Remote Sensing and Geographical Information System (GIS)

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INTRODUCTION

Now-a-days the field of Remote Sensing and GIS has become exciting and glamorous with rapidly expanding opportunities. Many organizations spend large amounts of money on these fields. Here the question arises why these fields are so important in recent years. Two main reasons are there behind this. 1) Now-a-days scientists, researchers, students, and even common people are showing great interest for better understanding of our environment. By environment we mean the geographic space of their study area and the events that take place there. In other words, we have come to realise that geographic space along with the data describing it, is part of our everyday world; almost every decision we take is influenced or dictated by some fact of geography. 2) Advancement in sophisticated space technology (which can provide large volume of spatial data), along with declining costs of computer hardware and software (which can handle these data) has made Remote Sensing and G.I.S. affordable to not only complex environmental / spatial situation but also affordable to an increasingly wider audience.

REMOTE SENSING

Meaning

Literally Remote Sensing means obtaining information about an object, area or phenomenon without coming in direct contact with it. If we go by this meaning of Remote Sensing, then a number of things would be coming under Remote Sensor, e.g. Seismographs, fathometer etc. Without coming in direct contact with the focus of earthquake, seismograph can measure the intensity of earthquake. Likewise without coming in contact with the ocean floor, fathometer can measure its depth. However, modern Remote Sensing means acquiring information about earth's land and water surfaces by using reflected or emitted electromagnetic energy.

From the following definitions, we can have a better understanding about Remote Sensing:

According to White (1977), Remote Sensing includes all methods of obtaining pictures or other forms of electromagnetic records of Earth's surface from a distance, and the treatment and processing of the picture data… Remote Sensing then in the widest sense is concerned with detecting and recording electromagnetic radiation from the target areas in the field of view of the sensor instrument. This radiation may have originated directly from separate components of the target area, it may be solar energy reflected from them; or it may be reflections of energy transmitted to the target area from the sensor itself.

According to American Society of Photogrammetry, Remote Sensing imagery is acquired with a sensor other than (or in addition to) a conventional camera through which a scene is recorded, such as electronic scanning, using radiations outside the normal visual range of the film and camera- microwave, radar, thermal, infra-red, ultraviolet, as well as multispectral, special techniques are applied to process and interpret remote sensing imagery for the purpose of producing conventional maps, thematic maps, resource surveys, etc. in the fields of agriculture, archaeology, forestry, geography, geology and others.

According to the United Nations (95^{th} Plenary meeting, 3^{rd} December, 1986), Remote Sensing means sensing of earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment.

According to James B.Campell (1996), Remote Sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's surface.

So the stages of Remote Sensing include (Fig.1):

- A source of electromagnetic radiation or EMR (Sun)
- Transmission of energy from the source to the surface of the earth, through atmosphere
- Interaction of EMR with earth's surface.
- Transmission of energy from surface to Remote Sensor mounted on a platform, through atmosphere
- Detection of energy by the sensor.
- Transmission pf sensor data to ground station
- Processing and analysis of the sensor data
- Final data output for various types of application

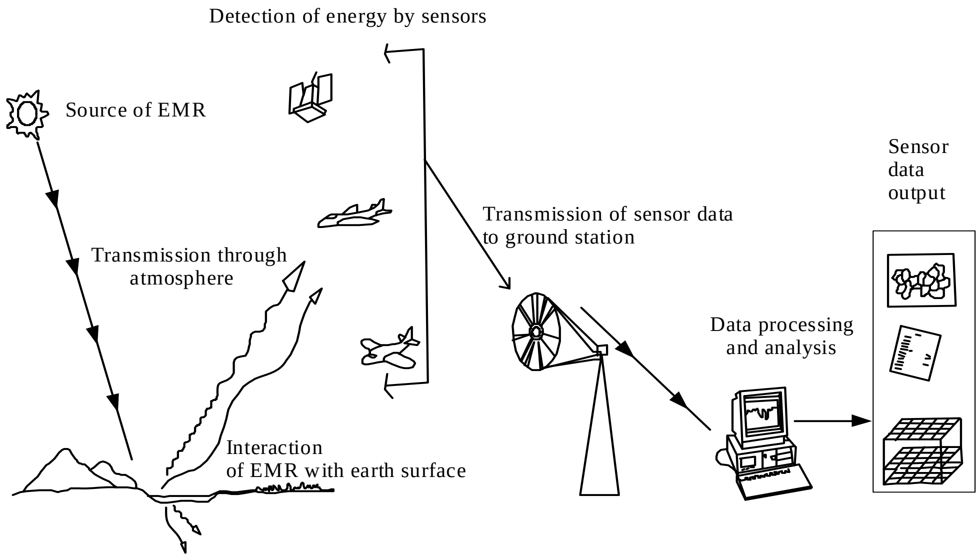

Fig.1: Stages of Remote Sensing

History of Remote Sensing

The knowledge about the history of Remote Sensing is necessary for better understanding of the subject and its scope, and also for future development, particularly for the welfare of human society. The development of remote sensing over time can be broadly divided into following six phases.

Phase I (Up till 1920): Initial Phase

Man always inquisitive about the things across a forest or a mountain, which he can not see directly. So, since time immemorial man has always tried to reach greater heights, such as tree tops, mountains etc. to observe phenomena of his interest on the earth surface, viz. to decide habitat places, farming and other day-to-day activities. This inquisitiveness to get a bird's eye view prompted man to take photographs of earth from elevated platforms. So, the initial photographs of earth were captured from elevated platforms on the surface of the earth. However, the actual beginning of Remote Sensing can be traced back in 1958, when free balloons were used for photography by the French Gaspard Felix Tournachon (known as Nadar) to photograph the village of Petil Becetre near Paris. In 1860, a part of Boston and Massachusetts were photographed from a captive balloon at 1200 feet height in USA. In 1909, the first aerial photograph was taken from an aero plane, piloted by Wilbur Write over Centocelli, Italy. World War I provided a boost in the use of aerial photography. During that time, aerial photographs were used for two purposes – spying and mapping.

Phase II (1920-1945): Development of Platforms and Sensors

Improvement in aero planes, cameras, films etc. resulted in the development of aerial photography during this period. The proper planning of flight for photographic purpose was also started. Topographical mapping was the main thrust of the aerial photography. However, a number of scientists like geologists, botanists, soil scientists, geographers began interpreting the photographs to get information of their interest, especially for development of natural resources. During this period photographic coverage were increased both on the large and medium scale. World War II gave a real boost to photo interpretation technique, which was widely used for military intelligence purposes. The mapping of strategic location, military targets and assessments of damages could be done accurately.

Phase III (1945-50): Development of Teaching and Training

After World War II, much emphasis on teaching and training of this technique was given due to previous experience of its wide use in different spheres. Many courses on Remote Sensing were started in reputed universities of United States and Western European countries. A commission on the utilization of aerial photographs was set up by International Geographical Union (IGU) in 1949. The members of the commission emphasized the need of knowledge of those parts of world which were not earlier photographed and also attention was given to cover more area by aerial photographs and techniques essential for interpretation.

Phase IV (1950-60): Development of Instruments for Interpretation

In this phase, the techniques of photo interpretation became much more an applied technique. A number of instruments was developed and introduced for interpretation during this period, which may be termed as a landmark in the progress of these techniques. It opened a new horizon for accurate and fast analysis and also for monitoring the changes. Hence a considerable advanced interpretation was made in many disciplines such as Geography, Geology, Geophysics, Agriculture and Archaeology.

Phase V (1960-1985): Significant Phase

This phase is very significant in the history of Remote Sensing as artificial satellites were launched in the space for acquiring information of earth surface. Though two American satellites, i.e. Explorer I and II were launched in 1958 and 1959 respectively under Explorer and Discover Programme, they were not important from Remote Sensing point of view. On 1st April, 1960, one satellite of eight members of TIROS (Television and Infrared Observation Satellites) family was launched as a research and development project. As TIROS's name suggested, the satellite carried two types of sensing devices – firstly, television, camera etc. which took picture of the visible spectrum; and secondly, infrared detectors which measured the non visible part of spectrum and provided information of local and regional temperature of earth's surface. The supply of remotely sensed data of earth surface was greatly increased with the launching of ERTS-I (Earth Resources Technology Satellite) on 23rd July, 1972. It was placed in a sun-synchronous polar orbit about 600 miles above the earth surface. It makes 14 revolutions in a day around the earth and its sensors were covering a series 160 kms. wide strip. Then it was followed by ERTS-2 in 1975. With the launch of this satellite, the name of these satellites has been changed from ERTS-1, 2 to LANDSAT-1, 2 respectively. Four other satellites in these series were launched one after another in this phase, with improved cameras and sensors. Beside this, many other satellites were launched in the space by European and Asian Countries during this period.

Phase VI (1985 onwards): Recent Development Phase

In this period, Remote Sensing technique has been improved in two ways. Firstly, there have been developments of sensors which can use infrared and microwave spectrum other than visible spectrum to get information about earth's surface. Secondly, there have been very important advances with respect to the platforms in which sensors are mounted. Besides, satellites have been launched for specific purposes and with specific capability. The ground resolution is continuously increasing till today. Hence, interpretation and mapping is becoming very easy, accurate and purposive. The European Radar satellite (ERS-I) launched in 1991 opened the avenue for systematic global observation in the microwave region. The French Satellite 'SPOT' is producing the imagery to provide the three dimensional view under stereoscope. The satellite – IKONOS, launched on 24th September, 1999 has 1 m. resolution in panchromatic and 4 m. resolution in multi-spectral cameras. USA, France and India have planned a series of satellites, with improved capability, so that the users are assured continuity of data.

Technical Components of Remote Sensing

Platforms

The base, on which remote sensors are placed to acquire information about the Earth's surface, is called platform. Platforms can be stationary like a tripod (for field observation) and stationary balloons or mobile like aircrafts and spacecrafts. The types of platforms depend upon the needs as well as constraints of the observation mission. There are three main types of platforms, namely 1) Ground borne, 2) Air borne and 3) Space borne.

1. Ground borne platforms: These platforms are used on the surface of the Earth. Cherry arm configuration of Remote Sensing van and tripod are the two commonly used ground borne platforms. They have the capability of viewing the object from different angles and are mainly used for collecting the ground truth or for laboratory simulation studies.
2. Air borne Platforms: These platforms are placed within the atmosphere of the Earth and can be further classified into balloons and aircrafts.
    a. *Balloons*: Balloons as platforms are not very expensive like aircrafts. They have a great variety of shapes, sizes and performance capabilities. The balloons have low acceleration, require no power and exhibit low vibrations. There are three main types of balloon systems, viz. free balloons, Tethered balloons and Powered Balloons. *Free balloons* can reach almost the top of the atmosphere; hence they can provide a platform at intermediate altitude between those of aircraft and space craft. Thousands of kilograms of scientific payloads can be lifted by free balloons. Unless a mobile launching system is developed, the flights can be carried out only from a fixed launching station. The free balloons are dependent on meteorological conditions, particularly winds. The flight trajectory cannot be controlled. All these make extremely difficult to predict whether the balloons will fly over the specific area of interest or not.

In India, at present, Tata Institute of Fundamental Research, Mumbai, has set up a National balloon facility at Hyderabad. *Teethered balloons* are connected to the earth station by means of wires having high tensional strength and high flexibility. The teethered line can carry the antenna, power lines and gas tubes etc. when wind velocity is less than 35 km. per hour at the altitude of 3000m., sphere type balloon is used. When the wind velocity is less than 30 km per hour, natural shape balloons are restricted to be placed. Tethered balloons have the capability of keeping the equipment at a fixed position for a long time and thus, useful for many remote sensing programmes. *Powered balloons* require some means of propulsion to maintain or achieve station over a designated geographic location. These can be remotely controlled and guided along with a path or fly above a given area within certain limitations.

b. *Aircrafts*: Aircrafts are commonly used as remote-sensing for obtaining Aerial Photographs. In India, four types of aircrafts are being used for remote sensing operations. These are as follows:

DAKOTA: The ceiling height is 5.6 to 6.2 km and minimum speed is 240 km./hr.

AVRO: Ceiling height is 7.5 km and minimum speed is 600 km./hr.

CESSNA: Ceiling height is 9 km. and minimum speed is 350 km./hr.

CANBERRA: Ceiling height is 40 km.and minimum speed is 560 km./hr.

The following special aircrafts are being used in abroad for remote sensing operations in high altitude photography.

U-2: Ceiling height is 21 km. (for strategic photographic). Minimum speed is 798 km./hr.

ROCKELL X-15 (Research Craft): Ceiling height is 108 km. and speed is 6620 km./hr.

The advantages of using aircrafts as remote sensing platform are : high resolution of data recorded, possibility of carrying large pay loads, capability of imaging large area economically, accessibility of remote areas, convenience of selecting different scales, adequate control at all time etc. However, due to limitations of operating altitudes and range, the aircraft finds its greatest applications in local or regional programme rather than measurements on global scale. Besides all these, aircrafts have been playing an important role in the development of space borne remote sensing techniques. Testing of sensors and various systems and sub systems involved in space borne remote sensing programme is always undertaken in a well equipped aircraft.

3. Space borne platforms: Platforms in space, i.e. satellites are not affected by the earth's atmosphere. These platforms move freely in their orbits around the earth. The entire earth or any part of the earth can be covered at specified intervals. The coverage mainly depends on the orbit of the satellite. It is through these space borne platforms, we get enormous amount of remote sensing data and as a result Remote Sensing has gained international popularity. According to the orbital mode, there are two types of satellites – Geostationary or Earth synchronous and sun-synchronous.

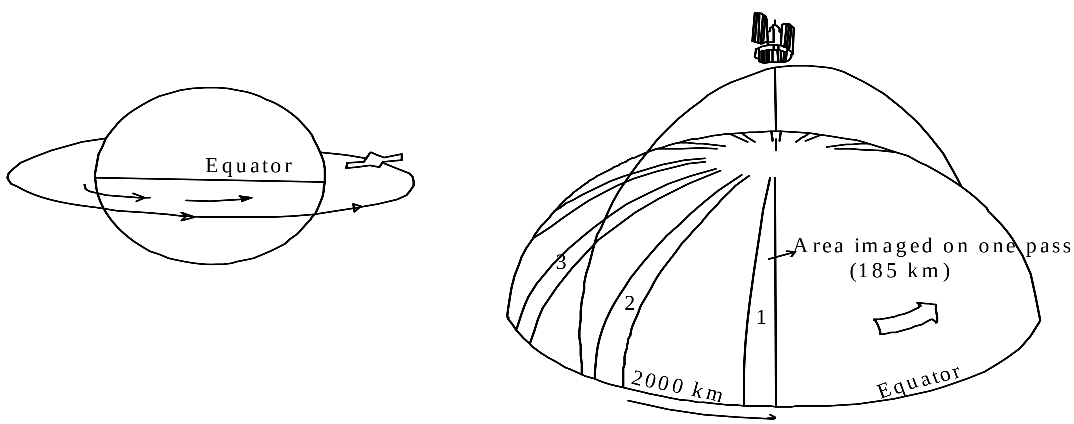

FIg.2 : Geo-stationary and Sun -Syncrhronous Satellites

a. *Geo-stationary Satellites:* Geostationary satellites are the satellites which revolve round the earth above the equator at the height of about 36,000 to 41,000 km., in the direction of earth's rotation. They make one revolution in 24 hours, synchronous with the earth's rotation (Fig.2). As a result, it appears stationary with respect to earth. These platforms always cover a specific area and give continuous coverage over the same area day and night. Their coverage is limited to 70 N and 70 S latitudes and one satellite can view one third globe. These are mainly used for communication and weather monitoring. Some of these satellites are INSAT, METSAT and ERS series.

b. *Sun-synchronous Satellites:* Sun-synchronous satellites are the satellites which revolved round the earth in north-south direction (pole to pole) at the height of about 300 to 1000 km. (Fig.2) They pass over places on earth having the same latitude twice in each orbit at the same local sun-time, hence are called sun-synchronous satellites. Through these satellites, the entire globe is covered on regular basis and gives repetitive coverage on periodic basis. All the remote sensing resources satellites may be grouped in this category. Few of these satellites are: LANDSAT, IRS, SPOT series and NOAA, SKYLAB, SPACE SHUTTLE etc.

Remote Sensors

Remote sensors are the instruments which detect various objects on the earth's surface by measuring electromagnetic energy reflected or emitted from them. The sensors are mounted on the platforms discussed above. Different sensors record different wavelengths bands of electromagnetic energy coming from the earth's surface. As for example, an ordinary camera is the most familiar type of remote sensor which uses visible portion of electromagnetic radiation.

Classification of Sensors

Remote sensors can be classified in different ways as follows.

1. *On the Basis of Source of Energy Used:* On the basis of source of energy used by the sensors, they can be classified into two types – Active sensors and Passive sensors.
    a. *Active Sensors:* Active sensors use their own source of energy and earth surface is illuminated by this energy. Then a part of this energy is reflected back which is received by the sensor to gather information about the earth's surface (Fig.3). When photographic camera uses its flash, it acts as an active sensor. Radar and laser altimeter are active sensors. Radar is composed of a transmitter and a receiver. The transmitter emits a wave, which strikes objects and is then reflected or echoed back to the receiver. The properties of an active sensor are: 1) It uses both transmitter and receiver units to produce imagery, hence it requires high energy levels. 2) It mostly works in microwave regions of EMR spectrum, which can penetrate clouds and is not affected by rain. 3) It is an all weather, day-night system and independent of solar radiation. 4) The RADAR signal does not detect colour information or temperature information, but it can detect the roughness, slope and electrical conductivity of the objects under study.

b. *Passive Sensors:* Passive sensors do not have their own source of energy. The earth surface is illuminated by sun/solar energy. The reflected solar energy from the earth surface or the emitted electromagnetic energy by the earth surface itself is received by the sensor (Fig.3). Photographic camera is a passive sensor when it is used in sun light, without using its flash. The properties of a passive sensor are: 1) It is relatively simple both mechanically and electrically and it does not have high power requirement. 2) The wavebands, where natural remittance or reflected levels are low, high detector sensitivities and wide radiation collection apertures are necessary to obtain a reasonable signal level. Therefore, most passive sensors are relatively wide band systems. 3) It depends upon good weather conditions.

2. On the Basis of Function of Sensors: On the basis of function of sensors, they are divided into two main types - Framing System and Scanning System.

a. *Framing system:* In framing system, two dimensional images are formed at one single instant. Here, a lens is used to gather the light which is passed through various filters and then focused on a flat photosensitive target. In ordinary camera, the target is film emulsion, whereas in vidicon camera, the target is electrically charged plate.

b. *Scanning System:* In scanning system, a single detector / a number of detectors with specific field of view, is used which sweeps across a scene in a series of parallel lines and collect data for continuous cells to produce an image. Multi Spectral Scanner, Microwave Radiometer, Microwave Radar, Optical Scanners are few examples of scanning system sensors.

3. *On the Basis of Technical Components of the System*: The sensors can be classified into three categories on the basis of technical components of the system and the capability of the detection. These are: 1) Multispectral imaging sensor systems, 2) Thermal remote sensing systems, and 3) Microwave radar sensing systems. The multispectral or multiband imaging systems may use conventional type camers or may use a combination of both cameras and scanners for various bands of electromagnetic energy. As for example, Return Beam Vidicon (RBV) sensor of Landsat uses both photographic and

scanning systems, which is similar to an ordinary TV camera. The thermal system uses radiometers, photometers, spectrometers, thermometers to detect the temperature changes where microwave sensing systems use the antenna arrays for collecting and detecting the energy from the terrain elements.

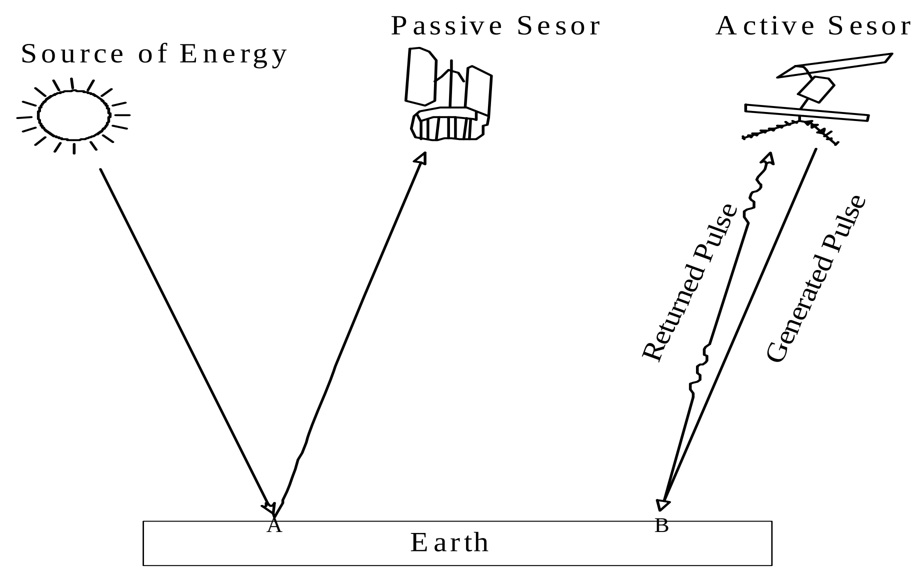

Fig.3 : ACtive and Passive Sensors

Function of Remote Sensing

A Source of EMR

Before discussing the source of EMR used for Remote Sensing purpose, we should know what EMR or electro magnetic radiation is. EMR is the dynamic form of radiated energy that propagates as wave motion equal to the velocity of light. The EMR is classified into different types on the basis of their wavelength as follows:

Kind of waves	Wavelength Range in micron
Cosmic Rays	<.0000001
Gamma Rays	.0000001 to .0001
X-rays	.001 to .01
Ultraviolet Light	.01 to .4

Visible Light	.4 to .7
Infra-red Light	.7 to 1000
Microwaves	1000 to 10^{6}
Radiowaves	more than 10^{6}

Out of these above types of EMR, Remote Sensing mostly uses the visible (0.4 to 0.7 microns), the reflected IR and thermal IR (.7 to 14 microns) and the microwave regions(1000 to 3000 microns).

There are mainly three sources of EMR used for remote sensing purpose, which illuminate the object. Sun is the first and main source. The sun's radiation covers ultraviolet, visible, infrared and radio frequency regions. The maximum radiation occurs around .55 microns. All objects on earth surface also emit EMR. The wavelength of these EMR depends upon the temperature and other characteristics of the object. Many common objects emit EMR having wavelength between .85 and .95 um. It is also possible to produce EMR of a specific wavelength or band of wavelengths by the sensor to illuminate the object. This is called active remote sensing while the first two (EMR from the sun and self emitted radiance by the object) are called passive remote sensing.

Transmission of Energy from the Source to the Surface of the Earth

While EMR is transmitted from the sun to the surface of the earth, it passes through the atmosphere. Here, electromagnetic radiation is scattered and absorbed by gases and dust particles. Besides the major atmospheric gaseous components like molecular nitrogen and oxygen, other constituents like water vapour, methane, hydrogen, helium and nitrogen compounds play important role in modifying electro magnetic radiation. This affects image quality. Regions of the electromagnetic spectrum in which the atmosphere is transparent are called atmospheric windows. In other words, certain spectral regions of the electromagnetic radiation pass through the atmosphere without much attenuation are called atmospheric windows. The atmosphere is practically transparent in the visible region of the electromagnetic spectrum and therefore, many of the satellite based remote sensing sensors are designed to collect data in this region. Some of the commonly used atmospheric windows are shown in

Figure 4. They are: 0.38-0.72 microns (visible), 0.72-3.00 microns (near infra-red and middle infra-red), and 8.00-14.00 microns (thermal infra-red).

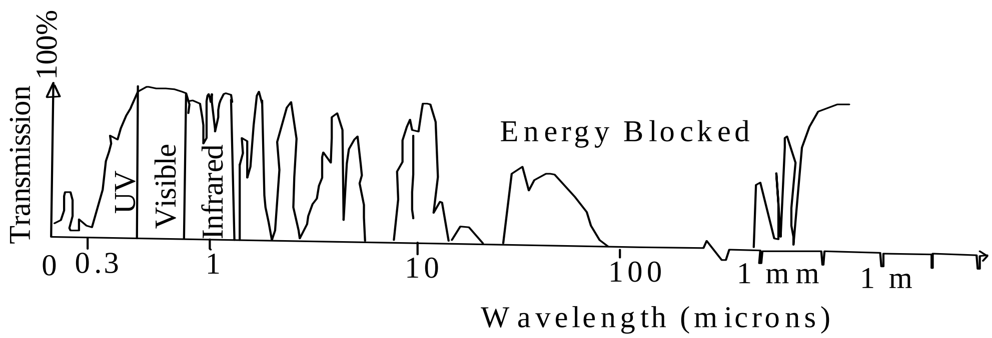

Fig.4 : Atmospheric Windows

Interaction of EMR with Earth's Surface

The electromagnetic radiation when interact on the earth, either gets reflected, absorbed, radiated or transmitted through the material. It depends upon the nature of the object and the wavelength interacts with it. When the object is smooth in comparison to the wavelength of the incident radiation, it gets reflected in the forward direction called specular reflection. When the surface is rough in comparison to the wavelength of the incident radiation, it is reflected uniformly in all directions, which is termed as diffused reflection. It may be noted that an object may appear rough in a particular wavelength region, is smooth in another wavelength region. As for example fine sand, which appears rough in the visible region, is smooth in the microwave region.

Transmission of Energy from Surface to Remote Sensor Mounted on the Platform

While EMR is transmitted from the surface of the earth to the sensor, it again passes through the atmosphere. Here, electromagnetic radiation is modified again in the same way as it is transmitted from the sun to the surface of the earth (discussed earlier).

Detection of the Energy by the sensor

The sensors like cameras or scanners mounted on platforms such as aircraft or satellite identify object and discriminates it from other objects on the basis of reflected/emitted electromagnetic energy received by it, which is called signature. The basic assumption is that each individual has a unique signature or finger print with which he can be identified. Likewise every object has a unique signature on the sensor, by which it can be identified. In general, we can say that any set of observable characteristics, which directly or indirectly leads to the identification of an object, is termed as signature. There are four major characteristics of objects which facilitate discrimination – spectral, spatial, temporal and polarization variations.

Spectral variations are the variations in the reflectance or emittance of object as a function of wavelength. Colour of objects is manifestation of the spectral variation in reflectance in the visible region. Vegetation looks green, because it reflects the 'green' part of the incident light preferentially. When the sensor uses wavelength region other than visible region, the objects do not give its natural colour as signature. As for example vegetation looks red when the sensor uses near infrared reflectance.

Spatial variations in the reflectance and emittance are attributes of the shape, size and texture of objects. In the visible region of the spectrum, we are quite familiar with spatial information provided by the shape, size etc. of an object as seen in photograph. The photographs of a hot spring will give similar shape and proportional to the size of actual hot spring. However, thermal scanner of a hot spring will give different look as per the temperature distribution across the surface of the hot spring.

Temporal variations relate to the reflectivity or emissivity with time e.g. the diurnal and seasonal variation. These variations play an important role in the detection of agricultural crops as well as soils. Two crops having similar spectral reflectance, but having different growing season can be distinguished by remote sensor. In case of rocks, diurnal variations in the emitted radiation (thermal infra-red region) have proved to be very significant in their identification.

Polarisation variation relates to the orientation of the electric field component of electromagnetic radiation. Objects can be distinguished from each other by making use of the differences in the polarization of the reflected EMR. Such observations have been particularly useful in microwave region.

Transmission and Processing of the Sensor Data Output

When sensors like cameras or multispectral scanners are mounted on aircraft, the images are recorded on films or magnetic tapes. When the aircraft lands, the films or tapes are physically transported to the laboratory for further processing. In case of satellites, there is no such possibility of physical retrieval of media containing data. In that case, the data is transmitted down to a ground station where it is recorded on magnetic tapes. The ground station therefore, needs to have an appropriate tracking antenna and communication link with the satellite.

Then the data is corrected in different methods to remove distortions caused due to motion of the platform relative to earth, platform attitude, earth curvature, non-uniformity of illumination, variations in sensor characteristics etc. This can be done either using electro-optical techniques or more popularly by using computer and is called processing of data. Then the output products are generated either in the form of photographs or in digital form. Then the photographs are analysed visually and digital data is analysed by computer software.

Remote Sensing Data Products and Their Interpretation

Data products

The main interest of social scientists and applied scientists is the data produced by Remote Sensing technique. The Remote Sensing data are of two types – pictorial and digital. These data products are described in the following paragraphs:

1. *Digital Data Products:* The digital data products give information in the form of array of small cells having quantitative values which is the function of the electromagnetic energy radiated from all objects within the field of view. A digital data product is called digital image. A digital image is a two dimensional array of pixels (picture elements). Each pixel represents an area on the earth’s surface and has an intensity value (represented by a digital number) and a location address (referenced by its row and column number). The intensity value represents the measured solar radiance in a given wavelength band reflected from the ground. The location address is a one-to-one correspondence between the column-row address of a pixel and the geographical coordinates (e.g. latitude and longitude) of the imaged location. The digital image is a vast matrix of numbers and is very often stored in a

magnetic tape and in particular in a computer compatible tapes (CCT). The digital data can be converted into photographic image.

2. *Pictorial Data Products:* The pictorial data products give information of objects on the earth surface in the form of photographs or images. The pictorial products provided by aircrafts are called aerial photographs. These are generally taken by sophisticated cameras which use visible portion of electromagnetic energy. Therefore, aerial photographs give the exact view / picture of objects on the earth surface on reduced scale. The aerial photographs may be black and white or may be coloured, it depends upon the camera used in aircraft. The pictorial data products provided by satellites are called satellite images. These images are generally taken by sensors which use both visible and invisible portion of electromagnetic energy. The satellite images can be black and white or can be coloured. The black and white pictures or images are produced from each band of digital data. For a particular band, black and white image is generated by assigning different shades of grey (white to black) to its digital data. Likewise unicolour images (blue, green, red etc.) can be generated by assigning different shades of blue / green/ red to a particular band data. When any three bands are combined, it gives multi coloured imagery. If images are taken in blue, green and red bands (visible portion of electromagnetic energy) respectively, they can be combined to give natural colour image. If images are taken in green, red (visible portion of electromagnetic energy) and infrared band (invisible portion of electro magnetic energy) and blue, green and red colours are assigned to them respectively and then they are combined together, it will produce a False Colour Composite (FCC) image. The FCC image does not give the exact picture / view of the earth's surface like aerial photographs. The lay person cannot visualize anything from FCC image. Only an expert can interpret it.

Data Interpretation

In the foregoing paragraphs, we have studied two major types of Remote Sensing data products, viz. pictorial and digital. The pictorial data products, such as aerial photographs and satellite imageries are interpreted visually. Likewise, digital data products or digital images are interpreted mathematically by using computer software. So, there are two ways of Remote Sensing data interpretation – 1) Visual Interpretation and 2) Digital Interpretation.

1. *Visual Interpretation:* Both aerial photographs and satellite imageries are interpreted visually. Photogrammetry is the science which study interpretation of aerial photographs. To interpret aerial photographs, a number of sophisticated instruments such as pocket stereoscope, mirror stereoscope, plotter is used in photogrammetry for measuring area, height, slopes of different parts of earth photographed and also for plotting different objects / themes from aerial photographs. With the development of science and technology, satellite imageries become more and more popular gradually. Satellite image interpretation is an art of examining images for the purpose of identifying objects and judging their significance. Interpreters study remote sensing image logically and attempt to identify, measure and evaluate the significance of natural and cultural features. Image interpretation technique requires extensive training and is labour intensive. Information extraction from imageries is based on the characteristics of image features, such as size, shape, tone, texture, shadow, pattern, association etc. Though this approach is simple and straight forward, it has following short comings: i) The range of gray values product on a film or print is limited in comparison to what can be recorded in digital form, ii) Human eye can recognize limited number of colour tones, so full advantage of radiometric resolution cannot be used, iii) Visual interpretation poses serious limitation when we want to combine data from various sources.
2. *Digital Interpretation*: Digital interpretation facilitates quantitative analysis of digital data with the help of computers to extract information about the earth surface. Digital interpretation is popularly known as 'Image Processing'. Image processing deals with image correction, image enhancement and information extraction. ***Image correction*** means to correct the errors in digital image. Errors are resulted due to two reasons. When errors are resulted due to defect in sensor (as for example if one of the detector out of 'n' number of detectors does not work), it is called radiometric error. When errors are resulted due to earth rotation, space craft velocity, atmosphere attenuation etc., it is called geometric error. Both radiometric and geometric errors / noise in images are reduced through different techniques with the help of computer. ***Image Enhancement*** deals with manipulation of data for improving its quality for interpretation. Some times digital image lacks adequate contrast, as a result different objects cannot be recognized properly. So, the image requires contrast improvement. Through different image enhancement technique,

contrast is improved in digital image. After image correction / rectification, and contrast enhancement, informations are extracted from the digital image, which is the ultimate goal of an interpreter. In ***Information Extraction***, spectral values of pixels are analysed through computer to identify / classify objects on the earth surface. In other words, spectrally homogenous pixels in the image are grouped together and differentiated from other groups. In this way, different features of earth are recognised and classified. The field knowledge and other sources of information also help in recognition and classification processes.

GEOGRAPHICAL INFORMATION SYSTEM

Meaning

The expansion of GIS is Geographic Information System which consists of three words, viz. Geographic, Information and System. Here the word 'Geographic' deals with spatial objects or features which can be referenced or related to a specific location on the earth surface. The object may be physical / natural or may be cultural / man made. Likewise the word 'Information' deals with the large volume of data about a particular object on the earth surface. The data includes a set of qualitative and quantitative aspects which the real world objects acquire. The term 'System' is used to represent systems approach where the complex environment (consists of a large number, of objects / features on the earth surface and their complex characteristics) is broken down into their component parts for easy understanding and handling, but is considered to form an integrated whole for managing and decision making. Now-a-days this is possible in a very short span of time with the development of sophisticated computer hardware and software. Therefore, GIS is a computer based information system which attaches a variety of qualities and characteristics to geographical location (Fig.5)and helps in planning and decision making.

A Geographic Information System (GIS) may be defined in different manners.

International Training Centre (ITC), Holland defined Geographic Information System (GIS) as a computerised system that facilitates the phases of data entry, data analysis and data presentation especially in cases when we are dealing with geo referenced data.

Indian Society of Geomatics (ISG) and Indian Space Application Centre (ISRO) defined GIS as a system which provides a computerised mechanism for integrating various geoinformation data sets and analysing them in order to generate information relevant to planning needs in a context.

According to Centre for Spatial Database Management and Solutions (CSDMS), GIS is a computer based tool for mapping and analysing things that exist and events that happen one earth.

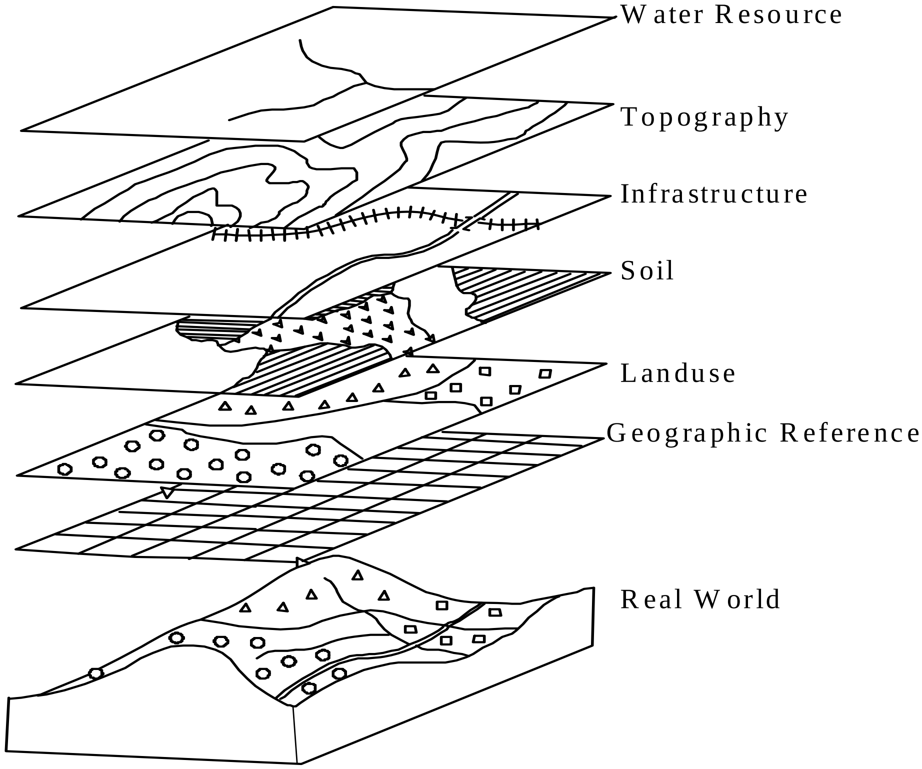

Fig.5 : Informaton sored as theme layers with each layer linked to a common spatial featurereferenced to a specific location

Burrough (1986) defined GIS as a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purpose.

Arnoff (1989) defined GIS as a computer based system that provides four sets of capabilities to handle geo referenced data, viz. data input, data management (data storage and retrieval), manipulation analysis and data output.

From the above definitions, we can conclude that a GIS user expects support from the system to enter geo referenced data to analyse it in various ways and to produce output (maps and other) from the data. GIS draws on concepts and ideas from many different disciplines, such as cartography, congitive science, computer science, engineering, environmental sciences, geodesy, landscape architecture, law, photogrammetry, public policy, remote sensing, statistics and surveying. So, it involves not only the study of the fundamental issues arising from the creation, handling, storage and use of geographic information, but it also examines the impacts of GIS on individuals and society and the influences of society on GIS.

Development of GIS

Keeping long tradition of map making as background, G.I.S. has been developed during mid 20th century with the development of computer science. The data analysis of geographic locations was being done by computers in government organizations and universities in U.S.A. during 1950s and 1960s. The first true operational G.I.S. was developed by Dr. Roger Tomlinson, Department of Forestry and Rural Development , Canada. It was called as Canada Geographic Information System (CGIS) and was used to store analyse and manipulate land related data. Dr. Roger Tomlison was also known as the 'Father of G.I.S'. In 1964, a laboratory of Computer Graphics and Spatial Analysis was established at the Harvard Graduate School of Design by Howard T. Fisher. This organization developed a number of important theoretical concepts of spatial data handling and in 1970s it distributed seminal software code and system such as 'SYMAP', 'GRID' and 'ODYSSEY'. This inspired subsequent commercial development. By early 1980s, M & S Computing(later Intergraph) and Environmental Systems Research Institute (ESRI) emerged as commercial vendors of G.I.S. software. ESRI released ARC/ Info and ARC View software in 1981 and 1992 respectively. By the end of 20th Century, the development of ARC View enabled viewing G.I.S. data through internet and eliminated many of the hardware and licensing expenses of software packages. Since then a number of organisations and universities have been doing research in the field of G.I.S. and developing user friendly softwares . Now there is a growing number of free, open source G.I.S. packages which run in a wide range of operating systems and perform specific tasks.

Requirements for GIS Operation

GIS primarily deals with geographic data to be analysed, manipulated and managed in an organized manner through computers to solve real world problems. So, GIS operation requires two things – computer system and geographic data.

Computer System

It includes both hardware and software. GIS runs through computer system ranging from portable personal computers (PCs) to multi-user super computers which are programmed by wide variety of software languages. In all ranges, there are a number things, that are essential for effective GIS operation. These include: 1)a processor with sufficient power to run the software, 2)sufficient memory for the storage of large volume of data, 3)a good quality, high resolution colour graphic screen and 4)data input and output devices (for example digitizers, scanners, keyboard, printers and plotters).

There are a wide range of software packages for GIS analysis, each with its own advantages and disadvantages. Even those lists are too long to be mentioned here, the important ones are different versions of ARC View, ARC Info, Map Info., ARC GIS, Auto Cad Map etc.

Data for GIS

A GIS without data is like a car without fuel. Without fuel, a car cannot move, likewise without data a GIS will not produce anything. Data for GIS can be obtained from different sources like aerial photographs, satellite imageries, digital data, conventional maps, Census, Meteorological department, field data (surveys/GPS) etc. These data obtained from various sources can be classified into two types – spatial data which describes location and attribute data which specifies the characteristics at that location. Spatial data tells us, “where the object is?” Attribute data tells us “What the object is?” or “How much the object is?” In other words, it tells the characteristics at that location.

Spatial Data

The spatial data or real world features are very complex. So, spatial data is simplified before they are entered into the computer. The common way of doing this is to break down all geographic features into three basic entity types – points, lines and areas. Points are ‘one dimensional' objects, used to represent features that are very small, e.g. a post box, an electric pole, a well or tube well etc. Only latitudinal and longitudinal values or a coordinate reference can be given to these features to explain their location. Lines are two dimensional objects and are used to represent linear features, for example roads and rivers. Lines are also used to represent linear features that do not exist in reality, such as administrative boundaries and international boundaries. Areas are three dimensional objects and are represented by closed set of lines and are used to define features such as agricultural fields, forest areas, administrative areas etc. Area entities are often referred to as polygons.

The representation of real world features using the point, line and area entity types appears relatively simple. However, the appropriate entity to represent real world features is often difficult and it depends upon the scale of the map. On a world map, cities are represented by points. It only gives information about number of cities shown on the world map. At national or regional scale, the 'point' entity to represent cities is considered too simple, as it tells us nothing about the real size of the city. In this case, cities are represented by 'area' entity. At the local scale, 'area' entity to represent cities would be considered too simple. In this case, cities are represented by mixture of 'point', 'lines' and 'areas' as entities. Points may be used to represent features such as electric poles, post boxes etc. Likewise lines and areas may be used to represent road networks and residential blocks respectively. So, the decision makers decide the 'entities' through which different features of real world would be represented.

Attribute Data

As it is mentioned earlier, attribute data tells the characteristics of different objects / features on the earth surface. These are descriptions, measurements or classification of geographic features. Attribute data can be both qualitative (like land use type, soil type, name of the city/river etc.) and quantitative (like elevation, temperature, pressure of a particular place, crop yield per acre etc.). So, the attribute can be both numeric and textual. The examples of attribute data of different spatial features like point (well), line (river), area (village) are shown in box 1. The attribute data are generally in tabular form.

Function of GIS

After having knowledge about computer system and having different types of data (spatial and attribute), let us see how GIS functions. Function of GIS is explained in following steps:

Data Entry

Both spatial and attribute data are entered into computer system by different input devices like scanner, digitizer, key board, mouse etc. Scanner, digitizer, mouse are used for entering spatial data. The attribute data available as reports, tables etc. are entered through key board. As the data is drawn from different sources, they have different scales, projections, referencing system etc. Therefore, there is a need to standardise the database to common standard. GIS software enables this operation by 'geo referencing' or 'rubber sheeting' method. This means stretching of maps in different directions so as to match with known coordinates.

Storing of Data

The different spatial entities which represent different features of real world can be stored in two different formats in the computer – in raster format and in vector format. The knowledge of these formats in which spatial data are stored, is required for decision makers as it affects the accuracy of data, their analysis, storing capacity of computer etc.

In ***raster format***, the entire study area is divided into regular grid or square cells organized into rows and columns. Individual cells are used for storing point, line and area entities. The point data are stored in individual cells. The line data are stored by linking cells into lines. The area units are stored by grouping cells into polygons. Figure 6 shows how different features are represented by three different entity types and stored in raster format. The size of the grid cell is very important as it influences the accuracy of spatial features. Figure 7 shows how the spatial character of the real world road network changes as the cell size of the raster format is altered.

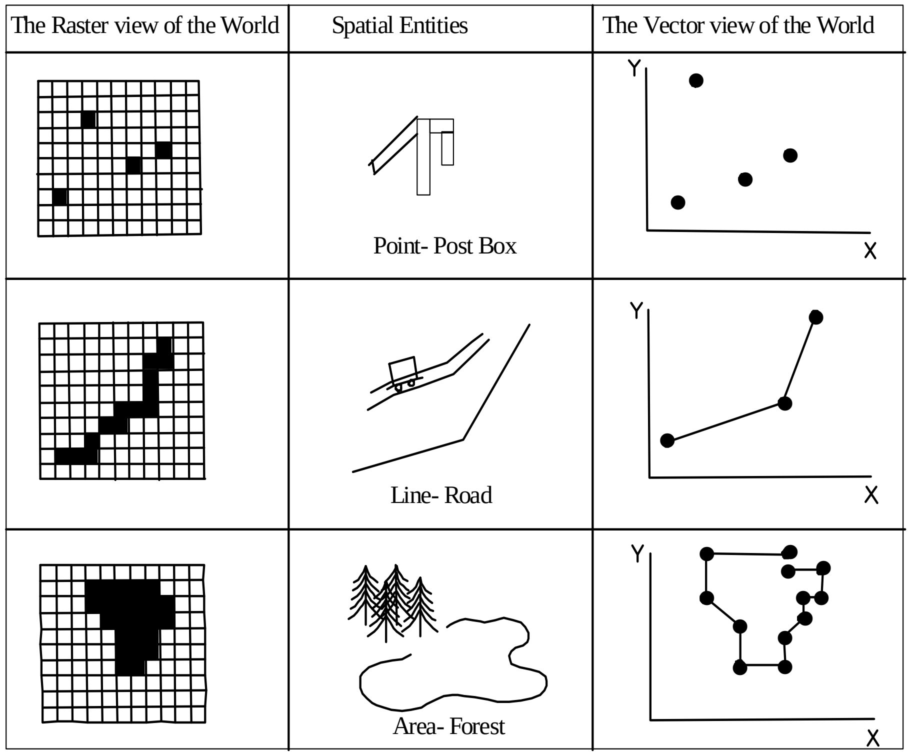

Fig.6 : Raster and Vector Format of Spatial Data

In ***vector format***, points, lines and area entities are stored by using coordinate system. A point is stored by single (x,y) coordinate pair (Fig. 6). A line entity is stored by connecting a series of points into chains. Likewise, aerial entity is stored by connecting a series of points into polygons. The number of points used to show spatial features is important in vector format, because it influences the accuracy of spatial features. Figure 7 shows how spatial character of the real world road network changes when the number of points in the vector format is changed.

The raster and vector format have their own advantages and disadvantages. Raster data led themselves for use with remotely sensed data, because digital remote sensing data are already presented in raster format. Compared with the raster GIS, some of the vector GIS operations are more accurate. For example, estimates of area based on polygons are more accurate than counts of raster cells, because raster cell boundary are not accurate and contain part of an adjacent feature. Vector format allows complex data to be stored in a minimum space. The raster data though voluminous, is more amendable for many spatial analyses. Now-a-days advantages can be taken from both the formats by conversing raster data to vector data and vice versa.

The attribute is stored in table form as shown in Table 1, 2 and 3. Then they are linked to their respective spatial data. For raster data, the attribute data of a particular feature is linked to cells forming that feature. For vector data, the attributes are linked to the point, line or polygon as the case may be. There are a number of ways in which the attribute data can be organised. The relational database model is the most popular. Consider 'table 1' which gives information about different tube wells. The entire table is called a 'relation'. Each row has the relation, which corresponds to the information about a given tube well, is called record. Each column which gives different information of the tube well is called a 'field' or 'attribute'.

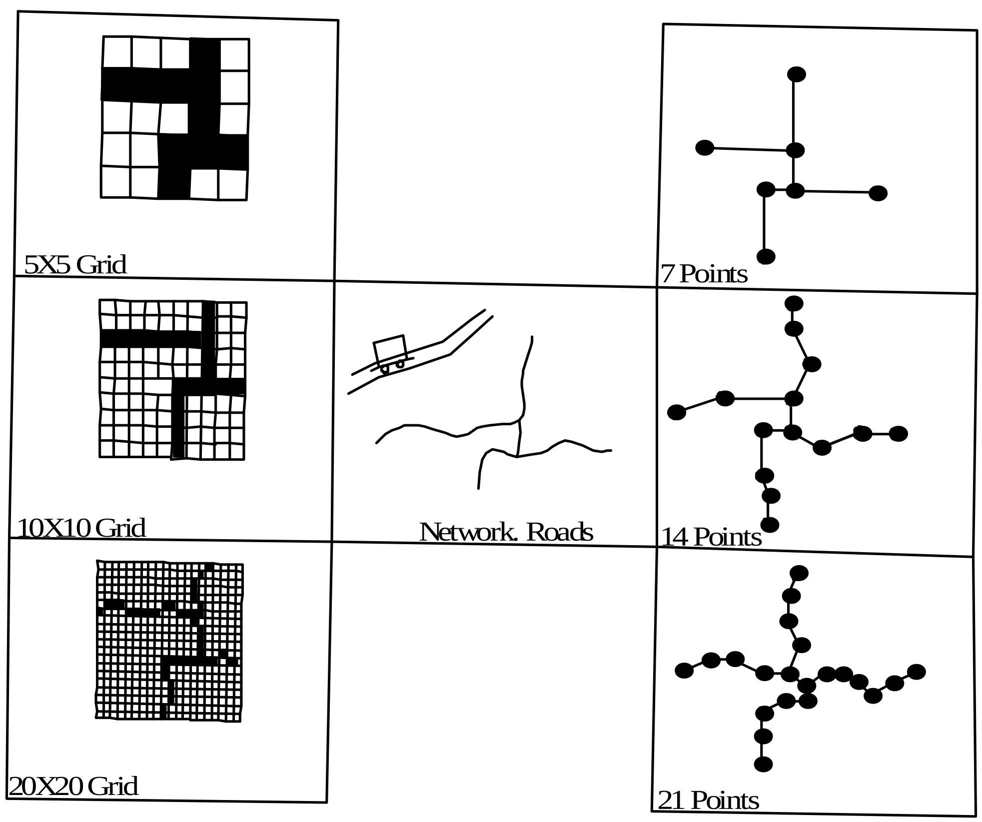

Fig.7 : Effect of changing resolution in Vector and Raster format

Table 1: Attribute Data of 'Point' Entity Tube Wells)

Tube Well code	Year of Construction	Depth of water table (m)	Chlorine content of water (mg/ litre)	Water extracted per day (litre)
1	1991	20	150	1500
2	1985	10	120	1600
3	2000	25	200	1450
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N	2002	15	100	2000

Table 2: Attribute Data of 'Line' Entity (Roads)

Road Code	Constructed in year	Type of Road	No. of buses plying / day	Heavy traffic hour
1	1981	Metalled	500	8 am – 11 am
2	1985	Metalled	550	9 am – 12 noon
3	1977	Unmetalled	200	7 am – 8 am
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N	1975	Unmetalled	150	8 am – 9 am

Table 3: Attribute Data of 'Area' Entity (Forest)

Code of Forest Patches	Tree Density	Type of Species	Occurrence of Forest Fires (Since 1990)	No. Of Tribals Living
1	70	Sal	50	60
2	60	mangrove	65	50
3	25	bamboo	70	45
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N	45	mixed	25	70

Data Analysis

Different types of spatial data analysis can be performed by GIS, viz. performing queries, proximity analysis, network analysis, overlay operations, model building etc.

Since GIS stores both spatial and non spatial data and links them together, it can ***perform different types of queries***. For example by joining the spatial data (map showing tube well location in Figure 6) and its attributes (shown in table1) and then by performing queries, one can see on map, the water of which tube wells having chlorine content more than 200 mg/litre. Likewise one can see on map (by joining road map shown in Figure 7 and its attributes given in Table 2) , the roads constructed before 1980 which need to be repaired. In the same way, which area of a given forest having more than 60 per cent tree density, can be shown on the map (By joining map of the forest shown in Figure 6 and its attribute table given in Table 3)

Proximity analysis can be done through buffering, i.e. identifying a zone of interest around a point, line or polygon. For example, 10 m. around on tube well can be marked for planting flower plants; or 50 m. along national highways (both sides) can be buffered for planting trees. A specified distance around the forest can be buffered as no habitation zone.

Network analysis is another important analysis done through GIS. For example optimum bus routing can be determined by examining all the field or attribute data (given in table 2) linked to road map / spatial data.

Overlay operation can be done through GIS by overlaying / integrating a number of thematic maps. Overlay operation allows creation of a new layer of spatial data by integrating the data from different layers. For example, a particular land use class having saline soils, slope less than 20%, drainage density less than 10 m. per squre km. can be created from four different thematic maps, viz. land use map, soil map, topographic map and water resource map (Fig. 5).

Model building capability of GIS is very helpful for decision makers. It is usually referred to as ‘what if’ analysis. For example, if a certain amount of water is released from a Dam, how much area would be inundated?

Conclusions

Remote sensing and GIS are integral to each other. The development of Remote Sensing is of no use without the development of GIS and vice versa. Remote Sensing has the capability of providing large amount of data of the whole earth and also very frequently. GIS has the capabilities of analyzing a large amount of data within no time. These voluminous data would have become useless without the development of GIS. Manual handling of one time remote sensing data would take years together, by the time a number of multi date data would have piled for analysis. Likewise capability of GIS would have no use without the development of Remote Sensing technology, which provides voluminous data.