

## **MODULE 1**

### **DEFINITION AND PROCESS OF REMOTE SENSING**

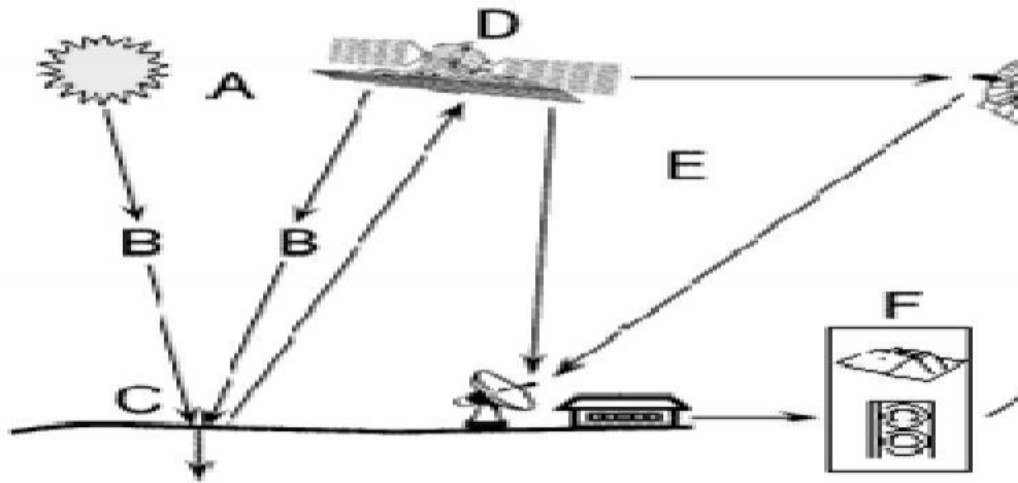
#### **INTRODUCTION**

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 realize 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 AND ITS COMPONENTS:**

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. However that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.-

#### **Components of Remote Sensing**



1. **Energy Source or Illumination (A)** – the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
2. **Radiation and the Atmosphere (B)** – as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.
3. **Interaction with the Target (C)** - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. **Recording of Energy by the Sensor (D)** - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.
5. **Transmission, Reception, and Processing (E)** - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).
6. **Interpretation and Analysis (F)** - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. **Application** (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

#### **HISTORY OF REMOTE SENSING:**

1839 - first photograph

1858 - first photo from a balloon

1903 - first plane

1909 first photo from a plane

1903-4 -B/W WW I and WW II infrared film

1960 - space

#### **ELECTROMAGNETIC SPECTRUM**

The first requirement for remote sensing is to have an **energy source to illuminate the target** (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation. All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory.

**Electromagnetic radiation** consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel along with the speed of light (c). Two characteristics of electromagnetic radiation are particularly important to understand remote sensing. These are the **wavelength and frequency**.

Electromagnetic radiation (EMR) as an electromagnetic wave that travels through space at the speed of light C which is  $3 \times 10^8$  meters per second. Theoretical model of random media including the anisotropic effects, random distribution discrete scatters, rough surface effects, have been studied for remote sensing with electromagnetic waves.

#### **Wavelength and frequency**

The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda ( $\lambda$ ). Wavelength is measured in meters (m) or some factor of meters such as **nanometers** (nm,  $10^{-9}$  meters), **micrometers** ( $\mu\text{m}$ ,  $10^{-6}$  meters) ( $\mu\text{m}$ ,  $10^{-6}$  meters) or centimeters (cm,  $10^{-2}$  metres). Frequency refers to the number of cycles of a wave passing a fixed point per unit of time.

Frequency is normally measured in **hertz** (Hz), equivalent to one cycle per second, and various multiples of hertz. Wavelength and frequency are related by the following formula:

$$c = \lambda \nu$$

where:

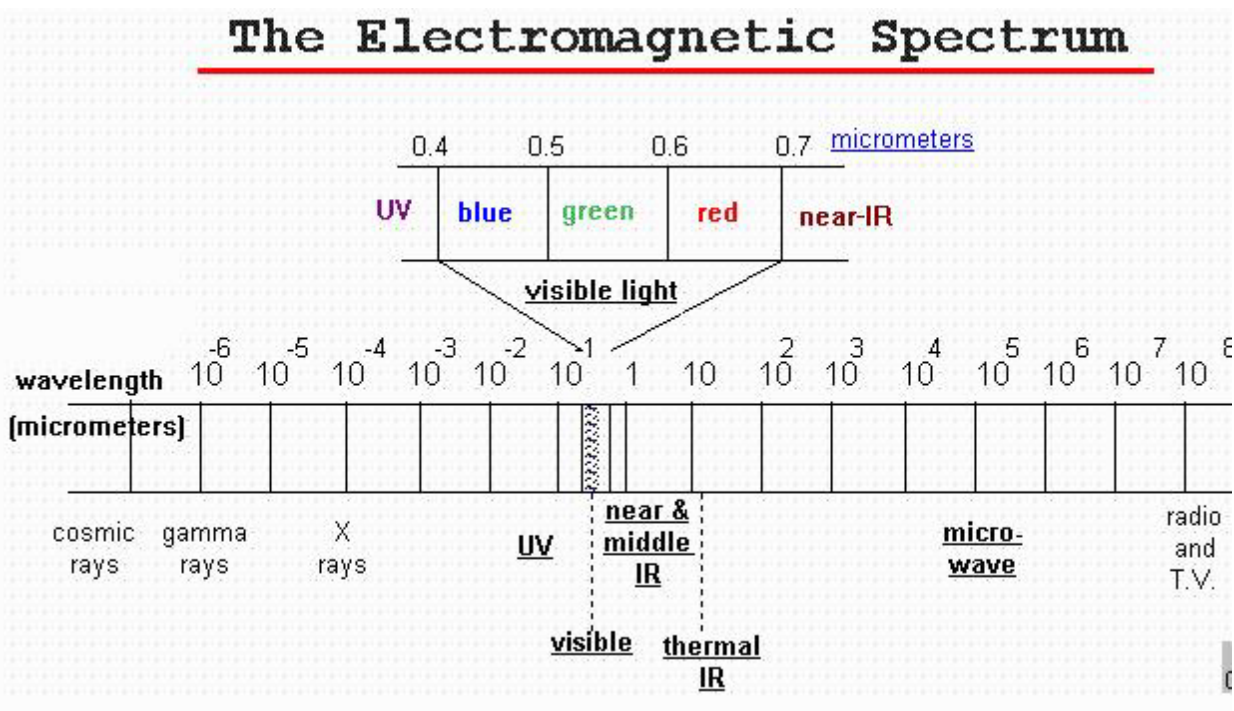
$\lambda$  = wavelength (m)

$\nu$  = frequency (cycles per second, Hz)

$c$  = speed of light ( $3 \times 10^8$  m/s)

Therefore, the two are inversely related to each other. Shorter the wavelength higher the frequency. The longer the wavelength, the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial in understanding the information to be extracted from remote sensing data.

The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.



#### WAVELENGTH REGIONS IMPORTANT TO REMOTE SENSING:

### 1 Ultraviolet or UV

For the most purposes ultraviolet or UV of the spectrum shortest wavelengths are practical for remote sensing. This wavelength beyond the violet portion of the visible wavelengths hence it name. Some earth surface materials primarily rocks and materials are emit visible radiation when illuminated by UV radiation.

### 2 Visible Spectrums

The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7  $\mu\text{m}$ . The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colours from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of **colors**.

**Violet:** 0.4 -0.446  $\mu\text{m}$

**Blue:** 0.446 -0.500  $\mu\text{m}$

**Green:** 0.500 -0.578  $\mu\text{m}$

**Yellow:** 0.578 -0.592  $\mu\text{m}$

**Orange:** 0.592 -0.620  $\mu\text{m}$

**Red:** 0.620 -0.7  $\mu\text{m}$

**Blue, green, and red** are the **primary colours** or wavelengths of the visible spectrum. They are defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various proportions. Although we see sunlight as a uniform or homogeneous colour, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colours when sunlight is passed through a **prism**, which bends the light in differing amounts according to wavelength.

### 3 Infrared (IR)

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7  $\mu\text{m}$  to 100  $\mu\text{m}$  more than 100 times as wide as the visible portion. The infrared can be divided into 3 categories based on their radiation properties- the reflected near- IR middle IR and thermal IR. The reflected near IR covers wavelengths from approximately 0.7  $\mu\text{m}$  to 1.3  $\mu\text{m}$  is commonly used to expose black and white and color-infrared sensitive film. The middle-infrared region includes energy with a wavelength of 1.3 to 3.0  $\mu\text{m}$ .

The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form in the form of heat. The thermal IR covers wavelengths from approximately 3.0  $\mu\text{m}$  to 100  $\mu\text{m}$ .

#### **4 Microwave**

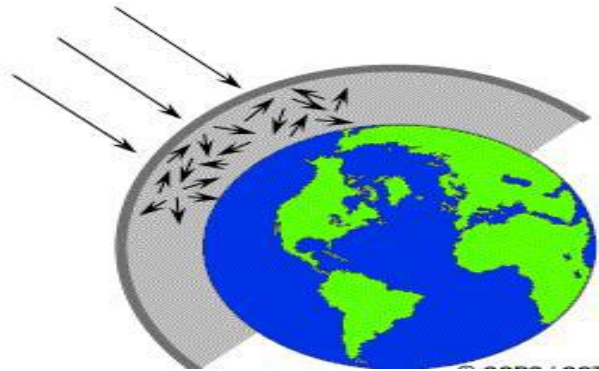
This wavelength (or frequency) interval in the electromagnetic spectrum is commonly referred to as a band, channel or region. The major subdivision The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for

radiobroadcast.

Region	Wavelength	Remarks
Gamma ray	<0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 to 3.0 nm	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.3 to 0.4 $\mu\text{m}$	Incoming wavelengths less than 0.3 $\mu\text{m}$ are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 to 0.4 $\mu\text{m}$	Transmitted through atmosphere. Detectable with film and photodetectors, but atmospheric scattering is severe
Visible	0.4 to 0.7 $\mu\text{m}$	Imaged with film and photodetectors. Includes reflected energy peak of earth at 0.5 $\mu\text{m}$ .
Infrared	0.7 to 1.00 $\mu\text{m}$	Interaction with matter varies with wave length. Atmospheric transmission windows are separated.
Reflected IR band	0.7 to 3.0 $\mu\text{m}$	Reflected solar radiation that contains information about thermal properties of materials. The band from 0.7 to 0.9 $\mu\text{m}$ is detectable with film and is called the photographic IR band.
Thermal IR	3 to 5 $\mu\text{m}$ band	Principal atmospheric windows in the 8 to 14 $\mu\text{m}$ thermal region. Images at these wavelengths are acquired by optical mechanical scanners and special vidicon systems but not by film. Microwave
Radar	0.1 to 30 cm	0.1 to 30 cm longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radio	>30 cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
		Longest wave length portion of electromagnetic spectrum. Some classified radars with very long wavelengths operate in this region.

## ENERGY INTERACTIONS WITH THE ATMOSPHERE

Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of scattering and absorption.



**Energy Interaction with Atmosphere**

## SCATTERING

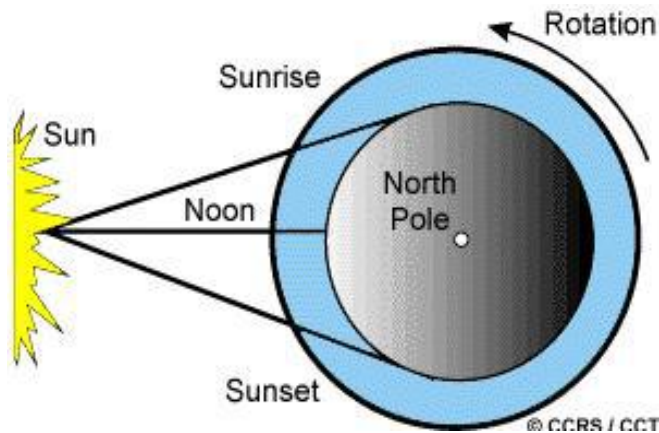
Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place.

## RAYLEIGH SCATTERING

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At **sunrise and sunset** the light has to travel farther through the atmosphere than at midday and the scattering of the



shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.



### Raleigh Scattering

### ABSORPTION

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapor are the three main atmospheric constituents which absorb radiation. **Ozone** serves to absorb the harmful (to most living things) ultraviolet radiation for the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight. **Carbon dioxide** referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming long wave infrared and shortwave microwave radiation (between 22 $\mu$ m and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).

### MIE SCATTERING

Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast. The final scattering mechanism of importance is called **nonselective scattering**. This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).

### ATMOSPHERIC WINDOWS

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 the figure.

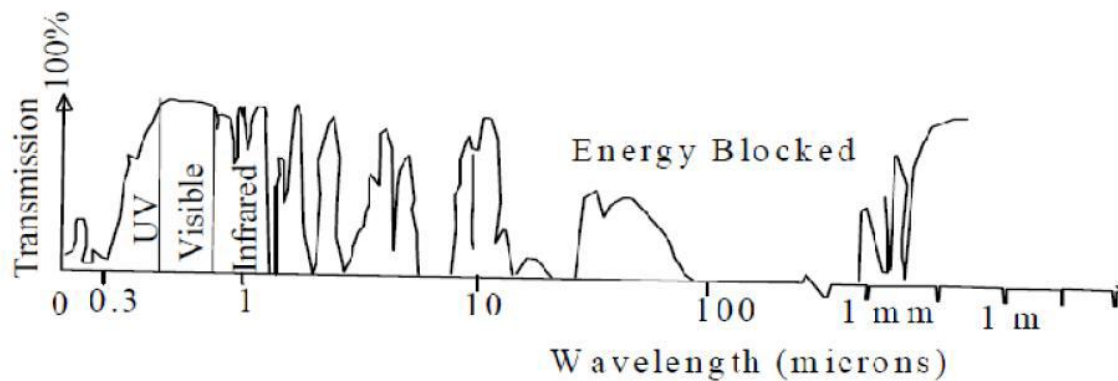


Figure . They are: 0.38-0.72 microns (visible), 0.72-3.00 microns (near infra-red and middle infra-red), and 8.00-14.00 microns (thermal infra-red).

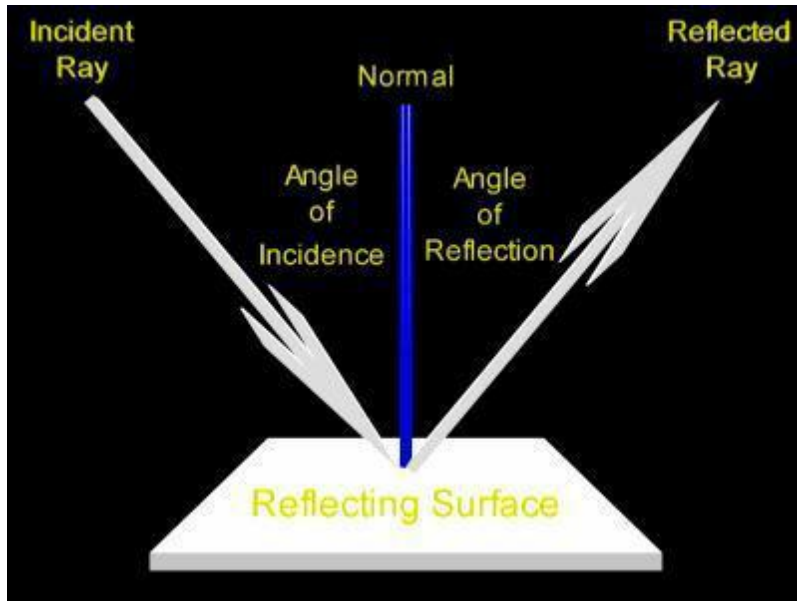
Transmission 100% UV Visible Infrared Energy Blocked 0.3 Wavelength (microns) 1 10 100 1 mm 1 m

## **SPECTRAL SIGNATURE CONCEPTS-TYPICAL SPECTRAL REFLECTANCE CHARACTERISTICS OF WATER, VEGETATION AND SOIL:**

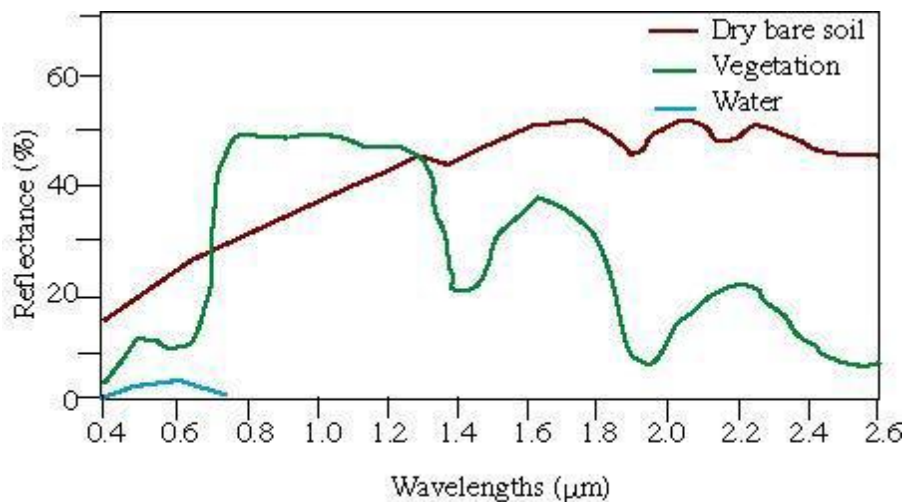
A basic assumption made in remote sensing is that a specific target has an individual and characteristic manner of interacting with incident radiation. The manner of interaction is described by the spectral response of the target. The spectral reflectance curves describe the spectral response of a target in a particular wavelength region of electromagnetic spectrum, which, in turn depends upon certain factors, namely, orientation of the sun (solar azimuth), the height of the Sun in the sky (solar elevation angle), the direction in which the sensor is pointing relative to nadir (the look angle) and nature of the target, that is, state of health of vegetation.

### **Spectral Reflectivity**

- Reflectivity is the fraction of incident radiation reflected by a surface
- The reflectance characteristics of Earth's surface features may be quantified by measuring the portion of incident energy that is reflected
- This is measured as a function of wavelength ( $\lambda$ ) and is called spectral reflectance ( $r\lambda$ ).



### SPECTRAL REFLECTANCE CURVE



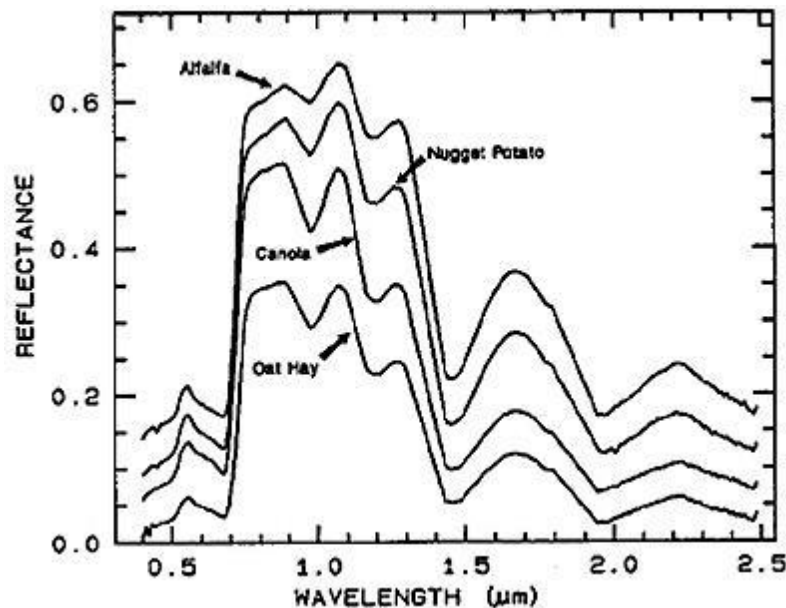
Typical spectral reflectance curves for vegetation, soil, and water.

- Chlorophyll strongly absorbs energy in the wavelength bands centred at about  $0.45\mu\text{m}$ (blue) and  $0.67\mu\text{m}$ (red)
- Our eyes perceive healthy vegetation as green in colour because of the very high reflection of green light

- If a plant is subject to some form of stress, it may decrease chlorophyll production resulting in less chlorophyll absorption in the blue and red bands
- Often the red reflectance increases to the point that we see the plant turn yellow (combination of green and red)

### Spectral reflectance of Vegetation

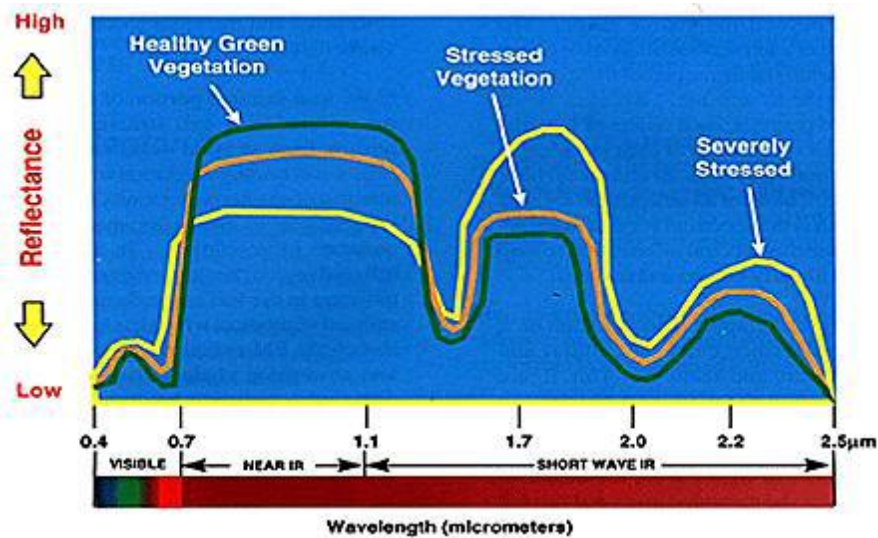
- In the range from about 0.7 to 1.3  $\mu\text{m}$  a plant leaf typically reflects 40 -50% of the energy incident upon it primarily due to the internal structure of plant leaves
- Because the internal structure of leaves are highly variable between plant species, reflectance measurements in this range often permit us to discriminate between species (even if they look the same in visible wavelengths)
- Many plant stresses alter the reflectance in this region, and sensors operating in this range are often used for vegetation stress detection



**Spectral reflectance of Vegetation**

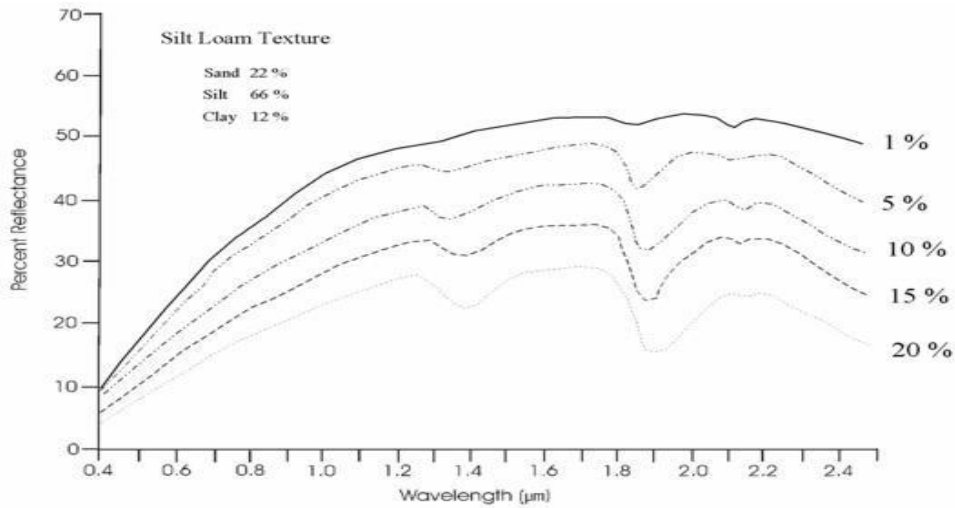
- Beyond 1.3  $\mu\text{m}$  energy incident upon vegetation is essentially absorbed or reflected with little to no transmittance of energy
- Dips in reflectance occur at 1.4, 1.9 and 2.7  $\mu\text{m}$  because water in the leaf absorbs strongly at these wavelengths (*water absorption bands*)
- Reflectance peaks occur at about 1.6  $\mu\text{m}$  and 2.2  $\mu\text{m}$ , between the absorption bands

- Throughout the range beyond 1.3  $\mu\text{m}$ , leaf reflectance is approximately inversely related to the total water present in a leaf which is a function of both the moisture content and the thickness of a leaf



### Spectral reflectance of Soil

- The factors that influence soil reflectance act over less specified spectral bands
- Factors affecting soil reflectance are moisture content, soil texture (proportion of sand, silt and clay), surface roughness, presence of iron oxide and organic matter content
- The presence of moisture in soil will decrease its reflectance -this effect is greatest in the water absorption bands at about 1.4, 1.9, 2.2 and 2.7  $\mu\text{m}$
- Soil moisture content is strongly related to the soil texture.



### Spectral reflectance of Water

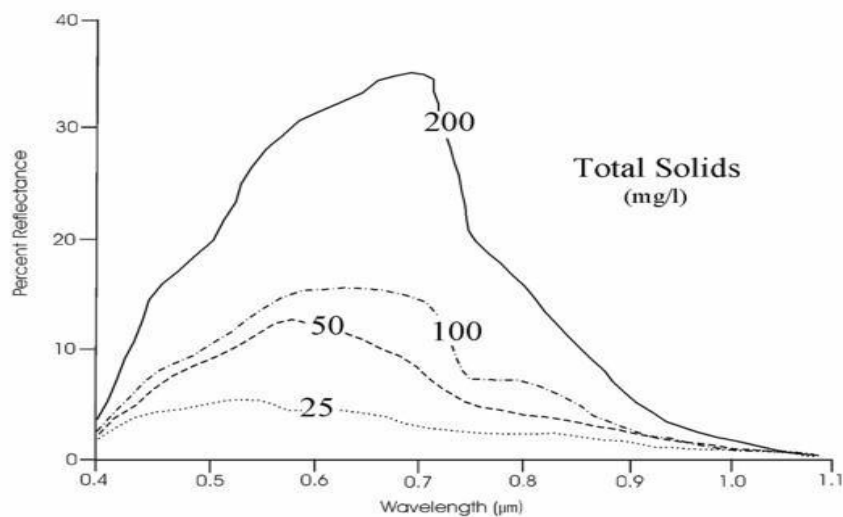
- Water (in soil, vegetation or water bodies) absorbs radiation at near-IR wavelengths and beyond (strong absorption bands at about 1.4, 1.9 and 2.7  $\mu\text{m}$ )

- Reflectance from a water body can stem from an interaction with:

- the water's surface (specular reflection),

- with material suspended in the water, or

- with the bottom of the water body



### **ELEMENTS OF VISUAL INTERPRETATION TECHNIQUES**

- ▶ A systematic study of aerial photographs and satellite imageries usually, involves several characteristics of features shown on an image and it depend upon field of application.
- ▶ Most of the application consider the following basic characteristics or variation in them which aid the visual interpretation process of satellites imagery
- ▶ Although there is a difference of opinion on the number of elements ,there is namely tone, size, shape, texture, pattern, location, association, shadow and resolution

**Tone:-** refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

**Shape:-** refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

**Size:-** of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use



**Pattern:-** refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees, and urban streets with regularly spaced houses are good examples of pattern.

**Texture:-** refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

**Shadow:-** is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

**Association:-** takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

**Site:-**refers to the vocational characteristic of object such as topography, soil, vegetation and cultural features

## **FALSE COLOUR COMPOSITE**

THE display OF colour assignment for any bands of a spectral image can be done entirely in the arbitrary manner in this case the colour of the target in the displayed image does not have any resemblance to its actual colour this resulting product is called FCC. A very common FCCs given for displaying a SPOT multispectral image is

R- near higher band

G- red bands » rivers

B- green bands

This false color composite beam allows vegetations to be detected in the image. In this type of FCC images vegetations appears in different shapes of red depending on the types and conditions

of the vegetations. Clear water appears as dark blue (higher green band reflectance), while turbid water appears cyan it means higher reflectance of red compared to clear water.

Bare soils roads and buildings may appear in various shades of blue yellow depending on their compositions.

## **RESOLUTION**

Resolution is a term used to describe the number of dots or pixels used to display an image. High resolution implies more pixels are used to create the image resulting in a clear image, low resolution will be having fewer pixels to create the image resulting in a less clear image.

### **SPATIAL RESOLUTION:**

- It is a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor. The greater the sensor's resolution, the greater the data volume and smaller the area covered. In fact, the area coverage and resolution are inter-dependent data these factors determine the scale of the imagery.
- Spatial resolution describes how much detail in a photographic image is visible to the human eye. The ability to resolve or separate, small details of the earth surface features.
- Spatial resolution is a complex concept which can, for the purpose of remote sensing of Polar Regions, be defined as the smallest object that can be detected and distinguished from a point.
- The factors affecting spatial resolution; Atmosphere, smoke, low light, blurred sensor system.

### **SPECTRAL RESOLUTION:**

- It refers to the dimension and number of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive. In other words sensitivity of a sensor to respond to a specific spectral wave energy.
- Narrow bandwidths in certain regions of the electromagnetic spectrum allow the discrimination of various features more easily.
- These waves include not only visible light but also non visible waves of electromagnetic radiation energy. Spectral resolution depends on Number of spectral bands, width of each band.
- Based on the number of spectral bands absorbed by sensor there are four types of spectral resolution.
  - Panchromatic-1 band
  - Colour-3 band
  - Multispectral-4+ bands
  - Hyper spectral-hundreds of bands

### **TEMPORAL RESOLUTION:**

It refers to how often a given sensor obtains imagery of a particular area. Ideally, the sensor obtains data repetitively to capture unique discriminating characteristics of the phenomena of interest.

## **RADIOMETRIC RESOLUTION:**

- It is the capability to differentiate the spectral reflectance/ remittance from various targets. This depends on the number of quantization levels within the spectral band. In other words, the number of bits of digital data in the spectral band will decide the Sensitivity of the sensor.
- It is the smallest difference in exposure that can be detected in a given film analysis. It is also the ability of a given sensing system to discriminate between density levels. In general, the radiometric resolution is inversely proportional to contrast, so that higher
- Contrast film is able to resolve smaller differences in exposure. Low contrast films have greater radiometric range while highest contrast films have smaller exposure range and lower radiometric range.

## MODULE 2:

The sensors are a transducer that converts the physical property into an electrical signal. The physical property can be weight, temp, pressure, force, electric, magnetic or electromagnetic

### **Sensors must have following significant characters**

- 1. Range:** Every sensor has a range in which they work with an acceptable error. It has the maximum and minimum value over which the sensor will work if the input is not in range then the output is unpredictable
- 2. Drift:** The signal level varies for the same input over a long period. This is the low frequency changed in the sensor with time. It is often associated with electronic aging of components (or) a reference standard sensor.
- 3. Sensitivity (additional):** It is defined as the ratio of the incremental change in the sensor output to the incremental change in the measured input.
- 4. Selectivity:** It's a system's ability to measure a target in the presence of others interference.
- 5. Resolution:** It's a minimal change of measure and that can produce a detectable (clear images) increment in the output.
- 6. Response and recovery time:** The response time is the time taken by the sensors for its output to reach 95% of its final value.

The recovery time is defined as the time taken by the sensor for its recovery to reach the final value.

**7. Linearity:** If the sensitivity of the sensor is constant for the range then it is called as linearity.

Linear sensors are easier to use while the nonlinear sensors require complex mathematical calculations

**8. Hysteresis:** It's a characteristic of a sensor by which the sensor produces a different set of output that the data is recorded in different directions.

**9. Calibration:** If a meaningful measurement is to be made it is necessary to tune the output of a sensor with accurately known input.

**10. Full scale output:** It's a difference between the output for maximum input and the output for minimum input.

**11. Precision:** precision of a sensor is its ability to produce same output when repeatedly measured of a same input

**12. Accuracy:** It defines how close the output is to the real value. It also defines the maximum error the sensor may produce.

## **Platform**

A platform is a vehicle or carrier for remote sensors for which they borne.

The platform on which a particular sensor is housed determine a number of attributes which makes detect the use of a particular sensor. There are three broad categories of remote sensing platforms.

- Ground based
- Air borne
- Space borne

**Ground based:** A wide variety of ground-based platforms are used in remote sensing. Some of the common ones are hand devices, tripods, towers and cranes.

### **Limitations:**

\*vehicle limited to roads and is confined to smaller areas along and around the road.

**Airborne:** Air borne platforms were sole non-ground-based platforms for early remote sensing. The first aerial images were required with a camera carried along by a balloon

Balloons are rarely used today because they are always not predictable. At present air planes are the most common airborne platforms.

**Space borne:** The most stable platform aloft is a satellite. The first remote sensing satellite was launched in 1960 for methodology purpose (weather forecasting). Then the space shuttle is a unique space craft that functions as a remote sensing satellite

## Fundamental sensor types

There are several broad categories of basic sensor system. Types such as

1. Passive and active sensors

2. Imaging and non-imaging sensors

### **1. passive v/s Active sensors**

- Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding areas.
- Reflected sunlight is the most common source of radiation measured by passive sensors.
- Examples of passive remote sensors include film photography, infrared, charge-coupled devices, and radiometers.

#### **Active sensor**

- Active sensors are the ones which uses the electromagnetic radiations as a source. It is a man made source.
- Active Remote sensors create their own electromagnetic energy that is transmitted from the sensor towards the terrain, interacts with the terrain producing a backscatter of energy and is recorded by the remote sensor's receiver.  
Examples are RADAR and LASER

### **2. Imaging versus Non-imaging (Scanning sensors)**

Data from imaging sensors can be processed to produce an image of an area within which smaller parts of the sensors. whole view are resolved visually.

Non imaging sensors usually are hand held devices that register only a single response value with no fine resolution

Imaging and non imaging data provides an opportunity to look at spatial relationships, objects shapes and to estimates physical size based on the data spatial resolution and sampling.

## Platforms

### **1. Land sat: [earth resource transformation satellite]**

Jointly managed by NASA and US geological society [USGS]. Land sat programme is the longest running interprise for acquisition of satellite imageries of earth on July 23<sup>rd</sup> 1972.

There was eventually renamed to Landsat for ERTS. LANDSAT 8 was the most recent satellite launched on 11<sup>th</sup> Feb 2013.

LANDSAT 9 is in development with the launch date laid 2020.

The instruments aboard LANDSAT satellites had acquired billions of images through the course of the machine.

The data are valuable resource for global change research and application in agriculture, forestry, geology, regional planning and education.

LANDSAT data can be downloaded to all users at no charge.

Common sensors used in LANDSAT are MSS(multispectral scanner), Enhanced Thematic Mapper(ETM), TM (thematic mapper), OLI (operational land Image), Thermal infrared sensor(TIR)

## **SPOT(satellite pour observation terre)**

It was set up in 1978 by France in partnership with Belgium and Sweden. The spot satellite offers acquisition and revisit to acquire image from anywhere in the world. The spot satellite payloads comprise of two identical high-resolution optical imaging instrument which can operate simultaneously on individual in either PAN or MSS.

### **SPOT-1**

It was launched by Air Bus on 30<sup>th</sup> June 2014,

## **IKONOS**

It is a commercial earth observation satellite with high resolution sensor. On September 24<sup>th</sup> 1999 at Vandenberg Air Force Base California, U.S

The first IKONOS was launched and is operated by a company called DigitalGlobe.

Its application includes both urban and rural mapping of natural resources and disaster management, Agriculture, Forestry, mining and construction

IKONOS has a primary aperture of 0.7m and a folded optical focal length of 10m. The detectors act with mass of about 171 kg

## **ENVISAT**

It is a large inactive earth observing satellite which is still in orbit. It is operated by European Space Agency.

ENVISAT was launched on 1<sup>st</sup> march 2002 and ended its transmission in 8<sup>th</sup> april 2012 following the unexpected loss of contact with satellite.

It carries a payload consisting of 10 instruments of advanced design and provides smooth transaction.

ENVISAT performed optical, RADAR and spectroscopic measurements of the land, atmosphere and ice ensuring data from ERS-1(European research satellite) and ERS-11. It weighs about 8211 kgs

## IRS

IRS-1B

IRS-P2

IRS-P4

IRS-1C

IRS-P6

IRS-1A

IRS-1D

## IRS-1A

IRS is the first series in remote sensing. Launched on 17<sup>th</sup> march 1988.

## IRS 1B

Launched on 29<sup>th</sup> aug 1991

Payloads LISS\_1,LISS 2b

## IRS-P2

Launched on 15<sup>th</sup> October 1994

Payloads are LISS 2A and LISS 2B

IRS-P4

Launch 26.05.1999, payloads OCM, MSMR

IRS\_P6

Launch 17<sup>th</sup> oct 2003, PSLV-C5

IRS-1C and 1D



On both tape recorders with capacity of 6240 enhanced, payloads like better special resolution with additional spectral bands.

## CARTOSAT

Its an Indian based satellite which started its machine in 2006. The most resent platform CARTOSAT-2 is launched on 23<sup>rd</sup> June 2017 with 30 co satellite at **sathis dhawan** space centre at **sri harikota**.

It orbits 14 times per day and carries two pan sensors

Applications: urban management, mineral exploration, disaster management etc

## **Basics of Digital image Processing**

- A digital image is a representation of two-dimensional image of finite set of digital values (or) pixels.
- Pixel value typically represent grey levels, colours, heights and opacity.
- Digitization implies that a digital image is an approximation of a real scene
- Digital image processing focuses on two major tasks.
  1. improvement of pictorial Information for human interpretation.

2. Processing of image data for storage transmission, and representation for autonomous machine perception.

## **The use of digital image processing techniques**

It has exploded and they are used for all kinds of tasks

Image enhancement

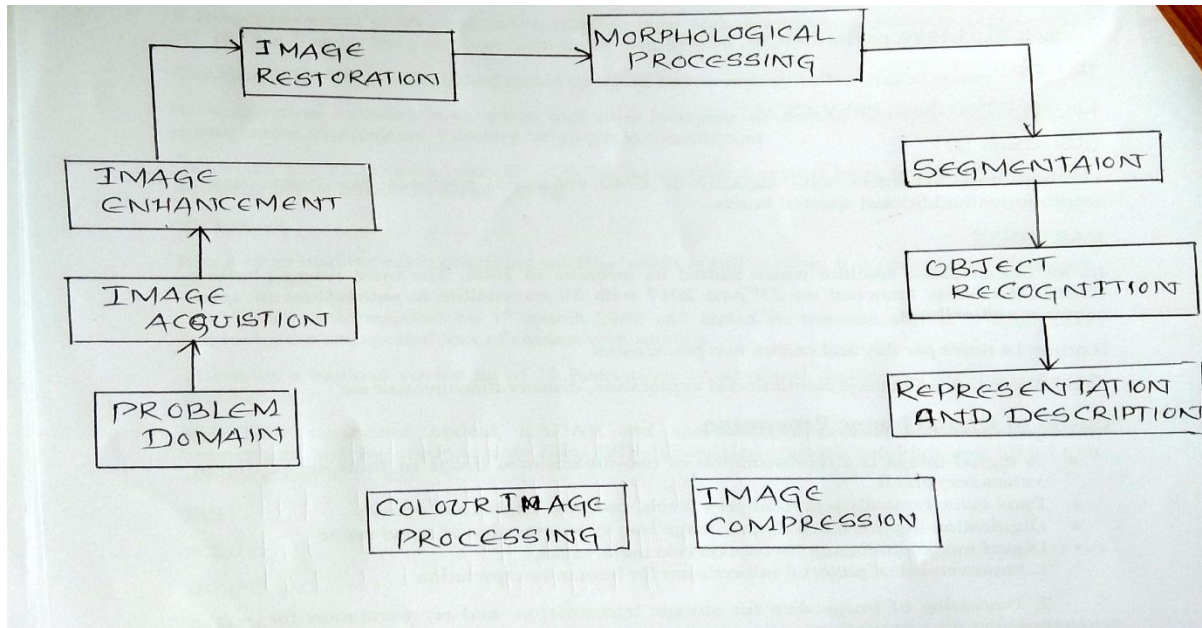
Medical visualization

Law enforcement

Industrial inspection

Human computer interface

## **Stages or process of DIP ( Digital image processing)**



## Digital data

Images with a continuous grey tone like a photograph are called analog images.

A group of divided small cells with integer values of average intensity, the centre representing the cell value is digital image.

Remote sensing data are the data digitised by a process of sampling and quantisation with electromagnetic energy which is detected by the sensors.

The data that is acquired by the sensor has errors, the correction in the images are classified into radiometric corrections and geometric corrections

**Radiometric corrections:** These are removal of sensors or atmospheric noise, more accurately represent ground conditions

**Geometric corrections:** conversion of data to ground coordinates by removal of distortion from sensor geometry. It enables mapping relative to data layers. It also enables mosaicing (merging two images each other) or comparison.

There are methods of geometric corrections which includes systematic errors and non-systematic errors.

## Systematic errors

When the geometric reference data or geometric sensor are given or measured geometric distortion can be theoretically or systematically avoided.

The source of systematic errors in RS are explained

**Scan skew:** caused when ground swath is not normal and is skew due to forward motion of the platform during the time of scan

**Platform velocity:** caused due to change in speed of the platform in along track scale distortion

**Earth rotation:** caused due to the rotation of earth during scan period resulting in along scan distortion.

**Mirror scan velocity:** caused when the ray of scanning is not constant resulting along scan geometric distortion.

**Panchromatic distortion:** caused when the intensity of the source is greater or lesser resulting in along scan image distortion.

## **Non-systematic error:**

Polynomials to transform from a geographic co-ordinate system to image system or vice versa will be determined by ground controlled points

Non-systematic errors are classified as below:

Attitude and altitude

**Attitude:** Errors due to attitude variation can be attributed to roll, pitch and yaw (shapes) of the satellite. Some of these errors can be corrected having knowledge about platform, ground-controlled points, sensors characters, space craft velocity.

**Altitude:** caused due to the departure of sensors, altitude resulting in change of scale.

## **Data formats:**

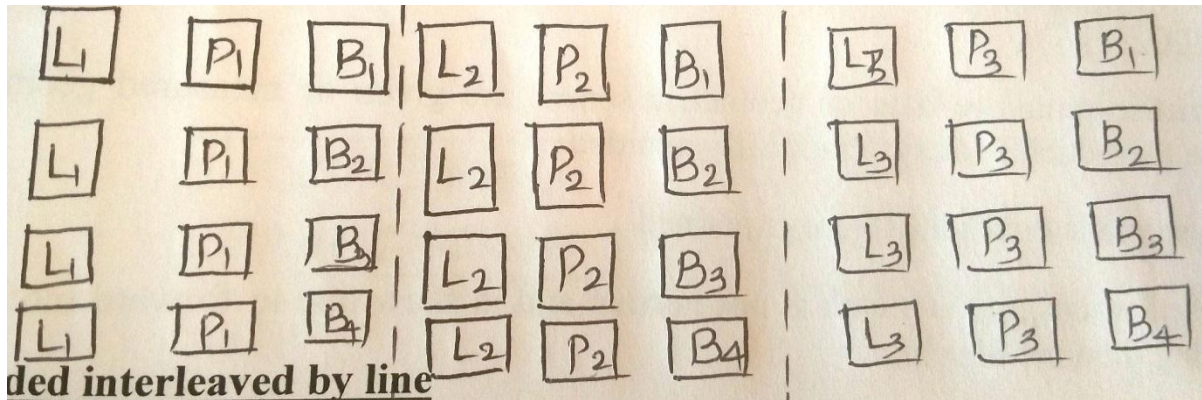
In order to properly process the remote sensing data the analyst must know how the data is organised, stored on the digital tapes (storage devices) and how data is processed to computer softwares.

There are 4 major data formats

1. Banded interleaved by pixel (BIP)
2. Banded interleaved by line (BIL)
3. Banded sequential format (BSQ)
4. Banded length and encoding format (BLE)

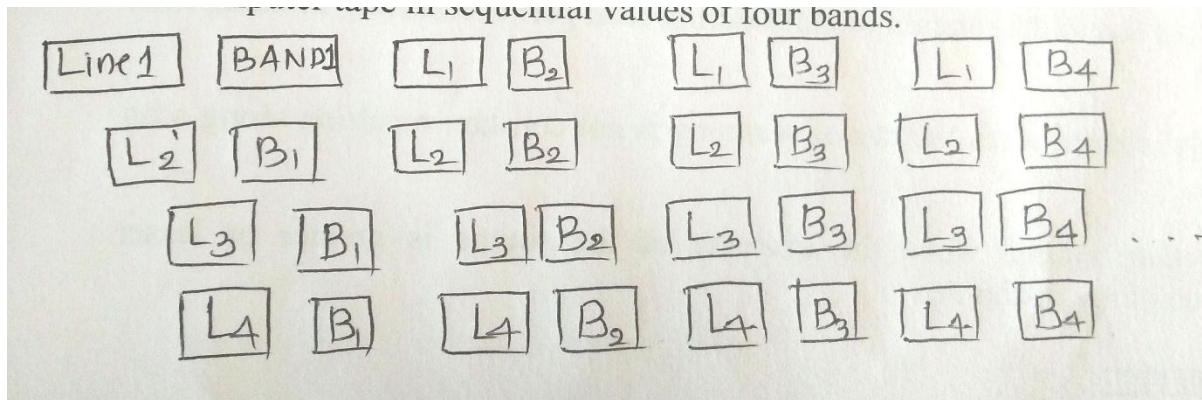
### **1 Banded interleaved by pixel**

One of the earliest data format used for the satellite data. This format treats pixel as the separate value. Brightness value of each pixel is sorted after the other.



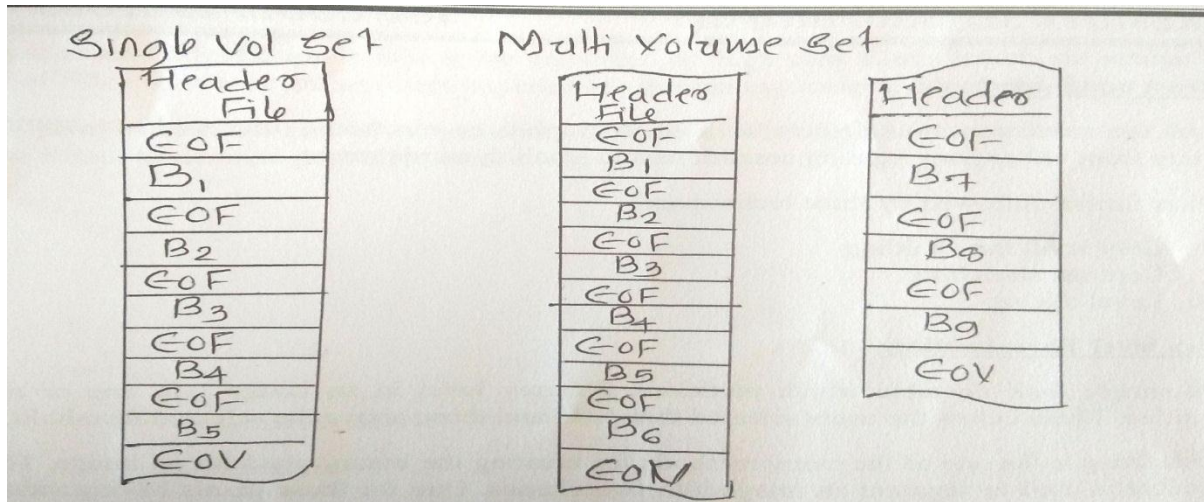
**2. Banded interleaved by line**

Just as banded interleaved by pixel format each pixel of data has a separate unit. The banded interleaved by line format is sorted by lines. Shows the logic of how the data is recorded in the computer tape in sequential values of four bands.



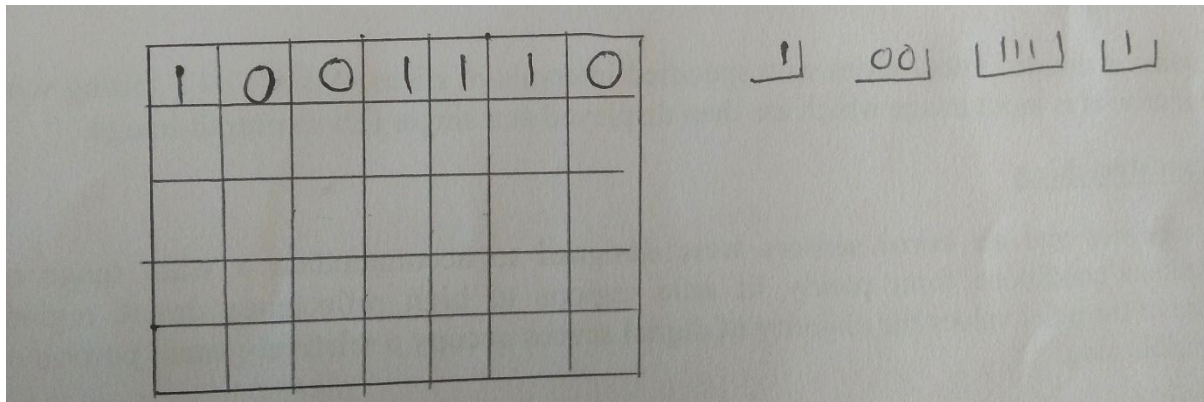
**3 Banded sequential format (BSQ)**

The banded sequential format requires that all data from single band covering the entire scene will be written as one file. Thus, if the analyst wanted to extract the area in the centre of the scene in four bands it would be necessary to read it into this location in four separate folders and to extract the desired information, many researchers like this format because it is not necessary to be serially posted unwanted information or run length



#### 4 BAND LENGTH AND ENCODING FORMAT

Its based on sequential format which keep tracking both the brightness value and number of times brightness value occur along the scale line. However, the data is exceptionally Heterogenous with very few similar brightness values, this format is no better than others.



#### Image enhancement

It is a technique that has been widely used in many applications of image processing where the subjective quality of image is an important tractor in calculating an image.

The goal of image enhancement is to improve the usefulness of an image for the assigned task.

The reasons for doing this includes

1. Highlighting, intersecting details in images.
2. Removing noises from images

3. Making images more visually appealing.
4. The techniques can be categorized as contrast manipulation, special manipulation and multi image manipulation

## **Contrast manipulation**

One of the most common defects of a photographic or electronic image. Poor contrast resulting from either poor lighting conditions and small dynamic range.

This is further followed by three techniques

1. Grey level thresholding
2. Contrast stretching
3. Level slicing

### **1 Grey level Thresholding:**

It's a simple look up table which partitions the grey level in an image into one or two categories. Those below the users selected threshold and those above the selected threshold.

Thresholding is the one of the many methods for creating the binary mass for an image. This procedure is used to segment an image into two classes. One for those pixels having values below an analyst and one for above those values.

### **Level slicing**

It is an enhancement technique where by the digital numbers (DN) distributed along the x-axis of an image.

Histograms is divided into a series with specified intervals of slices. All of DN's falling with a given interval is input image which are then displayed at a single DN in output image.

### **Contrast stretching**

Most satellites and air borne sensors were designed to accommodate a wide range of illumination conditions form poorly lit artic regions to high reflectance desert region. Because of the pixel values the majority of digital scenes occupy a relatively small portion of the possible range.

If the pixel values are displayed in their original form only a small range of gre

y values are displayed and will be used, resulting in low contrast display on which similar features might be undistinguishable.

### **Image filtering:**

It is a technique for modifying or enhancing an image.

E.g.: you can filter an image to emphasize certain features or remove other features. image processing operations is implemented with filtering includes smoothing, sharpening and edge enhancement Filtering is neighbourhood operation in which the values of any given pixel in the

output image is determined by applying some algorithm to the values of the pixels, in the neighbourhood.

**High pass filters:** it enhances difference between values of neighbouring pixels, these changes in values are represented by edges and lines.

**Edge:** the border between two types of surfaces (forest and field)

**Lines:** rivers, streets, roads which are enhanced by high pass filters which are similar than half of filter windows. these filters are used for sharpening images, edges and lines.

**Low pass filters:** the rate of smoothing depends on the size of filters window, we can use these filters to denoise post class correction.

## MODULE 3 AND 4

What is GIS? DESCRIBE THE DIFFERENT COMPONENTS OF GIS

GIS is computer system designed to capture Store, Manipulate, Analysis, Manage and display spatial or geospatial data

### COMPONENTS OF GIS

A GIS divided into five components,

1. HARDWARE
2. SOFTWARE
3. DATA
4. PEOPLE
5. METHODS OR PROCEDURE all these components need to be in balance for the system to be successful. no one part can run without the other

### PEOPLE

The people are the component who actually makes the GIS work. They are responsible for maintenance of the geographic database and provide technical support. People associated with GIS can be categorized into viewers, general users and GIS specialists

General users are people who use GIS to conducting business, performing professional, services and making decisions. They include facility managers, resource managers, planners, scientist, engineers, lawyers, business, entrepreneurs etc.

GIS specialists are the people who make the GIS work. They include GIS managers, Database administrators, and application specialists. System analysts and programmers.

### METHODS OR PROCEDURE

They include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed and finally presented in a final output. The procedure are the steps taken to answered the question need to be resolved

### HARDWARE

**Hardware:** It consists of the equipments and support devices that are required to capture, store process and visualize the geographic information. These include computer with hard disk, digitizers, scanners, printers and plottersetc.

### SOFTWARE:

Software is at the heart of a GIS system. The GIS software must have the basic capabilities of data input, storage, transformations, analysis and providing desired outputs. The interfaces could



be different for different software's. The GIS software being used today belong to either of the category –proprietary or open source. ArcGIS by ESRI is the widely used proprietary GIS software. Others in the same category are MapInfo, Micro station, Geomedia etc. The development of open source GIS has provided us with freely available desktop GIS such as Quantum, uDIG, GRASS, Map Window GIS etc., GIS software's.

## **DATA:**

The data is captured or collected from various sources (such as maps, field observations, photography, satellite imagery etc) and is processed for analysis and presentation.

Write brief note on objectives of GIS

Some of the major objectives of GIS are to

- Maximizing the efficiency of planning and decision making
- Integrating information from multiple sources
- Facilitating complex querying and analysis
- Eliminating redundant data and minimizing duplication
- Capacity to integrate information from many source

## **EXPLAIN THE ORIGIN AND MEANING OF GEOGRAPHIC INFORMATION SCIENCE**

GIS can answerer

Location information- means what exists at a point or particular location

Condition –identify location where certain condition exist

Trends- what has changed since?

Patterns -what spatial patterns exist?

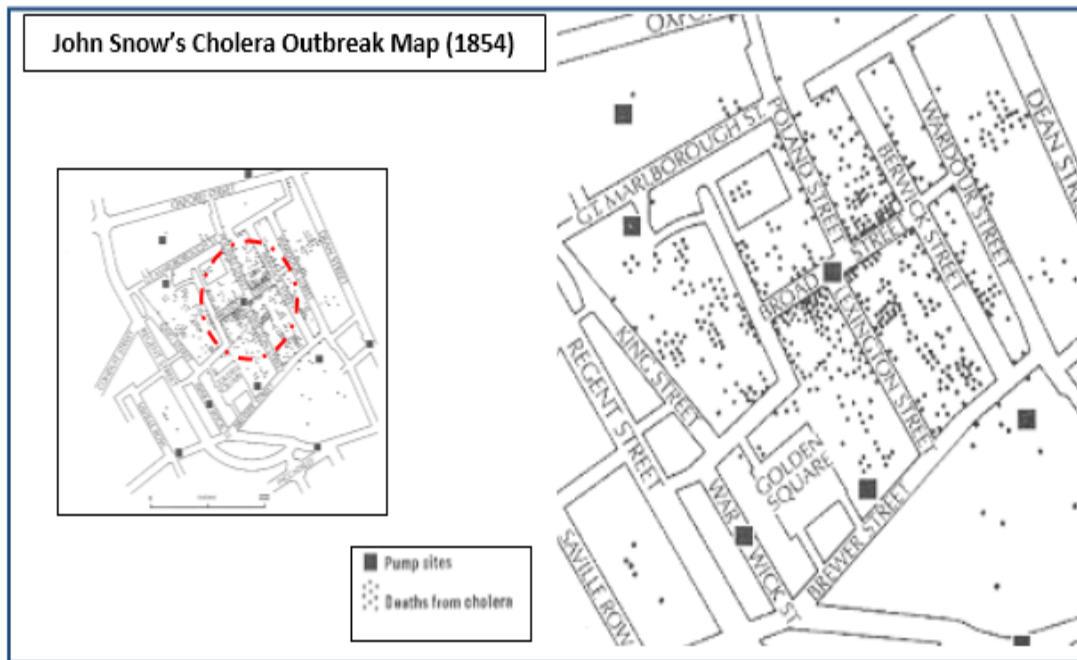
Modeling- what if

Mapmaking (representation of geographical information) has evidences to show independent evolution of maps in different parts of the earth. The direct evidence of mapping comes from Middle East in the form of Babylonian Clay Tablets as early as 1000 B.C which depicted earth as a flat circular disk.

Around 200 B.C, Eratosthenes calculated the circumference of earth accurately. Later came, Ptolemy and Al-Idrisi who made remarkable contributions in the field of cartography. Following them were Mercator and Newton, their work paved way for the upcoming cartographers and geographers to better understand the earth and the geographical phenomenon.

Putting layers of data on series of base maps to analyze things geographically has been into existence much longer than the introduction of computers to the geographical world.

The French cartographer Louis-Alexandre Berthier had drawn the maps of the Battle of Yorktown (1781) that contained hinged overlays to show troop movements.



### Early Developments in GIS

#### **Canada Geographic Information System (CGIS)**

- The earliest GIS, set up in mid 1960s by Roger Tomlinson and colleagues for Canadian Land Inventory.

It was developed as a measuring tool (to measure area), a producer of tabular information rather than a mapping tool.

#### **Harvard Laboratory**

- The Harvard laboratory for Computer Graphics and Spatial Analysis was established in 1964 by Howard Fisher at Harvard University.

The GIS packages developed were SYMAP, CALFORM, SYMVU, GRID, POLYVRT, ODYSSEY

## **Dual Independent Map Encoding (DIME)**

- Developed by US Bureau of Census in 1967 to conduct the 1970 census of population.

Digital records of all US streets were created to support automatic referencing and aggregation of census records.

## **Environmental Systems Research Institute (ESRI)**

- Jack Dangermond founded ESRI in 1969 to undertake GIS projects.

In 1981, ESRI launched ArcInfo (major commercial GIS software system) based on vector & relational database data model.

Longley et al (2001) have described the period from 1980 to 2000 as the era of commercialization in the field of GIS. The period marks the establishment of commercial GIS industries, research centers, GPS, OpenGIS Consortium, Internet GIS products along with publications on GIS and allied fields. The period after 2000 is referred to as the era of exploitation. In 2000, it was estimated that GIS was being used by one million core users and five million casual users.

## **Importance of GIS**

GIS informs not only about the activities and the events but also where they exist. The solutions to problems often require access to several types of information that can only be linked by geography. GIS allows to store and manipulate information using geography and to analyze patterns, relationships, and trends in that information to help in making better decisions.

## **Application of GIS**

GIS is involved in various areas. These include topographical mapping, socioeconomic and environment modeling, and education. The role of GIS is best illustrated with respect to some of the representative application areas that are mentioned below:

**Tax Mapping:** Raising revenue from property taxes is one of the important functions of the government agencies. The amount of tax payable depends on the value of the land and the property. The correct assessment of value of land and property determines the equitable distribution of the community tax. A tax assessor has to evaluate new properties and respond to the existing property valuation. To evaluate taxes the assessor uses details on current market rents, sale, maintenance, insurance and other expenses. Managing as well as analyzing all this information simultaneously is time consuming and hence comes the need of GIS. Information about property with its geographical location and boundary is managed by GIS. Land units stored in parcel database can be linked to their properties. Querying the GIS database can locate similar type of properties in an area. The characteristics of these properties can then be compared and valuation can be easily done

**Business:** Approximately 80 percent of all business data are related to location. Businesses manage a world of information about sales, customers, inventory, demographic profiles etc. Demographic analysis is the basis for many other business functions: customer service, site analysis, and marketing. Understanding your customers and their socioeconomic and purchasing behavior is essential for making good business decisions. A GIS with relevant data such as number of consumers, brands and sites they go for shopping can give any business unit a fair idea whether their unit if set up is going to work at a particular location the way they want it to run.

**Environment:** GIS is being increasingly involved in mapping the habitat loss, urban sprawl, land-use change etc. Mapping such phenomena need historical landuse data, anthropogenic effects which greatly affect these phenomena are also brought into GIS domain. GIS models are then run to make predictions for the future.

**Logistics:** Logistics is a field that takes care of transporting goods from one place to another and finally delivering them to their destinations. It is necessary for the shipping companies to know where their warehouses should be located, which routes should the transport follow that ensures minimum time and expenditures to deliver the parcels to their destinations. All such logistics decisions need GIS support.

## **EXPLAIN THE DIFFERENT STEPS INVOLVED IN GIS**

SPATIAL DATA INPUT

ATTRIBUTE DATA MANAGEMENT

DATA DISPLAY

DATA EXPLANATION

DATA ANALYSIS

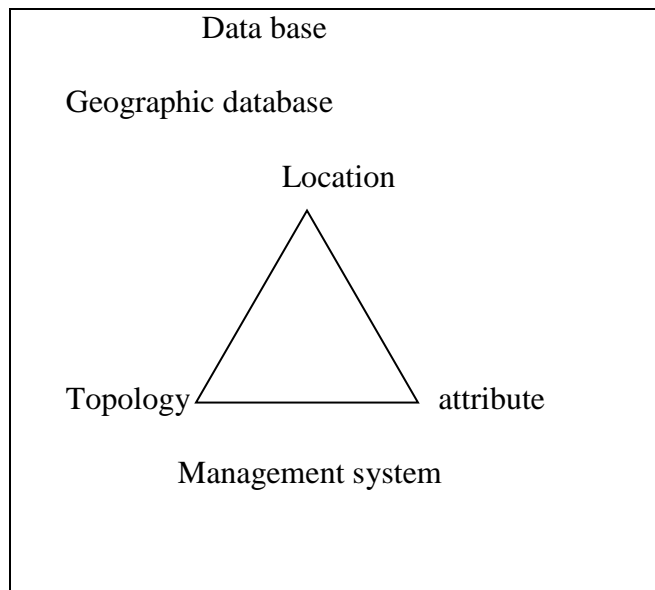
GIS MODELLING

1. Analysis and modeling in a GIS requires input of relevant data. The data consist of two types: spatial data representing geographic features (points, lines and areas) and attribute data (descriptive information). Data input should be done with utmost care, as the results of analyses heavily depend on the quality of the input data. In ILWIS data can be entered by: –
2. Digitizing, if you want to use data from analog (paper) maps; –
3. Keyboard entry, for entering tabular data; –
4. Scanning, if you want to use paper prints of satellite images, aerial photographs, maps
5. pictures; – Importing existing data files from other sources.

Maps aerial sensors field photographs observation

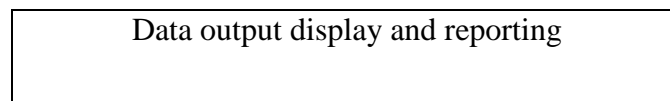
Computer digitations stereo scanners magnetic key board and plotter

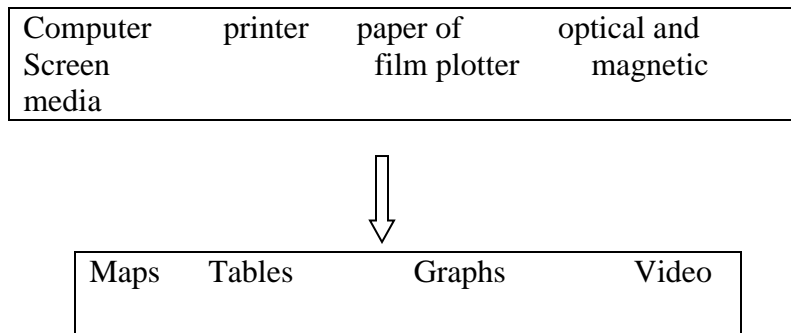
Data input



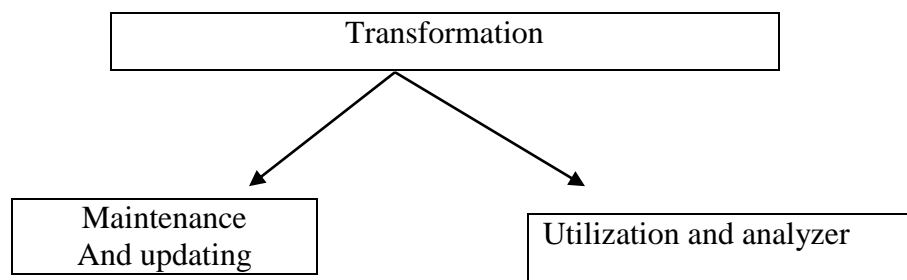
Data storage and data base management sorcess the way in which data about the location, linkages and attributes of geographical elements ( points, lines, atreas and more complex entities representing objects on the earth surface) are structured and organized, both with respect to the way they must be handled in the computer and how they are perceived by the uses of the system. The computer program used to organize the database is known as a database management system (DBMS)

**DATA OUTPUT AND PRESENTATION:-** concern the ways the data are displayed and how the results of analyzer are reported to the user. Data may be presented as maps, table in a variety of ways ranging from the ephemeral images on the computer screen through the hard copy, output drawn on the printer or plotter to information recorded on magnetic media in digital form





DATA transformation embraces two classes of operation, namely transformation added to remove error from the data as bring them up to data or to match them to other data sets and the large assay of analysis methods that may be applied to the data in order to achieve answer to the function asked of the GIS. Transformation can operate on the spatial, topological and the non spatial aspects of the data, either separately or in combination

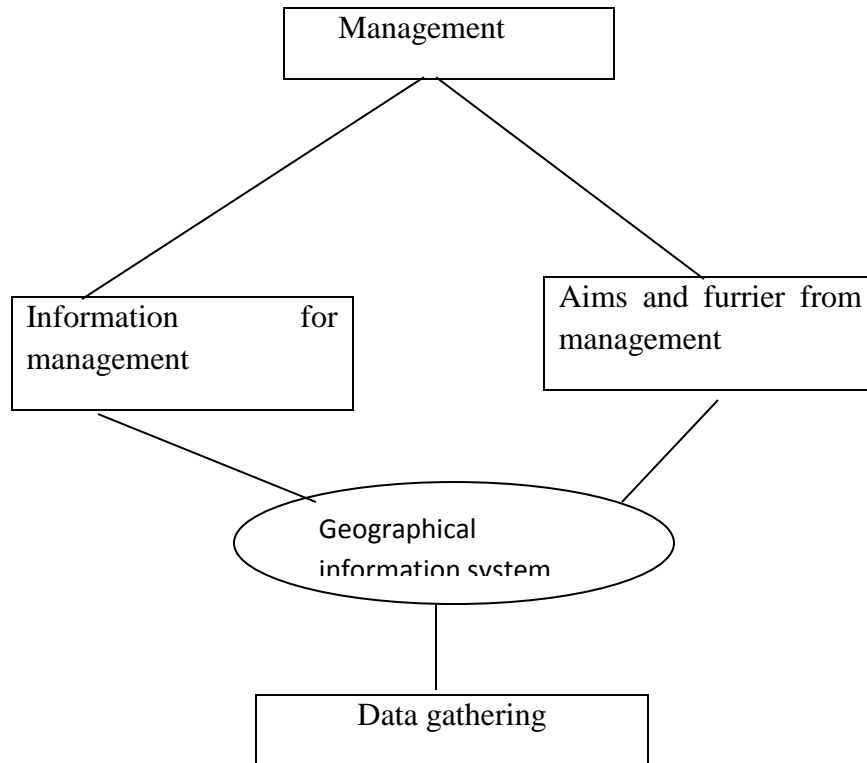


The interaction between user and GIS for data and query input and the writing of models for the data analysis in an aspect that has been neglected until recently. The introduction of the personal computer, the mouse or pointing device and multi windowing has made it much easier for many people to use completes through typing skills are still essential for most tasks.

#### Organizational context

Organizational aspect or context nothing but the way the information flows and the way in which the analysis is done. The organizational context involve three sub components

- a. data data isnothing but information bring used for the analysis
- b. b. people the people involved in the analysis and the creation of the information system.  
If also involve the uses
- c. methods the methods is nothing but the steps, procedure which are used for the analysis and in the making of the information system



### **Explain in detail on the different types of data utilize in GIS technology**

#### DATA TYPE

##### Spatial data

Also known as geospatial data or geographic information it is the data or information that identify of geographic location information system like feature and boundaries on earth such as natural or constructed featute oceans and more, spatial data is usually stored as co ordinate and topology and is data that can be mapped spatial data often accessed manipulated or analyzed through GIS

**DEFINITION 1** The conversion or abstraction of the earth and its properties to adatabase that define location and properties of individual features of interest

**DEFINITION 2.** Duplicating the real world in the computer by collecting information about things and where these things are located

Spatial data is : an inventory os assets land cover. Land use and other natural resources can be considered assets

Or

Non spatial data/a spatial/attribute data

In a GIS like any other information system all the usual data type's ie Boolean nominal ordinal integer real and also topological data can be considered

Usual data type (a spatial data )	Allowed values	Allowed operations
Boolean	0 to 1	Logical and indicator operation truth vs false hood
Nominal	Any name	Logival operation classification and identification
Ordinal	Numbers of 0 to $\infty$	Logical and ranking operation comparison of magnitude
Integers	Whole numbers $-\infty$ to $+\infty$	Logical operation integer, attribute
Real	Real numbers	All logical and numerical operation
GIS Specific data type topological	Whole numbers	Indicates links between entities

Spatial data and non spatial data

Spatial data

Spatial data of geo reference data is commonly characterized by the presence of two fundamental components

1. the physical dimension or class i.e the phenomena being reported

for example height of the forest canopy, demographic class, rock type , vegetation type details of a city etc,

2. the spatial location of the phenomena

for example specified with reference to common co ordinate system



### Non spatial/attribute/a spatial or tabular data

These are usually data tables that contain information about the spatial components of the GIS theme. These can be numeric and or character data such as timber type, timber volume, road size, well depth etc. The attributes are related back to the spatial feature by use of residual identifiers that are stored both with the attribute table and the feature qualitative (low, medium, high income) or quantitative the database allows use to manipulate information in many ways from simple listing of attributes, sorting feature by some attribute grouping by attribute and singling out groups by attribute

Non spatial data is divided into

Vector data and raster data

Vector data: - a vector data based GIS is defined by the vectorial representation of the geographic data. The most common representation of map is using vector data that consists of **Point, line and polygon**

Vector data

**Point data:-** layer described by point( or event) described by X,Y (LAT, LONG; EAST,NORTH )

**Line / polyline data:-** Layer described by x,y points ( line segments and polylines )

**Polygon data** – layers of closed line segments enclosing area that are described by attribute

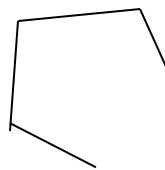
PONTS



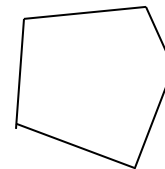
LINE



POLY LINE

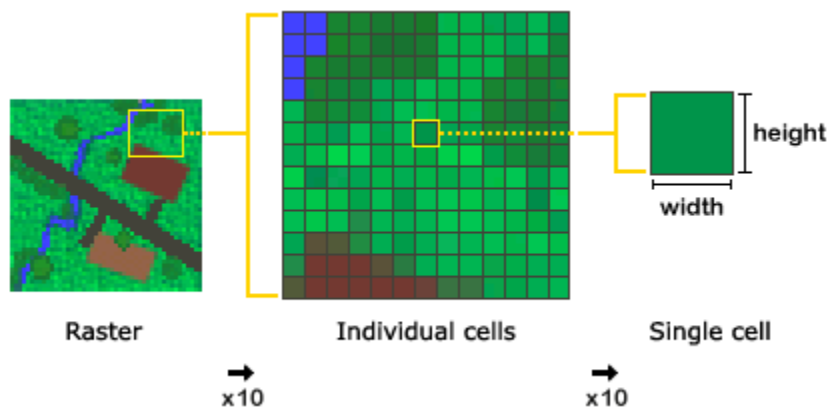


POLYGON



Polygon data can be multipart like the islands of the state Hawaii

b. Raster data consists of a matrix of cells organized into rows and columns where each cell contains a value representing information. Each as temp, raster's are digital aerial photographer, imagery from satellites, digital pictures or even scanned images



## Raster VS Vector

Geographic Information Systems (GIS) Data Models:  
Raster vs. Vector Models

*Raster Data Model*

A	1	1	1	2	2
B	1	1	1	2	2
C	1	1	3	2	2
D	3	3	3	3	3
E	3	3	3	3	3
	A	B	C	D	E

Raster models...

- represent continuous variation well
- represent discrete objects poorly
- have simple data structures
- require large file sizes

*Vector Data Model*

Graphical Coverage

ID	Variable 1
A	1
B	2
C	3

Relational Database

Vector models...

- represent continuous variation poorly
- represent discrete objects well
- have more complex data structures
- typically require smaller files sizes than raster models

10

Explain conceptual module of spatial information

1. Entities
2. Continuous fields
- 3.

Explain geometric modeling and temporal modeling

4. Geometric modeling

5. Temporal modeling

## MODULE-5

**HYPERSPECTRAL REMOTE SENSING**

Hyperspectral remote sensing, also known as imaging spectroscopy is a relatively new technique used by researchers and scientists to detect terrestrial vegetation, minerals and land use/land cover mapping. Though this data has been available since 1983 onwards, their widespread use is initiated primarily due to a number of complicated factors serving applications in various fields of engineering and science. Spectroscopy has been used by scientists, especially physicists for many years for identifying material composition. Many techniques employed for analyzing reflectance spectra have been developed in the field of analytical chemistry. It detects individual absorption features based on the chemical bonds in solids/liquids/gases. Technological advancements have enabled imaging spectroscopy to be extended beyond laboratory settings to satellites so that its applications can be focused over a global extent. In some books, hyperspectral has been used synonymously with the work imaging spectrometer.

Within the electromagnetic spectrum, it is well known that not all spectral bands are available for remote sensing purposes. Atmospheric windows or regions in which remote sensing is possible tend to separate the absorption bands. Hyperspectral images are measurements acquired within these atmospheric windows. The technique of hyperspectral remote sensing combines imaging and spectroscopy within a single system thereby resulting in large data sets that require sophisticated processing methods. Generally, hyperspectral data sets will be composed of about 100 to 200 spectral bands possessing relatively narrow bandwidths unlike the multispectral data sets which possess just 5-10 bands of relatively larger bandwidths. Some examples of hyperspectral sensors are Hymap or Hyperspectral Mapper used for airborne imaging and Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS) first deployed by NASA in early 1980s.

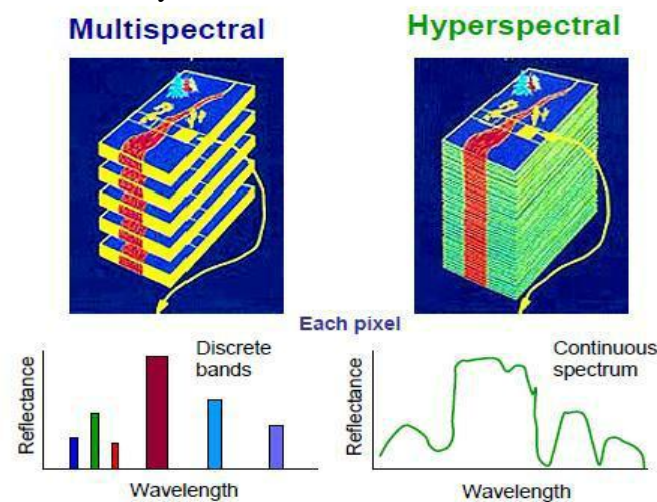


Figure 1: Multispectral Vs Hyperspectral Remote Sensing

represented in the Z direction. This allows us to look at hyperspectral images in two ways; one focusing on the spatial patterns in x-y plane and second is to analyse the properties of a specific location/pixel point along the Z direction.

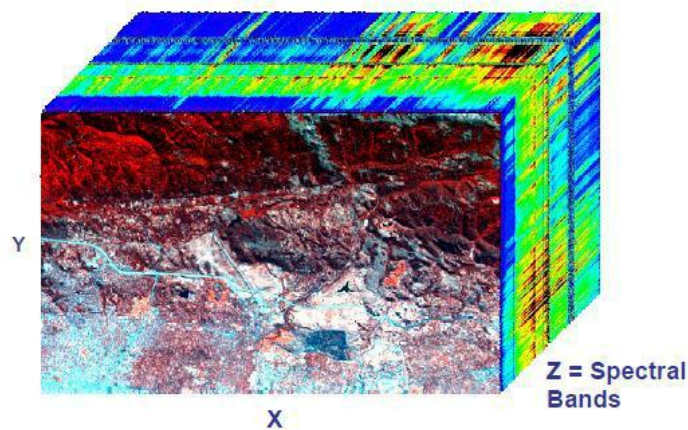


Figure 2: Visualization of a hyperspectral data cube

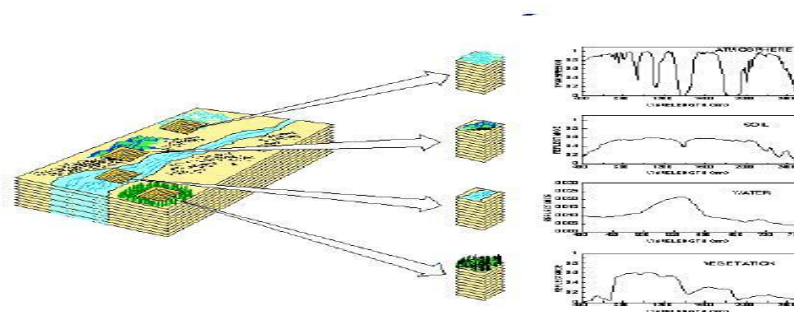


Figure 3: Concept of an Imaging Spectrometer

## 2. Hyperspectral sensor systems

One of the major issues with hyperspectral analysis is the lack of high quality data sets for most areas of interest. This situation is changing rapidly with the availability of hyperspectral aircraft sensors flown for both government and commercial purposes. Some of the initial studies involving hyperspectral sensing was conducted with data acquired using the Airborne Imaging Spectrometer (AIS) which collected data using 128 bands which were approximately 9.3 nm wide. The system which operated from an altitude of 4200 m above terrain resulted in a total of 32 narrow swath pixels with a resolution of approximately 8 x 8 m. Color composites can be generated using hyperspectral images by displaying three bands at a time, with one band displayed as blue, one as green and one as red. Commonly, the images of all bands will be displayed in isometric view wherein data is thought of as a cube. The top and side of the cube will represent color coded reflectance values corresponding to the 224 spectral bands.

The very first commercially made available hyperspectral scanner was the Compact Airborne Spectrographic Imager (CASI) which collected data using 288 bands between 0.4 and 0.9

$\mu\text{m}$  with an instantaneous field of view of 1.2 mrad. This system was used in combination with global positioning system (GPS) so as to correct for aircraft altitude variations. The Advance Airborne Hyperspectral Imaging Spectrometer (AAHIS) is another commercially produced hyperspectral scanner which captures information in around 288 channels within 0.40 to 0.90  $\mu\text{m}$  ranges. Another such instrument is the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) that collects data using 224 bands which are approximately 9.6 nm wide between bands 0.40 and 2.45  $\mu\text{m}$ . This resulted in a ground pixel resolution of approximately 20 m. As a follow up of AVIRIS, the Hyperspectral Digital Image Collection Experiment (HYDICE) was developed with the sole intention to advance hyperspectral scanner system with a higher spatial resolution. The TRW Imaging Spectrometer was developed for use in both aircraft and spacecraft which uses around 384 channels operating in the wavelength range between 0.40 to 2.45  $\mu\text{m}$  range. The HyMap (Hyperspectral Mapping) system, the first commercially available sensor to provide high spatial and spectral resolution data is built by Integrated Spectronics and is capable of sensing upto 200 bands. Its availability has tapped the potential of commercial use of airborne imaging spectrometry. It is possible for the airborne hyperspectral data to generate spectral reflectance curves for minerals that are similar to those generated within laboratory settings.

With the successful use of hyperspectral imagery from AVIRIS and HyMap, global availability of high quality hyperspectral data has been given priority to cater to the needs of various applications in engineering and sciences division. As a direct consequence, several satellite systems are under development like Orbview-4, ARIES-1 etc. Orbview-4 is capable of imaging earth at a spatial resolution of one meter panchromatic and four meter multispectral which includes an imaging instrument comprising of 280 channels. ARIES-1 is an Australian Resource Information and Environment Satellite, flying in low earth orbit and carrying a hyperspectral sensor using reflected visible and infrared light. It has 32 contiguous bands providing commercial use to the international remote sensing market place.

### **3. Hyperspectral Image Analysis**

Even though hyperspectral sensors enable to identify and discriminated between different earth surface features, these suffer from disadvantages. Some of these are an increased volume of data to be processed, poor signal to noise ratios and atmospheric interference. Hence, analysis of hyperspectral images relies on physical and biophysical models than on

other statistical techniques. Atmospheric gases and aerosols tend to absorb light at particular wavelengths. Atmospheric attenuation exists in the form of scattering (addition of extraneous source of radiance into the sensor's field of view) and absorption (negation of radiance). As a consequence, the radiance registered by a hyperspectral sensor cannot be compared to imagery procured at other times/locations.

Hyperspectral image analysis techniques are derived using the field of spectroscopy which relates the molecular composition of a particular material with respect to the corresponding absorption and reflection pattern of light at individual wavelengths. These images need to be subjected to suitable atmospheric correction techniques so that the reflectance signature of each pixel is compared with the spectra of known materials. The spectral information of known materials like minerals, soils, vegetation types etc will usually be collected in laboratory settings and stored as "libraries". Different means are employed to compare the reference spectra with the obtained spectral reflectance. Previously, individual absorption features were identified in the image by selecting one spectral band occurring in the low point and two bands located on either side of the absorption feature. This method will be subjected to noise in the image data. Also, it will be difficult to deal with overlapping absorption features. With an increase in the computational facilities, this approach has advanced to comparison of entire spectral signatures rather than individual absorption features within a signature. Another method is spectrum ratioing which is, dividing every reflectance value in the reference spectrum by the respective value of the image spectrum. The disadvantage of this method is that it fails when the average brightness of the image spectrum is higher/lower than the average brightness of the reference spectrum as is observed over a topographically shaded slope. Another technique commonly adopted is the spectral angle mapping (SAM). This method considers an observed reflectance spectrum as a vector within a multidimensional space. It allows the number of dimensions to be equal to the number of spectral bands. The advantage of this method is that even with an increase/decrease in the overall illumination, the vector length will increase/decrease but its angular orientation will remain constant. In order to compare two spectra, it is required that the multidimensional vectors are defined for each spectrum and the angle between the two vectors be calculated. An angle value smaller than the given tolerance level will result in a match (between the library reference spectrum and the image pixel spectrum) even if one spectrum is brighter than the other. For a hyperspectral sensor with 300 or more bands, it becomes difficult for humans to visualize the dimensionality of space wherein vectors are located. Different

methods exist to process hyperspectral imagery. Though it is not possible to cover the entire topic in this module, one such method is discussed below.

### 3.1 Derivative Analysis

A digital image can be represented in terms of a 2 dimensional function that has a pixel value (DN number) associated with each row (r) and column (c) so that pixel value= $f(r,c)$ . But this function is not continuous for every possible values of r and c and hence is non differentiable in nature. Hence, to estimate the rate of change at a particular point, the method of differences is adopted. Assume that the spectral reflectance curve of a target is collected by a hyperspectral sensor. Let  $y_i$  and  $y_j$  denote the adjacent, discrete reflectance values on this curve at wavelengths  $x_i$  and  $x_j$  such that the first difference value can be given by the expression

$$\frac{y_j - y_i}{x_j - x_i}$$

The first difference essentially gives the rate of change of function y with respect to its distance along the x axis. Similarly, we can also obtain the second difference which gives the rate of change of slope with distance along the x axis. This shows how rapidly the slope is changing. The first and second differences calculated for one dimensional spectra or 2 dimensional images provide means to approximate the derivatives of a discrete function which cannot be calculated. The analysis of position and magnitude of absorption bands in the pixel spectrum can be estimated using the derivative analysis. The derivative methods tend to amplify any noise if present in the data. Hence, various methods of noise removal are applied to hyperspectral data ranging from simple filtering approaches to more complex wavelet based methods.

### 3.2 Atmospheric Correction

As mentioned earlier, atmosphere influences remote sensing measurements by the two major phenomenons of scattering and absorption. The effects of absorption are more pronounced due to water vapor with smaller contributions from ozone, carbon dioxide etc, The main step to analyse hyperspectral imagery is to convert the data into reflectance values such that the individual spectra can be compared with either laboratory libraries or field data. The laboratory setting enables provision to calibrate the initial wavelengths. For example, in the visible and near infrared regions of the electromagnetic spectrum, the narrow atmospheric



bands at 0.69, 0.72 and 0.76  $\mu m$  can be utilized to calibrate wavelengths. Several methods exist to empirically correct the atmospheric effects. Some techniques involve subtraction of average normalized radiance value of each channel from each normalized spectrum resulting in a residual image. Another method dealing with calculating the internal average relative reflectance involves estimating an average spectrum for an entire imaging spectrometer dataset. This can then be used for dividing each spectrum in the data set by the average spectrum. The point to be noted is that all of these methods tend to eventually produce images and spectra that have characteristics similar to reflectance. Hence, they result in relative reflectance i.e., reflectance relative to a reference spectrum and not absolute reflectance. The disadvantage associated with such practices is the presence of artifacts that gets incorporated as the reference spectrum themselves might possess spectral characteristics related to specific absorption features. On the positive note, conversion to an apparent reflectance doesn't require a priori knowledge regarding the site. To circumvent these issues, a standard area on the ground can be used to correct the data to reflectance wherein two or more ground locations can be chosen with albedos which span a wider range. Then, multiple pixels can be selected within the data set associated with each ground target which can be incorporated within a linear regression setting to estimate the gain and offsets required to convert the digital number to reflectance values. Solution of this equation will provide estimates of the standard error for each parameter at each wavelength. The final step in reflectance correction is to multiply the instrument digital number values with the gain factor and to add the corresponding offset values. This will essentially remove atmospheric effects of scattering and absorption, geometry effects and other instrument related artifacts.

Model based atmospheric correction techniques are also being developed like the Atmospheric Removal Program (ATREM). Here, a three channel ratioing approach is undertaken to estimate the water vapor on a pixel by pixel basis using the AVIRIS data. For different water vapor amounts, a number of theoretical water vapor transmittance spectra can be calculated using radiative transfer modeling. Such a modeled spectra can be run through the three channel ratioing method and used to generate look up tables of water vapor concentrations. These values can be used to convert the AVIRIS apparent reflectance measurements to total column water vapor. As a result, we obtain the spatial distribution of various water vapor concentrations for each pixel of AVIRIS data. This image can then be used along with transmittance spectra derived for each of the atmospheric gases to produce a scaled surface reflectance. The currently available models to correct atmospheric effects

enable to quantitatively derive the physical parameters and analyze data without a priori knowledge.

#### 4. Applications

a) Land use applications: Generally, remotely sensed images will be processed using digital image processing methods like supervised and unsupervised classification. With the availability of hyperspectral data of increased spatial and spectral resolution, the potential for land use classification has increased manifold. This imagery acquired in various spectral bands complement the existing information from traditional remotely sensed images. A special mention is to be made about vegetation mapping as it has unique spectral signatures during various stages of its growth that varies with species type. Improved classification is ensured using the hyperspectral imagery owing to the improved quality in the reference spectra.

b) Ecological Applications: Vegetation indices derived using hyperspectral sensors conclude better and more sensitive than those derived using optical images. Knowledge regarding the reflectance spectrum of vegetation is crucial for many applications. The biophysical factors which affect the spectrum of active vegetation are the leaf chemistry which is responsible for the absorption characteristics of leaf spectrum in the visible wavebands. Different vegetation has different spectral reflectance curves which can be characterized using vegetation indices. These indices are essentially ratios that measure the steepness of the red-infrared region of the spectral reflectance curve but not its position within the spectrum. Using data from hyperspectral sensor, it is possible to characterize this steep rise in the reflectance curve in terms of a single wavelength.

#### c) Water Quality

Hyperspectral images have been used to assess the water quality in many open water aquatic ecosystems indirectly by classifying trophic status of lakes, characterizing algal blooms, predicting total ammonia concentrations to monitor wetland water quality changes. Using remotely sensing images, the chlorophyll content is usually estimated which in turn can be used for monitoring algal content and therefore water quality. Due to the narrow contiguous bands, hyperspectral images allow for a better detection of chlorophyll and algae.

#### d) Flood Detection

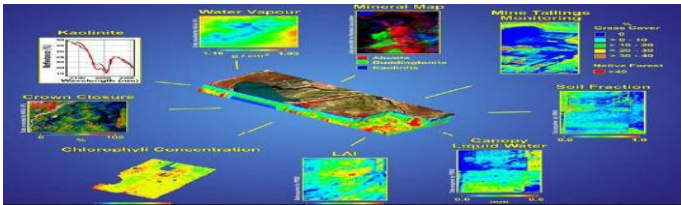
Previously, though satellite remote sensing enabled monitoring of inundated areas during floods or any other natural calamity, near real time flood detection was not possible. To provide real time information about natural disasters like floods, timely information of water conditions is required at sufficient spatial and temporal resolutions. Using sensors such as Hyperion on board the EO-1 satellite, this is made possible. Many studies of USGS and NASA utilize satellite based observations of precipitation, topography, soil moisture, evapotranspiration etc into early warning systems. The hydraulic information obtained using remotely sensed images can be applied in flood routing studies to generate flood wave in a synthetic river channel. Research is also underway to estimate river discharge using satellite microwave sensors with an aim to improve warning systems.

e) Evapotranspiration (ET): Information regarding evapotranspiration is crucial for various applications involving irrigation, reservoir loss study, runoff prediction, climatology etc to name a few. Even though it cannot be measured by direct means, hyperspectral sensors offer means to estimate components of energy balance algorithms for

spatially mapping ET values. Typically AVHRR and MODIS data are used to estimate evaporative fraction which is a ratio of ET and available radiant energy. More information can be obtained in Batra et al (2006), Eichinger et al 2006 etc. Analysis of hyperspectral images possesses great potential to advance the quality of spectral data obtained by sensing earth surface features. Research is currently underway to optimize the analysis of large volumes of hyperspectral imagery. As mentioned earlier, this is crucial for various applications such as identification of aerosols, gas plumes etc.

#### f) Geological Applications

Hyperspectral remote sensing has great potential not only to identify but also to map specific chemical and geometric patterns of land which can be relied to identify areas with economically valuable deposits of minerals/oils.



### 4: Applications of hyperspectral remote sensing

#### Internet and GIS

Internet is a global network of computers connected through communication devices to one another for information sharing. The use of internet for information dissemination and resource sharing has undergone a rapid growth over the last few years. This is attributed to its capability to integrate information from various sources in a seamless manner. The web environment facilitates sharing of data and cooperation among users across the globe. The computers on the internet communicate with each other via Transmission Control Protocol/Internet Protocol and use client-server architecture. The World Wide Web (WWW) is a system of Internet servers and is most used aspect of the internet. It supports hypertext to access several Internet protocols on a single interface. Hypertext Transfer Protocol (HTTP) is the client-server protocol that takes request from the client and transmits the request to web server, which then sends back its response. HTTP is used to communicate queries and response across the Internet.

The recent developments in IT sector have resulted in development of computing architectures that has helped GIS on desktop to come and become functional over the internet. The GIS functionality is made available through a web browser and a viewer with a simple, user-friendly interface. During 1960s-1970s, for a GIS to work, hardware, software and data were needed to be present at one place on one computer. The LAN (local area network) based desktop GIS follows the client-server model where the GIS programs on computers (clients) communicate with the server. In this case the GIS programs are installed on the computers and one has to access these computers to use the GIS. With the advent of distributed GIS, users do not need to purchase and install expensive GIS software in order to access and work with maps and databases. Distributed GIS makes use of internet and wireless network for data processing and communication. The users can access GIS tools and data from internet or wireless data services. Thus web based GIS offers advantages such as worldwide access, a standard interface and a cost effective maintenance over a stand-alone GIS system.

WebGIS can perform all GIS functions such as capturing, storing, editing, analysis and visualization. Given below is a brief about its strengths:

- a) Visualization and Querying: GIS data and results are mostly represented as maps. Every feature on map has certain information associated with it. On querying one may come to know the location of a particular feature and the properties associated with it.
- b) Collection of Geographical Information: Various organisations collect spatial information on web. One way of doing this is by developing an application which is opened to public where public is asked for feeding in the spatial information. The Wikimapia website which has more than 18 million places marked by the registered as well as anonymous internet users is an example of such kind. Use of mobile GIS where field crew collects information, validate it and post the updated information to the server and database kept in the office is another way of collecting geographical information.
- c) Dissemination of geospatial information: A lot of geospatial information is distributed through the WebGIS platform. For example, India-WRIS is a web based platform through which one can visualize as well as download the geospatial data related to water resources of India. In a similar manner various organisations have been disseminating the data through such geospatial portals.

