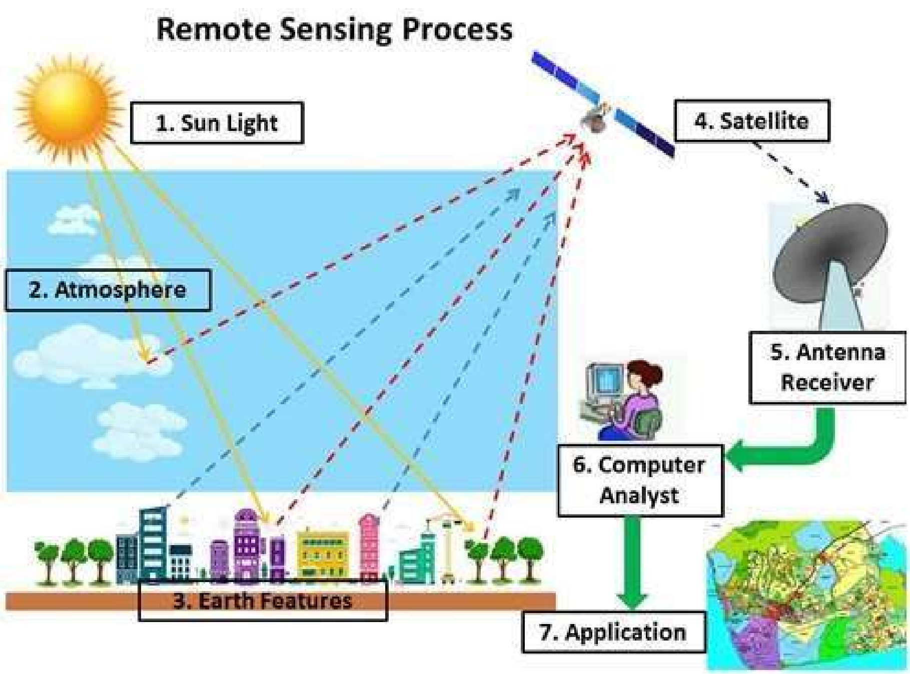
REMOTE SENSING AND GIS

IV-I

REMOTE SENSING

Remote Sensing : Acquisition of Information about an object or phenomenon without Making Physical contact with the object

The term Remote sensing generally refers to the use of aircraft based sensor technologies to detect and classify objects on earth, including on the surface and in the atmosphere.



Remote Sensing

Our five senses

- Sight
- hearing
- Smell

Remote sensing

- taste
- touch

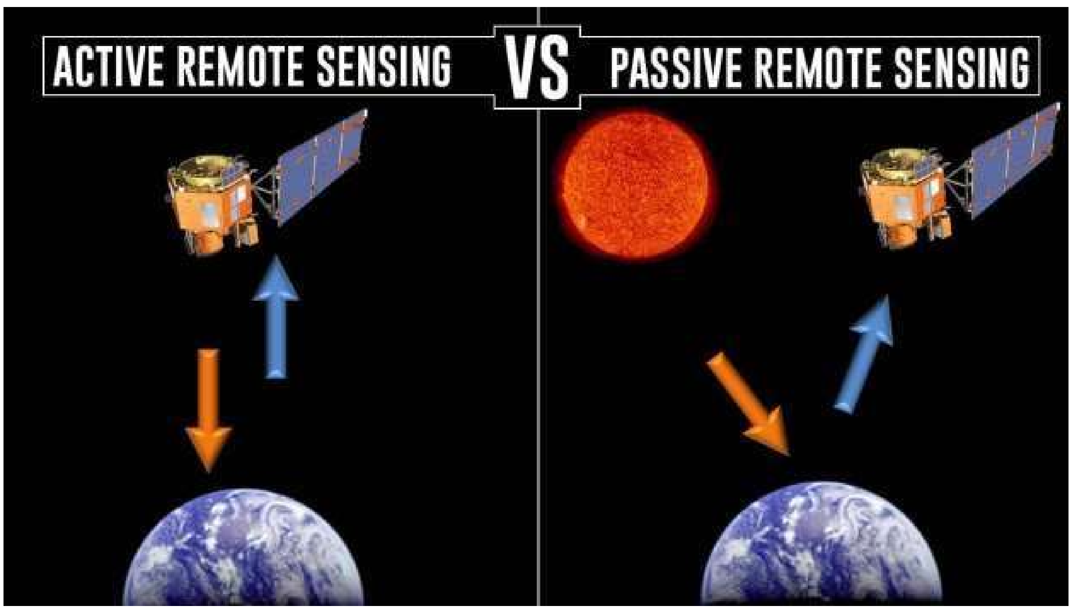
Only sensing

What is Remote Sensing?

Types of Remote Sensing: Active and Passive

Passive : The sun provides a very convenient source of energy for remote sensing. Remotes sensing systems which measures energy that is naturally available are called passive sensors.

Active: Active sensor on the other hand provide their own source of energy for illumination. The radiation reflected from the target is detected and measured by the sensor. Advantages for active sensors includes the ability to obtain measurements anytime regardless of the time of day or seasons.



Advantages and Disadvantages of Remote Sensing

Advantages: 1) Large area coverage

2) RS allow repetitive coverage of the same area

3) RS allow for easy collection of data over variety of scales and resolution.

4) Remote Sensing data can easily be processed and analyzed fast.

5) It is easier to locate floods and forest fires that has spread over a large region which makes easier to plan rescue mission easily and fast.

Disadvantages: 1) Remote sensing is fairly expensive method of analysis.

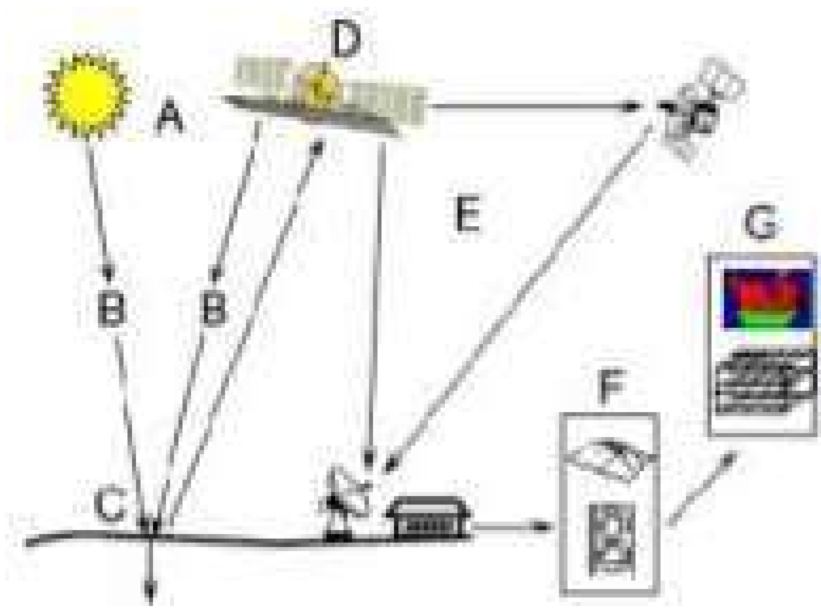
2) Remote sensing requires a special kind of training to analyze the images.

3) It is expensive to analyze repetitive photographs.

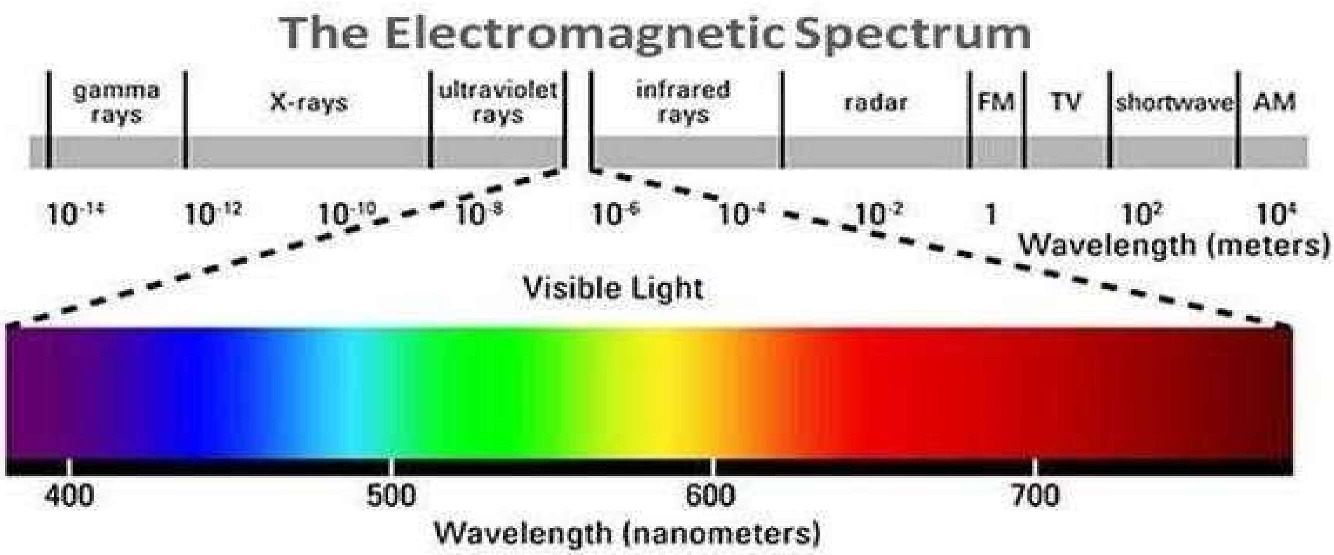
ELEMENTS INVOLVED ELECTROMAGNETIC REMOTE SENSING PROCESS

Elements of Remote sensing:

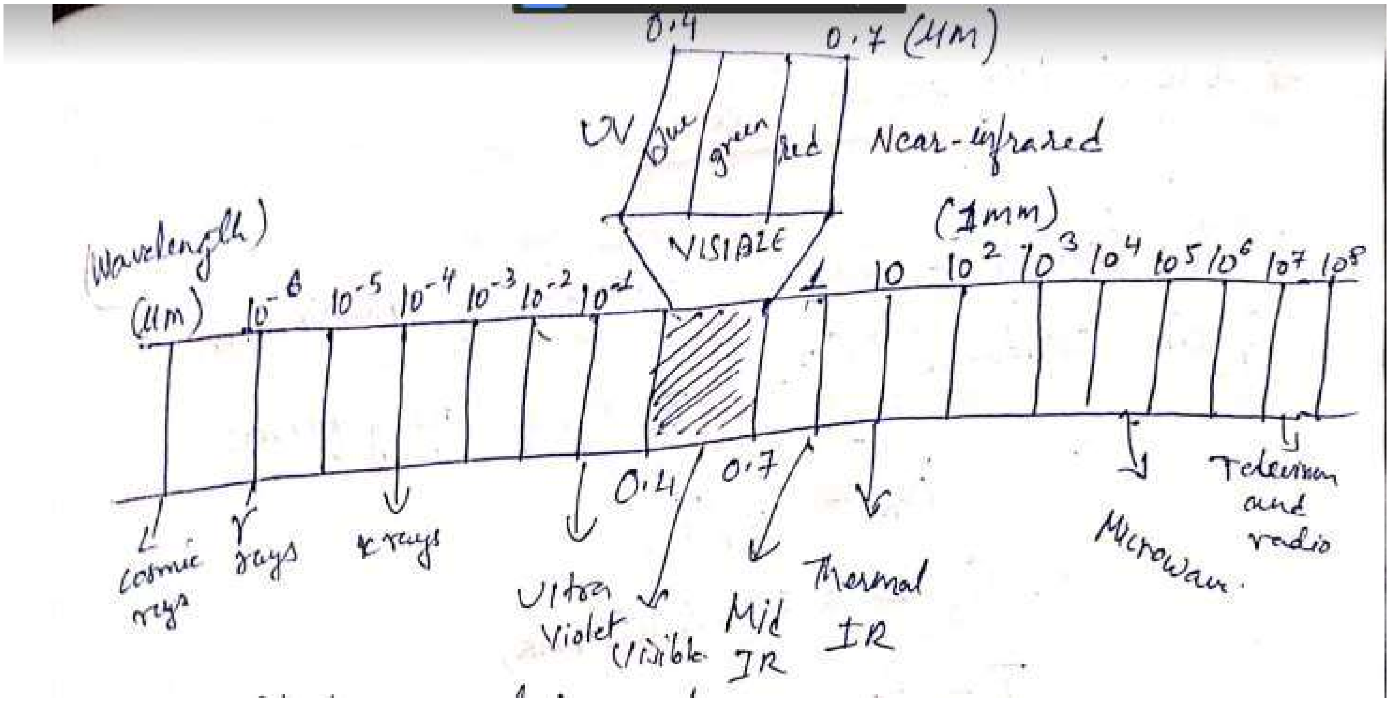
1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B)
3. Interaction with the Target (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception, and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)



ELECTROMAGNETIC SPECTRUM



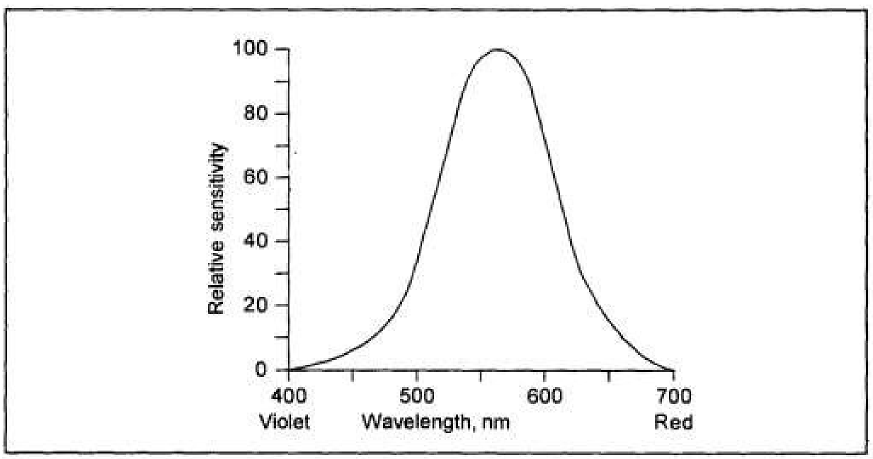
Electro magnetic radiation is a form of energy propagated through free space or Through a material medium in the form of electromagnetic waves. Electromagnetic radiation has a dual nature its exhibits wave properties and particulate properties.


0.4
0.7 (μm)
UV
blue
green
red
Near-infrared
(1mm)
VISIBLE
(Wavelength)
(μm)
10^-6 10^-5 10^-4 10^-3 10^-2 10^-1
1 10 10^2 10^3 10^4 10^5 10^6 10^7 10^8
0.4
0.7
cosmic rays
γ rays
x rays
Ultra Violet
Visible
Mid IR
Thermal IR
Microwave
Television and radio

Electromagnetic Spectrum is the all of possible frequencies of electromagnetic radiation. The wavelengths and frequencies vary from shorter wavelength high frequency cosmic wave to long wavelength low frequency radio waves.

In brief, The electromagnetic spectrum is the continuum of energy that ranges from meters to nano meters in wave length, travels at the speed of light and propagates through a vacuum like a outer space.

Spectral Wave Bands – Visible light is electromagnetic radiation with wavelengths between 0.4 µm (micrometer) and 0.7 µm. The eye is not uniformly sensitive to light within this range and has its peak sensitivity at 0.55 µm. This peaks in the response function of the human eye corresponds closely to the peak in the Sun's radiation emittence distribution.



- Wavelength longer than the visible red are sub divided into the infrared (IR) microwave and radio frequency waveband.

- The infrared waveband, extending from **0.7 µm to 1 µm** is not a uniform region.

- Short wavelength or near IR between **0.7 µm to 0.9 µm behaves** like visible light and can be detected by special photographic film.

- The **region of spectrum** composed of electromagnetic radiation with wavelength between **1mm and 300cm** is called the microwave band and radiation at these wavelengths beyond the microwave band is the valuable region for remote sensing.

- The microwave band is thus a valuable region for remote sensing.

- Beyond the microwave region is the radio band of very long wavelength used in certain Applications.

Table 2.1 Electromagnetic spectral regions (Sabines, 1987)

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

ENERGY RESOURCES

Energy Resources: **The sun** provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called passive sensors.

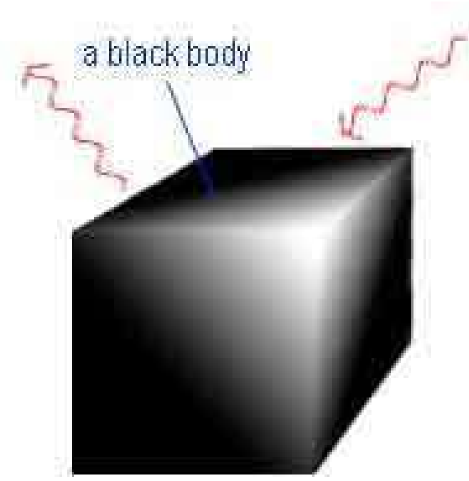
Just as our eyes need objects to be illuminated by light so that we can see them, sensors also need a source of energy to illuminate the earth's surface. The sun is the natural source of energy. This energy is in the form of electromagnetic radiation (EMR). The following subsections explain the classification of remote sensing.

The energy source used in the ***visible and reflective infrared remote sensing*** is the sun. The sun radiates EM energy with a peak wavelength of about 0.5 µm. Remote sensing data obtained in the visible and reflective infrared regions mainly depends on the reflectance of objects on the ground surface. Therefore, information about objects can be obtained from the spectral reflectance. However laser radar is exceptional because it does not use the solar energy but the laser energy of the sensor.

Energy Source and its Characteristics

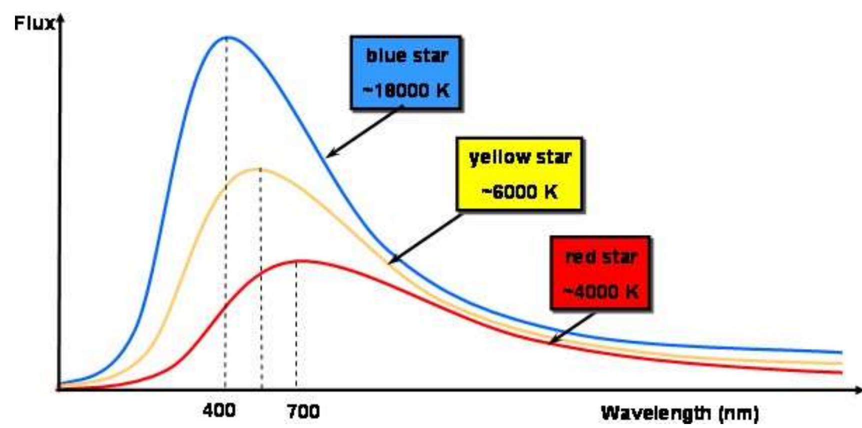
Radiation emitted by objects

- **The type of light produced by an object will depend on its temperature**
- All objects that have a temperature greater than 0° K emit radiation
- hot objects emit more radiation



Black Body Radiation

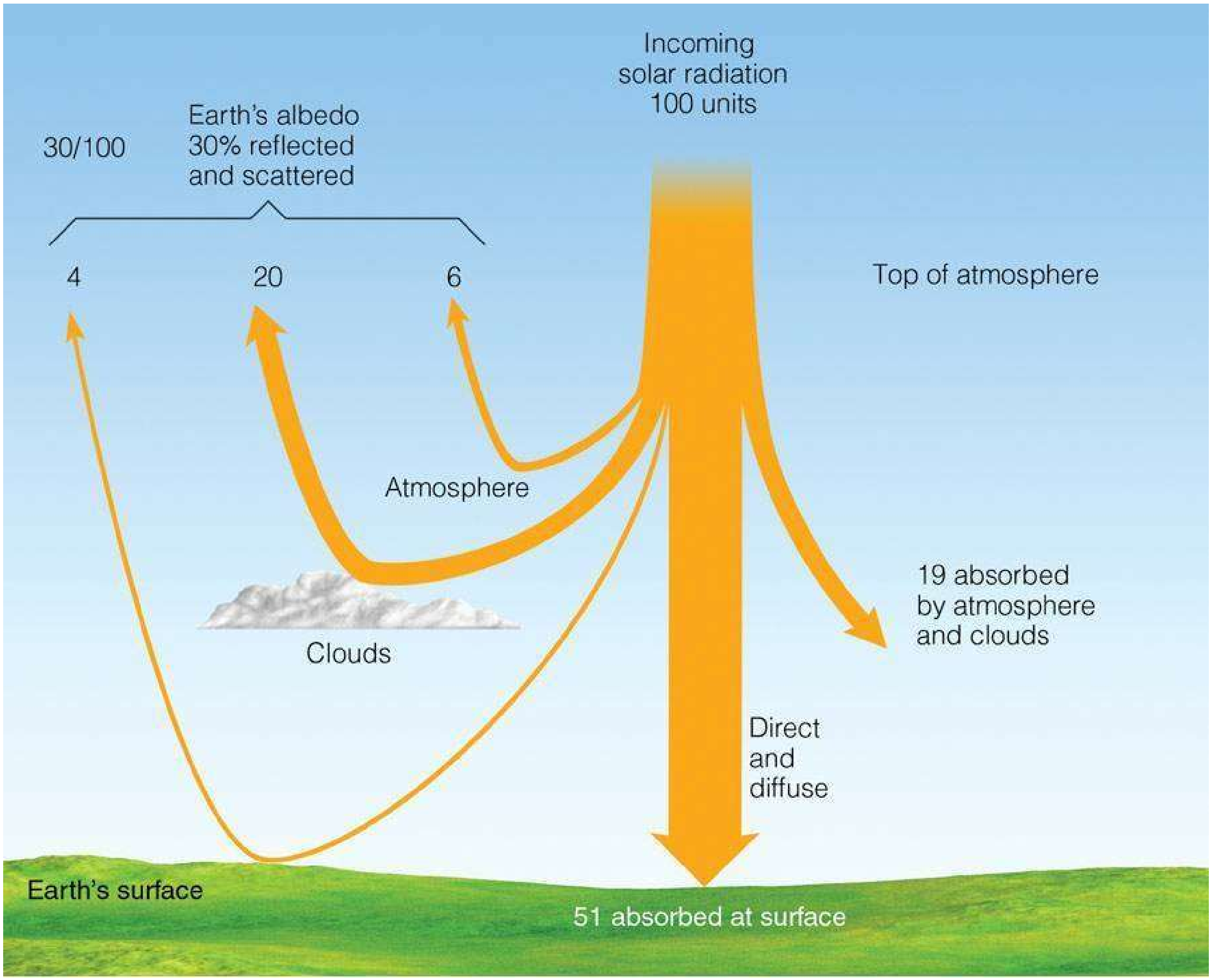
- *Black Body* - any object that is a perfect emitter and a perfect absorber of radiation
- object does not have to appear "black"
- sun and earth's surface behave approximately as black bodies



ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES AND ATMOSPHERE

- All electromagnetic radiation detected by a remote sensor has to pass through the atmosphere twice, before and after its interaction with earth's atmosphere.
- This passage will alter the speed, frequency, intensity, spectral distribution, and direction of the radiation.
- As a result **atmospheric scattering and absorption**. These effects are most severe in visible and infrared wavelengths, the range very crucial in remote sensing.
- During the transmission of energy through the atmosphere, light interacts with gases and particulate matter in a process called ***atmospheric scattering.***

Interaction of incoming solar radiation with the Atmosphere



- Based on the figure, about half of the incoming short wave radiation makes it to the surface
- only about 19% is absorbed by gasses in the atmosphere
- Therefore, the atmosphere is fairly transparent to incoming solar radiation.

Scattering mechanism

The two major processes in scattering are

1. **Selective scattering :**
    a. Rayleigh
    b. Mie and
    c. Raman scattering

2. **Non-selective scattering:**

Rayleigh Scattering : Occurs when the 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. The fact that the sky appears blue during the day time because of this phenomenon as the sunlight passes through the atmosphere, the shorter wavelength (i.e. blue) of visible spectrum are scattered more than the longer visible wavelength

Mie Scattering : Occurs when the particles are just about the same size as the wavelength of the radiation. Dust, Pollen, smoke and water vapor are common causes of the mie scattering which tends to effect longer wavelengths than those affected by Rayleigh scattering.

Raman Scattering : Size of effective atmospheric particles in any size collision with molecules resulting in a loss or gain in energy this can decrease or increase wavelength.

Non- Selective Scattering: The final scattering mechanism of importance is called non-selective scattering. This occur when the particles are much larger than the wavelength of the radiation

Type of Scatter of particles	Size of effective atmospheric particles	Type of effective atmospheric particles	Scatter of particles	Effect of scatter on visible and near visible wavelength
Rayleigh	Smaller than the wavelength of radiation.	Gas molecules	Molecule absorbs high energy radiation and re-emits. skylight scatter is inversely proportional to fourth power of wave length.	Affects short visible wave lengths, resulting in haze in photography, and blue skies.
Mie	Same size as the wavelength of radiation.	Spherical particles, fumes and dust	Physical scattering under overcast skies.	Affects all visible wave lengths
Non-selective	Larger than the wavelength of radiation.	Water droplets and dust.	Physical scattering by fog and clouds.	After all visible wave lengths equally, resulting white fog and clouds
Raman	Any	Any	Photon has elastic collision with molecule resulting in a loss or a gain in energy; this can decrease or increase wave length.	Variable

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 molecules in the atmosphere to absorb energy at various wavelength, ozone, carbon dioxide and water vapor are three main atmospheric constituents which absorb radiation

Ozone: Absorbs the harmful UV radiation from sun without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

Carbon Dioxide: referred to green house gas. This is because it tends to absorb radiation strongly in infrared portion of the spectrum that area associated with thermal heating which serves to trap heat in side the atmosphere

Water Vapor: Water vapor in the atmosphere absorbs much of the incoming long wave infrared and shortwave microwave radiation

Because these gases absorb electromagnetic energy in very specific regions of the spectrum.

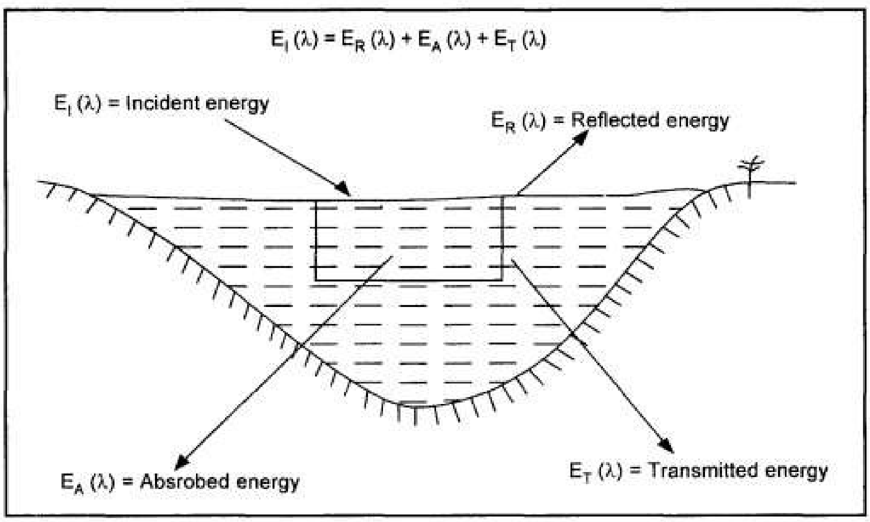
Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus are usefull to remote sensors

Atmospheric windows

- While passing through the atmosphere, electromagnetic radiation is scattered and absorbed by gasses and particulates. Besides the major gaseous components like molecular nitrogen and oxygen, other constituents like water vapour, methane, hydrogen, helium and nitrogen compounds play an important role in modifying the incident radiation and reflected radiation.
- This causes a reduction in the image contrast and introduces radiometric errors.
- Regions of the electromagnetic spectrum in which the atmosphere is transparent 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 0.38 - 0.72 µm (visible), 0.72 -3.00 µm (near infrared and middle infrared) and 8.00 -14.00 µm (thermal infrared).

Energy Interactions with Earth's Surface Materials

When electromagnetic energy is incident on any feature of the earth's surface such as a water body, various fractions of energy get reflected, absorbed and transmitted.



$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Where, E_I = Incident energy

E_R = Reflected energy

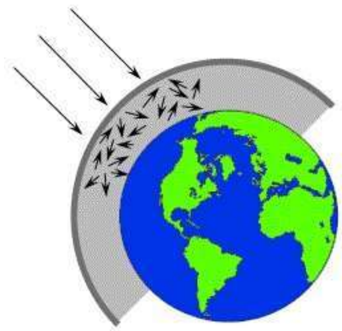
E_A = Absorbed energy

and, E_T = Transmitted energy

Energy Interactions with Earth Surface Features

There are three forms of interaction that can take place when energy strikes, or is incident upon the surface.

These are:



1. Absorption (A)
2. Transmission (T)
3. Reflection (R)

The total incident energy will interact with the surface in one or more of these three ways.

The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

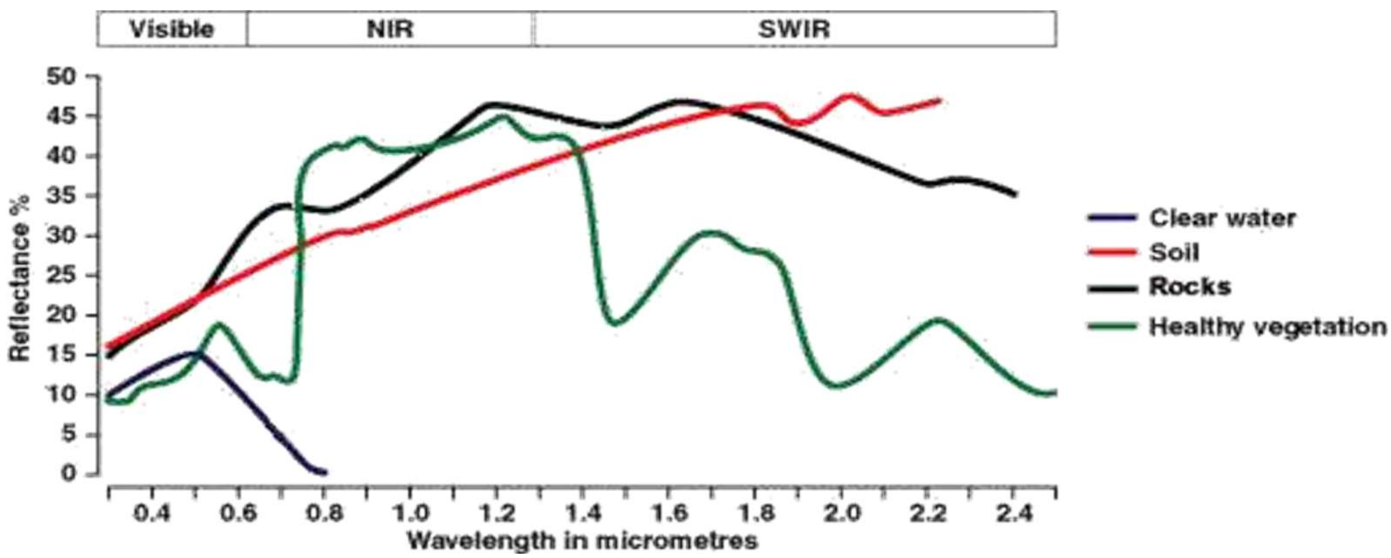
- Absorption (A) occurs when radiation (energy) is absorbed into the target
- Transmission (T) occurs when radiation passes through a target.
- Reflection (R) occurs when radiation "bounces" off the target and is redirected.

According to principles of physics, it is known that are called reflectance, absorbance, and transmittance. $\frac{E_R(\lambda)}{E_I(\lambda)}$; $\frac{E_A(\lambda)}{E_I(\lambda)}$ and $\frac{E_T(\lambda)}{E_I(\lambda)}$

A measure of 1.0 means that 100% of the incident radiation is reflected off the surface, And a measure of '0' means that 0% is reflected.

Spectral Reflectance Curves: A basic assumptions made in that specific target has an Individual and characteristic manner of interaction is described by the spectral response of a target in a particular wavelength region of electromagnetic spectrum

SPECTRAL SIGNATURE



Vigorous Vegetation: Spectral reflectance curves for vigorous vegetation manifests the peak and valley configuration. The valleys in the visible portion of the spectrum are indicative of pigments in plant leaves.

Dip in reflectance that can be seen at wavelengths of 0.65 **µm, 1.4 and 1.9µm** are attributes to absorption of water by leaves.

Soil: The soil curve shows a more regular variation of reflectance. Factors that evidently affect soil reflectance are moisture content, soil texture, surface roughness, and presence of organic matter. The term spectral signatures can also b used for spectral reflectance curves.

Water: The characteristic spectral reflectance curve for water shows that about 0.5**µm,** a reduction in reflectance with increasing wavelength, so that in the near infrared range, the reflectance of water significantly affected by the presence of dissolved suspended Organic and inorganic material and depth of water body shows the spectral reflectance Curves for visible and near infrared wavelengths at the surface and at 20m depth

SATELLITE CHARACTERISTICS: ORBITS AND SWATHS

- The path followed by a satellite is referred to as its **orbit.**
- Satellite orbits are matched to the capability and objective of the sensor(s) they carry.
- Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth.

A satellite is launched (lifted) from the Earth's surface by a rocket. Once the satellite reaches its orbit, it continues to move in its orbit and does not require the push from the rocket any more. Satellite orbits can be at different distances from the Earth.

The path followed by a satellite is referred to as its orbit.

Two important types of orbits are:

- *Geostationary orbits*

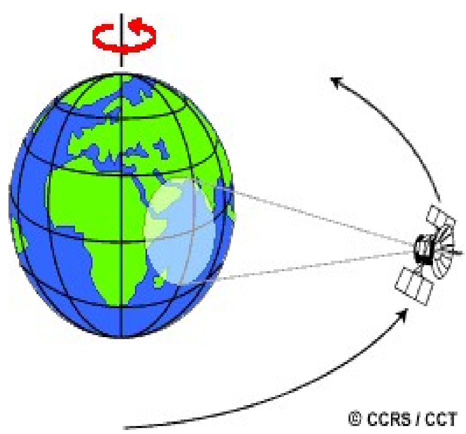
are in the same plane as the equator and are about 36000 km away from the Earth.(Ex weather and communication satellites, INSAT,GOES, METEOSAT)

- *Polar orbits*

pass very close to the north and south poles (also known as near-polar orbits). They are about 700 to 800 km away from the Earth.

Geostationary orbits

- Satellites at very high altitudes, which view the same portion of the Earth's surface at all times have **geostationary orbits**.
- These geostationary satellites, at altitudes of approximately **36,000 kilometres**, revolve at speeds which match the rotation of the Earth so they seem stationary, relative to the Earth's surface.
- This allows the satellites to observe and collect information continuously over specific areas.
- Weather and communications satellites commonly have these types of orbits.
- Due to their high altitude, some geostationary weather satellites can monitor weather and cloud patterns covering an entire hemisphere of the Earth.



Geostationary orbits (Geosynchronous Equatorial Orbit)

(**from *geo* = Earth + *synchronous* = moving at the same rate).**

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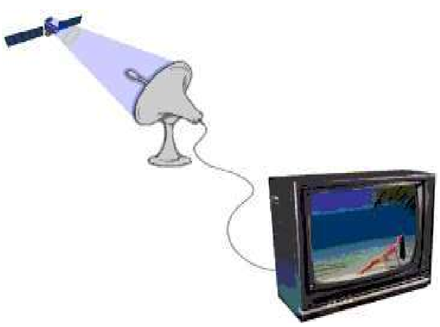
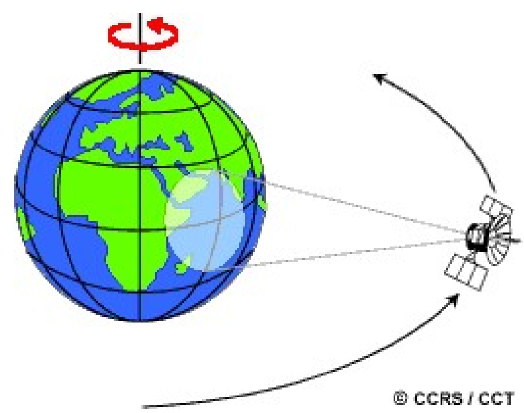




Near-polar orbits (or) sun-synchronous

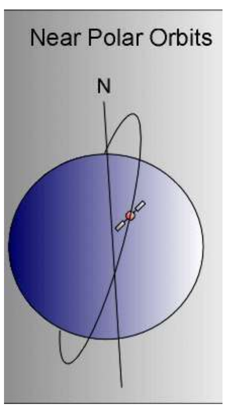
• These are **near-polar orbits**, so named for the inclination of the orbit relative to a line running between **the North and South poles.**

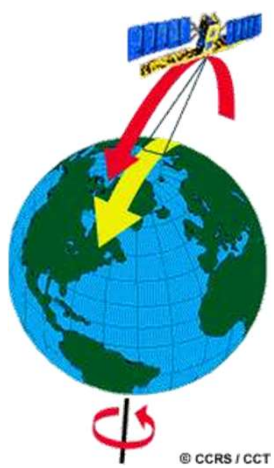
• Many of these satellite orbits are also **sun-synchronous** such that they cover each area of the world at a constant local time of day called **local sun time**.

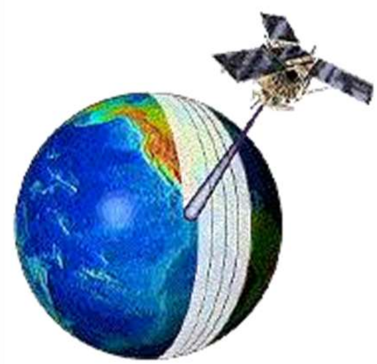
• At any given latitude, the position of the sun in the sky as the satellite passes overhead will be the same within the same season. This ensures consistent illumination conditions when acquiring images in a specific season over successive years, or over a particular area over a series of days.

• This is an important factor for monitoring changes between images or for mosaicking adjacent images together, as they do not have to be corrected for different illumination conditions. Eg: **LANDSAT, IRS and SPOT**

These orbits have an inclination near 90 degrees. This allows the satellite to see virtually every part of the Earth as the Earth rotates underneath it. It takes approximately 90 minutes for the satellite to complete one orbit.





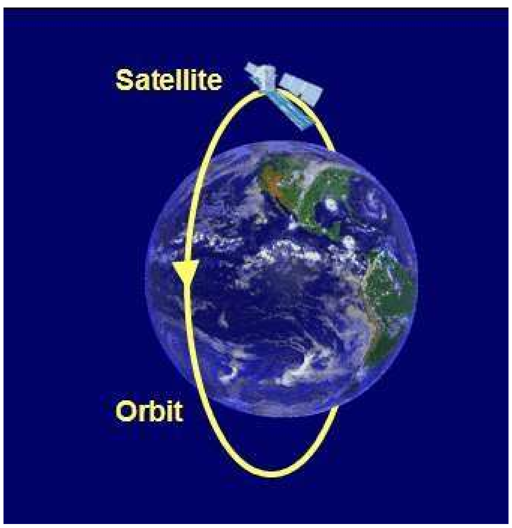


Satellites

A satellite is something that moves around something else. Satellites follow a fixed path, **known as an orbit.**

Scientists have sent many satellites into outer space that revolve around the Earth. These satellites continuously take pictures of the Earth. We can use these satellite images to study the Earth.

The science of acquiring and studying these images is called satellite remote sensing.



Depending on their use there are different kinds of satellites.

• ***Communication satellites***

help to provide radio, television and phone coverage. These satellites always look at the same point on the Earth as they revolve around the Earth (geostationary).

• ***weather satellites***

are geostationary. Others are in polar orbit. They all provide information that is used for weather forecast.

• ***Navigational satellites***

are special satellites that help us to find our exact location on the Earth. GPS (Global Positioning Systems) receivers that you can now buy at many stores use these satellites to show us our location.

• ***Satellites for planetary/astronomical studies***

point away from the Earth and are used to study outer space and other planets.

• ***Earth observing satellites***

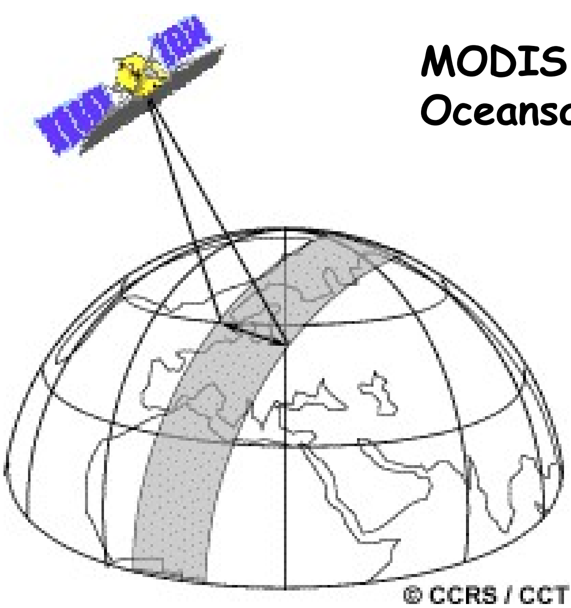
are specially designed to study the processes on Earth. Many of these satellites occupy near-polar orbits. Some also operate in other orbit types.

swath

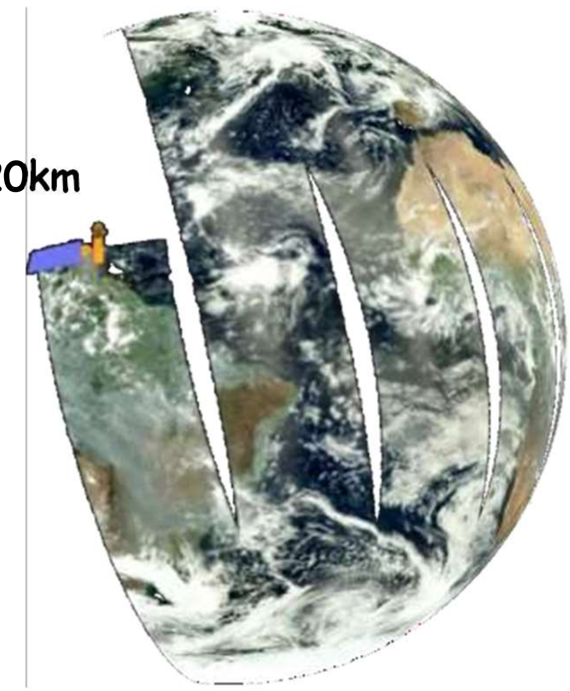
• As a satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface. The area imaged on the surface, is referred to as the swath.

• Imaging swaths for spaceborne sensors generally vary between tens and hundreds of kilometres wide.

• The satellite's orbit and the rotation of the Earth work together to allow complete coverage of the Earth's surface, after it has completed one complete cycle of orbits.



MODIS=2300km
Oceansat-2=1420km



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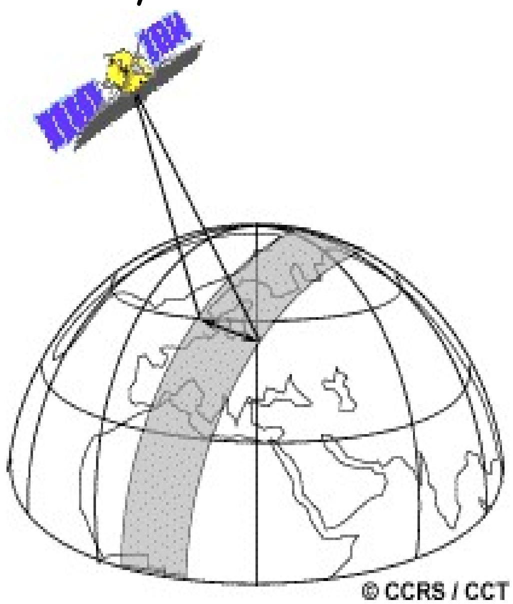
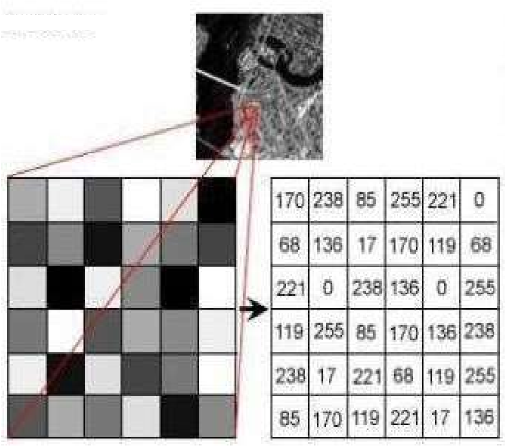


SENSOR RESOLUTION

Resolution **refers to the smallest size an object or detail can be represented in an image**. Higher resolution means that pixel sizes are smaller, providing more detail. For example, 30cm resolution satellite imagery can capture details on the ground that are greater than or equal to 30cm by 30cm



TYPES OF RESOLUTION

- **SPATIAL**
- **SPECTRAL**
- **RADIOMETRIC**
- **TEMPORAL**

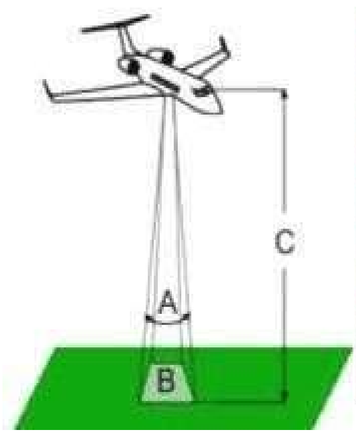
Spatial Resolution

✓spatial resolution of the sensor and refers to the size of the smallest possible feature that can be detected.

✓Spatial resolution of passive sensors depends primarily on their Instantaneous Field of View (IFOV).

✓The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B).

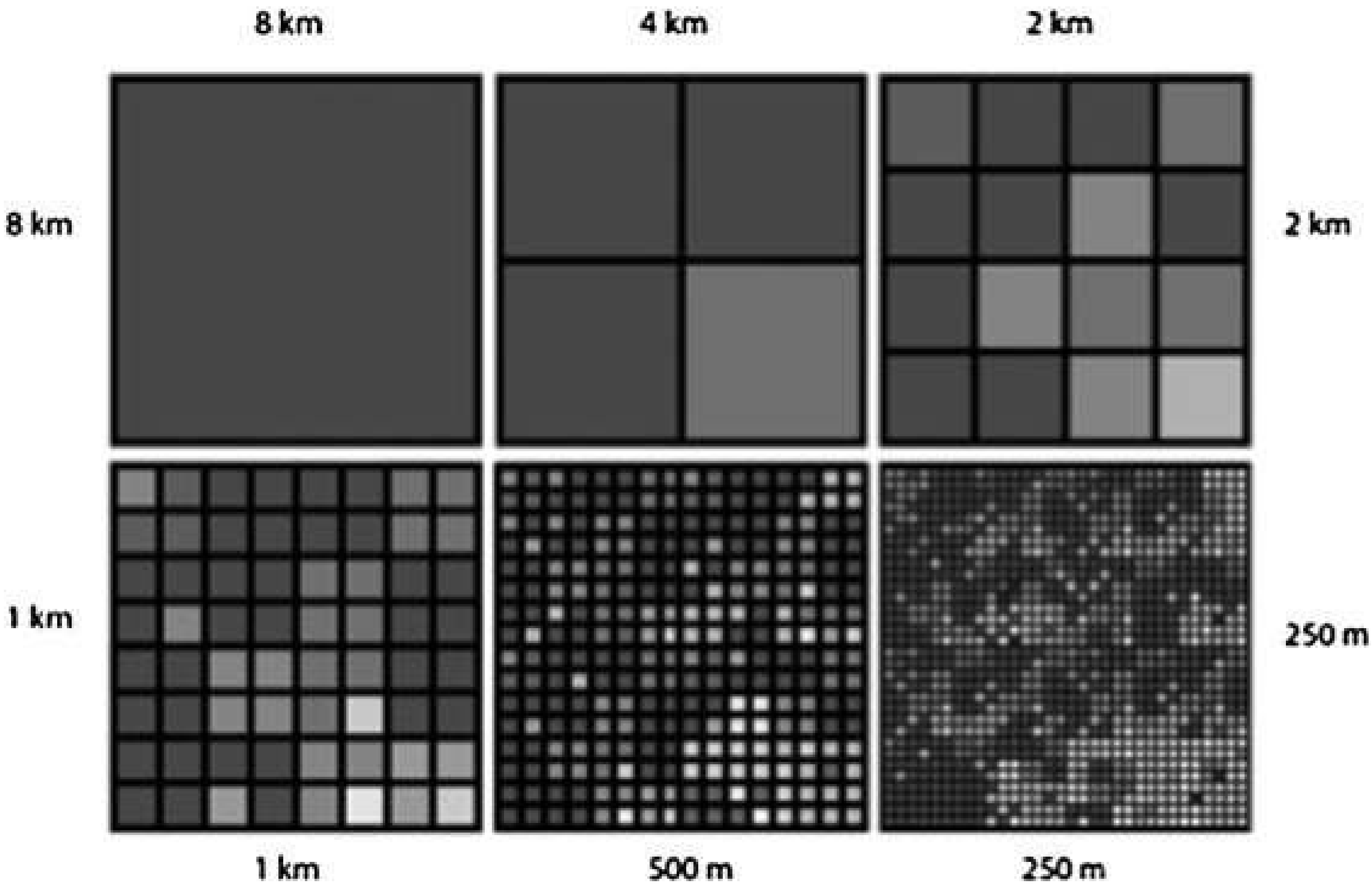
✓The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the resolution cell and determines a sensor's maximum spatial resolution.



80 meter

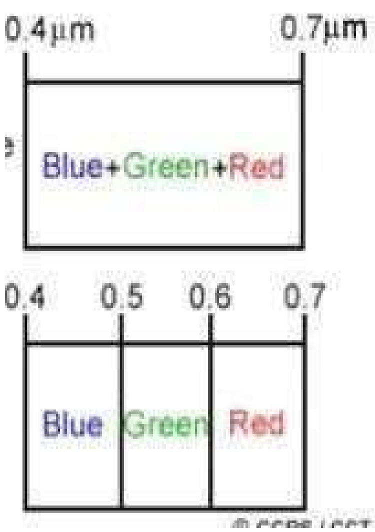
15 meter

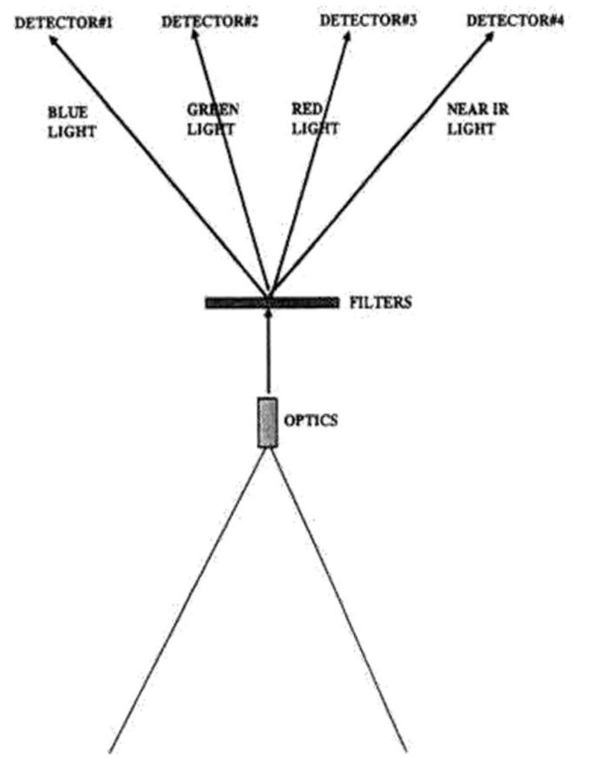
1 meter Resolution


8 km
4 km
2 km
8 km
2 km
1 km
250 m
1 km
500 m
250 m

Spectral Resolution

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

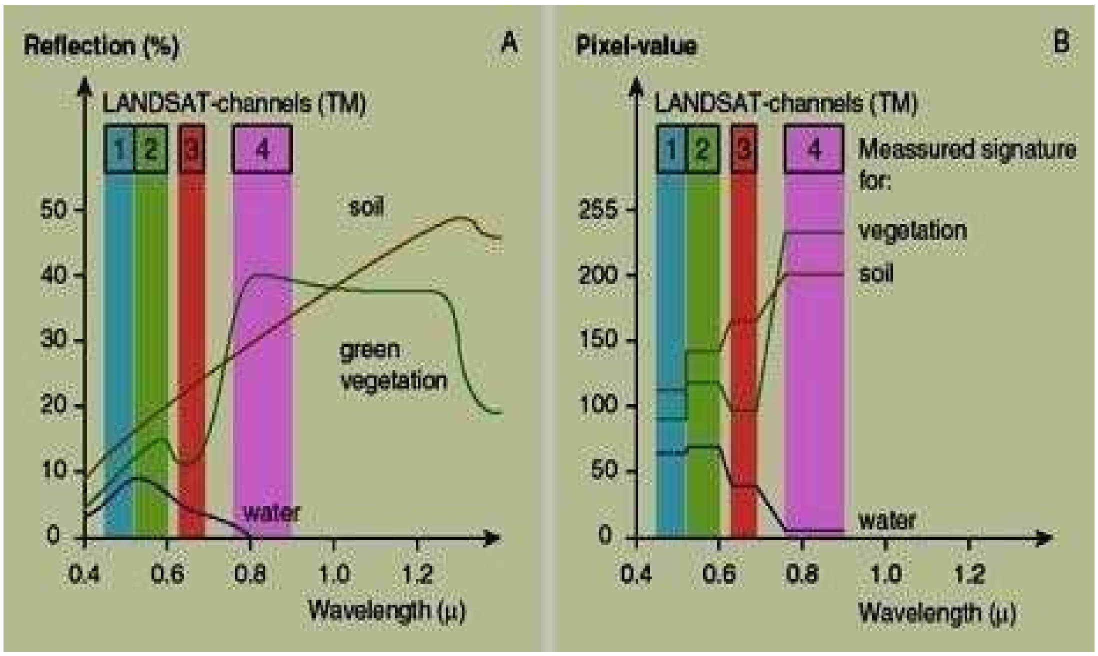




Simplified example of a multispectral digital remote sensing system.

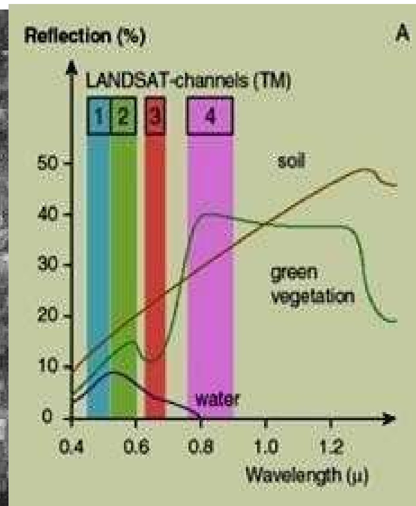
Spectral Signatures

Different surface types such as water, bare ground or vegetation reflects radiation differently in various channels. The radiation reflected as a function of the wavelength is called the spectral signature of the surface.



Band 1	0.45 - 0.52	30
Band 2	0.52 - 0.60	30
Band 3	0.63 - 0.69	30
Band 4	0.76 - 0.90	30

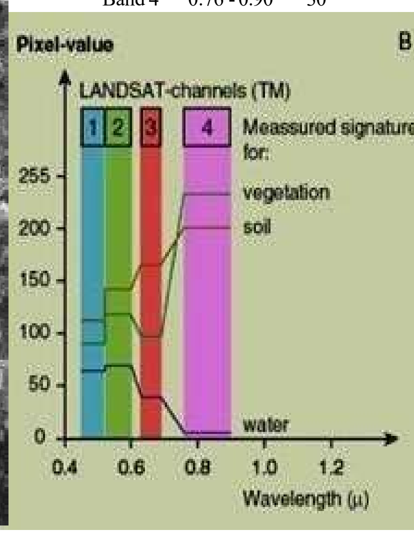
LANDSAT-



Band 1	0.45 - 0.52	30
Band 2	0.52 - 0.60	30
Band 3	0.63 - 0.69	30
Band 4	0.76 - 0.90	30

LANDSAT-

LANDSAT-

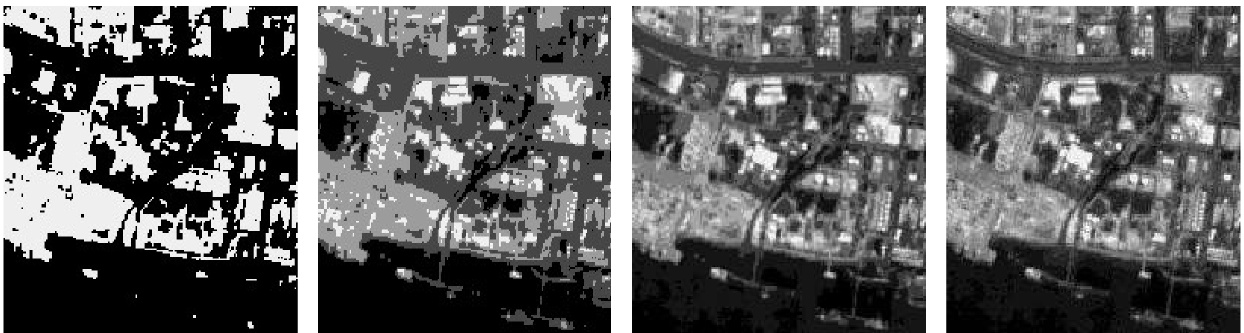


LANDSAT-

RadiometricResolution

✓The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy.

✓The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.



2-bit	4-bit	8-bit	16-bit
2^2=4	2^4=16	2^8=256	2^{16}=65536
0-3	0-15	0-255	0-65535

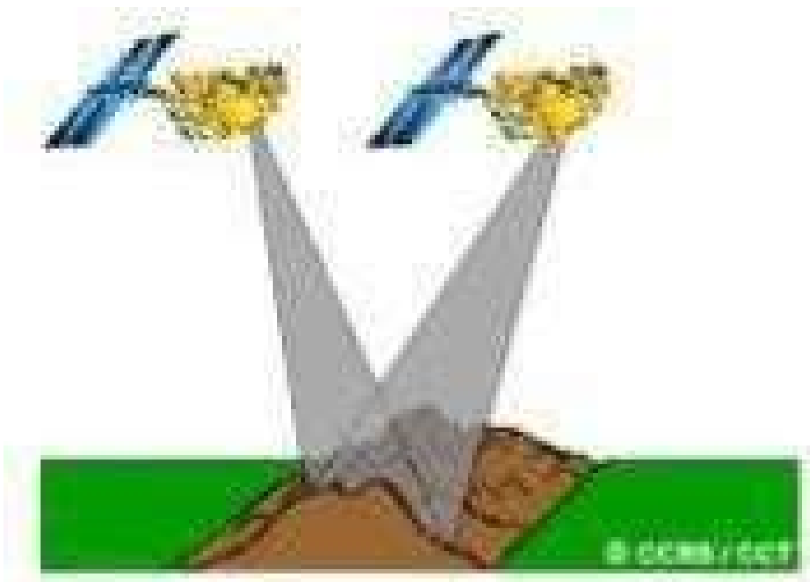

8-bit


4-bit

Temporal Resolution

✓The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data.

✓Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal imagery.



REMOTE SENSING PLATFORMS AND SENSORS

Sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

Remote sensor to collect and record energy reflected or emitted from a target or surface.

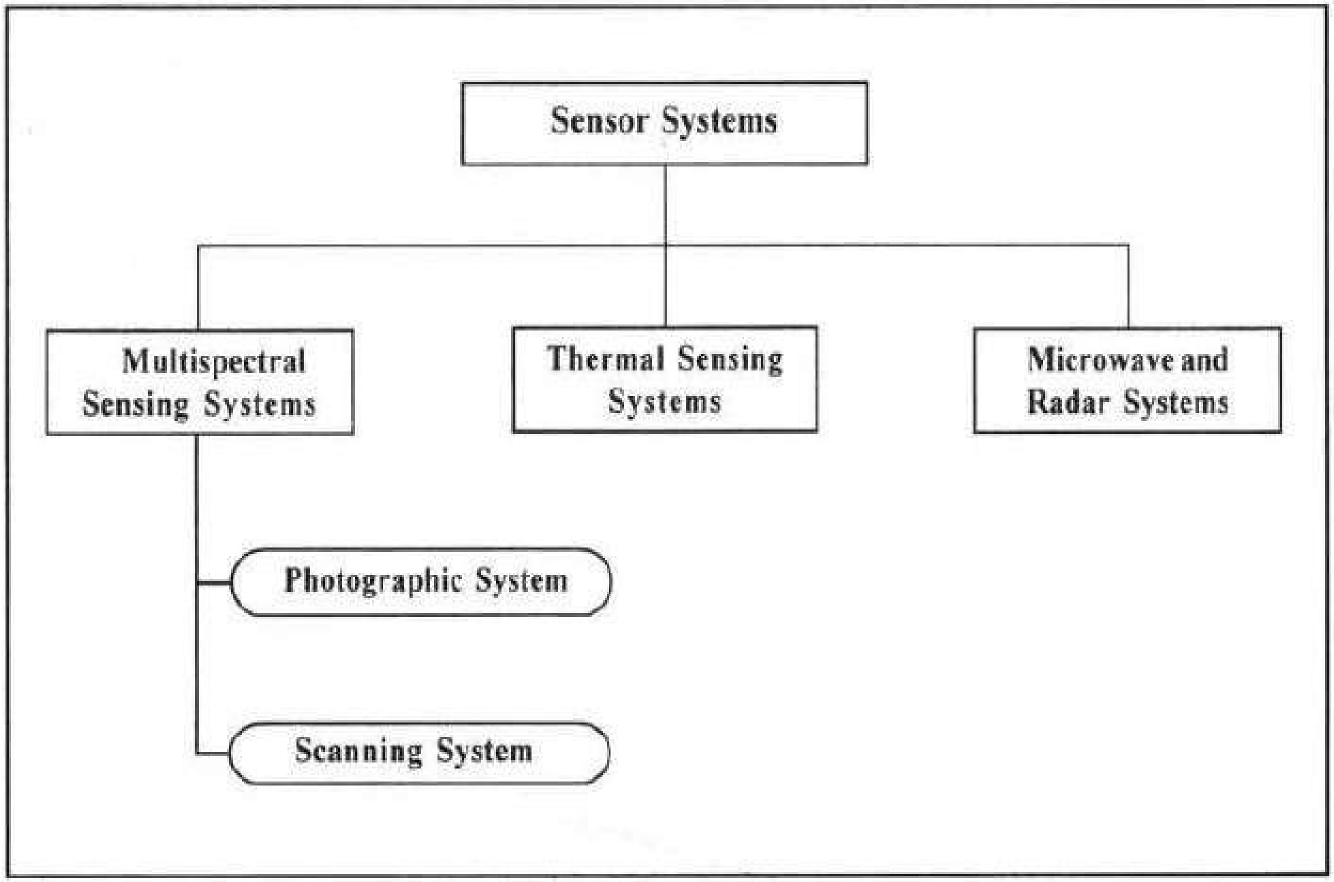
Sensor must reside on a stable platform

Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere.





Classification of Imaging Sensor Systems



Imaging Sensor Systems

- Various components of sensor systems operating in the visible, infrared, thermal and microwave regions of the electromagnetic spectrum.
- Useful wavebands are mostly in the visible and the infrared for passive remote sensing detectors and in the radar and microwave region for active type of sensors.
- All the imaging sensor systems are classified based on technical components of the system and the capability of the detection by which the energy reflected by the terrain features is recorded. The classification scheme is

  (a) Multispectral imaging sensor systems

  (b) Thermal remote sensing systems, and

  (c) Microwave radar sensing systems.

Multispectral Imaging Sensor Systems

- In the case of multiband photographic system, different parts of the spectrum are sensed with different film-filter combinations.
- Multiband digital camera images and video images are also typically exposed on to the camera's sensor (s) through different filters.
- Electro-optical sensors, such as, the thematic mapper of Land sat, typically sense in at least several bands of electromagnetic spectrum.

Two Types of Multispectral Imaging Sensor System

The Photographic System - Suffers from one major defect of considerable distortion at the edges. This is due to large lens opening. From lens theory, we know that distortion can be minimized and resolution considerably improved by using a narrow beam light. This can be achieved by a system called scanning system.

A Multispectral Scanner - Operate on the same Principle of a sensing in multiple spectral bands, but such instruments can sense in many more bands and over a greater range of electromagnetic spectrum.

Multi-spectral images are acquired by means of two basic process across-track and along track scanning. Multispectral scanner systems built up two dimensional images Of terrain for swath beneath the platform.

Second type of multispectral scanning system is along track scanning system.

Thermal Sensing Systems

Thermal scanner is one of the most important thermal sensing systems, a particular kind of across track multispectral scanner which senses in the thermal portion of Electromagnetic spectrum by means of inbuilt detectors. These systems are restricted to Operating in either **3 to 5 µm or 8 to 14** µm range of wavelength.

Microwave Imaging System

The fundamental principle of microwave sensing and conceptual design of radar.
It is stated that microwave region of the electromagnetic spectrum includes radiation with wavelength longer than 1mm, imaging.

Microwave instruments do not, however, rely on the detection of solar or terrestrial emissions. The properties of the operational synthetic aperture radar (SAR) systems and Radarsat systems
are presented along with other sensing systems

LATEST TRENDS IN REMOTE SENSING PLATFORMS OR SENSORS

Since the launching of high resolution IKONOS satellites series, number of high resolution Satellite have been launched. The important among them are

1) Quick Bird
2) Cartosat-1
3) Resourcesat-1

Quick Bird

Quick bird- Quick bird was launched on 18th October 2001. This is currently the highest Resolution commercial satellite data available

Quick bird acquires 61 cm(2 foot) resolution Panchromatic (Black & white) and 2.44 mt (8 foot) multispectral imagery.

At 61 cm resolution, buildings, roads, bridges and other detailed infrastructure became Visible.

Quick Bird

Cartosat-1

Cartosat-1 was successfully launched by the ninth flight of ISRO polar satellite launch Vehicle. The CARTOSAT carries two panchromatic cameras that take black and white Stereoscopic pictures in the visible region of electromagnetic spectrum. The imageries have a Spatial resolution of 2.5 mt and cover a swath of 30 km

Resourcesat-1

Resourcesat-1 is conceptualized and designed to provide continuity in operational remote sensing with its superior capabilities and Its objectives is to provide continued remote sensing data for integrated land and water
Management and agricultural and its related applications.

IRS SATELLITES

Table 1. Major specifications of present IRS series of satellites

Satellites (year)	Sensor	Spectral bands (μm)	Spatial res. (m)	Swath (km)	Radiometric res. (bits)	Repeat cycle (days)
IRS-1A/1B	LISS I	0.45–0.52 (B)	72.5	148	7	22
(1988, 1991)		0.52–0.59 (G)				
		0.62–0.68 (R)				
		0.77–0.86 (NIR)				
	LISS-II	Same as LISS-I	36.25	74	7	22
IRS-P2 (1994)	LISS-II	Same as LISS-I	36.25	74	7	24
IRS-1C/1D	LISS-III	0.52–0.59 (G),	23.5	141		
(1995, 1997)		0.62–0.68 (R)				
		0.77–0.86 (NIR)			7	24
		1.55–1.70 (SWIR)	70.5 (SWIR)	148		
	WiFS	0.62–0.68 (R)	188	810	7	24 (5)
		0.77–0.86 (NIR)				
	PAN	0.50–0.75	5.8	70	6	24 (5)
IRS-P3 (1996)	MOS-A	0.755–0.768(4 bands)	1570 × 1400	195	16	24
	MOS-B	0.408–1.010(13 bands)	520 × 520	200	16	24
	MOS-C	1.6 (1 band)	520 × 640	192	16	24
	WiFS	0.62–0.68 (R)	188	810	7	5
		0.77–0.86 (NIR)				
		1.55–1.70 (SWIR)				
IRS-P4 (1999)	OCM	0.402–0.885 (8 bands)	360 × 236	1420	12	2
	MSMR	6.6, 10.65, 18, 21 GHz	150, 75, 50 and	1360	–	2
		(V & H)	50 km respectively			
IRS-P6 (2003)	LISS-IV	0.52–0.59 (G)				
		0.62–0.68 (R)				
		0.77–0.86 (NIR)	5.8	70	10 (7)	24 (5)
	LISS-III	0.52–0.59 (G),				
		0.62–0.68 (R)	23.5	141	7	24
		0.77–0.86 (NIR)				
		1.55–1.70 (SWIR)				
	AWiFS	0.52–0.59 (G),				
		0.62–0.68 (R)	56	737	10	24(5)
		0.77–0.86 (NIR)				
		1.55–1.70 (SWIR)				
IRS-P5 (Cartosat-1) 2005	PAN (Fore (+26°) & Aft (–5°)	0.50–0.85	2.5	30	10	5
Cartosat-2 (2007)	PAN	0.50–0.85	0.8	9.6	10	5

DATA INTERPRETATION AND VISUAL INTERPRETATION TECHNIQUES

Remote sensing is the process of Remote and measuring objects
from a distance without directly coming physically into contact with them.

Visual image interpretation is process of identifying what we see on the images and communicate the information obtained from these images to others for evaluating this significance.

It is not restricted to making decision concerning what objects appear in images, but it also usually includes a determination of their relative locations and extents.

Levels of Interpretation Key

The image interpretation process can involve various levels of complexity from a simple Direct recognition of objects in the scene to the inference of site conditions.

An example of this can be a national highway or a major river on the national highway or a Major river on the satellite imagery, most particularly on a false color composite

If the interpreter has some experience , the interpretation of their linear feature, road And river may be straight forward.

For example interpretation of a IRS LISS III false color composite imagery for the Identification of 18 km pipeline from patanchruvu to Amberpet of Hyderabad city which carries the industrial effluents is an indirect approach.

In this case the actual pipelines can not be seen, but there are often changes at the ground surface caused by the buried pipeline which are visible on FCC.

The process of interpretation should also consider the dates to identify the ground Cover types.

Keys that provide useful references of refresher materials and valuable training aids for Interpreters are called image interpretation keys

There are two types of keys: **selective key** and **elimination key.**

The **selective is also called reference key** which contains numerous example images With supporting text.

The elimination key is arranged so that the interpretation process step by step from General to the specific, and leads to the elimination of all the features.

Basic Elements of Image Interpretation

A systematic study of aerial photographs and satellite imageries usually involves several characteristics of features shown on an image.

(i) Tone
(ii) Texture
(iii) Association
(iv) Shape
(v) Size
(vi) Shadow
(vii) Site Factor or topographic Location
(viii) Pattern

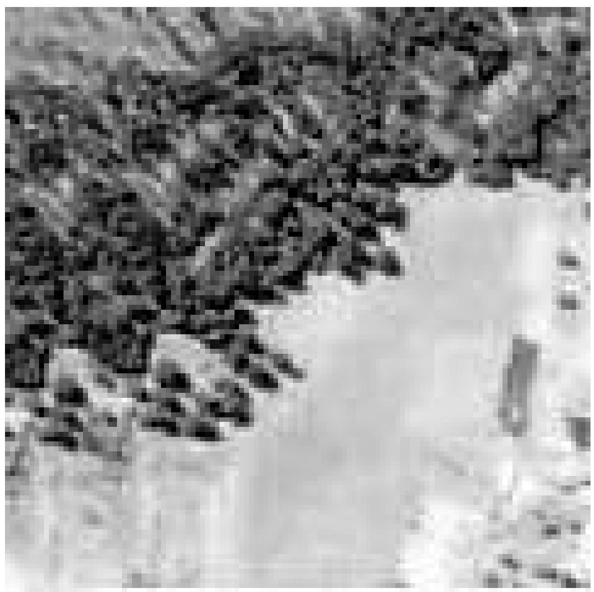
1. **Tone** refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features.

2. **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.

3. **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.

4. 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.

5. **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.

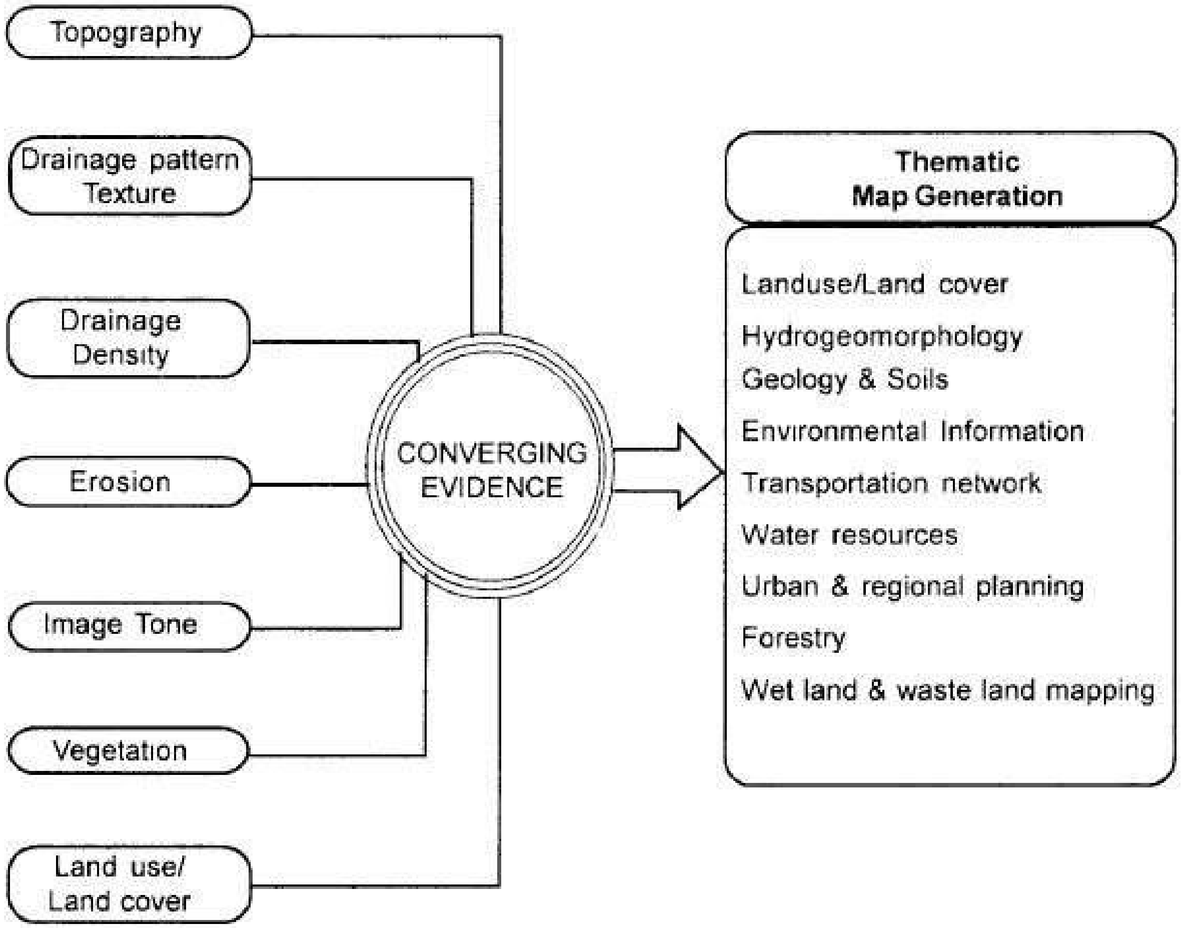


6. **Shadow** is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less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

7. 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.

CONCEPT OF CONVERGING EVIDENCE

- Terrain information can be derived from the visual image interpretation of aerial or space Image through the identification, evaluation and analysis of all the key elements.
- This image interpretation process is like the work of a detective trying to put all the pieces of evidence together to solve a mystery.
- Information derived through the analysis of the above key terrain elements can be converged and by combining all the evidences of image element identification, the inferences can be drawn.
- The inferences will be useful for GIS data input, manipulation and analysis. The process of converging the description of all the interpreted results or information's of these key elements is called "convergence evidence"


Topography
Drainage pattern Texture
Drainage Density
Erosion
Image Tone
Vegetation
Land use/ Land cover
CONVERGING EVIDENCE
Thematic Map Generation
Landuse/Land cover
Hydrogeomorphology
Geology & Soils
Environmental Information
Transportation network
Water resources
Urban & regional planning
Forestry
Wet land & waste land mapping

INTERPRETATION OF TERRAIN EVALUATION

The study of terrain is essential and a prerequisite for proper planning and utilization
of land resources .

The purpose could be short term military requirement for certain localized zones. The aim of terrain study is to gather maximum and systematic information on various aspects of the ground so that proper evaluation of this information can be done to meet the requirements of different users.

The detailed method of terrain study s as follows.

Area of Study

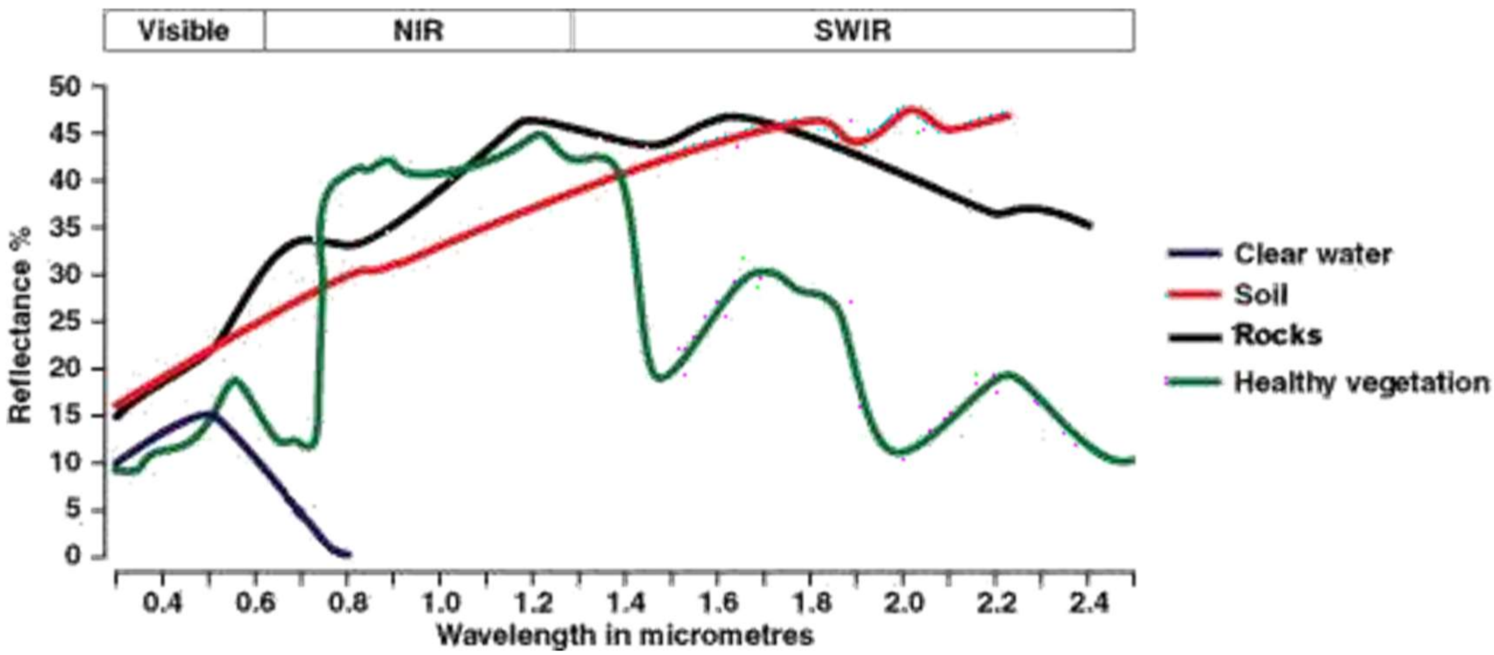
1) **Library work**: collection of basic material and background information
2) **Laboratory Exercise**: Scanning of Air photos, checking of quality , scale etc..
3) **Ground Reconnaissance** : Initial Field Traverses
4) **Study of Aerial Photos**: Delineation of facets and planning of field work
5) **Detailed field work:** checking of photo characteristics, recording terrain data, collecting soils samples field tests for moisture content and soil strengths

6) Laboratory Test : Soil test, rock identification
7) Completion of Reports: confirmatory reconnaissance if required finalization of report, Typing of cards and preparation of maps.

The recognition elements uses for photo interpretation aids to describe different terrain Units are:

(1) Position in landscape and association with other terrain units.
(2) Morphology, surface configuration and micro relief.
(3) Drainage pattern, texture and density, internal and external drainage.
(4) Erosion features and gully sections
(5) Land use and cultural features.
(6) Vegetation
(7) Total variation and special photo texture

SPECTRAL PROPERTIES OF SOIL, WATER AND VEGETATION



Vigorous Vegetation: Spectral reflectance curves for vigorous vegetation manifests the peak and valley configuration. The valleys in the visible portion of the spectrum are indicative of pigments in plant leaves.

Dip in reflectance that can be seen at wavelengths of 0.65 **µm, 1.4 and 1.9µm** are attributes to absorption of water by leaves.

Soil: The soil curve shows a more regular variation of reflectance. Factors that evidently affect soil reflectance are moisture content, soil texture, surface roughness, and presence of organic matter. The term spectral signatures can also b used for spectral reflectance curves.

Water: The characteristic spectral reflectance curve for water shows that about 0.5**µm,** a reduction in reflectance with increasing wavelength, so that in the near infrared range, the reflectance of water significantly affected by the presence of dissolved suspended Organic and inorganic material and depth of water body shows the spectral reflectance Curves for visible and near infrared wavelengths at the surface and at 20m depth

CONCEPTS OF DIGITAL IMAGE PROCESSING

The basic character of digital image data through the image appears to be continuous tone photograph. It is composed of the two dimensional array of discrete picture elements or pixels.

The intensity of each pixel corresponds to the average brightness or radiance measured electronically over the ground area corresponding to each pixel.

A digital image is defined as the matrix of digital numbers (DNs). Each digital number is the output of the process of analog to digital conversion.

Each parcel of land can be represented as a pixel on the image and each pixel is occupied by a digital number and is called pixel value or digital number shows the radiometric resolution of remote sensing data.

Image qualitative and quantitative Analysis

- Preprocessing
- Image Registration
- Image Enhancement
- Image Classification and Analysis

Pre-processing

• Remotely sensed raw data, received from imaging sensor mounted on satellite platforms generally contain flaws and deficiencies.

• The correction of deficiencies and removal of flaws present in the data through some methods are termed as pre-processing methods

• All pre-processing methods are considered under three heads, namely,

(i) Geometric correction

(ii) Radiometric correction and

(iii) Atmospheric correction

Geometric correction

The transformation of a remotely sensed image into a map with a scale and projection properties is called geometric correction.

S.No.	Effect	Source of error
1.	Platform	altitude, attitude, scan-skew mirror, scan velocity
2.	Scene effect	earth rotation, map projection
3.	Sensor effect	Mirror sweep
4.	Scene and sensor effect	panorama, perspective

Radiometric correction

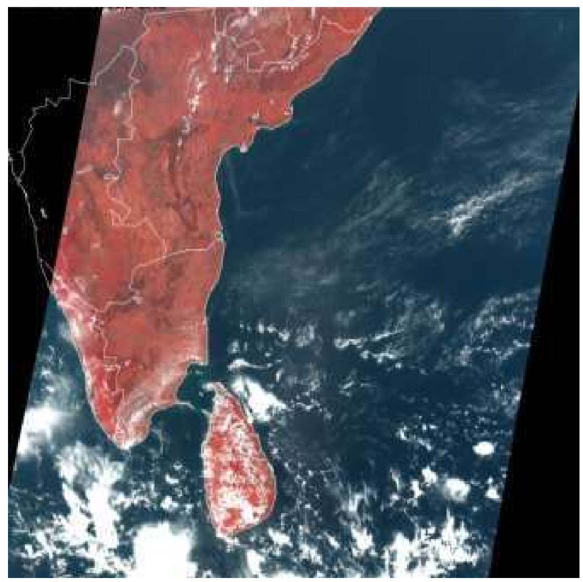
The radiance measured by any given system over a given object is influenced by factors, such as, changes in scene illumination, atmospheric conditions, viewing geometry and instrument response characteristics

Atmospheric correction

Because of the presence of haze, fog, or atmospheric scattering, there always exists some kind of unwanted signal value. These errors are called atmospheric corrections

Pre-processing operations, sometimes referred to as image restoration and rectification, are intended to correct for sensor- and platform-specific radiometric and geometric distortions of data. Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response. Each of these will vary depending on the specific sensor and platform used to acquire the data and the conditions during data acquisition. Also, it may be desirable to convert and/or calibrate the data to known (absolute) radiation or reflectance units to facilitate comparison between data.

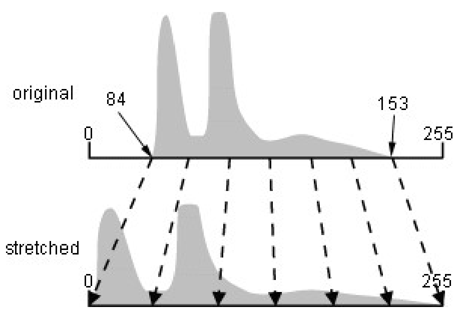
Before

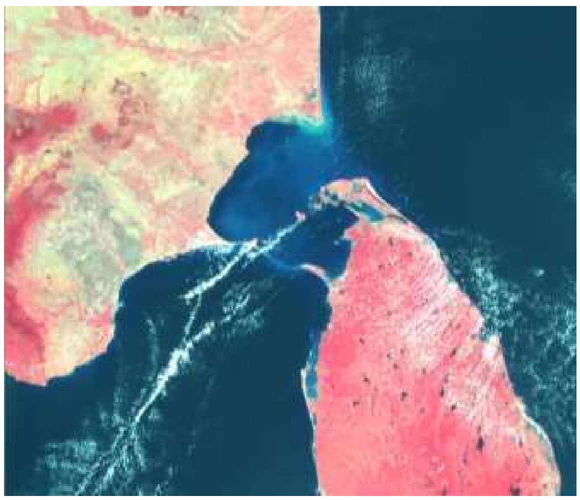


After

Image Enhancement

In raw imagery, the useful data often populates only a small portion of the available range of digital values (commonly 8 bits or 256 levels). Contrast enhancement involves changing the original values so that more of the available range is used, thereby increasing the contrast between targets and their backgrounds. The key to understanding contrast enhancements is to understand the concept of an **image histogram**. A histogram is a graphical representation of the brightness values that comprise an image. The brightness values (i.e. 0-255) are displayed along the x-axis of the graph. The frequency of occurrence of each of these values in the image is shown on the y-axis.



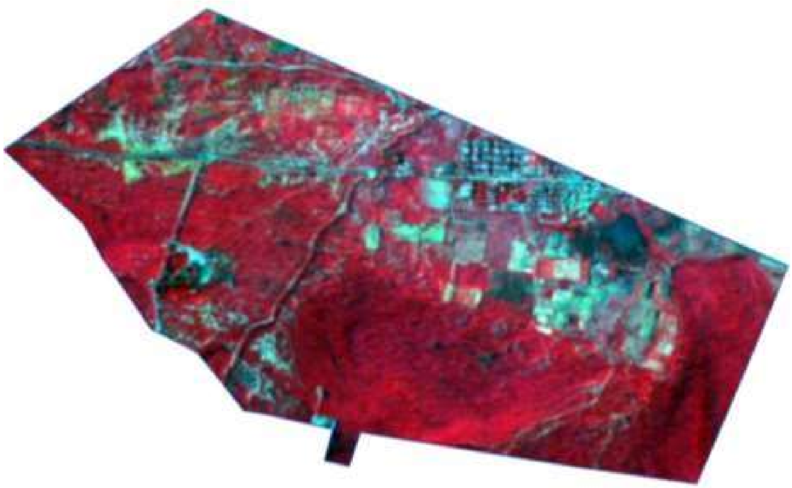


Before

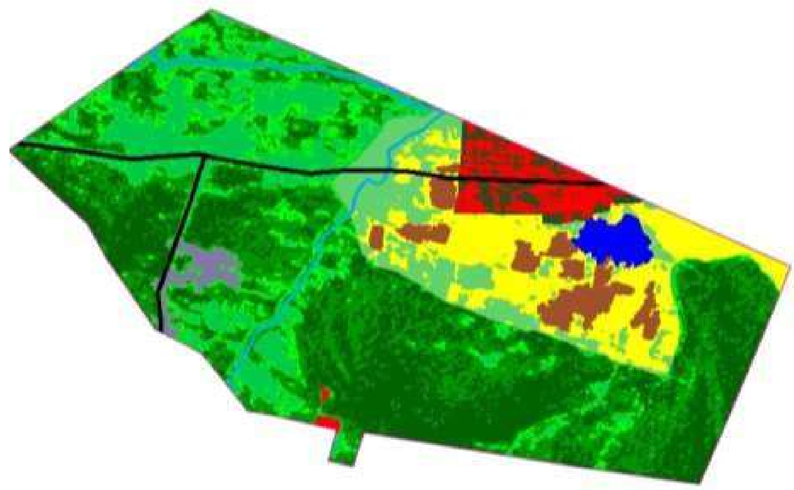
After

/.Image Classification and Analysis

Digital image classification uses the spectral information represented by the digital numbers in one or more spectral bands, and attempts to classify each individual pixel based on this spectral information. This type of classification is termed **spectral pattern recognition**.



FCC



Classified

CLASSIFICATION TECHNIQUES AND ACCURACY ESTIMATION

Image classification is a procedure to automatically categorize all pixels in an image of terrain into land cover classes.
Normally, multispectral data are used to perform the classification of spectral pattern present within the data of each pixel is used as the numerical bases for categorization.

The concept is dealt under the broad subject namely, pattern recognition.

Spectral pattern recognition involves the categorization of image pixel on the basis of the spatial relationship with pixels surrounding them.

Image classification techniques are grouped into two types, namely Supervised and Unsupervised.

The classification process may also include features, such as land surface elevation and soil types that are not derived from the image.

1) Supervised Classification: A supervised classification algorithm requires a training Sample for each class, that is collection of data point known to have come from the class of interest.

The three basic steps involved in a typical supervised classification procedure are follows

1) **Training Stage**: The analyst identifies representative training areas and develops numerical description of the spectral signatures of each land cover types

ii) **Classification Stage**: Each pixel in the image data set is categorized into the land cover classes if the pixel is insufficiently similar to any training data set usually labeled unknown.

iii) **The Output stage**: results may be used in number of different ways.

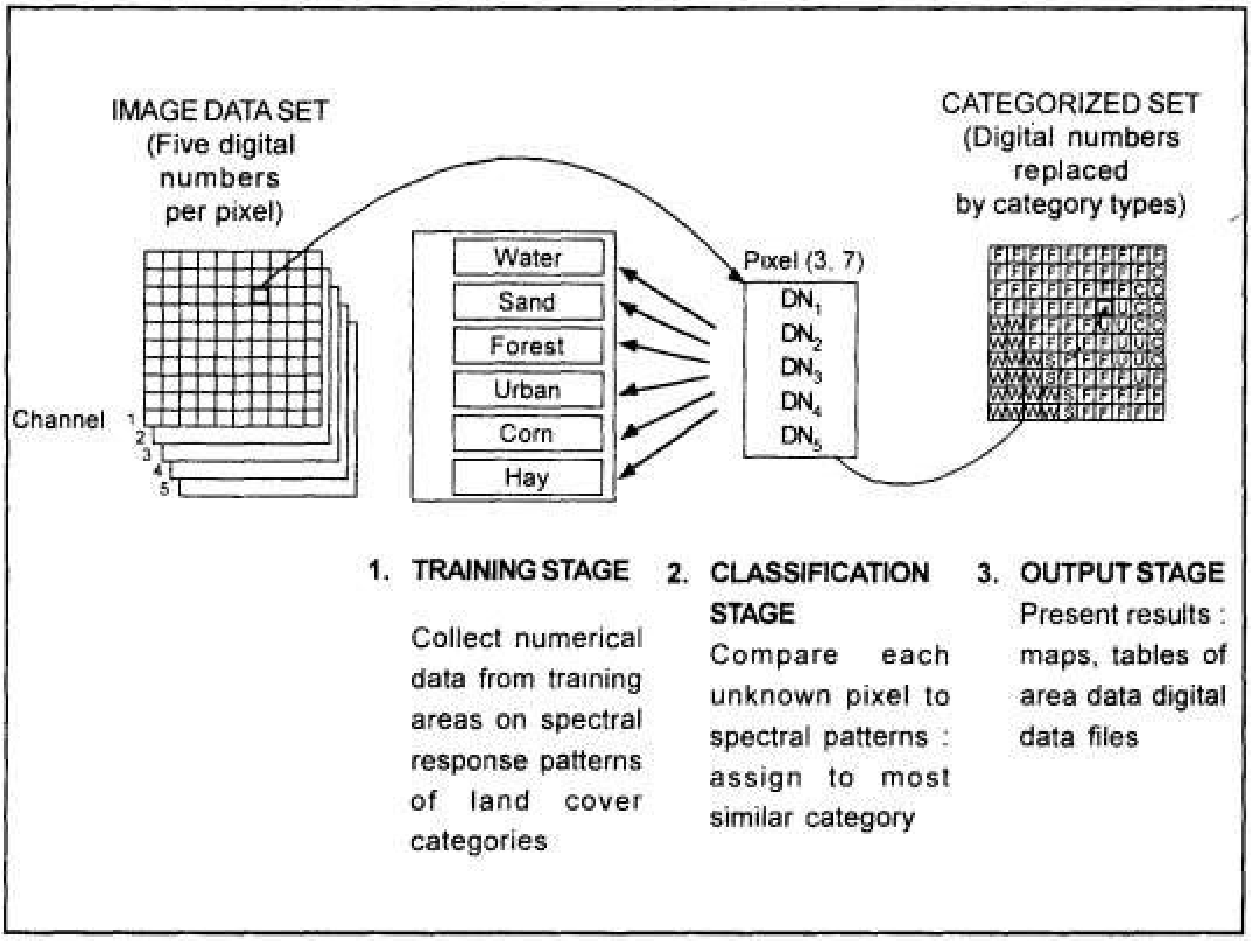


Fig. 6.23 Basic steps supervised classification.

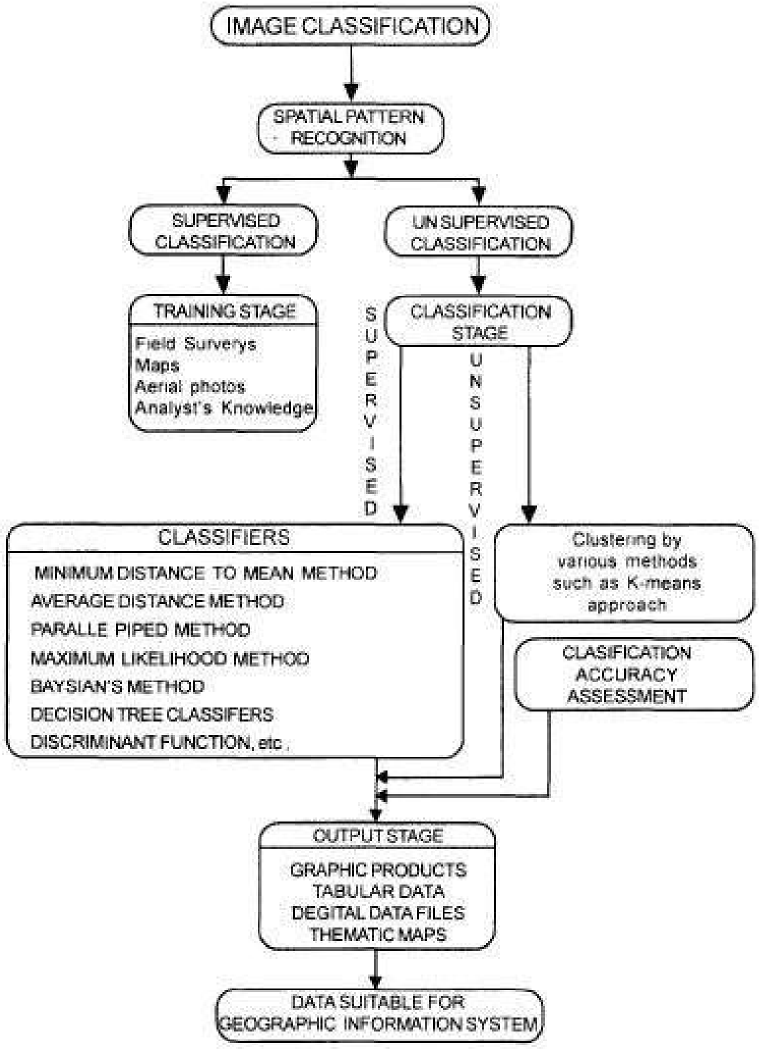


IMAGE CLASSIFICATION
SPATIAL PATTERN RECOGNITION
SUPERVISED CLASSIFICATION
UN SUPERVISED CLASSIFICATION
TRAINING STAGE
Field Surverys
Maps
Aerial photos
Analyst's Knowledge
SUPERVISED
CLASSIFICATION STAGE
UNSUPERVISED
CLASSIFIERS
MINIMUM DISTANCE TO MEAN METHOD
AVERAGE DISTANCE METHOD
PARALLE PIPED METHOD
MAXIMUM LIKELIHOOD METHOD
BAYSIAN'S METHOD
DECISION TREE CLASSIFERS
DISCRIMINANT FUNCTION, etc ,
Clustering by various methods such as K-means approach
CLASIFICATION ACCURACY ASSESSMENT
OUTPUT STAGE
GRAPHIC PRODUCTS
TABULAR DATA
DEGITAL DATA FILES
THEMATIC MAPS
DATA SUITABLE FOR GEOGRAPHIC INFORMATION SYSTEM

2) Unsupervised Classification: Unsupervised classification algorithms do not compare point To be classified with training data. Rather, unsupervised algorithms examine a large number of unknown data vectors and divide the into classes based on properties inherent to the data themselves.