GI-01

KRISHNA KANTA HANDIQUI STATE OPEN UNIVERSITY

POST GRADUATE CERTIFICATE PROGRAMME IN GEOINFORMATICS

COURSE 1

FUNDAMENTALS OF GIS

CONTENTS

UNIT-1: Basics of Geoinformatics
UNIT-2: Understanding Maps
UNIT-3: Map Projection in GIS
UNIT-4: Basics of Geodesy and Spatial Referencing Systems
UNIT-5: Introduction to Geographic Information Systems
UNIT-6: Introduction to Database Management System
UNIT-7: GIS Data Types
UNIT-8: Sources and Nature of Geospatial Data

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Post Graduate Certificate Programme in Geoinformatics

Course 1
GI-01 FUNDAMENTALS OF GIS

MARKS 100
DETAILED SYLLABUS

Credits - 4

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COURSE INTRODUCTION

"Fundamentals of GIS" is the first course of this programme which is designed to provide the details of Geoinformatics and Geographic Information System, maps and its projections in GIS, GIS data types and its sources etc. It will help the learners to understand the relationship between people, climate, landforms, land use, river system, vegetation and much more. They will be able to develop their computer and management skills as a part of geospatial technology using GIS tool.

This Course is divided into eight units.

The **first unit** covers the concept of Geoinformatics, major fields of Geoinformatics, introduction to cartography and surveying, significance of Geoinformatics and multidisciplinary nature and applications of Geoinformatics.

The **second unit** includes the definition of a map, properties of maps, various types of maps and present day significance of maps.

The **third unit** introduces us to map projection systems, map projections for hemispheres and the world, map projections for continents and regions, Universal Transverse Mercator projection and International Terrestrial Reference Frame in GIS.

The **fourth unit** covers the shape and size of the earth, ellipsoids and datum and co-ordinate systems used in GIS.

The **fifth unit** covers the importance of basic concepts of Geographic Information Systems, components of a GIS, advantages of GIS, social and institutional context of GIS and contemporary development of GIS.

The **sixth unit** covers the overview of database in computer science, basics of database system, fundamentals of geo-database management system and creation of geo-database for applications in geo-informatics.

The **seventh unit** includes the raster data, vector data, TIN, topological relationships and raster and vector data formats.

The **eighth unit** covers the spatial and non-spatial data,Digital Elevation Model (DEM)and other data sources, data input output processes and devices,data verification, correction and storage, data conversion in GIS.

Each unit of this block has some questions as "Check Your Progress", to be answered by the learners while going through the units. The learners can tally their answers with the answers given at the end of each unit as "Answers to Check Your Progress". This will help them in judging their performance. The units of this block include some along-side boxes to help you know some of the difficult, unfamiliar terms. The learners will come across some "Activity" within the units which will help them in gaining practical experience in the related topics.

UNIT- 1 : BASICS OF GEOINFORMATICS

UNIT STRUCTURE

1.1 Learning Objectives

1.2 Introduction

1.3 Concept of Geoinformatics

1.4 Major fields of Geoinformatics

1.5 Introduction to Cartography and Surveying

1.6 Significance of Geoinformatics

1.7 Multidisciplinary Nature and Applications of Geoinformatics

1.8 Let us Sum up

1.9 Further Readings

1.10 Answers to Check Your Progress

1.11 Model Questions

1.1 LEARNING OBJECTIVES

After reading this unit, you will be able to-

- understand the basic concept of geoinformatics
- describe the overview of major fields of geoinformatics
- learn about cartography and surveying
- enlighten the significance of geoinformatics
- get an idea of geoinformatics applications.

1.2 INTRODUCTION

In this unit, we are going to discuss the basics of geoinformatics. The unit deals with the overview of geoinformatics with its major fields. The unit is also going to provide a preliminary introduction to cartography and surveying, which are very essential for map making. The unit is concluded with detail description of the significance and major application of geoinformatics.

1.3 CONCEPT OF GEOINFORMATICS

Geoinformatics is now-a-days a widely increasing technological subject domain in geospatial decision making. Right from academic-research curriculum to defence management and environmental conservation, geoinformatics skills play a vital role. The term 'geoinformatics' is derived from two words namely 'geo' meaning earth and 'informatics' meaning processing of information of the earth's features. Hence, geoinformatics primarily concentrated on earth's information from spatial perspective. Geoinformatics can be defined as a subject domain that is associated with earth's environment and the management geo-environmental issues through the inputs of space technologies. It is a

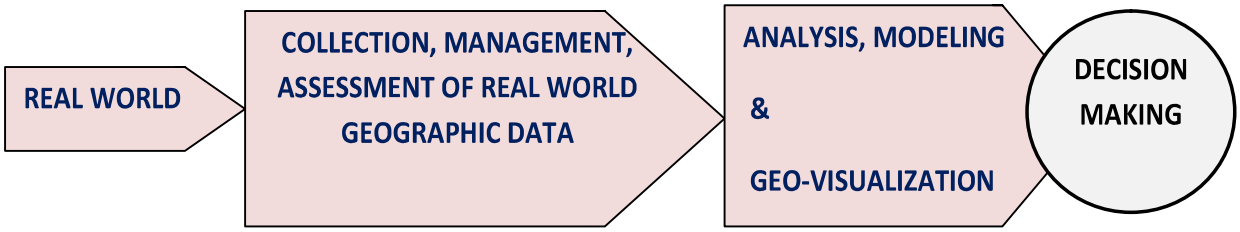


Figure 1.1: Geoinformatics basic

discipline that combines earth related information using information technology tools. In Wikipedia, geoinformatics is defined as "the science and the technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering". Jachimski (2001) defined geoinformatics as "the science of the gathering, processing and dissemination of information which is spatially defined within the Earth's system". Geoinformatics utilizes computer and spatial infrastructures in order to collect, store, organize, analyse and geo-visualize geographic data for scientific interpretation of real world entities. Real world entities include natural and human-made features of the earth's environment, while geoinformatics assesses the spatial relationships, spatial association, spatial organization of these earth's features, objects with special emphasis on spatio-temporal aspect, i. e. where, what, when, how, etc. Geoinformatics

as a full-fledged subject domain mainly developed after the 1990's. At present, geoinformatics represents a significant share in the global digital infrastructure for decision making. A popular and most familiar product of geoinformatics is the Google Map, which we are using in our daily routine to organize place search as well as navigation purpose. The location-wise daily weather updates and predictions, that we are getting at real time are the results of geoinformatics inputs.



CHECK YOUR PROGRESS

Q.1: Define geoinformatics.

.....

Q.2: Describe the role of geoinformatics.

.....

1.4 MAJOR FIELDS OF GEOINFORMATICS

Geoinformatics is a subject domain that combines various fields of earth sciences, spatial sciences, computer sciences, and information and communication technologies. The major fields or branches of Geoinformatics include the following:

Photogrammetry: The science of map making from aerial photographs.

(i) Aerial photography*:** It refers to the acquisition and measurements of ground features with help of precision camera mounted on aerial vehicle like airplane, helicopter, balloons, etc. Aerial photography is a part of ***Photogrammetry technology. Aerial photographs provide a bird's eye view of the ground. Three dimensional visualization of ground surface can be possible with the help of ***stereoscopic*** instrument over overlapped aerial photographs. Aerial photography played a vital role during the World War I. Aerial photography mainly developed in the early part of the 20th century especially in Europe and North America.

Stereoscopic view: Visualization of same spot from two locations.

(ii) ***Cartography:*** It refers to the science, art and technique of map mapping, map producing and map-based interpretation. Cartography is a significant field of Geoinformatics. Cartography is mainly associated with representation of earth's features (both natural & human-made) for human communication through map. Maps depict the 3-dimensional earth's surface onto 2-dimensional plane at reduced scale with standardized symbols.

(iii) ***Computer science:*** Computer science provides the basic digital architecture for Geoinformatics. Computer science is associated with hardware, software, programming, digital technologies for interacting with data.

(iv) ***Geodesy:*** Geodesy is the Earth science of accurately measuring and understanding Earth's geometric shape, size, orientation in space and gravitational field. The field also incorporates studies of how these properties change over time and equivalent measurements for other planets.

(v) ***Geographic Information System:*** Geographic Information System or GIS is a computer-based system for collecting, storing, manipulating, transforming, analyzing and displaying geographic data. In GIS, geographic data or spatial data or geospatial data will mean the graphic data of space. GIS also allows interacting, questioning, viewing, and extracting information from the geographic data in order to establish spatial pattern and relationship, locational significance of the earth's features. Dr. Roger Tomlinson (1933-2014) of Canada is generally recognized as the 'father of GIS'. He is the visionary geographer who conceived and developed the first GIS for use by the Canada Land Inventory in the early 1960s.

(vi) ***Global Navigational Satellite System (GNSS):*** GNSS is concerned to provide satellite-based autonomous geospatial positioning, timing and navigation information with the help

IRNSS: Indian Regional Navigation Satellite System: This is an augmentation of GPS for better accuracy. It provides real time positioned and timing services.

of radio signals transmitted by the satellites to the electronic receiver devices. GNSS was first developed by the United States as Global Positioning System (GPS) during 1980s for civilian use. Later on, Russia developed GLONASS, European Union developed Galileo, China developed BeiDou, and India is developing ***IRNSS*** for satellite-based navigation purposes.

(vii) Remote Sensing: remote sensing is the science and technique of acquiring information about the objects and earth's environmental features from distance with the help of electromagnetic sensors mounted on satellites. Remote sensing techniques utilize photographic bands, infrared and microwave wavelengths in order to acquire information of the earth's environment. Remote sensing technology as a civilian discipline mainly developed during 1980s after the lunch of United States LANDSAT satellite program. Based on data acquisition technique, there are two types of remote sensing methods, namely active and passive remote sensing. Active remote sensing uses radar sensor and can able to operate day and night, while passive remote sensing uses optical sensor and can operate during the day.

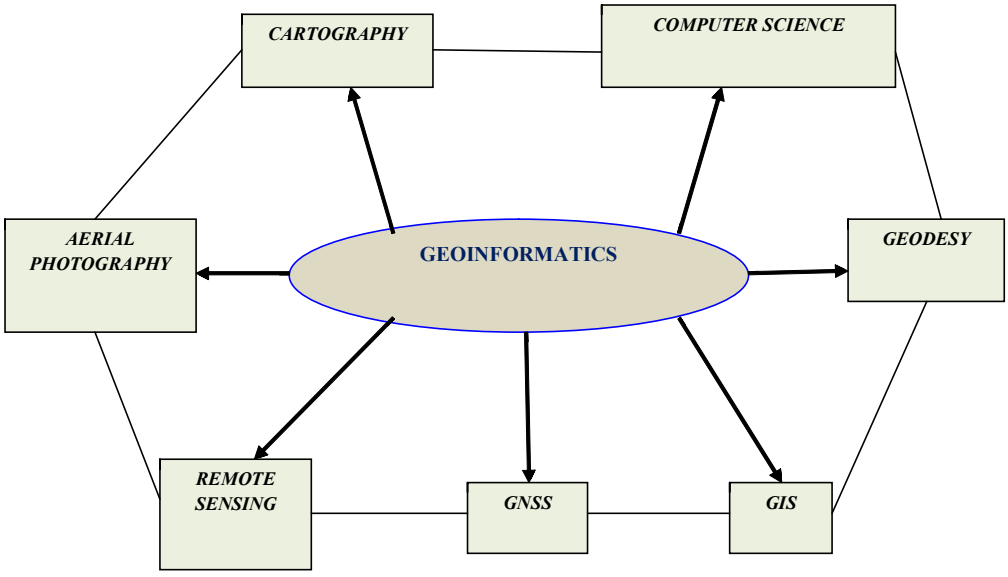


Figure 1.2: Fields of Geoinformatics



CHECK YOUR PROGRESS

Q.3: Who is the father of GIS?

.....

Q.4: Define Remote Sensing.

.....

1.5 INTRODUCTION TO CARTOGRAPHY AND SURVEYING

Cartography is the main basis for map-making and geo-visualization, it provides the foundation of geoinformatics. Surveying is that branch of science which deals with making measurements needed to locate accurately the details of the earth's surface.

Cartography is the study and practice of designing, constructing and producing maps. It is the science and art of map making. The term 'cartography' is derived from two Greek words *'chartis'* meaning map and *'graphein'* meaning study (Misra, 2014). Therefore, the primary concern of cartography is mapping. Cartography is the classical science of mapping. The origin of cartography as an independent science dates back to second century A. D. when Greek cartographer Ptolemy first prepared the World Map. Since then to till date, cartography is evolving with new paradigms, approaches of mapping that depict the earth's environment over space and through time. From classical or traditional cartography to digital cartography now-a-days, this has been providing the basis for geo-visualization through maps. Humans are using the maps for communication as well as the spatial pattern of natural and human-made features of the earth's environment. Cartography is helping human societies with correct interpretation of earth's environment through maps, and these maps are created in different formats like hardcopy paper maps to softcopy digital maps, for example, *Google Map*. As map is the prime tool for geo-visualization and also an integral part of geoinformatics, therefore, in the process of map-mapping for representing geographic data the cartographers should include some basic key properties of map-making.



Figure 1.3: Ptolemy's World Map



Figure 1.4: India with adjacent countries as viewed in Google Map

These properties include *scale, distance, direction, shape, area, map projection, map symbols, map location and theme,* etc. In geoinformatics also the same principle of map-mapping is taken into consideration. The *scale* of a map is the ratio of map distances and corresponding ground

distances. A *map projection* is the representation of 3-dimensional globe on a 2-dimensional plane with the help of network of parallels of latitude and meridians of longitude. The network/grid of the lines of longitude and the parallels of latitude is called graticule. The *map symbols* are the standardized forms of colours, shades and symbols in order to represent various natural as well as human-features with their locations onto maps. The *location* of the map represents the area of earth's surface that the map depicts, and the *theme* of map includes the subject matter or topic that the map visualization, e. g. population density map of India, forest cover map of North-Eastern States of India, etc.

Surveying refers to the collection and recording of ground data from the field with the help of surveying instruments. These surveyed data are then represented onto map for scientific display and representation of earth's location and features. Surveying of the ground also helps in updating the map of a location with newer and changing detail of the feature concerned. The process of measurement in surveying includes the measurement of angle, distance, direction, recording of numerical values of the locations surveyed. There are two types of surveying in cartography. These two types include Geodetic surveying and Plane surveying. If surveying is carried out for larger area with greater distances then the curvature of the earth is taken into consideration and hence, this type of surveying is called geodetic surveying. Remote sensing surveying, aerial photographic surveying etc. are the examples of ***geodetic surveying***. On the other hand, if surveying is carried out for smaller areas and distances where earth is considered as flat instead of curvature then this type of surveying is known as plane surveying. For example, plane table surveying, prismatic compass surveying, handheld GPS surveying etc. are the example of plane surveying.

Geodetic surveying: It is a primary level of surveying with due consideration of the shape of the earth, the absolute location and altitude of a place is determined.

The *Survey of India* established in the year 1767 is the oldest scientific department and organization of the Government of India associated with the National Survey and Mapping for civilian, military, aeronautic, regional planning, tourism, academic and other miscellaneous purposes and uses. The headquarter of the Survey of India is located in Dehradun of Uttarakhand of India.



CHECK YOUR PROGRESS

Q.5: What is surveying?

.....

Q.6: What is the mapping agency of India? When was it established?

.....

1.6 SIGNIFICANCE OF GEOINFORMATICS

Geoinformatics is one of the most popular fields in 21st century. Due to its geospatial characteristics, geoinformatics is widely utilized by various stakeholders of different sectors at global, regional and local levels. Geospatial data driven information are mass accepted and these are very significant for human communication. Geoinformatics helps users and stakeholders for scientific interpretation with spatio-temporal visualization of facts and data. Geoinformatics is becoming a very important digital tool for decision makers worldwide. With the help of geoinformatics, it has become possible to assess data and facts of the earth's environment which were not possible earlier with traditional technologies, e. g. acquiring information about remote and inaccessible places with satellite imageries. Besides, following are some important points that draw significance of geoinformatics:

(i) Geoinformatics provide cost-effective and timely information about earth's natural resources and environment.

(ii) Satellite imagery data of geoinformatics has global coverage with synoptic view of the area.

(iii) With the help of geoinformatics, it has become possible for visualization of geospatial data.

(iv) Geoinformatics is integration technology. It includes various fields, technologies and hence, geoinformatics results can easily reach masses for correct decision making.



CHECK YOUR PROGRESS

Q.7: Write the properties of satellite imagery?

.....

.....

1.7 MULTIDISCIPLINARY NATURE AND APPLICATIONS OF GEOINFORMATICS

Geoinformatics is a multidisciplinary science. Geoinformatics is the integration of cartography, GIS, GNSS, remote sensing, ICT etc. These disciplines including some other related disciplines on earth science, spatial sciences, digital technologies have been increasingly providing sound theoretical as well as applied inputs in the development of geoinformatics. Geoinformatics is a decision support system for monitoring, planning and management of resources and infrastructure. For this multidisciplinary nature and integrated approach of geoinformatics, various sectors of organization, industries, stakeholders, and academician are utilizing geoinformatics tools for assessment, observations, modelling, planning, policy implication and most importantly spatial decision making. Therefore, the diffusion and popularization of geoinformatics globally increases at rapid rate and these ultimately help in reaching masses of users from various backgrounds.

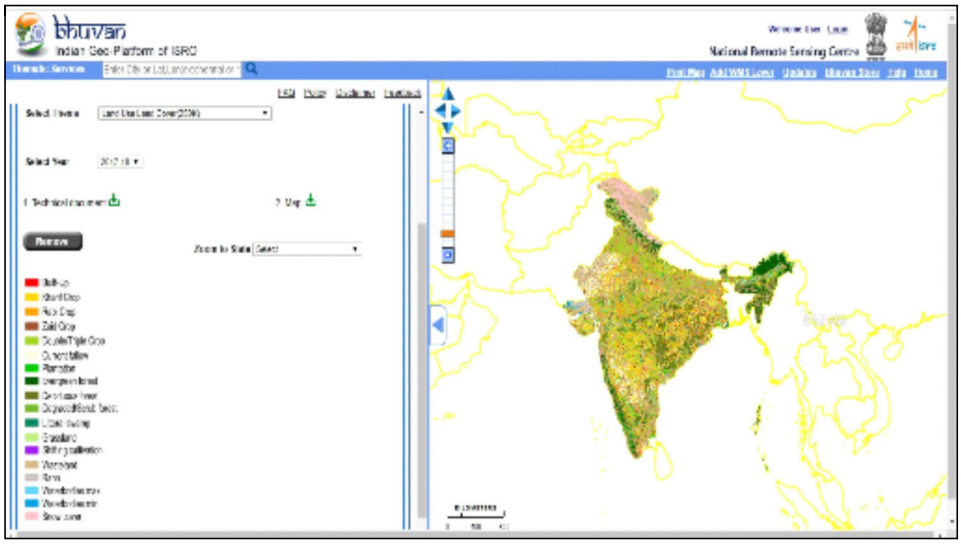


Figure 1.5: ISRO's Bhuvan geo-portal (a product of



Figure 1.6: School geo-portal of MHRD, India

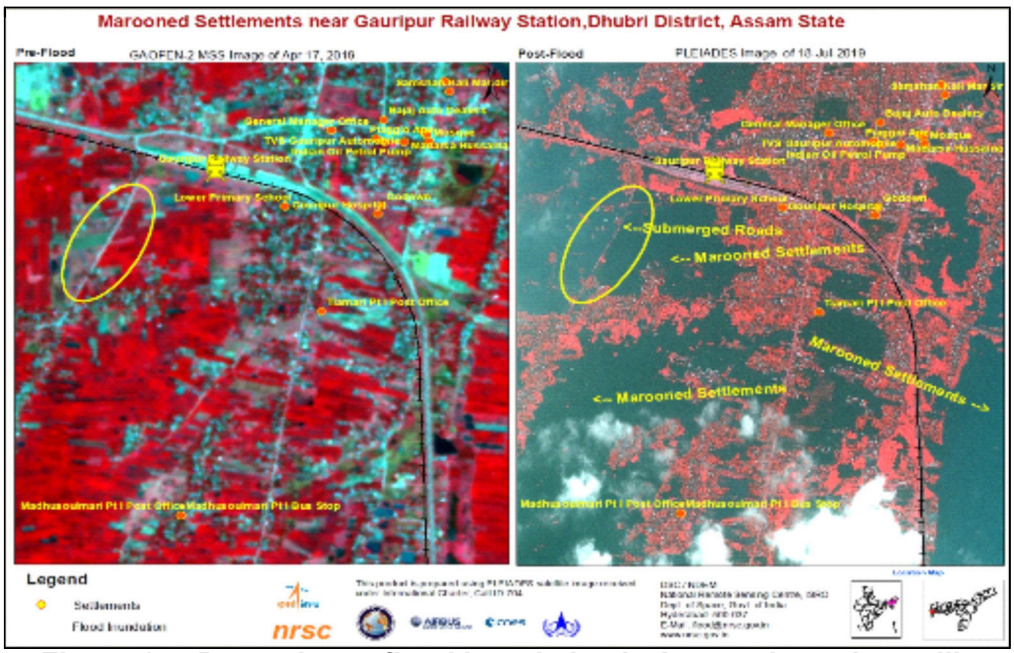


Figure 1.7: Pre and post flood inundation in Assam through satellite

Geoinformatics has multi-faceted applications in different areas like, academic and research, climatology, geology, forestry, oceanography, agriculture, archaeology, demography, tourism, health, natural resource management, regional planning and development, disaster management, military and defence, navigation, transport network development,

environmental management, modelling and conservation, business location planning and crime management etc. Some specific applications of geoinformatics are mentioned below:

(a) Site suitability analysis.
(b) Change detection analysis of land use and land cover using multi-temporal satellite imageries.
(c) Real time tracking and navigational services.
(d) Hazard zones mapping and locational susceptibility assessment.
(e) Damage assessment of pre, during and post disasters.
(f) Geo-tagging of services and assets.
(g) Electoral mapping.
(h) Epidemic spread and vulnerability mapping.
(i) Location-based business services management.
(j) Government policies implications through geo-portal services.
(k) 3-dimensional visualization, modelling and simulation of earth's environment and resources.



CHECK YOUR PROGRESS

Q.8: What are the major areas of application of geoinformatics?

.....

.....

.....



1.8 LET US SUM UP

- Geoinformatics can be defined as a subject domain that is associated with earth's environment and the management geo-environmental issues through the inputs of space technologies.
- At present, geoinformatics represents a significant share in the geospatial data infrastructure for decision making.

- The major fields of geoinformatics include cartography, computer science, geodesy, GIS, GNSS, and remote sensing including cartography aerial photography and photogrammetry.
- Cartography is the main basis for map-making and geo-visualization, it provides the foundation of geoinformatics.
- Surveying is that branch of cartography which deals with making measurements needed to locate accurately the details of the earth's surface.
- Geoinformatics helps users and stakeholders for scientific interpretation with spatio-temporal visualization of facts and data. Geoinformatics is becoming a very important digital tool for decision makers worldwide.
- Due to its multidisciplinary nature, various sectors of organization, industries, stakeholders, and academician are utilizing geoinformatics tools for assessment, observations, modelling, planning, policy implication and most importantly spatial decision making.



1.9 FURTHER READINGS

1. *Fundamentals of Cartography by R. P. Misra, Concept Publishing Company, New Delhi, 2014.*
2. *Introduction to Geospatial Technologies by Bradley A. Shellito, W. H. Freeman and Company, New York, 2017.*
3. *Principals of Geographic Information Systems from ITC, Netherlands, 2001.*
4. *https://en.wikipedia.org/wiki/Geoinformatics*
5. *http://egyankosh.ac.in/*



1.10 ANSWERS TO CHECK YOUR PROGRESS

Q.No. 1: Geoinformatics can be defined as "the science and the technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering".

Q.No. 2: Dr. Roger F. Tomlinson (1933-2014) of Canada is generally recognized as the 'father of GIS'.

Q.No. 3: Geoinformatics assesses the spatial association and spatial organisation of earth's surface features both in time and space dimension. It creates largest volume of data on geoinformation and digital data infrastructure for planning and spatial decision making processes.

Q.No. 4: Remote sensing is the science and technique of acquiring information about the objects and earth's environmental features from distance with the help of electromagnetic sensors mounted on satellites.

Q.No. 5: Surveying refers to the collection and recording of ground data from the field with the help of surveying instruments. The absolute and relative locations are determined with the help of surveying.

Q.No. 6: The *Survey of India* is the mapping agency of India. It was established in the year 1767.

Q.No. 7: Satellite imagery has synoptic coverage of an area and it portrays the characteristics of earth surface features.

Q.No. 8: Geoinformatics has multi-facets applications in different areas like, academic and research, climatology, geology, forestry, oceanography, agriculture, archaeology, demography, tourism, health, natural resource management, regional planning and development, disaster management, military and defence, navigation, transport network development, environmental management, modelling and conservation, business location planning and crime management etc.



1.11 MODEL QUESTIONS

Q.1: Which are the two words from where the term 'geoinformatics' is derived?

Q.2: What is aerial photography?

Q.3: What is geodesy?

Q.4: Define GNSS.

Q.5: What are the key properties of a map?

Q.6: Where is the headquarter of the Survey of India?

Q.7: Write a short note on surveying?

Q.8: Write about the basic of GNSS.

Q.9: Mention the significance of geoinformatics.

Q.10: Mention the main applications of geoinformatics.

*** *** ***

UNIT- 2: UNDERSTANDING MAPS

UNIT STRUCTURE

2.1 Learning Objectives

2.2 Introduction

2.3 Definition of map

2.4 Properties of map

2.5 Types of map

2.6 Present day significance of maps

2.7 Let us Sum up

2.8 Further Readings

2.9 Answers to Check Your Progress

2.10 Model Questions

2.1 LEARNING OBJECTIVES

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

- explain the meaning of a map
- identify the map properties
- explain about different types of maps
- explain the significance of maps in the present times

2.2 INTRODUCTION

In the previous unit we have discussed the basics of geoinformatics. This unit focuses on the meaning of a map and how it differs from a sketch. In this unit you are going to learn about the different properties and types of maps. This unit also deals with the present day significance of maps.

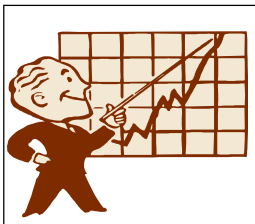
2.3 DEFINITION OF MAP

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 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 this cannot be represented all at a time. Maps are drawn on a planimetric surface.

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 on is, of course, 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, mathematically produced maps.

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.



CHECK YOUR PROGRESS

Q.1: Define a map.

.....

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

.....

2.4 PROPERTIES OF MAP

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 or characteristics of a map that are distorted to some degree, depending on the map projection used. These characteristics include Conformality or orthomorphism (shape), Equivalence (area), True direction and True distance.

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.

Conformality or Orthomorphism:

Conformality orthomorphism means having the right shape. A conformal or an orthomorphic map is a map in which shape mapped area of earth surface is identical to the corresponding area the earth's surface. A conformal or othomorphic 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 map are useful for large scale mapping and phenomenon with circular radial patterns such as radio broadcasts for average wind directions. Some map projection 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 in a map for 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.

.....

.....

Q.4: What do you mean by equivalence?

.....

.....

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

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2.5 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.

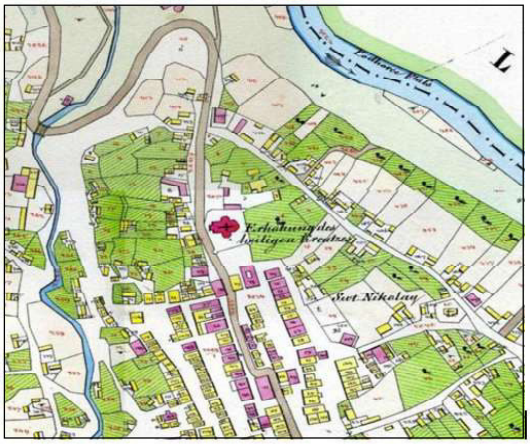
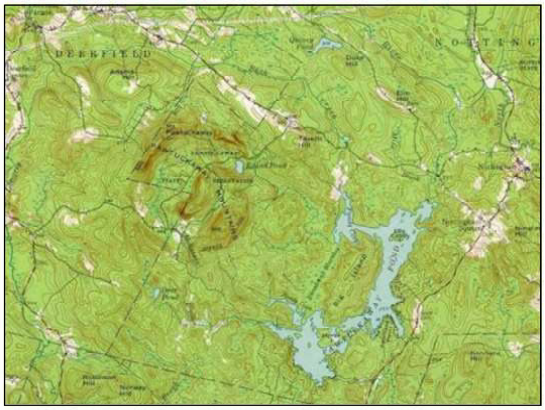


Fig. 2.1: A cadastral map

Topographic Map:

A topographic map indicates different physical landscape features on 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.2.2: A topographical 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 about 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 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.

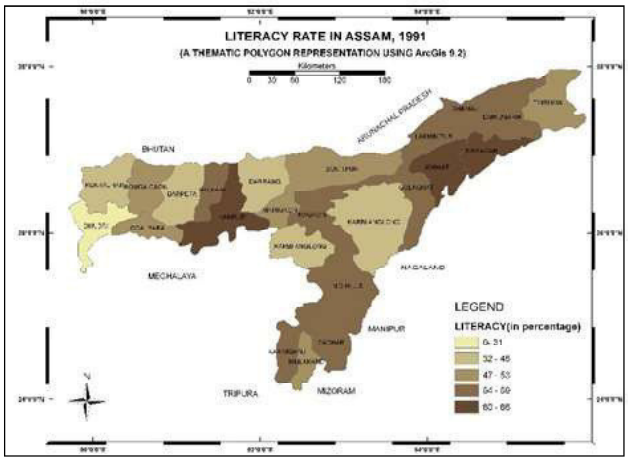


Fig.2.3: A thematic map of literacy distribution

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 in the map. Although some physical features show up on political maps, including major mountain ranges, the use of this is to provide geographical reference indicating any physical features. These boundaries and locations are usually based on people instead of the natural world.



Fig. 2.4: 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 land forms like deserts, mountains, lakes and plains. Their topography style provides a complete picture of the local terrain.


Fig. 2.5: A physical map

Climate Map:

A climate map shows knowledge about the climate of a region. It display things like the precise climatic zones of an area using the temperature,



Fig. 2.6: A climate map

such as, how much snow an area gets or average amount of cloudy days. These maps normally use colors to point out different climatic areas.

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 a smaller line thickness.

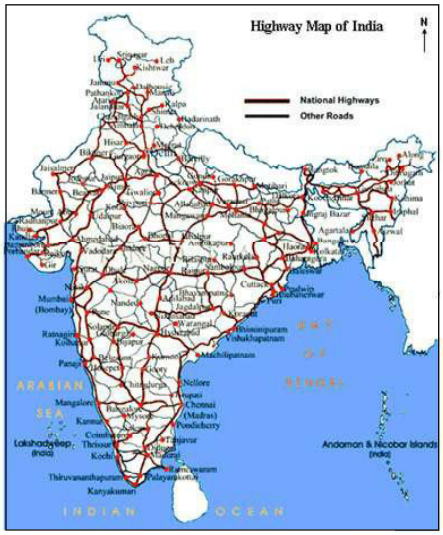


Fig. 2.7: A map displaying road network

General Reference Map:

These are the basic maps which 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 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.

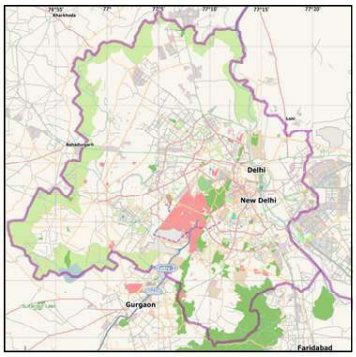
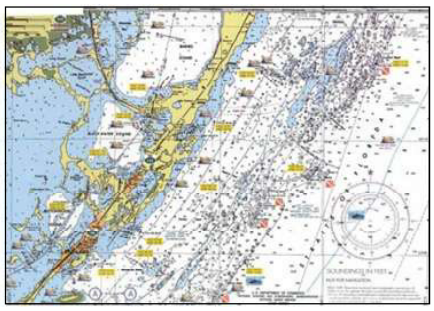


Fig. 2.8: A Reference Map

Navigational Chart Map:

It is a map that shows the layout of the shoreline and seafloor. Navigational charts are important tools that helps 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 are essential to avoid accidents in and around the water like submerged rocks, as well as, providing additional navigational aids.


Fig. 2.9: 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 topographical map.

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Q.8: What is thematic map?

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2.6 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 solve the increasingly 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. 2.10

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. 2.11

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.

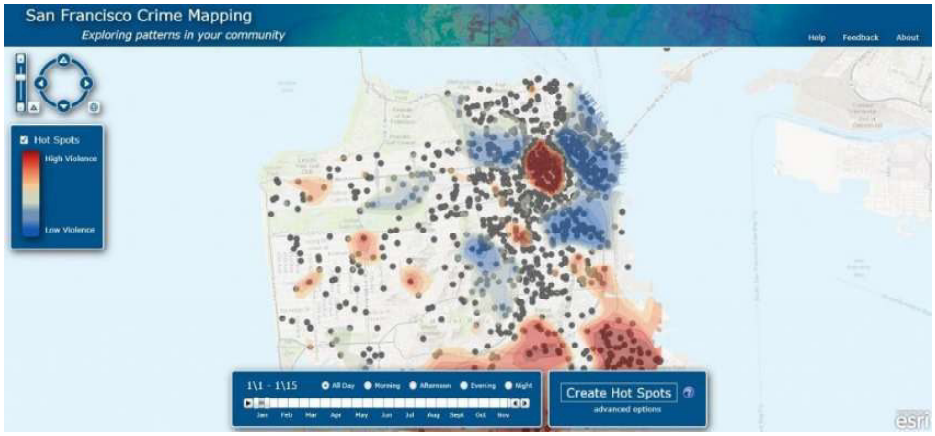


Fig. 2.12

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



Fig. 2.13

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?

.....



2.7 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. For specific purpose, the shape and area is also preserved in a map.
- 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 have changed from basic expressions of locations to works of art, extremely accurate, mathematically produced maps.
- Different 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.
- There are four basic properties of a map that are distorted to some degree, depending on the map projection used. These characteristics include 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.
- Maps help in finding patterns in from a huge volume of data.
- Maps help us to perform analysis.



2.8 FURTHER READING

1) Kang-Tsung Chang, *Introduction to Geographic Information System,* Published by McGraw-Hill, 2002.

2) Suren Talukder, *Introduction to Map Projections*, published by EBH Publishers (India), 2008.



2.9 ANSWERS TO CHECK YOUR PROGRESS

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.

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.

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.

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.

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.

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

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.

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 includes Dot map, Isopleth map, Choropleth map and Choro- chromatic map

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.



2.10 MODEL QUESTIONS

Q.1: What is cartography?

Q.2: Explain the evolution of ma 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- 3: MAP PROJECTION IN GIS

UNIT STRUCTURE

3.1 Learning Objectives

3.2 Introduction

3.3 Map Projection Systems

3.4 Map Projections for Hemispheres and the World

3.5 Map Projections for Continents and Regions

3.6 Universal Transverse Mercator Projection

3.7 International Terrestrial Reference Frame in GIS

3.8 Let us Sum up

3.9 Further Readings

3.10 Answers to Check Your Progress

3.11 Model Questions

3.1 LEARNING OBJECTIVES

After reading this unit, you will be able to-

- explain the basic concept of map projection
- describe about map projections for hemispheres, world, continents and regions
- enlighten the significance of Universal Transverse Mercator Projection
- get an idea of International Terrestrial Reference Frame in GIS.

3.2 INTRODUCTION

In the previous unit we have focussed on the meaning of map used in GIS. In this unit, we are going to discuss the basics of map projection systems. The unit deals with the overview of map projection, different types of map projections used in GIS. Some conceptual ideas about Universal

Transverse Mercator Projection and International Terrestrial Reference Frame in GIS are also discussed in this unit.

3.3 MAP PROJECTION SYSTEMS

Map is an important cartographic tool. Map has different element like location, scale, symbols, standardization and generlization, map projection. Each of these map elements are necessary to preapre a map of any place. Map projection is also a necessay element for map making in cartography and GIS. Map projection can be defned as a technique to transform and represent the 3-dimension earth surface on a flat or plane surface using graticules. Graticules refer 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 to a globe, and then this generationg 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).

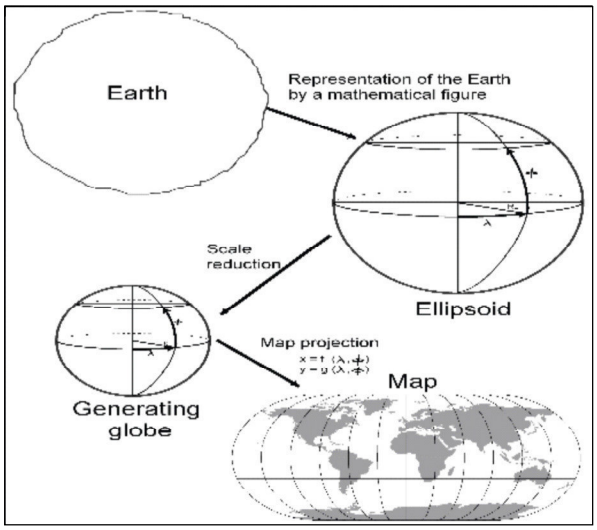


Figure 3.1: Map projection process (after Canters

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 graticules of the globe is projected on the cone surface. The latitude of the globe where the cone surface is tangent, 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.

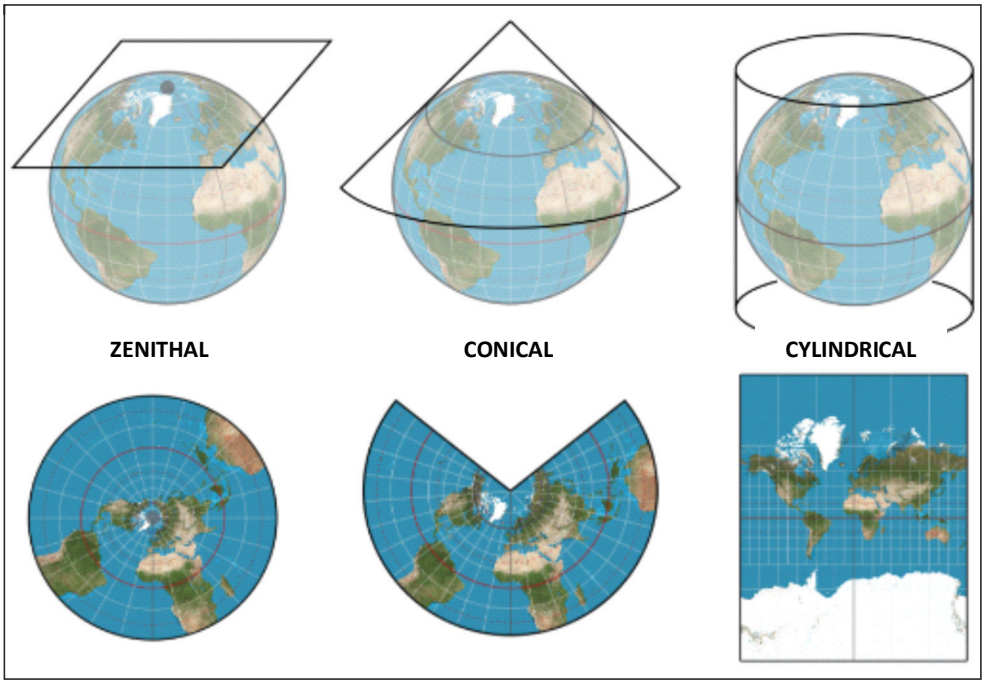


Figure 3.2: Types of map projection based on developable surface (https:// gistbok.ucgis.org/***).***

(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 the 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 the suitable map projection that preserves all map projection properties like scale, shape, area, distance and directions. Hence, the choosing of map projection is dependent on the purpose, requirement and need 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.1: Define map projection.

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Q.2: What is Zenithal map projection?

.....

3.4 MAP PROJECTIONS FOR HEMISPHERES AND THE WORLD

Every map projection has certain properties and use. 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 3.1: Map projections for Hemispheres

Map projection	***Properties***	***Limitations***
Zenithal Equal Area	Parallels are concentric circles.Preserves equal area 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. Suitable for two-hemisphere map.	Does not have equal area properties.

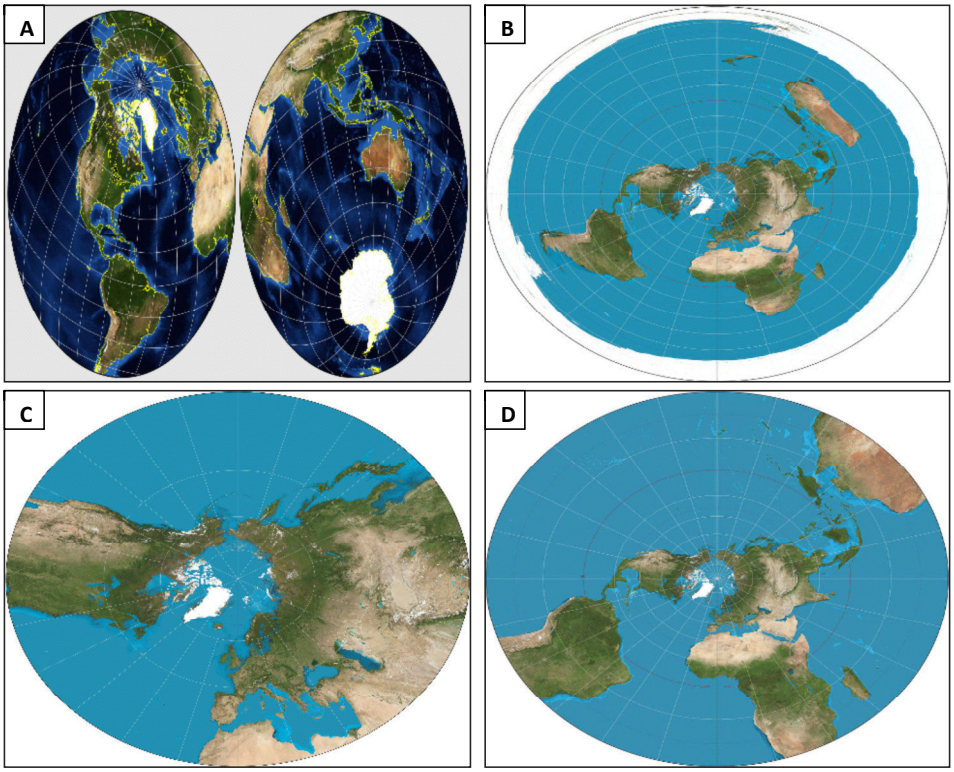


Figure 3.3: A=Zenithal Equal-Area projection, B=Zenithal Equidistant projection, C=Zenithal Gnomonic projection, D=Zenithal Stereographic projection.

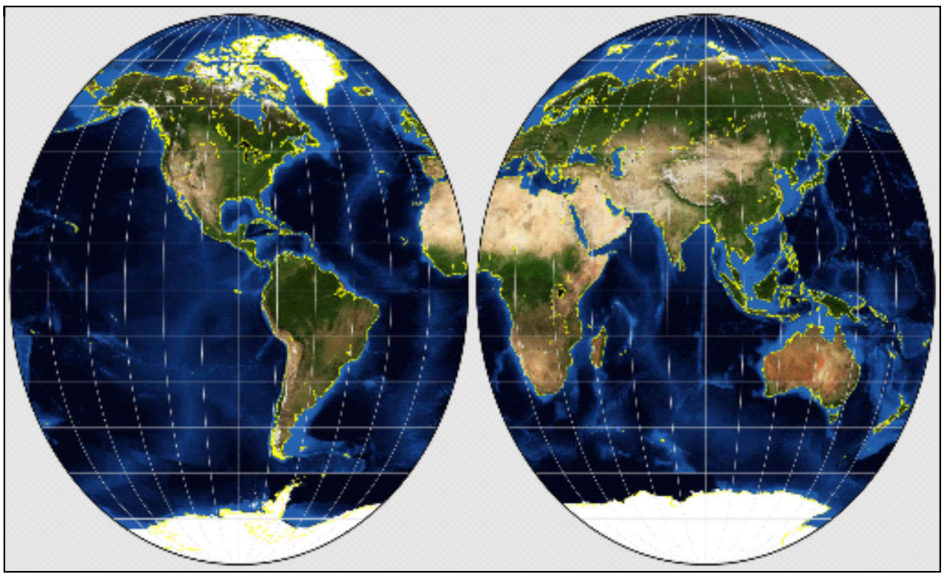


Figure 3.4: Apian map projection showing two-hemispheres.

Table 3.2: 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.

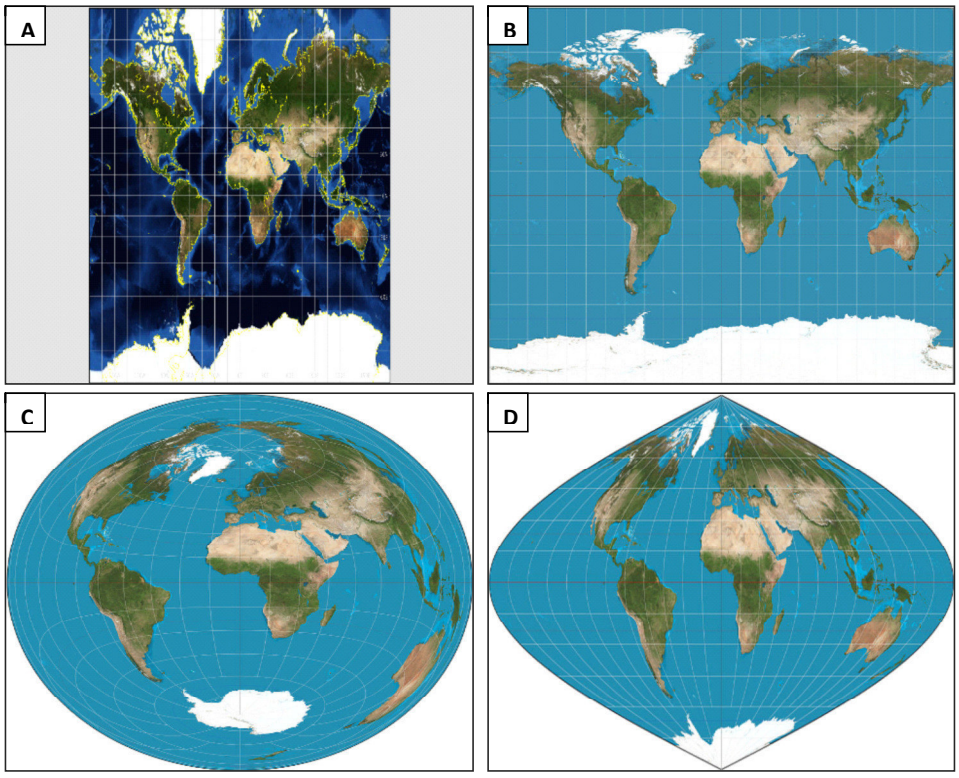


Figure 3.5: A=Mercator's projection, B= Gall's Stereographic projection, C= Lambert Azimuthal Equal Area projection, D= Sinusoidal projection.



CHECK YOUR PROGRESS

Q.3: Mention two properties of Zenithal Equal-Area map projection.

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Q.4: Mention two properties of Mercator's projection.

.....

3.5 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 suitable for representing smaller regions and areas. Therefore, there are various location-specific, country & continent specific, region specific suitable map projections in GIS. Some of these map projections are briefly mentioned below:

Table 3.3: 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.

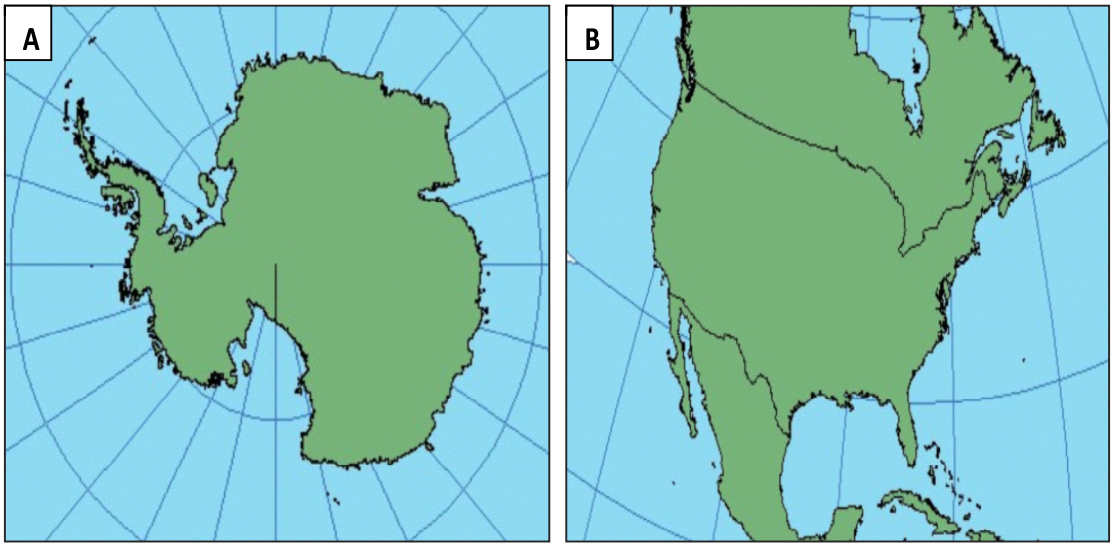


Figure 3.6: A= Polar Zenithal Stereographic projection, B= Conical Equidistant projection.

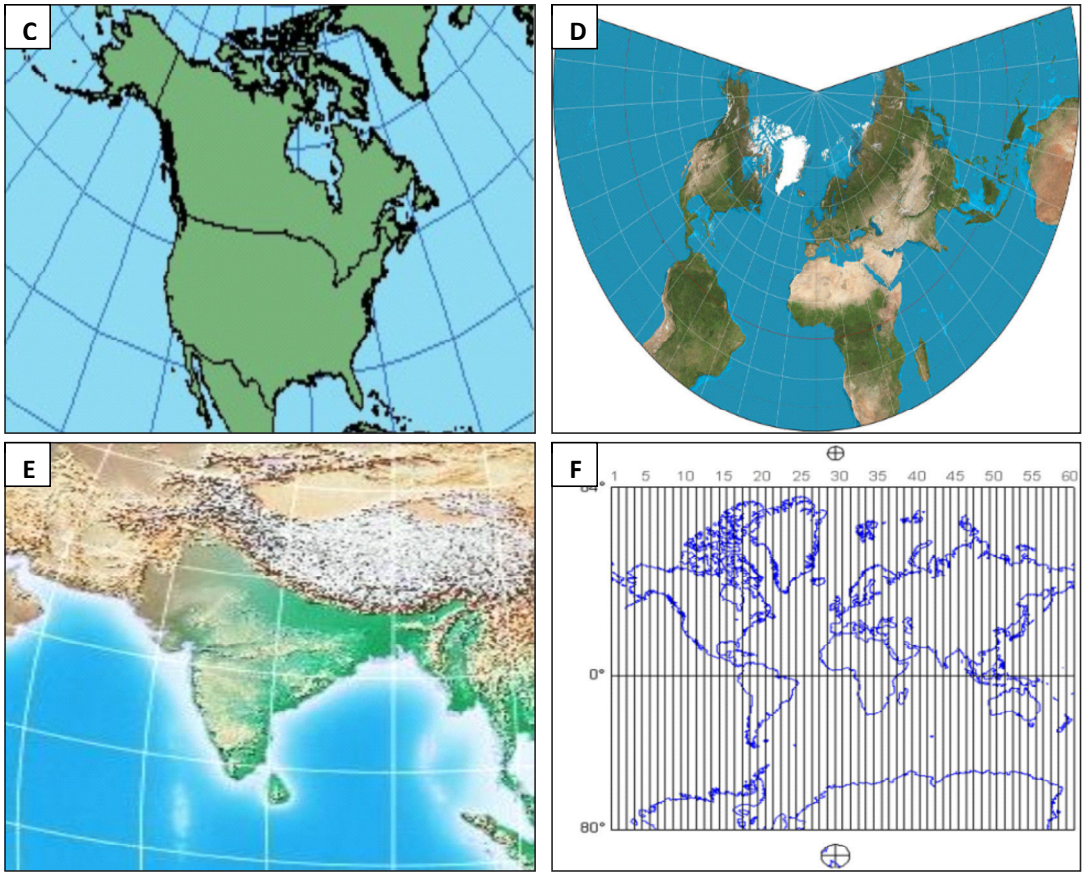


Figure 3.7: C= Alber's Conical Equal Area projection, D= Lambert's conformal Conical projection, E= Bonne's Conical projection, F= Universal Transverse Mercator projection.



CHECK YOUR PROGRESS

Q.5: Mention two properties of Bonne's conical projection?

.....

.....

3.6 UNIVERSAL TRANSVERSE MERCATOR PROJECTION

Universal Transverse Mercator also knows as UTM, is a popular and one of the most widely projection systems in GIS. Universal Transverse Mercator uses a tranverse cylinder, secant to the horizontal reference. UTM is derivation from Tranverse 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 representaion 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 central meridian. The shape of each zone is like a boat bulging in the middle and tapering to a point on the ploes. A rectangular representation is shown in figure 3.8.

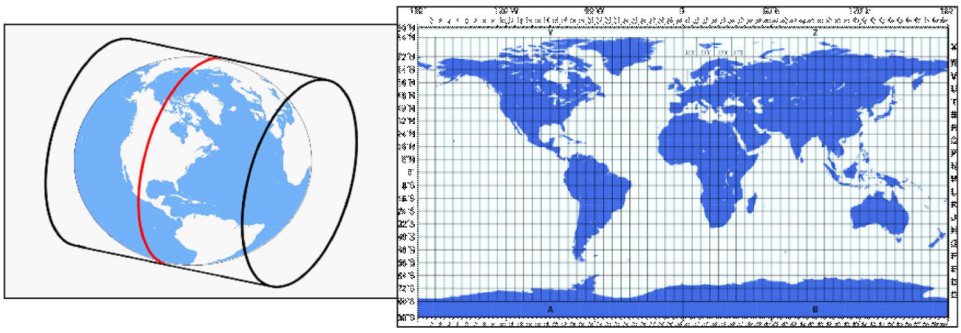


Figure 3.8: UTM projection system



CHECK YOUR PROGRESS

Q.6: Which is the UTM zone for Assam?

.....

.....

.....

3.7 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 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.7: What is the full form of ITRF?

.....

.....

.....



3.8 LET US SUM UP

- Map projection can be defned as a technique to transform and represent the 3-dimension earth surface on a flat or plane surface using graticles.
- A map projection uses mathematical formulas to relate spherical coordinates on the globe to flat, planar coordinates.
- Based on the developable surface there are *Zenithal projection*, *Conical projection* and *Cylindrical Projection*.

- Based on area, shape, direction and scale there are *Equal-area projection*, *True-shape projection*, *True-bearing projection* and *True-scale projection.*
- Gall's projection, Sinusoidal projection, Mercator's projection etc. are used for world mapping; while Zenithal Gnomonic projection, Apian projection etc. are used for hemisphere mapping.
- Conical projections like Bonne's, Alber's Lambert's etc. are mostly used for regional country and continent mapping in GIS.
- UTM is the most widely used map projection system for zonal and small area mapping. UTM preserves shapes, angles with directions for smaller areas. UTM is very much suitable for large scale mapping in GIS.
- ITRF is a 3-dimensional Cartesian coordinate system used in GIS and other ground surveying systems.



3.9 FURTHER READING

1. *Fundamentals of Cartography by R. P. Misra, Concept Publishing Company, New Delhi, 2014.*
2. *Principals of Geographic Information Systems from ITC, Netherlands, 2001.*
3. *Reference Systems for Surveying and Mapping by H. van der Marel, Delft University of Technology, Netherlands, 2014.*
4. *Understanding Map Projections by ESRI, 2004.*
5. *https://en.wikipedia.org/wiki/List_of_map_projections*
6. *http://egyankosh.ac.in/*



3.10 ANSWERS TO CHECK YOUR PROGRESS

Q.No.1: 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.

Q.No.2: 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.

Q.No.3: Two properties of Zenithal Equal Area projection includes: Parallels are concentric circles; Preserves equal area properties.

Q.No.4: Two properties of Mercator's projection includes: Preserves true-bearing and Rhumb line can be drawn as straight line showing constant direction.

Q.No.5: Two properties of Bonne's projection includes: Central meridian is a straight line; An equal area projection.

Q.No.6: UTM 46 north zone represents Assam in GIS grid systems with 93Ú meridian as central meridian.

Q.No.7: International Terrestrial Reference Frame (ITRF).



3.11 MODEL QUESTIONS

Q.1: What are different types of map projection based on developable surface?

Q.2: What is Conformal map projection?

Q.3: What is Equal Area map projection?

Q.4: Define Conical map projection.

Q.5: Mention two map projections in GIS that are used for hemisphere mapping.

Q.6: Mention one Polar map projection.

Q.7: Mention two world map projections.

Q.8: Define UTM projection in GIS.

Q.9: Mention the significant properties of UTM projection.

Q.10: Define ITRF.

*** *** ***

UNIT- 4: BASICS OF GEODESY AND SPATIAL REFERENCING SYSTEMS

UNIT STRUCTURE

4.1 Learning Objectives

4.2 Introduction

4.3 Shape and Size of the Earth

4.4 Ellipsoids and Datum

4.5 Co-ordinate Systems

4.6 Let us Sum up

4.7 Further Readings

4.8 Answers to Check Your Progress

4.9 Model Questions

4.1 LEARNING OBJECTIVES

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

- explain about the complexities pertaining to the shape and size of the earth
- explain about the different measurement frameworks and principles adopted for making horizontal and vertical measurements on the earth
- explain about the different earth models used for map-making
- explain about coordinate systems used in GIS.

4.2 INTRODUCTION

In the previous unit, you have learnt about the map projection in GIS. In this unit you are going to learn about the different Earth models and coordinate systems used for map- making. This unit focuses on the shape

and size of the Earth and its associated complexities and transformations. This unit will also provide you the earth models used for map making and co-ordinate systems used in GIS.

4.3 SHAPE AND SIZE OF THE EARTH

The Earth is really a fascinating 3-dimensional object in space. It is rotating about its axis and also it is revolving around the sun with tremendous velocity. In ancient times, it was considered to be a flat body but today we are very much familiar about its shape and size. The science which deals with shape and size of the Earth is known as Geodesy. The basic knowledge of Geodesy is prerequisite to understand the Geographic Information System in a better way. In a 3-dimensional object, the location of a point is determined by a specific co-ordinate system, known as geographic co-ordinate system. It is a 3-dimensional co-ordinate system. Earth's surface is not flat over large distances. The first step to map spatial features on the earth's surface is to select a model that approximates the shape and size of the Earth. The simplest model is a sphere, which is typically used in map projections. But the Earth is not a perfect sphere as it is wider along the Equator than between the Poles. Hence the better approximation to the shape of the Earth is a spheroid, also called an ellipsoid, an ellipse rotated about its minor or major axis. The notion that the earth is spherical in shape was developed by the ancient Greeks in the 2nd century B.C. In the 17th century, Isaac Newton deduced considerations that the Earth is slightly flattened at the poles and bulged slightly at the Equator, due to Earth's rotation on its axis. This was subsequently confirmed by field observations. This shows it is an oblate ellipsoid, in which the radius to the polar regions are slightly less than that to its equatorial belt because its internal materials bulge outward in response to centrifugal forces developed by Earth's rotation. Large clumps of dense rock and soil modify this ellipsoidal surface. The Earth's equatorial radius is approximately 21 km longer than its polar radius. The average radius of the Earth is considered to be 6371 km. On small scale maps, including single-sheet world maps, the oblateness is negligible. The irregular shape of the Earth makes it impossible to transform the geometric relations

perfectly. The ellipsoid- geoid model is usually applied for representing the shape of the Earth. The ellipsoid is the reference surface for horizontal position whereas the geoid is the reference surface for elevation. Specific ellipsoids are better suited for specific situations. For a relatively small area the Earth's surface can be thought of as a plane. On the other hand, when high accuracy of large areas is needed, it is necessary to use a more accurate and reliable model of the Earth such as an ellipsoid or a geoid.

Table 4.1: Earth's size and dimensions

Polar radius	6356.6 km
Equatorial radius	6378.2 km
Equatorial circumference	40,075 km
Surface area	510,900,000 sq.km



CHECK YOUR PROGRESS

Q.1 Earth's equatorial radius is approximately _____ longer than its polar radius.

Q.2 The _____ model is applied for representing the shape of the earth.

4.4 ELLIPSOIDS AND DATUM

Ellipsoid:

Spherical Earth models represent the shape of the Earth with a sphere of specified radius but they fail to model the actual shape of the Earth. Since it is flattened slightly at the poles and bulges at the equator, the geometrical figure used in geodesy to most nearly approximate the shape of the earth is an ellipsoid. The ellipsoid is the figure that will be obtained by rotating an ellipse about its axis. An ellipsoid is defined in terms of three dimensions: semi major axis, semi minor axis and ellipsoidal height. The size is represented by the radius at the equator as the semi major axis. The shape of the ellipsoid given by the flattening, which indicated how closely an ellipsoid approaches a spherical shape. The difference between the ellipsoid representing the Earth and a sphere is very small. Ellipsoidal model is the

mathematical model of the Earth that defines an ellipsoid with an equatorial radius and a polar radius. An ellipsoid suitable for map of India may not be suitable for USA. The best of these models can represent the shape of the earth over the smoothed and averaged sea- surface. The spheroid provides a mathematically simple surface for performing surveying and navigation computations over a wide area. It also provides a reference surface for base mapping and Geographic Information Systems.

Flattening of an ellipsoid is given, f= (a – b) / a

Where, f = Flattening

a = semi major axis

b = semi minor axis

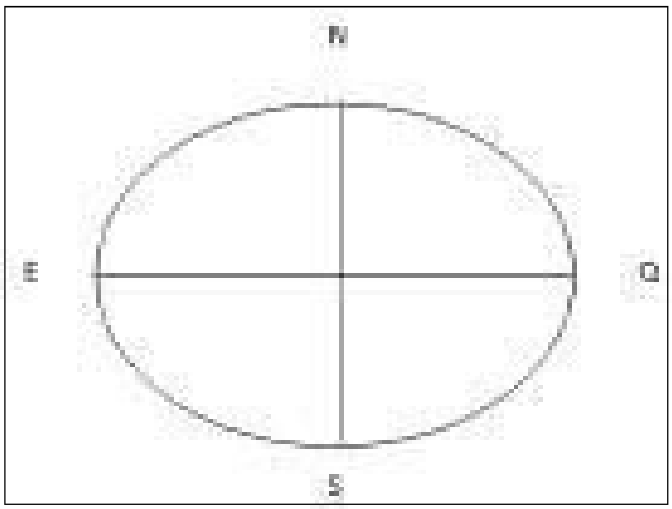


Figure 4.1: Elements of an Ellipse

Datum:

The parameters which are required for a 'curved- earth' reference model of the world is known as a geodetic datum. The major axis, minor axis and their orientation, rotation, translation and ellipsoidal height decides its shape and hence these are considered as datum parameters. It is a simplified representation of the size and shape of the earth and acts as the origin and orientation of the coordinate systems used to map the earth. Two types of datum are considered in geodesy - **a horizontal datum** which forms the

basis for computations of horizontal surveys in which the curvature of the earth is considered, and **a vertical datum** to which elevations are referred. The datum is the initial point reference point for specific geodetic surveys and triangulation works. It assumes that the gravity potential of the earth is constant everywhere. The vertical geodetic datum coincides with the Mean Sea Level. With the help of datum parameters, an ellipsoidal model explains the scale, position and direction relationship of a reference surface to position on the earth. Geodetic datum is classified into two categories: local geodetic datum and geocentric datum.

Local Geodetic datum

A local geodetic datum best approximates the size and shape of a particular part of the earth's sea level surface, and hence a poor approximation of the other areas. The center of its spheroid does not coincide with the earth's center of mass. Till recent times, most country's spatial information systems were based on local geodetic datum. An example of a local geodetic datum is the NAD 27.

Table 4.2: Common Local Datums

Local datum	**Acronym**	**Best for**	**Comment**
North American Datum of 1927	NAD27	Continental US	This is an old datum but still prevalent because of the wide use of older maps.
European Datum of 1950	ED50	Western Europe	Developed after World War II and still quite popular today. Not used in the UK.
World Geodetic System 1972	WGS72	Global	Developed by the Department of Defense.
World Geodetic System 1984	WGS84	Global	Developed by the Department of Defense.

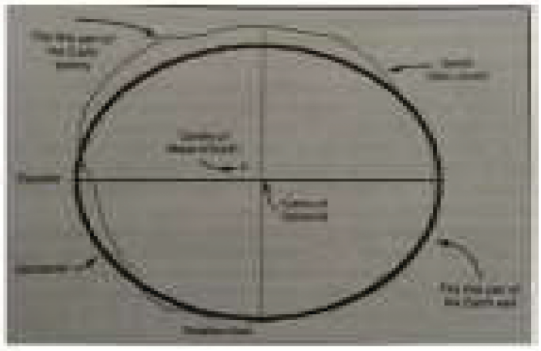


Figure 4.2: A local geodetic datums



CHECK YOUR PROGRESS

Q. 3: Define an ellipsoid.

.....

Q.4: What is a Datum?

.....

Q.5: Give two examples of local geodetic datum.

.....

4.5 CO-ORDINATE SYSTEMS

Co-ordinate systems enable geographic datasets to use common locations for integration. A co-ordinate system is a reference system used to represent the locations of geographic features, imagery, and observations, such as Global Positioning System (GPS) locations, within a common geographic framework.

Each co-ordinate system is defined by the following:

- Its measurement framework, which is either geographic (in which spherical co-ordinates are measured from the earth's center) or planimetric (in which the earth's coordinates are projected onto a two-dimensional planar surface).

- Units of measurement (typically feet or meters for projected coordinate systems or decimal degrees, minutes, seconds are also used for global / geographic co-ordinate system for latitude-longitude).

- The definition of the map projection for projected co-ordinate systems.
- Other measurement system properties such as a spheroid of reference, a datum, one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions.

Geographic Co-ordinate System

A geographic co-ordinate system is a reference system for identifying locations on the curved surface of the earth. Locations on the earth's surface are measured in angular units from the center of the earth relative to two planes: the plane defined by the equator and the plane defined by the prime meridian (which crosses Greenwich England). A location is therefore defined by two values: a latitudinal value and a longitudinal value.

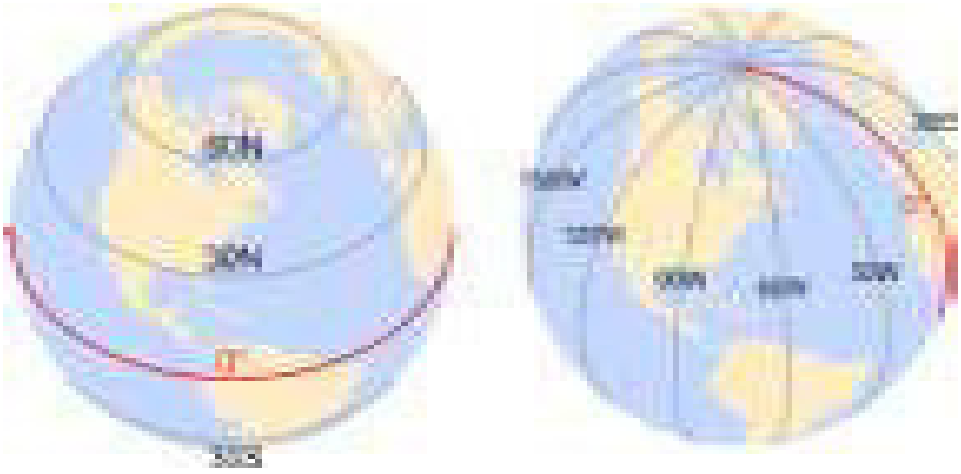


Figure.4.3: Examples of latitudinal lines are shown on the left and examples of longitudinal lines are shown on the right. The 0° degree reference lines for each are shown in red (equator for latitudinal measurements and prime meridian for longitudinal measurements).

A latitude measures the angle from the equatorial plane to the location on the earth's surface. A longitude measures the angle between the prime meridian plane and the north-south plane that intersects the location of

interest by the two planes passing through each. For example Guwahati is located at 26°11'04'' North and 91°44'09'' East. In a GIS system, the North-South and East-West directions are encoded as signs. North and East are assigned a positive (+) sign and South and West are assigned a negative (-) sign. Guwahati's location is therefore encoded as +26°11'04'' and +91°44'09''.

Projected Co-ordinate System

A projected co-ordinate system is defined on a flat, two-dimensional surface. Unlike a geographic co-ordinate system, a projected co-ordinate system has constant lengths, angles, and areas across the two dimensions. A projected co-ordinate system is always based on a geographic co-ordinate system that is based on a sphere or spheroid / ellipsoid. In a projected co-ordinate system, locations are identified by x,y co-ordinates on a grid, with the origin at the center of the grid. Each position has two values that reference it to that central location. One specifies its horizontal position and the other its vertical position. The two values are called the x-co-ordinate and y-co-ordinate. Using this notation, the co-ordinates at the origin are x = 0 and y = 0. On a gridded network of equally spaced horizontal and vertical lines, the horizontal line in the center is called the x-axis and the central vertical line is called the y-axis. Units are consistent and equally spaced across the full range of x and y. Horizontal lines above the origin and vertical lines to the right of the origin have positive values; those below or to the left have negative values. The four quadrants represent the four possible combinations of positive and negative X and Y co-ordinates.

The Universal Transverse Mercator (UTM) grid system is the most commonly used projected co-ordinate system. The UTM grid system divides the Earth's surface between 84°N and 80° S into 60 zones. Each zone covers 6° of longitude and is numbered sequentially with Zone 1 from 180° W. Each zone is further divided into the Northern and Southern Hemispheres. The designation of a UTM zone therefore carries a number and a letter. For example, UTM zone 44N refers to the zone between 78E and 84E in the northern hemisphere and UTM zone 44S refers to the zone between 78E

and 84E in the southern hemisphere. Similarly, Guwahati falls in the UTM Zone 46N.

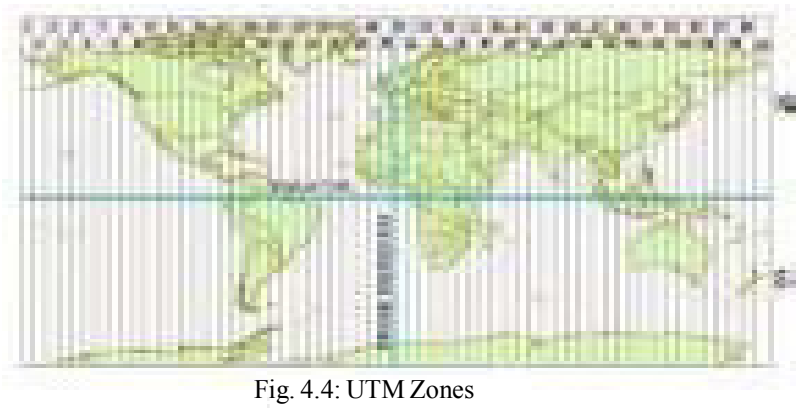


Fig. 4.4: UTM Zones

Planar Co-ordinate System

Planar projections project map data onto a flat surface touching the globe. A planar projection is also known as an azimuthal projection or a zenithal projection. This type of projection is usually tangent to the globe at one point but may be secant also. The point of contact may be the North Pole, the South Pole, a point on the equator, or any point in between. This point specifies the aspect and is the focus of the projection. The focus is identified by a central longitude and a central latitude. Possible aspects are polar, equatorial, and oblique. Polar aspects are the simplest form. Parallels of latitude are concentric circles centered on the pole, and meridians are straight lines that intersect with their true angles of orientation at the pole. In other aspects, planar projections will have graticular angles of 90 degrees at the focus. Directions from the focus are accurate. Great circles passing through the focus are represented by straight lines; thus the shortest distance from the center to any other point on the map is a straight line. Patterns of area and shape distortion are circular about the focus. For this reason, azimuthal projections accommodate circular regions better than rectangular regions. Planar projections are used most often to map Polar Regions. It is also a type of projected system of co-ordinates.

Some planar projections view surface data from a specific point in space. The point of view determines how the spherical data is projected onto the flat surface. The perspective from which all locations are viewed varies between the different azimuthal projections. The perspective point may be the center of the earth, a surface point directly opposite from the focus, or a point external to the globe, as if seen from a satellite or another planet. Azimuthal projections are classified by the perspective point.

- The gnomonic projection views the surface data from the center of the earth.
- The stereographic projection views it from pole to pole.
- The orthographic projection views the earth from an infinite point, as if from deep space.



CHECK YOUR PROGRESS

Q.6: What is a coordinate system?

.....

Q.7: What are the different coordinate systems used in GIS?

.....



4.6 LET US SUM UP

- The simplest model that approximates the globe is a sphere, which is typically used in map projections.
- The earth is not a perfect sphere as it is wider along the Equator than between the Poles.
- The Earth's equatorial radius is approximately 21 km longer than its polar radius, with average radius being 6371 km.
- The ellipsoid- geoid model is usually applied for representing the shape of the earth.

- Since the earth is flattened slightly at the poles and bulges at the equator, the geometrical figure used in geodesy to most nearly approximate the shape of the earth is an ellipsoid.
- The ellipsoid is the figure that will be obtained by rotating an ellipse about its axis.
- An ellipsoid is defined in terms of three dimensions: semi major axis, semi minor axis and flattening.
- Flattening of an ellipsoid is given, $f = (a - b) / a$ where; f= Flattening
  a = semi major axis
  b = semi minor axis
- A 'curved- earth' reference model of the world is known as a geodetic datum.
- It is a simplified representation of the size and shape of the earth and acts as the origin and orientation of the co-ordinate systems used to map the earth.
- Geodetic datum is classified into two categories: local geodetic datum and geocentric datum.
- A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations, such as Global Positioning System (GPS) locations, within a common geographic framework.
- A geographic co-ordinate system is a reference system for identifying locations on the curved surface of the earth.
- A projected coordinate system is defined on a flat, two-dimensional surface.
- The Universal Transverse Mercator (UTM) grid system is the most commonly used projected coordinate system.
- The UTM grid system divides the Earth's surface between 84°N and 80° S into 60 zones, each zone covers 6° of longitude
- A planar projection is also known as an azimuthal projection or a zenithal projection.



4.7 FURTHER READINGS

1) Basudeb Bhatta, *Remote Sensing and GIS*, published by Oxford University press, 2008.
2) Kang-Tsung Chang, *Introduction to Geographic Information System,* Published by McGraw-Hill, 2002.
3) Masood A. Siddiqui, Concepts and Techniques of Geoinformatics, published by Sharda Pustak Bhawan, Allahabad,2017
4) Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, *Geographic Information Systems and Science*, Published by Wiley, 2010.



4.8 ANSWERS TO CHECK YOUR PROGRESS

Q. No. 1: 21 km

Q. No. 2: Ellipsoid- Geoid

Q. No. 3:

An ellipsoid is a 3- dimensional geometric figure that resemble a sphere, but whose equatorial axis is slightly longer than its polar axis.

Q. No. 4:

A 'curved- earth' reference model of the world is known as a geodetic datum. It is a simplified representation of the size and shape of the earth and acts as the origin and orientation of the coordinate systems used to map the earth.

Q. No. 5: NAD27 and WGS72

Q. No. 6:

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

Q. No. 7:

The different coordinate systems used in GIS are:

a. Geographic coordinate system

b. Projected coordinate system



4.9 MODEL QUESTIONS

Q.1: Explain the problems associated with the approximation of the earth's shape and size.

Q.2: What are the dimensions used in an ellipsoid?

Q.3: What is flattening?

Q.4: Explain the different types of Datum.

Q.5: Explain the parameters considered while defining a coordinate system.

Q.6: Discuss the UTM coordinate system.

Q.7: Define latitude and longitude.

Q.8: Explain the Planar coordinate system in detail.

*** *** ***

UNIT- 5: INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS (GIS)

UNIT STRUCTURE

5.1 Learning Objectives

5.2 Introduction

5.3 Basic Concepts of GIS

5.4 Components of GIS

5.5 Advantages of GIS

5.6 Social and Institutional Context of GIS

5.7 Contemporary Development of GIS

5.8 Let us Sum up

5.9 Further Readings

5.10 Answers to Check Your Progress

5.11 Model Questions

5.1 LEARNING OBJECTIVES

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

- explain the Geographic Information Systems (GIS)
- identify the components of GIS
- list out the advantages of GIS
- describe the social and institutional context of GIS
- discuss the contemporary development of GIS

5.2 INTRODUCTION

In the previous unit, you have learnt about basics of Geodesy and spatial referencing systems. In this unit, we are going to provide you an introductory knowledge of Geographic Information System. Geographic

Information System (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. Social and institutional context of GIS are also discussed in this unit. It will also help you to discuss the data types, data structure and data input output processes of GIS. Data verification, correction, storage and data conversion methods in GIS are also a part of discussion in this unit.

5.3 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.

Spatial decision support system: GIS is also a multiple criteria decision making tool, several maps are used for this purpose to derive a map of particular decision by meeting conditions or goals from various layers of maps.

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, information system most often refers to a system containing electronic records, which involves input of 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 as geographically referenced data. 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.

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?

.....

.....

5.4 COMPONENTS OF GIS

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

These components are discussed below:-

Computer System:

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



Figure 5.1 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 softwares are ArcGIS, MapInfo, Geomatica, TNTmips, and Autodesk Map etc. The open source softwares are - ILWIS, QGIS and there are many such softwares.

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.

.....

.....

5.5 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 symbolised 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.

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.

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 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.5: 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.

5.6 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.

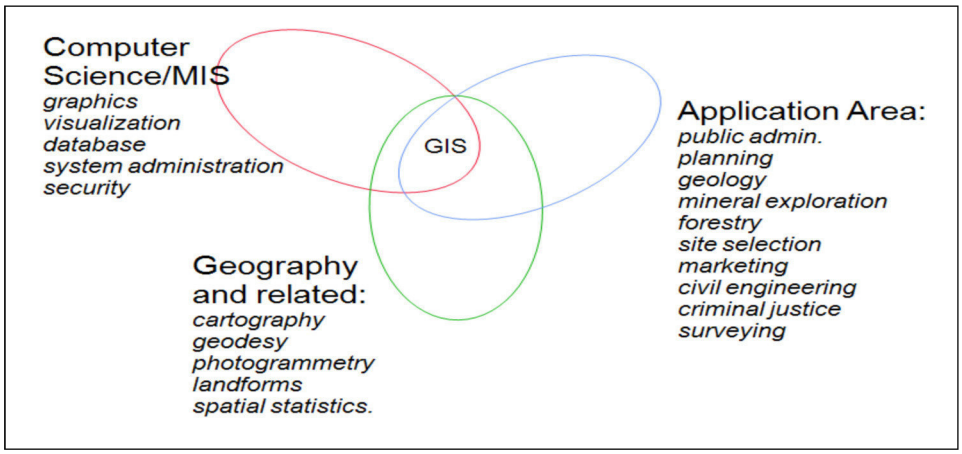


Figure 5.2: Example of applications of GIS

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.

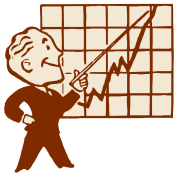
3. Public safety and defense user uses GIS for crime analysis, fire prevention, emergency management, military/defense etc.

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.6: 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.

5.7 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 development 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 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 a first free and open source GIS software under 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

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.7: What is the full form of ILWIS?

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5.8 LET US SUM UP

- A Geographic Information System is a computer system for capturing, storing, querying, analyzing and displaying geospatial data.
- The ability of GIS to manage Geospatial data establishes GIS as an important tool for a wide variety of applications.
- To use GIS properly, we must be familiar with the technology, as well as, the basic concepts that drive the technology.
- Like any other information technology, GIS requires the following four components; 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.

- 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 mostly among others.



5.9 FURTHER READINGS

- *Geographic Information Systems and Science* by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind.
- *Remote Sensing and GIS* by Basudeb Bhatta.
- *Introduction to Geographic Information System* by Kang-Tsung Chang.
- *Remote Sensing and Geographical System* by Anil K. Jamwal.
- 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



5.10 ANSWERS TO CHECK YOUR PROGRESS

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

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.

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

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

Q. No. 5:

i. True
ii. False
iii. True
iv. True
v. False

Q.No. 6:

i. True
ii. False
iii. True
iv. False
v. True
vi. False

Q. No. 7: The full form of ILWIS is Integrated Land and Water Information System.



5.11 MODEL QUESTIONS

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

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

Q.3: Give a brief description about the advantages of GIS in different sections.

Q.4: How is GIS useful in social and infrastructural context? Explain.

Q.5: Write about the contemporary development of GIS.

*** *** ***

UNIT- 6: INTRODUCTION TO THE DATABASE MANAGEMENT SYSTEM

UNIT STRUCTURE

6.1 Learning Objectives

6.2 Introduction

6.3 Overview of the Database in Computer Science

6.4 Basics of the Database System

6.5 Fundamentals of the Geo-Database Management System

6.6 Creation of a Geo-Database for Geoinformatics Applications

6.7 Let Us Sum up

6.8 Further Readings

6.9 Answers to Check Your Progress

6.10 Model Questions

6.1 LEARNING OBJECTIVES

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

- illustrate the concept of database in computer science
- get an idea of the database system
- discuss the fundamentals of the geo-database management system
- describe the Creation of geo-database for Geoinformatics Applications

6.2 INTRODUCTION

In the previous unit you have learnt about the Geographic Information System (GIS) and various data processing methods. In this unit, we are going to provide you an introductory knowledge of the Database Management

System. This unit also provides you the fundamentals of the Geo-Database Management System. Creation of geo-database for geoinformatics applications is also discussed in this unit.

6.3 OVERVIEW OF DATABASE IN COMPUTER SCIENCE

A database is a systematic collection of data which is stored and accessed digitally from a computer system in the form of figures and records. The Database Management System (DBMS) is a computer application that the end users make use of in order to capture and analyze the required data. The DBMS software further embodies the core facilities provided to administer the database. The sum total of the database, the DBMS and its related applications are referred to as a "database system". The term "database" is also used to refer to any of the DBMS, the database system or an application associated with the database.

Database management procedures are classified according to the database models that they support. The concept of 'relational database' became dominant in the 1980s, which models data as rows and columns in a series of tables, and the vast majority used SQL for writing and querying data. In the 2000s, non-relational databases, also known as the NoSQL became popular, because of their use of different query languages.

"Database" refers to a set of related and organized data and the access to such a data is provided by a "database management system" (DBMS) which consists of an integrated set of computer software. This computer application enables the users to interact with one or more databases and thus provides access to all the information contained in the database. The DBMS comprises of various functions which allow entry, storage and retrieval of large volume of information and at the same time provides ways to manage these information in an organized and systematic manner. The term "database" is often used to refer to both a database and the DBMS because of the close relationship between them. In the world of professional information technology, the term database is often used to refer

to any collection of related data whereas size and usage requirements of such data necessitate the use of a database management system.

DBMSs provide different functions that allow management of a database and data included in it which can be classified into four main functional groups:

- **Data definition –** The DBMS enables creation of data and also modification of definitions that define the organization of the data that has been created.
- **Update –** It includes addition, modification and deletion of the actual data.
- **Retrieval –** The DBMS provides information in a format directly usable or for further processing by other applications. This retrieved data may be made available in a form which is the same as it was stored in the database or in a new form obtained by altering or combining existing data from the database.
- **Administration –** This includes registering and monitoring the users, ensuring data security and data integrity, dealing with concurrency control, and recovering information that has been corrupted by some event such as an unexpected system failure.



CHECK YOUR PROGRESS

Q.1: What is a database?

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

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6.4 BASICS OF THE DATABASE SYSTEM

A database is a collection of logically related data designed to meet information needs of one or more users. These data are often organized in database table(s). A table is a set of data elements or values that is

organized by using a model of horizontal and vertical columns. The columns, also known as fields or attributes, are identified by name and the rows. Also known as recodes or tuples, they are identified by the values appearing in a particular column.

A database is a collection of records stored in a computer in a systematic way so that it can be consulted by a computer program to answer questions. For better storing and retrieval of data each record is usually organized as a set of related data elements. The items retrieved as answer to queries become information that can be used to make decisions. The computer program used to manage and query a database is known as the Database Management System (DBMS).

Any DBMS makes things easy for the user to create a database and to maintain it. Maintaining a database involves performing various data manipulation operations on the tables in databases. These operations include: Adding records, Querying, Modifying records and Deleting records. These operations enable the user to store, retrieve and update data in the database. Some examples of the DBMS are Microsoft Access, Oracle, Sybase and SQL.

A DBMS facilitates the following:

- Table: Containing data in the form of fields and records.
- Queries: Selected information is displayed in the screen.
- Reports: Formatted printed information.
- Forms: Screens created to add, modify and delete records.

The facilities offered by a DBMS vary a great deal depending on the level of sophistication. A DBMS provides following advantages over a conventional system:

- Independence of data and program
- Data shareability
- Non- redundancy of data
- Centralized control
- Data security and integrity
- Performance and efficiency



CHECK YOUR PROGRESS

Q.3: Define a DBMS.

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Q.4: What are the components of a database?

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Q.5: Give two examples of the DBMS.

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6.5 FUNDAMENTALS OF THE GEO-DATABASE MANAGEMENT SYSTEM

A geodatabase is a collection of geographic datasets of various types and formats. It is the primary mechanism used to organize and use geographic information. A Geo-database contains three primary dataset types:

- Feature classes
- Raster datasets
- Tables

The first step towards building a geodatabase is creating a collection of these dataset types. The users start the process by building a number of these fundamental dataset types followed by adding or extending the geodatabases with more advanced capabilities like adding topologies, networks or subtypes in order to model the GIS behavior, maintain data integrity, and work with important sets of spatial relationships.

A Geo-database storage includes both the scheme and rule base for each geographic dataset along with the simple tabular storage of the spatial and attribute data. All three primary datasets in the geodatabase namely, feature classes, attribute tables, and raster datasets as well as other geodatabase elements are stored using tables. The spatial datasets are stored as either vector features or rasters. Their geometries are stored and managed in fields along with traditional attributes.

A feature class is stored as a table. Each row represents one feature. In the polygon feature class the shape field holds the polygon geometry for each feature. The value specifies that the field contains the coordinates and geometry that define one polygon in each row. A key geodatabase approach is to power the database management system (DBMS) to scale the GIS datasets to extremely large size and number of users. Tables provide the primary storage mechanism for geographic datasets. Structured query language (SQL) is very strong at querying and processing the rows in tables, and the geodatabase is designed to control these capabilities. Various geodatabase elements are used to extend the geodatabase's capabilities for data management. The geodatabase representation includes the properties for coordinate systems, coordinate resolution, feature classes, topologies, networks and relationships. This graphic information persists in a collection of geodatabase tables in the DBMS. These tables define the integrity and behavior of the geographic information.



CHECK YOUR PROGRESS

Q.6: Define a geodatabase.

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Q.7: Mention the types of datasets of a geodatabase.

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6.6 CREATION OF A GEO-DATABASE FOR GEOINFORMATICS APPLICATIONS

There are three primary ways to create geo-databases:

- Design and create a new, empty geodatabase and subsequently define the schema and load datasets into it.
- Copy and modify an existing geodatabase schema and subsequently load datasets into the copied geodatabase.
- Create a copy of the schema and contents from an existing geo-database.

Table: 6.1 Dataset types which can be created in a geo-database

Type	Description
Feature dataset	A set of thematically related feature classes (typically used to manage a topology, network or terrain).
Feature class	A collection of features of the same type (such as wells, parcels and streets) with a common set of attribute fields.
Table	A collection of non- spatial attributes of the same type (such as a table with information about parcel owners). Attribute tables can be used for many purposes.
View	One can define a database view on tables in the data-base (Disabled for file geodatabases).
Relationship class	Creates an association between records in one table with records included in another.
Raster dataset	A single raster or image data layer covering an extent.
Mosaic dataset	Mosaic datasets are used to manage, display, serve and share raster data.
Geoprocessing toolbox	A series of user-created geoprocessing tools, scripts and models.



CHECK YOUR PROGRESS

Q.8: Write three different ways in which geodatabase can be created in geoinformatics.

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6.7 LET US SUM UP

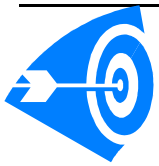
- A database is an organized collection of data, generally stored and accessed electronically from a computer system.
- The database management system (DBMS) is the software that interacts with end users, applications and the database itself to capture and analyze the data.
- A “database” refers to a set of related data and the way it is organized.
- Access to this data is usually provided by a ‘database management system’ (DBMS) consisting of an integrated set of computer software that allows users to interact with one or more databases and provides access to all of the data contained in the database.

- A DBMS facilitates the following:
    - Table
    - Queries
    - Reports
    - Forms
- A DBMS provides following advantages over a conventional system:
    - Independence of data and program
    - Data shareability
    - Non- redundancy of data
    - Centralized control
    - Data security and integrity
    - Performance and efficiency
- A geo-database is a collection of geographic datasets of various types.
- A geo-database contains three primary dataset types:
    - Feature classes
    - Raster datasets
    - Tables



6.8 FURTHER READINGS

1. Basudeb Bhatta, *Remote Sensing and GIS*, published by Oxford University Press, 2008.
2. Kang-Tsung Chang, *Introduction to Geographic Information System,* Published by McGraw-Hill, 2002.
3. Masood A. Siddiqui, Concepts and Techniques of Geoinformatics, published by Sharda Pustak Bhawan, Allahabad,2017
4. Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, *Geographic Information Systems and Science*, Published by Wiley, 2010.



6.9 ANSWERS TO CHECK YOUR PROGRESS

Q. No. 1:

A database is an organized collection of data, generally stored and accessed electronically from a computer system. A "database" refers to a set of related data and the way it is organized. A Database, thus, is a collection of logically related data designed to meet the information needs of one or more users. These data are often organized in database table(s).

Q. No. 2:

The functions of a DBMS includes: Adding records, Querying, Modifying records and Deleting records. These operations enable the user to store, retrieve and update data in the database.

Q. No. 3:

The database management system (DBMS) is a software that interacts with end users, applications and the database itself to capture and analyze the data. The computer program used to manage and query a database is known as the Database Management System (DBMS).

Q. No. 4:

The components of a DBMS comprises of database table(s). A table comprises of a set of data elements or values that is organized using a model of horizontal and vertical columns. The columns, also known as fields or attributes, are identified by name and the rows. They also known as recodes or tuples, are identified by the values appearing in a particular column.

Q. No. 5:

Two examples of the DBMS are Microsoft Access and Oracle.

Q. No. 6:

A geo-database is a collection of geographic datasets of various types.A key geodatabase concept is the dataset. It is the primary mechanism used to organize and use geographic information.

Q. No. 7:

A geo-database contains three primary dataset types:

- Feature classes
- Raster datasets
- Tables

Q. No. 8:

There are three primary ways which help us to create geo-databases:

- Design and create a new, empty geodatabase and subsequently define the schema and load datasets into it.
- Copy and modify an existing geodatabase schema and subsequently load datasets into the copied geodatabase.
- Create a copy of the schema and contents from an existing geodatabase.



6.10 MODEL QUESTIONS

Q.1: Explain what a database is and the concept of the DBMS.

Q.2: Explain the development of database.

Q.3: What are the functions of a DBMS?

Q.4: Explain the different datasets that can be created in a geodatabase.

*** *** ***

UNIT- 7: GIS DATA TYPES

UNIT STRUCTURE

7.1 Learning Objectives

7.2 Introduction

7.3 Raster Data

7.4 Vector Data

7.5 TIN

7.6 Topological Relationships

7.7 Raster and Vector Data Formats

7.8 Let us Sum up

7.9 Further Readings

7.10 Answers to Check Your Progress

7.11 Model Questions

7.1 LEARNING OBJECTIVES

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

- explain the basic concept of raster and vector data
- describe the overview of the TIN
- illustrate about topological relationships
- get an idea of raster and vector data formats.

7.2 INTRODUCTION

In the previous unit, we have discussed about the database management system. In this unit, we are going to provide you the basics of GIS data types. The unit deals with the raster data and vector data types used in the GIS. The unit is also going to focus on a preliminary overview of the TIN model, topological relationships in a GIS including raster and vector file formats.

7.3 RASTER DATA

Continuous fields and discrete objects define two conceptual views of geographic phenomena, but they do not solve the problem of digital representation. A continuous field view contains an infinite amount of data. If it defines the value of the variable at every point, then there are an infinite number of points in any defined geographic area. Continuous data is also referrd to as continuous field, non-discrete or surface data.

A discrete object has known and definable boundaries. It is easy to precisely define where the object begins and ends. Discrete objects are also require an infinite amount of information for full description. For example, a coastline contains an infinite amount of information if it is mapped in infinite detail. A lake is a discrete object within the surrounding landscape. Thus, continuous fields and discrete objects are nothing more than conceptualizations, or ways in which we think about geographic phenomena. They are not designed to deal with the limitations of computers. The two methods-**raster** and **vector** are 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.

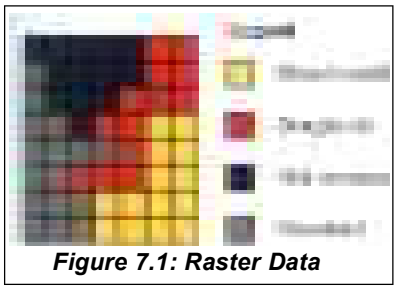


Figure 7.1: Raster Data

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.



CHECK YOUR PROGRESS

Q.1: What is raster data?

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7.4 VECTOR DATA

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

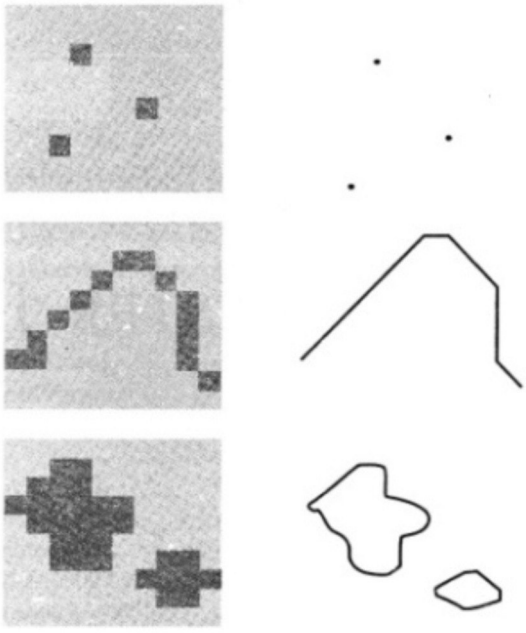


Figure .
Representation of point, line, and area features: raster format on the left and vector format on the right.

Figure 7.2: Vector data

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.

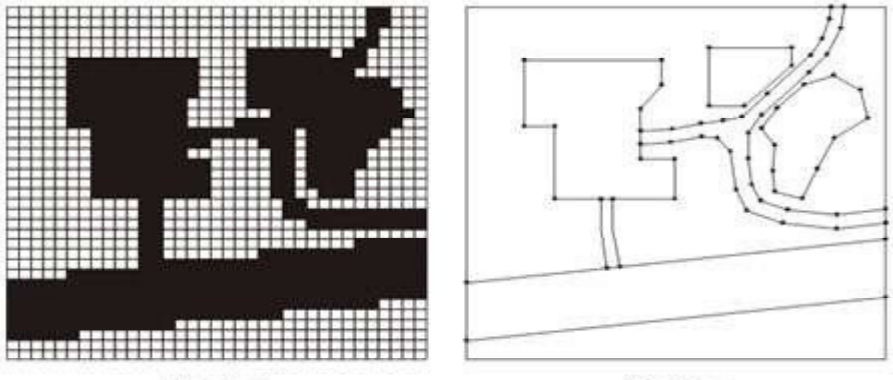


Figure 7.3: Difference between raster and vector data



CHECK YOUR PROGRESS

Q.2: What is vector data?

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7.5 TIN

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).

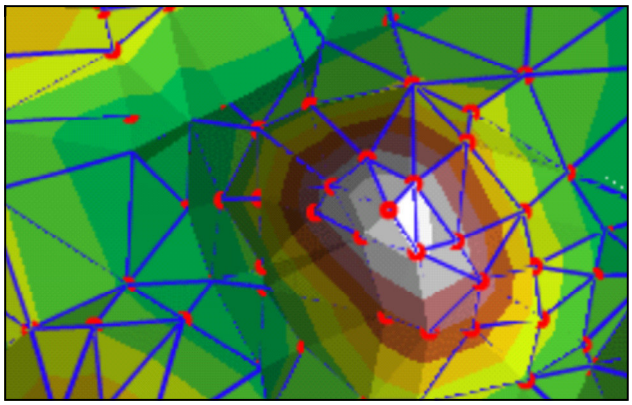


Figure 7.4: A TIN model in GIS



CHECK YOUR PROGRESS

Q.3: What is a TIN?

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7.6 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.4: What is topology?

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7.7 RASTER AND VECTOR DATA FORMATS

Raster and vector are the two main methods for representing geographic data in the GIS. Raster is basically pixel-based representation of the ground. In the vector location it is represented with a pair of *x* and *y* coordinates. There are various file formats of both raster and vector data with the GIS support capabilities. Some important raster and vector data file formats are discussed below:

(A) Raster file formats: Some widely used raster data file formats include-

(i) JPEG- it is a raster data file format that has a file extension type *.jpeg* or *.jpg*. JPEG refers to Joint Photographic Experts Group. JPEG is a standard compression technique for storing full-color and grayscale images.

(ii) PNG means Point Network Graphics and it is represented with *.png* file extension. PNG gives a well-compressed raster file that supports a large range of bit depth.

(iii) GIF means Graphic Interchange Format and it is represented by *.gif* file extension type. GIF is suitable for representing sharp-edge images in the GIS.

(iv) TIFF means Tagged Image File Format and it is represented by *.tif, .tiff* file extension type. TIFF is a very popular raster file format that stores image data in detail. A geo-referenced TIFF imagery is called *GeoTIFF* file and has *.geotiff* file extension.

(v) IMG refers to Image file and has *.img* file extension. The IMG is the native raster data file format for Erdas Imagine software. The IMG also stores raster data in detail with depth and quality.

(B) Vector file formats: Some important vector data file formats in the GIS include-

(i) SHP refers to Shape file and it has *.shp* file extension in the GIS. Shapefile is a native vector file format of the ESRI ArcGIS software. SHP is now-a-days most widely used vector file format in all GIS software. A SHP stores location, attribute and shape of the feature or element in vector data. A SHP file format includes *.shp, .prj, .shx, .dbf, .xml* etc. associated file formats in order to completely represent a vector feature in the GIS.

(ii) KML refers to Keyhole Markup Language and it has *.kml or .kmz* file extension type. The KML is a native file format of Google Earth software.

(iii) GeoJSON is an open source vector file format used in the GIS. GeoJSON feature includes points, strings, lines, polygons etc. representing locations, streets, highways, parcels of land etc. in GIS.

(iv) GPX refers to GPS exchange format. It is an XML file format for storing coordinate data and has *.gpx* file extension. It can store waypoints, tracks, and routes in the GPS. A GPX file format is an open source file format and this is a popular as well as widely used GPS file format for vector data.

(v) TIGER refers to Topologically Integrated Geographic Encoding and Referencing. The TIGER is a vector file format used by the United Sates Census Bureau to describe population data including land attributes such as roads, buildings, rivers, lakes, land parcels etc.



CHECK YOUR PROGRESS

Q.5: What is the .shp file format?

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7.8 LET US SUM UP

- Raster and vector data are two main GIS data types for representing geographic data.
- Raster data is pixel-based and vector data is coordinate-based.
- TIN or Triangulated Irregular Network is a GIS data model for 3-dimensional surface or terrain represntation in GIS.
- Topological relationships in the GIS can be easily establised with the vector data.
- There are different types of raster and vector file formats in the GIS. Some popular raster file formats include .img, .jpg, .geotiff, .png, and some popular vector file formats include .shp, .kml, .gpx, .GeoJASON etc.



7.9 FURTHER READINGS

1. *Introduction to Geospatial Technologies by Bradley A. Shellito, W. H. Freeman and Company, New York, 2017.*
2. *Introduction to Geographic Information System by Kang-Tsung Chang.*
3. *Principals of Geographic Information Systems from ITC, Netherlands, 2001.*
4. *https://en.wikipedia.org/wiki/Geoinformatics*
5. *http://egyankosh.ac.in/*



7.10 ANSWERS TO CHECK YOUR PROGRESS

Q.No.1: 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.

Q.No.2: Vector data has a precise direction, length and shape and can be defined by co-ordinate geometry.

Q.No.3: 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.

Q.No.4: Topology is the study of those properties of geometric objects that remain invariant under certain transformations such as, bending or stretching.

Q.No.5: SHP refers to Shapefile and has *.shp* file extension in a GIS. Shapefile is a native vector file format of ESRI ArcGIS software. SHP is now-a-days most widely used vector file format in all GIS software.



7.11 MODEL QUESTIONS

Q.1: Mention useful properties of the raster data.

Q.2: Mention useful properties of the vector data.

Q.3: What is the application of TIN model?

Q.4: Elaborate topological relationships in a GIS.

Q.5: Explain raster and vector data file formats in a GIS.

Q.6: Mention the properties of the GeoTIFF and the GPX file formats.

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UNIT- 8: SOURCES AND NATURE OF GEO-SPATIAL DATA

UNIT STRUCTURE

8.1 Learning Objectives

8.2 Introduction

8.3 Spatial and Non-spatial Data

8.4 DEM (SRTM, GTOPO, GLOBE, LiDAR) and Other Data Sources

8.5 Data Input-Output Processes and Devices

8.6 Data Verification, Correction and Storage

8.7 Data Conversion in the GIS

8.8 Let us Sum up

8.9 Further Readings

8.10 Answers to Check Your Progress

8.11 Model Questions

8.1 LEARNING OBJECTIVES

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

- explain the Spatial and the Non-spatial data
- get the idea about DEM, SRTM, LiDAR and other data
- understand the data input-output processes and devices
- discuss the data verification, correction and storage in the GIS
- explain the data conversion in the GIS

8.2 INTRODUCTION

In the previous unit we have discussed about GIS data types. This unit will provide you the sources and nature of geo-spatial data. The Geographic Information System (GIS) can be considered both as science and technology, a discipline, and an applied problem-solving methodology. The GIS today is

both an increasingly mature technology and a strategically important interdisciplinary meeting place. This unit will help you to discuss the spatial and the non-spatial data in the GIS data input and output processes of the GIS including data verification, correction, storage and data conversion methods.

8.3 SPATIAL AND NON-SPATIAL DATA

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 in 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.

A. 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 objects located on the Earth surface such as a building, a 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.

B. Non-spatial data:

The 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 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.



Figure 8.1: Example of Google Earth map



CHECK YOUR PROGRESS

Q.1: What is the difference between the spatial and the attribute data?

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8.4 DEM (SRTM, GTOPO, GLOBE, LiDAR) AND OTHER DATA SOURCES

The Digital Elevation Model (DEM) is a 3-dimensional remote sensing product. The DEM records the elevation of the location including the latitude and

the longitude. The United States Geological Survey (USGS) first developed the DEM for representing 3-dimensional earth surface. According to the USGS, the DEMs are arrays of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system. The grid cells are spaced at regular intervals along south to north profiles that are ordered from west to east. Each pixel or grid on a DEM contains the altitude value of that location on a reference datum. The DEM is a specific type of terrain and landscape model of the earth. The DEM data in the GIS are mainly visualized in two ways:

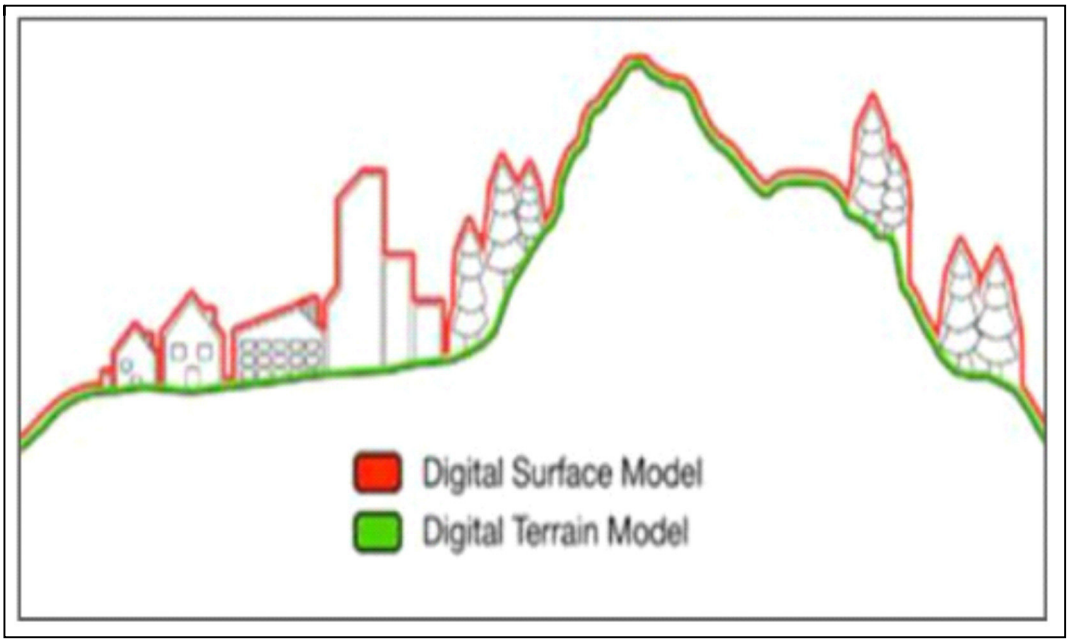


Figure 8.2: Difference between DSM & DTM
(Source: geoimage.com.au)

Rectangular grid elevation matrix for raster data structure and *Triangulated Irregular Network (TIN)* in vector data structure. There are two types of digital models of elevation used in the GIS. These are *Digital Terrain Model (DTM)* and *Digital Surface Model (DSM).* The DTM (or DEM) only represents the bare earth surface elevation, while the DSM includes the surface elevation with surface features like tree height, building height etc. There are some methods through which the DEM can be obtained. These methods include–

(a) Microwave remote sensing,
(b) LiDAR,
(c) Aerial Photogrammetry,
(d) Drone imagery and drone survey,
(e) Topographical maps,
(f) Real Time Kinematic GPS,
(g) Theodolite or total station survey.

Using a DEM in a GIS platform some important terrain parameters like relief, slope, aspect, terrain ruggedness, surface elevation profile can be extracted for topographic analysis. Besides, the DEM data can also be used in hydrological, meteorological, ecological, disaster modeling with the help of the GIS.

SRTM: SRTM refers to the Shuttle Radar Topography Mission. This is a remote sensing mission launched by NASA in 2000 for obtaining the surface elevation data (or DEM) of the earth using the Interferometric Synthetic Aperture Radar (InSAR). After 2014, the SRTM satellite data are made freely available by NASA for public use. There are two types of SRTM DEM data: 1-arc second- or 30-meter spatial resolution SRTM and 3-arc second- or 90-meter spatial resolution SRTM.

GTOPO: It is a DEM data developed by the United States Geological Survey (USGS). The GTOPO30 is a global Digital Elevation Model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer). The GTOPO30 was derived from several raster and vector sources of topographic information.

GLOBE: It refers to the Global Land One-kilometer Base Elevation (GLOBE) data. The GLOBE is a DEM data with 30 arc seconds (approximately 1 kilometer) resolution. The GLOBE DEM was developed by National Oceanic and Atmospheric Administration (NOAA).

LiDAR: It means to Light Detection and Ranging. The LiDAR is another kind of accurate DEM product. The LiDAR data records elevation of an area with grid pixel value. The LiDAR DEM provides the highest and the best accuracy results. In remote sensing, the LiDAR sensor is used to acquire elevation data using the 3-D laser scanning technique.

OTHER DATA SOURCES: Some other elevation data sources that can be used in the GIS include:

(a) The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). It is a global DEM jointly developed by NASA and Japan Aerospace Exploration Agency. The ASTER data has 30-meter resolution.

(b) The JAXA's Global ALOS 3D World is another elevation data that represents surface elevation of an area at 30-meter resolution. This ALOS DSM data is developed by Japan Aerospace Exploration Agency (JAXA).

(c) Drone survey generated DSM and DEM.

(d) DGPS generated DEM.

(e) Derivation of the DEM through contour and height information from topographical maps.



CHECK YOUR PROGRESS

Q.2: What is a DEM?

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Q.3: Mention three basic terrain parameters.

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8.5 DATA INPUT-OUTPUT PROCESSES AND DEVICES

The Data Input process is the operation of encoding the data and writing them. In the GIS, data input process covers all aspects of transforming data collected from existing maps, field observations and sensors into a compatible digital form. Data input to the geographical information system can be best described under three headings given below:

- Adding or entering the spatial data; manual input to a vector system, manual input to a grid system, digitizing and automated scanning.

- Adding or entering the non-spatial, associated attributes
- Linking the spatial to the non-spatial data.

The Data output process is the operation of presenting the results of data manipulation in a form that is understandable to a user. The output data should allow transferring data to other computer systems. In the GIS, the most compatible formats for output are maps, graphs, tables etc. Common GIS capabilities for data outputs are:

- Zooming/windowing to select area for output
- Scale change
- Color change
- Modifications to text and lines
- 3D representation etc.

DEVICES:

A. Input Devices:

1. Sensors are a primary source of data for a GIS and are used to measure some features of the geographic environment
2. The Digitizer is the most common device for extracting spatial information from maps and photographs
3. Keyboard
4. Pointing devices: -Mouse, Touchpad, Joysticks etc.
5. Scanners etc.

B. Data Output Devices:

1. Pen Plotters
2. B/W & Colour Printers
3. Ink Jet Plotters
4. Electrostatic Plotters
5. Thermal Plotters
6. Optical Film Writers



CHECK YOUR PROGRESS

Q.4: Fill in the blanks:

i. _____ is compatible with the remote sensing imagery.

ii._____ always offer accurate map output.

iii. In the GIS we basically use _____ data and _____ data.

iv. A _____ is described by an infinite number of points.

v. _____ is a simple data structure.

8.6 DATA VERIFICATION, CORRECTION AND STORAGE

Data Verification in the GIS has two main steps:–

- First is to make sure that the attribute data are properly linked to the spatial data; the labels should be unique and should not contain null values.
- The second step is to verify the accuracy of data.

Data verification is difficult because inaccuracies can be attributed to a large number of factors including observation errors, outdated data and data entry. An important task associated with the spatial data editing is removing digitizing errors or **data correction**. Newly digitized maps, no matter how carefully prepared, always have some errors. Existing layers may be outdated or may contain errors from initial digitizing. Therefore, roads, land parcels, forest inventory as well as other data require regular revision and updating.

In the GIS, **Data storage** concerns the way in which the data about the position, linkages (topology) and attributes of geographical elements are structures and organized, both with respect to the way they are to be handled in the computer and the way they are perceived by the users of the systems. The computer system used to organise the data into database that is known as the **Database Management System.**

Data Base Structure:

A data base structure is a specialized format for organizing and storing data. General data structure types include the array, the file, the

record, the table, the tree and so on. Any data structure is designed to organise data to suit a specific purpose so that it can be accessed and worked with in appropriate ways. In computer programming, a data structure may be selected or designed to store data for the purpose of working on it with various algorithms. Detailed information of the Data Base structure, its function and uses have elaborated in the course 3 (Spatial Data Modelling and Database Management).

8.7 DATA CONVERSION IN THE GIS

Data conversion is a standard functionality in a GIS package. We need to use this functionality to take advantage of having both the vector and the raster data for a GIS project. The conversion of the vector data to the raster data is called the **Rasterization**. Again, the conversion of the raster data to the vector data is called the **Vectorization**. These two conversion methods are used in different computer algorithms.

The rasterization is simpler than the vectorization. The rasterization involves three basic steps:

1. The first step sets up a raster with a specified cell size to cover the area extent of the vector data and initially assigns all cell values as 0.
2. The second step changes the values of those cells that correspond to point, lines or polygon boundaries.
3. The third step fills the interior of the polygon outline with the polygon value.

The Vectorization involves three basic elements:

1. **Line thinning:** Raster lines must be thinned, ideally to a 1-cell width, for Vectorization.
2. **Line extraction:** It is the process of determining where individual lines begin and end.
3. **Topological Reconstruction:** The Topological Reconstruction involves connecting extracted lines as well as showing where digitizing error exists.



CHECK YOUR PROGRESS

Q.5: What do you mean by the rasterization and the vectorization?

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8.8 LET US SUM UP

- There are two types of geographic data used in a GIS: the spatial and the attribute data.
- The Digital Elevation Model (DEM) is a geo-spatial data that represents height information. SRTM, GTOPO, GLOBE, LiDAR, ASTER are various DEM products.
- Data Input is the operation of encoding the data and writing them. On the other hand, data output is the operation of presenting the results of data manipulation in a form that is understandable to a user.
- A data base structure is a specialized format for organizing and storing data. General data structure types include the array, the file, the record, the table, the tree, and so on.
- We need to use data conversion functionality to take advantage of having both the vector and the raster data for a GIS project.



8.9 FURTHER READINGS

- *Geographic Information Systems and Science* by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind.
- *Remote Sensing and GIS* by Basudeb Bhatta.
- *Introduction to Geographic Information System* by Kang-Tsung Chang.

- *Remote Sensing and Geographical System* by Anil K. Jamwal.
- 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



8.10 ANSWERS TO CHECK YOUR PROGRESS

Q. No. 1: The Spatial data represents information about the location, size and shape of an object located on the Earth surface.

The Attribute data is information appended in tabular format to spatial features. Some popular sources to gather the attribute data are town planning and management departments, fire departments etc.

Q. No. 2: DEM means the Digital Elevation Model that represents the elevation of the earth's surface.

Q. No. 3: Relief, Slope and Aspect are the three basic terrain parameters.

Q. No.4:

i. Raster data
ii. Vector data
iii. Spatial, Non-spatial
iv. Line
v. Raster

Q. No. 5: The conversion of the vector data to the raster data is called the Rasterization. Again, the conversion of the raster data to the vector data is called the Vectorization.



8.11 MODEL QUESTIONS

Q.1: What do you mean by the spatial and the non-spatial data? Differentiate.

Q.2: Differentiate the DTM and the DSM.

Q.3: Discuss about the SRTM.

Q.4: Discuss the methods of obtaining a DEM.

Q.5: Write the application areas of the DEM data in a GIS.

Q.6: Write about some process of data input and data output in GIS.

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