools, fire stations, or libraries. By specifying a collection of criteria that represent desirable locations for the business or public facility, image interpretation is often used to identify sites that satisfy project requirements. Remote sensing methods are often employed to classify styles of land use over large areas in an exceedingly practical, economical and repetitive fashion.



CHECK YOUR PROGRESS

Q.1: What is the difference between land use and land cover?

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6.4 WATER RESOURCE MANAGEMENT

Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) can play important roles in water resources management, such as surface water, groundwater investigation, dynamic monitoring of ecology and estimation of water amount necessary for keeping and recovering ecological environment, existing irrigation area investigation and irrigation planning, soil moisture and drought monitoring, investigation of soil salinization, planning, monitoring and effect evaluation of returning cultivated and to forest or grassland, dynamic monitoring of desertification and soil erosion, variation of river course and sedimentation in lakes and reservoirs, site selection of water project and its planning, design, construction and management. Water resources investigation and discharge in river channels are often accurately controlled by hydrological measurement, while the world of reservoirs and lakes is often determined by remote sensing. On the basis of this idea, water storage in the lake and reservoir could also be determined by means of the stage area volume curve.

This kind of curve can also be worked out on the basis of multitemporal (flood, middle and dry periods) remote sensing images. Groundwater is the most important reproduced natural resource, especially for livelihood, animal husbandry and agriculture in arid regions. Remote sensing can provide information about geology, hydrogeology geomorphology and urban environment analysis. They are helpful for searching groundwater, provides a clue for field investigation, and improve successful possibilities. For finding groundwater, the penetration of radar is useful to directly find shallow layer groundwater within the places with ancient river channels and also the plain area ahead of mountains. Remote sensing has the flexibility for observation in these aspects. With the advantage of the high temporal resolution of meteorological satellites, it is possible to differentiate cloud and snow cover because of the movement of clouds.

6.5 DISASTER MANAGEMENT

Droughts and Floods are water-related natural disasters that affect a wide range of environmental factors and activities related to agriculture, vegetation, human and wildlife and local economies. Remote sensing techniques make it possible to obtain and distribute information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircraft or satellites.

Monitoring and assessment of drought through remote sensing and GIS depend on the factors that cause drought and the factors of drought impact. Based on the causative factors, drought can be classified into Meteorological, Hydrological and Agricultural droughts. Drought is a normal, recurrent feature of climate and occurs in all climatic zones, although its characteristics vary significantly from one region to another. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts of drought. The consequences of these impacts illustrate indirect impacts. Remote sensing

and GIS technology significantly contribute to all the activities of drought management.

The remote-sensing-based method for the identification of drought-prone areas uses historical vegetation index data derived from National Oceanic and Atmospheric Administration (NOAA) satellite series. It provides spatial information on drought-prone areas depending on the trend in vegetation development, frequency of low development and their standard deviations. Remote sensing utilization for drought prediction can benefit from climate variability predictions. The new assimilation techniques have produced a stronger impact of spatial data on the quality of weather and seasonal climate predictions.

Geographic Information Systems (GIS) successfully visualize the extent of flooding and also prepare flood maps to provide flood damage estimation maps and flood risk maps. The GIS must be used together with a hydraulic method to estimate the flood profile within a given return period. After 1970, Hydrologic Engineering Centers River Analysis System (HEC-RAS) software was developed by U. S. Army Corps of Engineers (USACE) and is widely utilized in Europe and America. Due to flash floods high levels of water within the streets and roads, cause many problems like bridge collapse, building damage and traffic problems. it's impossible to avoid the risks of floods or prevent their occurrence, however, it's plausible to work on the reduction of their effects and to chop back the losses which they will cause. Mapping flash flood is helpful to planners, risk managers, and disaster response or emergency services during extreme and intense rainfall events. we use SPOT and SRTM DEMs data that accuracy assessment is achieved by using checkpoints, obtained by GPS observations. Analytical Hierarchical Process (AHP) helps to outline the relative impact weight of flood contributing factors to induce a composite flood hazard index (FHI). The contributing factors during this study are runoff, soil type, surface slope, surface roughness, drainage density, distance to the main channel, and land use. The areas in high-risk flood zones are acquired by superimposing the flood hazard index map with the zone boundaries layer. The affected population number and expanse are determined and compared.



CHECK YOUR PROGRESS

Q.2: Classify drought based on causative factors.

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Q.3: Define Analytical Hierarchical Process.

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Q.4: What are the contributing factors to induce a composite flood hazard index?

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6.6 RURAL DEVELOPMENT

The capabilities within the advance of high-resolution satellites and extensive network of associated infrastructure have contributed to the growing interest in the appliance of GIS for a spread of development needs. The areas which are receiving the main attention include natural resources information assessment, monitoring and management, watershed development, environmental planning, urban services, and land use planning.

GIS provides a superior service to the user organizations to assist in their own decision-making process for developmental planning. A better Graphical User Interface (GUI) could also be built using GIS, because it provides very widespread and fast access to information, both graphically and non-graphically.

This makes the system healthier in terms of its communication with a variety of users. Geographical information systems are open and might still evolve to match with our ever-changing needs. GIS database with indicators are specifically relevant for analyzing and projecting divergences between rural and urban-industrial areas in India. This GIS should assist decision-makers and planners in formulating rural development policies at the regional and national levels. GIS technology initiates new visions for rural development

in India by identifying innovative initiatives in lagging rural regions and by developing alternative development scenarios, which give special emphasis to options outside the quality sectors of agriculture and forestry. GIS assists decision-makers and planners in formulating rural development policies at the regional and national levels.

The population of the planet is increasing exponentially, and the land available to accommodate the identical remains limited. Urbanization is the new threat the environment is fighting with. Humans are actively engaging in encroachment of the lands within the forest areas. The need of the hour isn't just urbanization but smart urbanization; to plan urban development smartly so on accommodate more in less, which too nicely and efficiently.

GIS has become ubiquitous. It's pervading almost every sphere of human life today. Using GIS in urban planning, planners can take urbanization to a new extent.

GIS provides planners, surveyors, and engineers with the tools they have to style and map their neighborhoods and cities. Visualization, spatial analysis, and spatial modelling are the foremost frequently used GIS functions in plan making. GIS can help to store, manipulate, and analyse physical, social, and economic data of a city. Planners can then use the spatial query and mapping functions of GIS to examine the prevailing situation within the town. Through map overlay analysis, GIS can help to spot areas of conflict of exploitation with the environment by overlaying existing exploitation ashore suitability maps.

Using the multi-layered mapping feature of GIS, a municipal planning committee can visualize a spread of things, for example, major agricultural land, surface water, high flood frequency, and highly erodible land. This information is used by planners in developing urban infrastructures. GIS can significantly help in examining components or conducting a feasibility study of a location for a particular purpose, as an example to determine the suitability of a location for the event of a bridge or dam. Feasibility studies of smaller structures like schools and hospitals can even be selected effectively using GIS. It should be used to ascertain

the feasibility of a part for waste disposal and treatment. Planners make use of GIS to smooth the progress of citizen participation and community input as they develop a vision for the community that improves the standard of life for all citizens.



CHECK YOUR PROGRESS

Q.5: How GIS technology initiate new visions for rural development in India?

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6.7 URBAN PLANNING

Mapping could be a fundamental function of Geographic Information Systems (GIS), which offer a visible interpretation of information. GIS-based mapping helps governments achieve healthier governance as they're able to solve problems more quickly and efficiently. Proper maps help to achieve better land-use planning, road and utility maintenance, emergency management, infrastructure evaluation and development, and property management. Mapping is often of great help when it involves organizing urban growth and solving housing issues related to the increasing population.

GIS is getting increasingly employed in urban planning within developed and developing countries. GIS tools help planners to examine problems more rapidly and systematically, prepare solutions, and supervise improvement toward long-standing objectives for the community. Many planning departments that had obtained mapping systems in the past have shifted to GIS. With the increase in user-friendliness and also the number of functions of GIS software, and also the marked decrease in the costs of GIS hardware.

Identification of the patterns of geographic regions and analyses of spatial and temporal changes would help immensely in the design of proper infrastructure facilities. Patterns of sprawl and analyses of spatial

and temporal changes can be done cheaply and efficiently with the help of spatial and temporal technologies like Geographic Information System (GIS) and Remote Sensing (RS). The assorted stages within the formulation and implementation of a sustainable regional development strategy are often generalized as the determination of objectives, resource inventory, analyses of this situation, modelling and projection, development of designing options, selection of designing options, plan implementation, and plan evaluation, monitoring and feedback. The spatial patterns of the geographical region over different time periods are often systematically mapped, monitored and accurately assessed from satellite data (remotely sensed data) along with conventional ground data. Mapping conurbation provides a “picture” of where this type of growth goes on, helps to identify the environmental and natural resources threatened by such sprawls and to suggest the likely future directions and patterns of sprawling growth. Remote sensing and GIS is also used separately or together for application in studies of geographical area. GIS analyses, database manipulation and models into one analyses system. Remote sensing applications are increasing very rapidly with the availability of high-resolution data from the state of the art satellites like IRS-1C/1D/P4 and LANDSAT. The advancement in constituents and software within the realm of remote sensing also enhances remote sensing applications. IRS-1C/1D/P4 provides data with good spectral resolution (LISS data) and so the spatial resolution of 5.6 m in panchromatic mode. The remote sensing satellites with high-resolution sensors and broad coverage potential provide data with better resolution, coverage, and revisit to meet the growing applications needs.



CHECK YOUR PROGRESS

Q.6: Define urban sprawl.

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6.8 MONITORING AND EVALUATION OF PROJECTS

Geoinformatics is the application of geographic information systems (GIS) and related technologies in the collection, management, analysis, and dissemination of geospatial data. Geoinformatics can be a useful tool in monitoring and evaluating research and development projects. This technology enables researchers to visualize, analyze, and interpret spatial data, making it easier to identify patterns and trends in the data. One key application of geoinformatics in monitoring and evaluating research and development projects is the tracking of project progress. Geoinformatics can be used to track the progress of research and development projects by mapping the location and progress of various project activities. This helps project managers to identify any delays or issues and take corrective action if necessary. Another application of geoinformatics in monitoring and evaluating research and development projects is the identification of project impacts. Geoinformatics can be used to map the location and extent of project impacts, such as changes in land use, water quality, or biodiversity. This information can be used to assess the effectiveness of the project and make adjustments to improve its outcomes. Geoinformatics can also be used to support data management in research and development projects. By using GIS technologies, researchers can manage, store, and analyze large amounts of data from various sources, including satellite imagery, aerial photographs, and ground-based surveys. This makes it easier to integrate and analyze data, identify trends, and make informed decisions. Finally, geoinformatics can be used to support communication and stakeholder engagement in research and development projects. By using GIS technologies to visualize and share project data, researchers can improve communication with stakeholders, including local communities, policymakers, and funding agencies. This can help to build support for the project and ensure that it meets the needs of all stakeholders.

In conclusion, geoinformatics is a valuable tool for monitoring and evaluating research and development projects. This technology can help researchers to track project progress, identify project impacts, support data management, and improve communication with stakeholders. By using geoinformatics, researchers can improve the outcomes of research and development projects and ensure that they meet the needs of all stakeholders.



6.9 LET US SUM UP

- Land cover corresponds to the physical condition of the ground surface, for example, forest, grassland etc., while land use reflects human activities such as the use of the land, for example, industrial zones, residential zones, agriculture fields etc.
- Droughts and Floods are water-related natural disasters that affect a wide range of environmental factors and activities related to agriculture, vegetation, human and wildlife and local economies.



6.10 FURTHER READING

1. Agarwal, C. S and Garg, P. K. 2000: Textbook on Remote Sensing in Natural Resource Monitoring and Management - A. H. Wheeler, New Delhi-1.
2. Gautam, N. C., Raghavswamy, V. And Nagaraja, R. (Chief Editor) 1994: Space Technology and Geography, NRSC, Hyderabad.
3. Guha, P.K. 2013: Remote Sensing for the Beginner, Affiliate East West Publishers, New Delhi.
4. Heywood, Ian, Cornelius, S. 2011: An Introduction to GIS 4th Edition, Pearson, New Delhi.
5. Jensen, J. R. 2011: Remote Sensing of the Environment - An Earth Resource Perspective: Pearson Education., New Delhi.

6.11 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1: Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture; it does not describe the surface cover on the ground. For example, recreational land use could occur in a forest, shrubland, grasslands, or on manicured lawns.

Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil, or other; it does not describe the use of land, and the use of land may be different for lands with the same cover type. For example, a land cover type of forest may be used for timber.

Ans. to Q. No. 2: Drought is a normal, recurrent feature of climate and occurs in all climatic zones, based on the causative factors, drought can be classified into Meteorological, Hydrological and Agricultural droughts.

Ans. to Q. No. 3: The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology.

Ans. to Q. No. 4: The contributing factors are runoff, soil type, surface slope, surface roughness, drainage density, distance to the main channel and land use.

Ans. to Q. No. 5: GIS technology initiates new visions for rural development in India by identifying innovative initiatives in lagging rural regions and by developing alternative development scenarios, which give special emphasis to options outside the quality sectors of agriculture and forestry.

Ans. to Q. No. 6: Urban sprawl, also called sprawl or suburban sprawl, is the rapid expansion of the geographic extent of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation.



6.12 MODEL QUESTIONS

Q. 1: Explain the role of remote sensing to monitor land-use change.

Q. 2: Explain the application of remote sensing in watershed management.

Q. 3: Write a note on the application of remote sensing in disaster management.

Q. 4: Explain the benefits and applications of satellite images and aerial photographs.

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