REMOTE SENSING AND GIS

by

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DEFINITION OF REMOTE SENSING

- Remote Sensing is an application of photogrammetry in which imagery is acquired with a sensor, other than (or in addition to), a conventional camera through which a scene is recorded, such as by electronic scanning, using radiations outside the normal visual range of the film and camera – microwave, thermal infrared, ultraviolet as well as multispectral. Special techniques are applied to process and interpret remote sensing imagery for the purpose of producing conventional maps, thematic maps, resource surveys and so on, in the fields of agriculture, archaeology, forestry, geography, geology and others.

REMOTE SENSING IS AN APPLICATION OF PHOTOGRAMMETRY

- In which imagery is acquired with a sensor, other than (or in addition to), a conventional camera through which a scene is recorded, such as by electronic scanning, using radiations outside the normal visual range of the film and camera – microwave, thermal infrared, ultra violet as well as multi spectral.

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- Photogrammetry The art and science of technology of taking relative measurements on photographs about physical objects and environment. These measurements are obtained by Interpretation of photographic images.

- In 1839, Aerial photography-Topographic surveying – (1840) North America by Captain Deville, the surveyor general of Canada. In 1902, Invention of aeroplane by Wright-Brothers led to advanced aerial photography.

- Photo-Interpretation "The art of examing the photographic images of objects for the purpose of identifying those objects and deducing their significance".

- Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation.

  (e.g.) Human sight, smell and Hearing.

  Recognization of words – Remote sensing.

- Remote sensing of earth resources encompasses all information above or below the Earth, collected from a distance, such as aerial photographs, satellite images etc..

- Remote sensing Images, obtained from the orbiting satellites are capable of providing quantitative as well as qualitative information about objects.

- 1950 – Started. But in 1960, Launching of – First US Meteorological satellite TIROS – 1.

TYPE OF REMOTE SENSING DATA

Aerial	Satellite
* Platform used: Aircraft	Satellite
*Data products: Black & White &Coloured	Black& White, FCC,CCT,CDs

Applications

Aerial satellite RS applications

- Agriculture
- Forestry, Snowfall
- Environmental studies
- Disaster management
- Oceanography
- Terrain Investigation
- LU/LC
- Soil
- SW &GW
- Geology & Geomorphology

- Forestry mapping
- Hydrology
- Res.Sedimentation
- River morphology
- Watershed conservation
- Flood estimation
- Geology Investigation
- Soil mapping
- LU/LC mapping
- Corp yield forecast

ADVANTAGES

1. Satellite images – permanent record, provide useful + in various wave bands
2. Large area coverage – regional surveys – of large features
3. Repetitive coverage allows monitoring of dynamic themes like water, agriculture, etc.
4. Easy data acquisition over inaccessible area.
5. Data acquisition @ different scales of resolutions
6. Single RS image – Different purposes of applications
7. Compatible to Computer – for processing
8. Lab analysis – Reducing the field work. (Cost effective)
9. Map revision @ moderate to small scales is economical and faster
10. Colour composites can be produced from 3 individual band images, which provide better details of the area than a single band image or aerial photograph.
11. Stereo – satellite data may be used for 3D- studies.

DISADVANTAGES

1. Expensive for small areas, particularly for one-time analysis.
2. Specialized training for analysis of images.
3. Interpretation equipments, for digital Interpretation, is costly.

With the advent of different type of sensor systems, the range of data products that are now available for mapping purposes, besides conventional photographs, has increased. These products are listed bellow:

1. Space photographs: These include metric & non metric, black & white, colour & infrared (dia positives & negatives) mosaics and ortho – photographs.

2. Satellite images: These include LANDSAT MSS &TM,SPOT HRV,IRS LISS I, LISS II & LISS III, etc. dia positives & negatives, FCCs, stereo pair, computer compatible tapes, floppies and CDs

Basic physical principles of Remote sensing / Wave theory

In physical terms , RS is concerned with the Measurement and estimation of the variations in electromagnetic (EM) energy which occur when energy of this type interacts both with the earth's atmosphere & with the earth's surface.

The terms EM energy refers to all energy which travels in a periodic harmonic manner at the velocity of light using the well-known relationship.

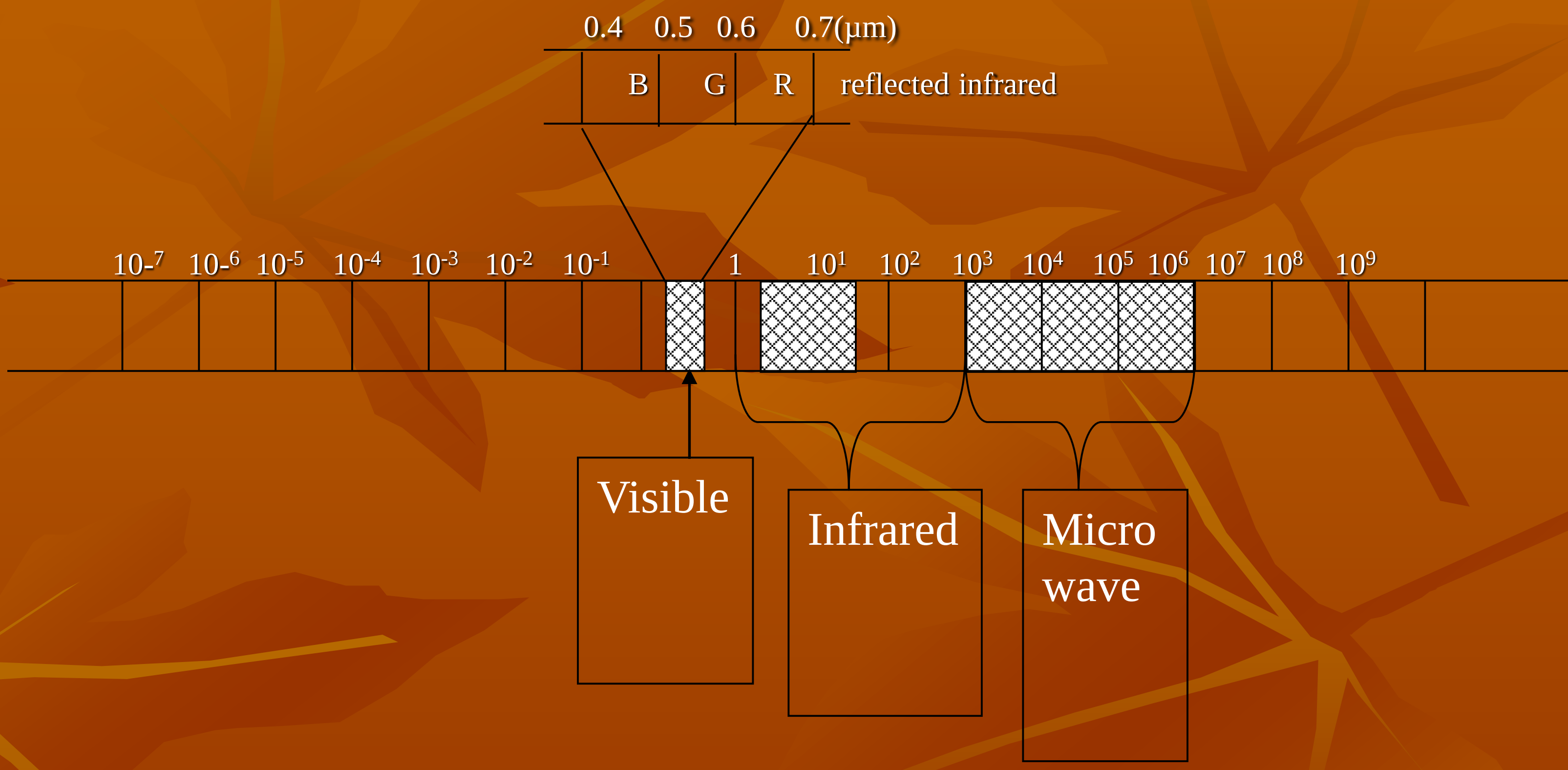
$$\lambda = c/f$$

Where λ is the wave length

f is the frequency

c is the velocity of EM energy

THE EM SPECTRUM



EM spectrum – Region of Interest of Spectral range for Remote Sensing

i) Visible - 0.36-0.79 µm @ 0.5 µm

ii) Infrared between visible and microwave region — Reflected IR / Thermal IR

iii) Microwave – 1mm (10^3 µm) – 1m (10^6 µm)

REFLECTED AND EMITTED EM ENERGY

Distinction between Reflected & emitted energy:

During daylight, the radiant energy from a scheme consists of 2 components

i) At wavelength upto about 3 µm, the energy is predominantly– reflected sunlight

*Human eyes & photographic film are sensitive to reflected energy with in this wavelength rays

ii) In contrast at longer wavelength (i.e) greater than about 3 µm the dominant type of radiation energy is that which is emitted by a body rather than that which is reflected.

(e.g.) Infrared region of the EMS

With in this region it is apparent that as the wavelength increase the emitted infrared component becomes progressively more sight perfected infrared – can not be sensed by photographic emulsion

STEFAN – BOLTZMANN LAW

It is possible to quantify the amount of energy a body is emitted by means of …………… Law which states that

$$W = C\varepsilon T^4$$

Where

W- is the Radiant emittance, watts m^{-2}

ε - is the emissitivity of the object

C - is the S – B constant equal to 5.7x10-8 watts m^{-2} k^{-4}

T - is the absolute temperature of the object (k)

Three significant conclusions may be drawn from this law:

I)The energy emitted from a body increases very rapidly with an increase in temperature. II) Emissivity (ε) of an object is defined as a factor which describes how efficiently an object radiates energy in comparison to a "black body" which has an emissivity value of one.

Emissivity is defined as

$$E(\lambda) = \frac{\text{Radiant emittance from an object @ a temperature}}{\text{Radiant emittance from a black body @ the same temp.}}$$

Where E (λ) represents the emissivity @ a particular Wave length value

Range of emissivity between 0 and 1

Table 1

Emissivity of a selection of materials

(Within the 8-14 μm W.L band)

Material		Ave. emissivity
Clay soil	-	0.98
Water	-	0.97
Sandy soil	-	0.88
Gravel	-	0.88
Buffled stainless steel	-	0.16

III It should be possible to infer indirectly the temperature of the body knowing the emissivity of the object.

This represents the basis of the technique of thermal infrared RS (Range: 3-14 μm)

WIEN'S DISPLACEMENT LAW

This law states that

$$\lambda max = \frac{2897}{T}$$

Where λ max = Wave length of max spectral emittance &

T = temperature (^{o}k)

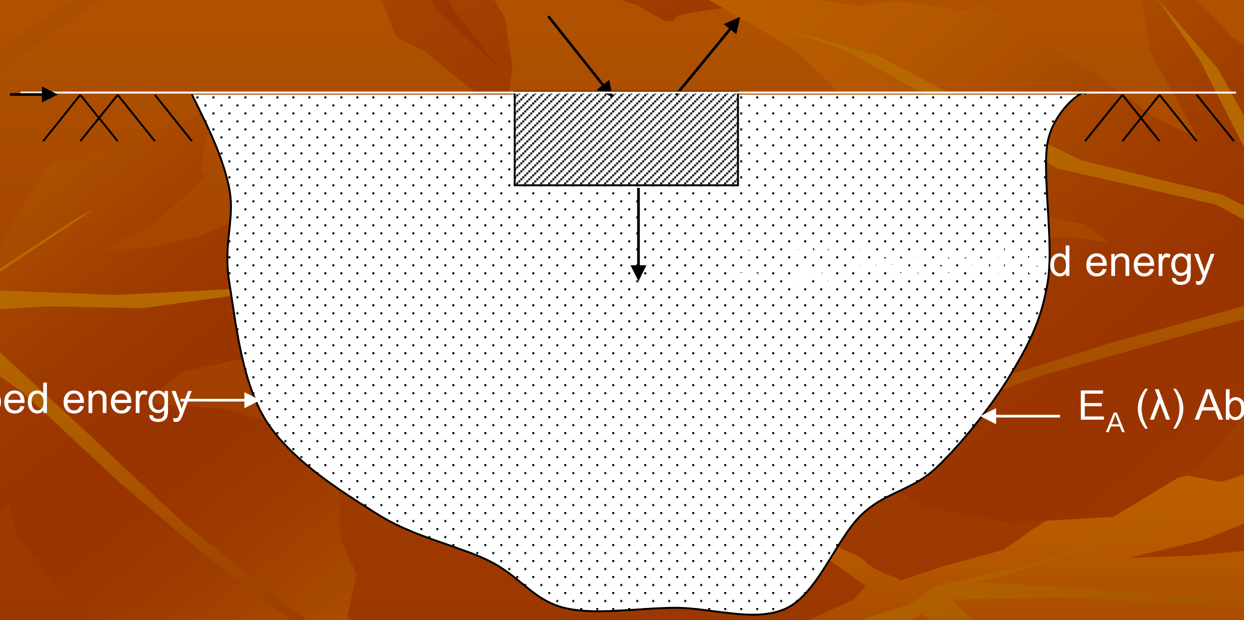
To quantity the wave length at which the maximum spectral emittance will occur

#This law explains the Wave length shift or displacement, which occurs in the values associated with the energy emitted from the sun (0.5 µm) and from the earth surface (9.7 µm)

PRINCIPLE OF CONSERVATION ENERGY

When EM energy is incident on the Earth's features , three fundamental energy interactions with the features are possible

EI (λ) Incident energy ER (λ) Reflected energy



E_A (λ) Absorbed energy

E_A (λ) Absorbed energy

Fig-Basic Interaction between EM energy & Earth surface features Applying the Principle of conservation of energy

$$EI(\lambda) = ER(\lambda)+EA(\lambda)+ET(\lambda)$$

The proportions of ER(λ), EA(λ) &ET (λ) will vary for different earth features depending on their physical & chemical characteristics conditions.

RS may be defined as a method, hereby information about the physical & chemical characteristics of objects can be obtained with the help of a sensor which records reflected EM energy from these objects.

An ideal Remote Sensing system may have the following components

1. Source of EM energy
2. Medium (eg) which interact with this energy(atmosphere)
3. Ground object
4. Sensor to detect & record the changes in EM energy.

ATMOSPHERIC WINDOWS

There are certain region of the EMS which can penetrate through without any significant loss of radiation. Such regions are called the Atmospheric Windows as shown in Fig.

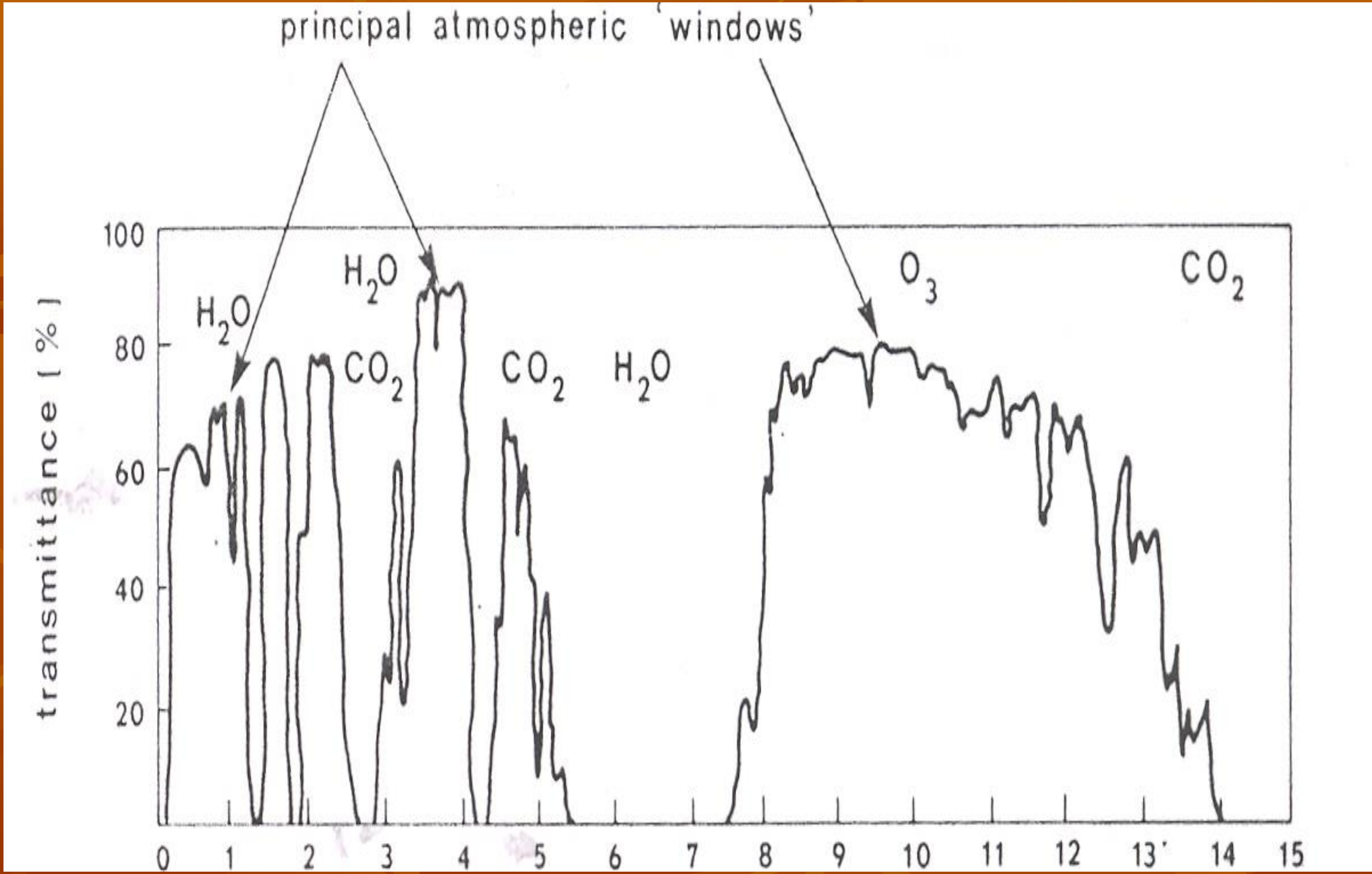
Fig. explains this concept in relative to the visible and infrared parts of the spectrum. In several regions, for example the visible the atmosphere is highly transmittance and consequently is almost totally free from the effects of absorption.

Regions with a high atmosphere transmittance are generally referred to as atmospheric windows.

It is important that RS Systems should operate within those portions of the EM spectrum which coincide with these atmospheric windows.

e.g.. Thermal Infra Red region: Wavelength region 3-14 µm, two Atmospheric windows exit.

1st is from 3-5.5 µm; II is from 8-14 µm


principal atmospheric 'windows'
transmittance [%]
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
H2O
H2O
CO2
CO2
H2O
O3
CO2

RADIATION & THE ATMOSPHERE

Atmospheric influence EM radiations in two respect

Scattering

This is caused primarily by the presence of molecules of gas + dust + smoke particles in the atmosphere

Absorption

Absorption of EM radiation occurs primarily the attenuating nature of molecules of ozone, Co_2 and water vapour in atmosphere. Because these gases absorb EM radiation in specific wave length bands, they govern which regions of spectrum can be sensed .

TYPES OF SCATTERING

Rayleigh scattering occurs in upper atmosphere, caused predominantly by the interaction of gas molecules which have diameters much less than the radiation λ. This is the main reason for the presents of haze on RS imaginary	Mie scattering (lower atmosphere) mainly a product of the interaction of dust and smoke particles with the EM signal	Non selective scattering when the particles of diameter greater than that of radiation wavelength. eg. Scattering by water droplets (dia ≈ 50 μm) as they interact with radiation within the visible spectrum λ ≈ 0.5 μm

Spectral signature:

- This ability to spectrally define a feature or surface is often referred to as defining the "Spectral signature" of the feature.
- This term implies that features are uniquely and absolutely defined by measuring this parameter.
- Quantitative measurement of the properties of an object at one or several wavelengths
- Black body Radiation A black body is hypothetical ideal radiation that absorbs and reemits all energy incident on it. A black body transforms heat energy into radiant energy at the maximum possible rate is termed as black body radiation. Eg. If the sun is a perfect emitter it would be an ideal black body.

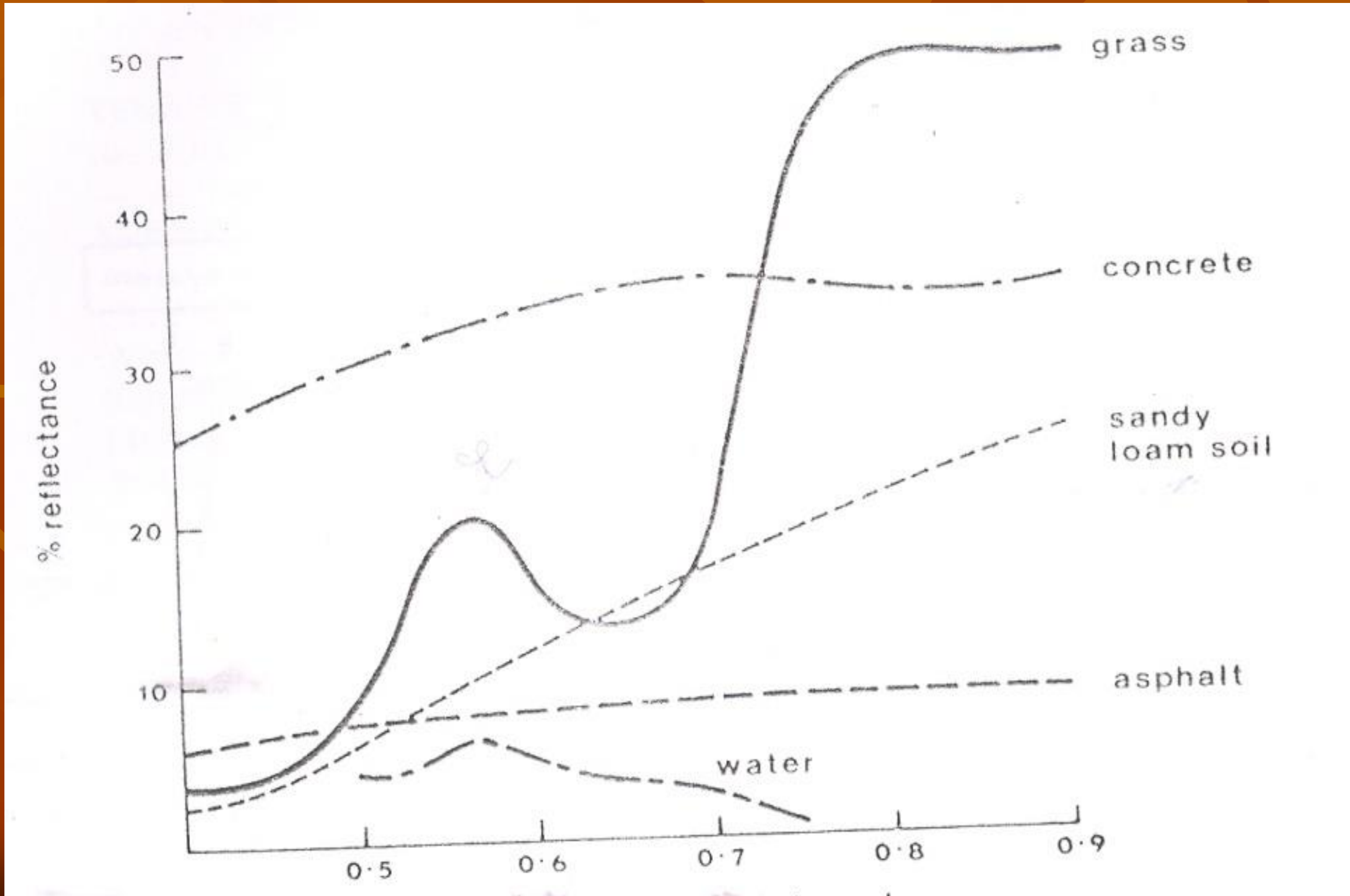
Planck's Law/ Partical theory: It explains the photo-electric effect. Planck's Law defines the spectral existance of a black body (Henderson, 1970)

Spectral reflectance patterns /characteristic reflectance of earth objects with EM spectrum

This can be quantified by measuring the proportion of energy reflected by the feature

- Certain surfaces (Grass) have considerably different reflectance characteristics in the visible & I/R regions of the spectrum. In contrast (Asphalt) has a relatively stable, low reflectance in both regions.
- Most appropriate regions of the spectrum for differentiating between the surfaces is the infrared. A clean hierarchy of reflectance exists from grass with a high reflectance through concrete sandy loam soil to asphalt & water which have a relatively low reflectance. In contrast in the blue/green region of the visible spectrum ($\lambda \sim 0.5\mu m$) the discrimination between asphalt & sandy loam soil surfaces is very poor

- This may indicate for (eg) that difficulty may arise in the interpretation of these surfaces from conventional aerial photography
- The graph again illustrates the very low reflectance of water surfaces in the I/R of the spectrum.



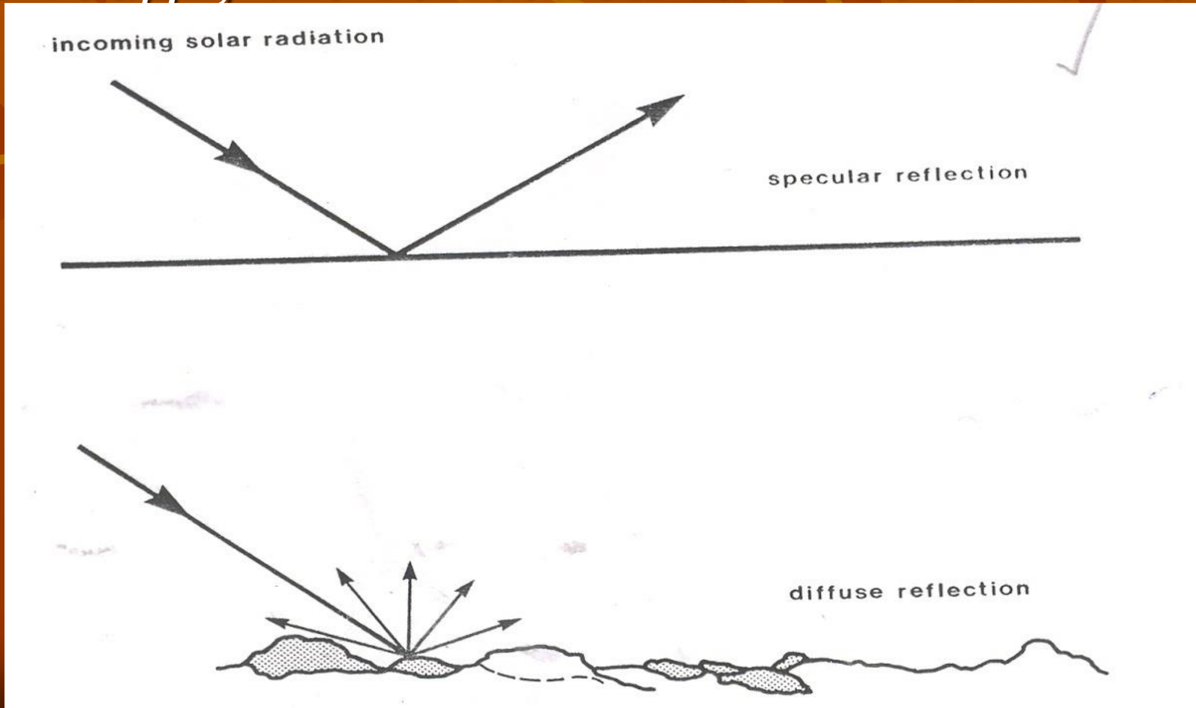
EM Radiation & the earth surface

- Specular & diffuse reflection & its relations to surface roughness.

- Some features may appear very different . when it is examined by sensors which are able to record reflectance or emittance outside the visible spectrum.
- For example, water surfaces appear black when imaged on to a photographic emulsion sensitive to reflected I/R radiation. Reason: Total absorption of I/R radiation by water. In contrast , viewing the same water surface with a photographic emulsion sensitive to the visible region of the spectrum may provide details about submerged features which may not have been sensed.
- Reflective properties of the terrain is the function of surface roughness.

Specular and Diffused Reflection of earth's objects

- The reflective properties of the terrain can be classified as being either Specular or Diffused.
- Reflective properties is a function of the surface roughness.
- When the surface is relatively smooth, specular reflection occurs.
- When the surface is rough, the reflection is more diffused as shown in figure.



Multispectral scanners (MSS)

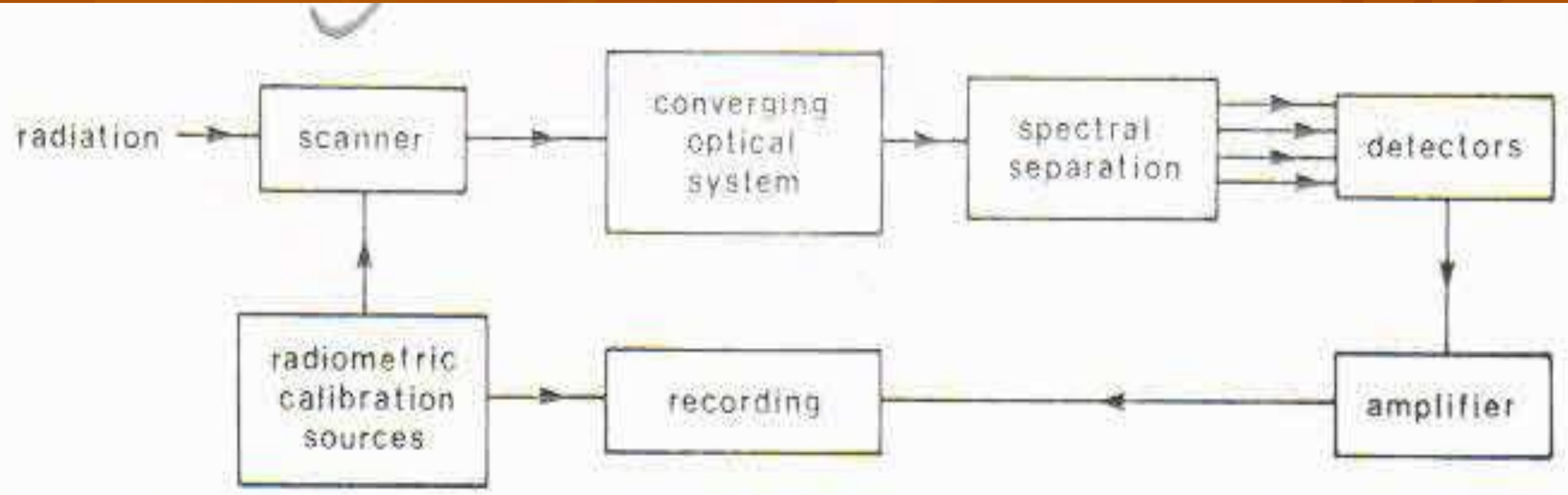


Figure 3.5 Components of a multispectral scanner system (adapted from Swain and Davis, 1978).

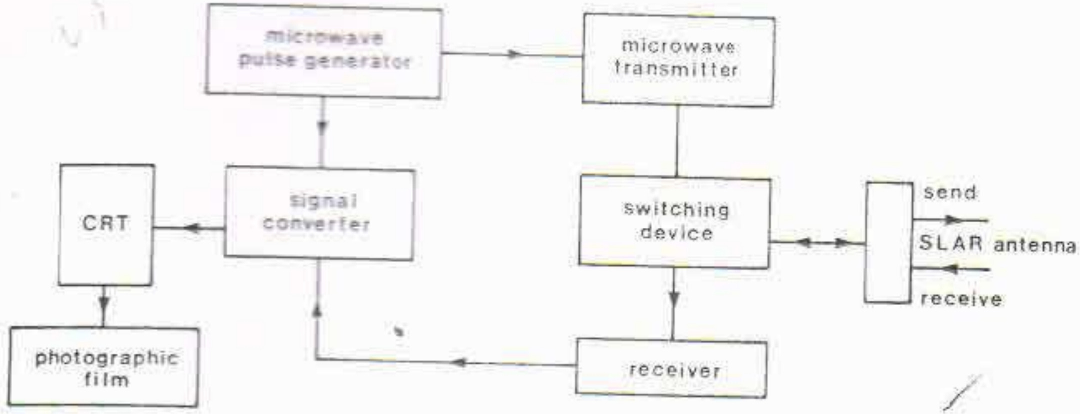
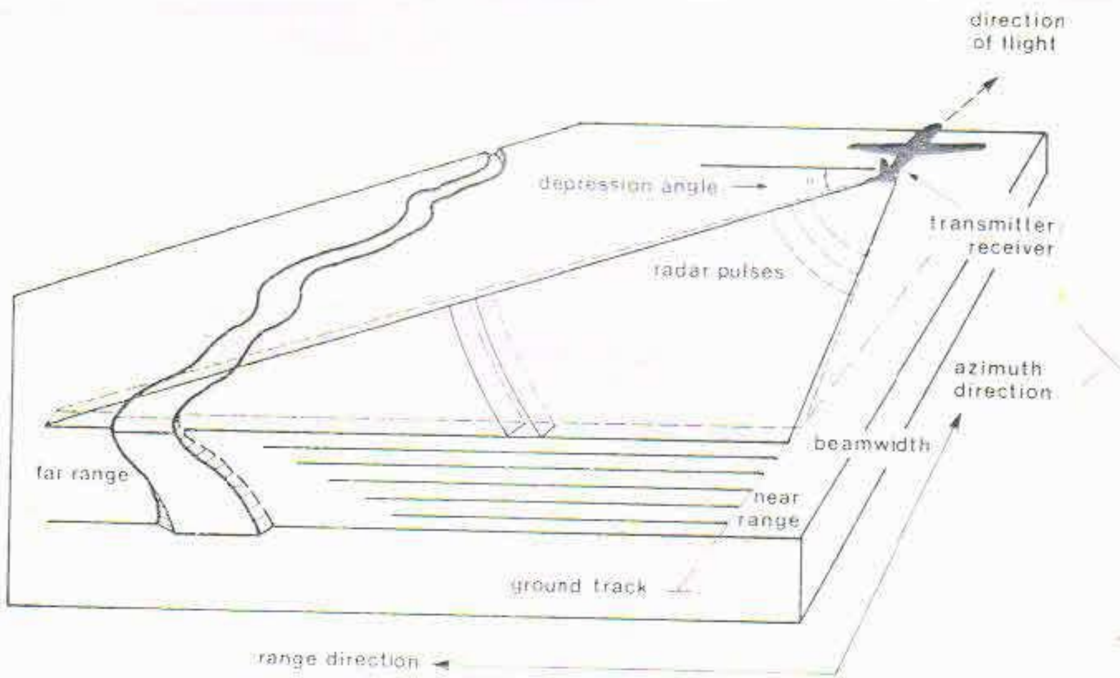


Figure 3.25 Components of a typical SLAR system.



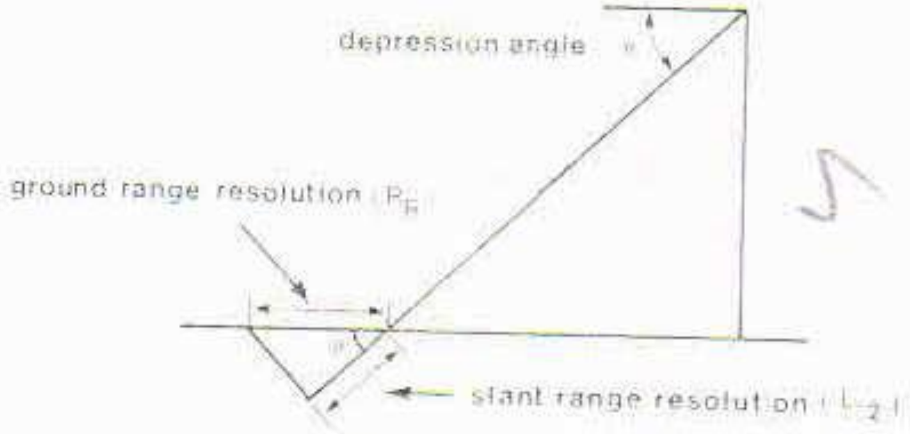


Figure 3.26 Geometry of a SLAR system.

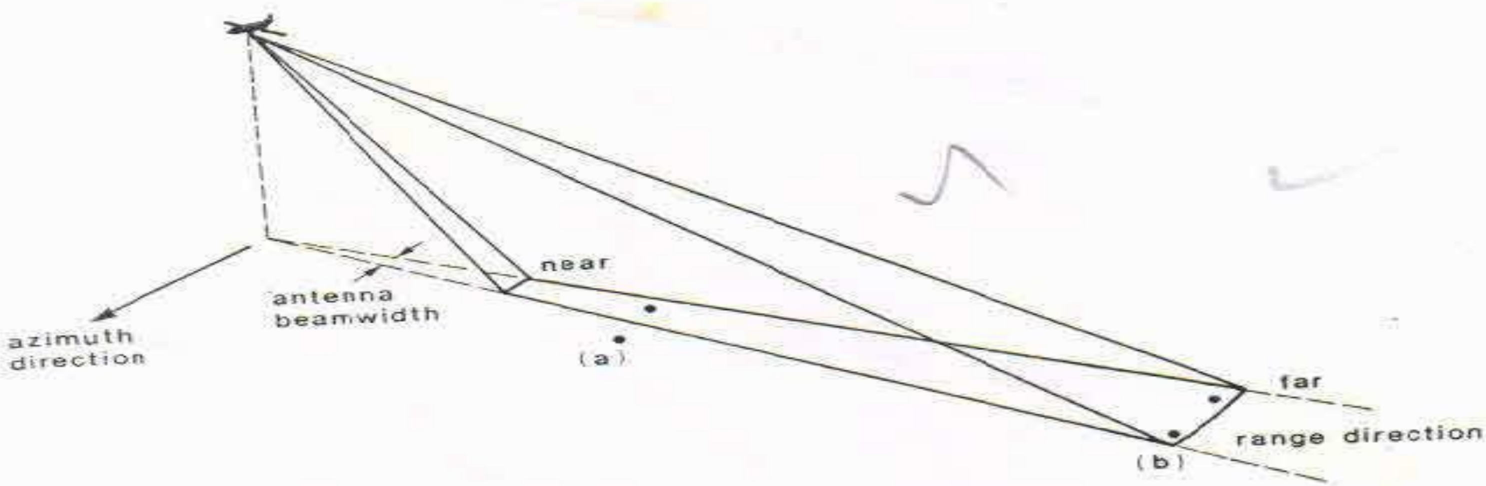


Figure 3.27 Azimuth resolution of a real aperture radar system. (Adapted from Lillesand and

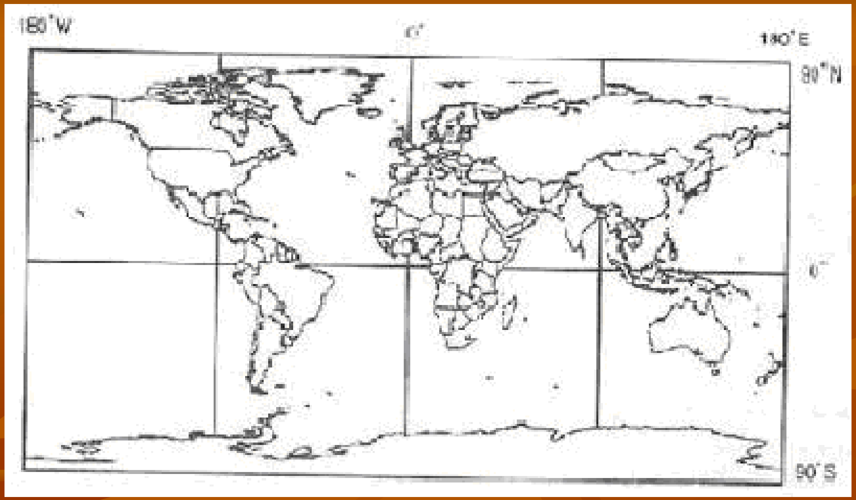


Figure 1. The Geographical Grid of the world

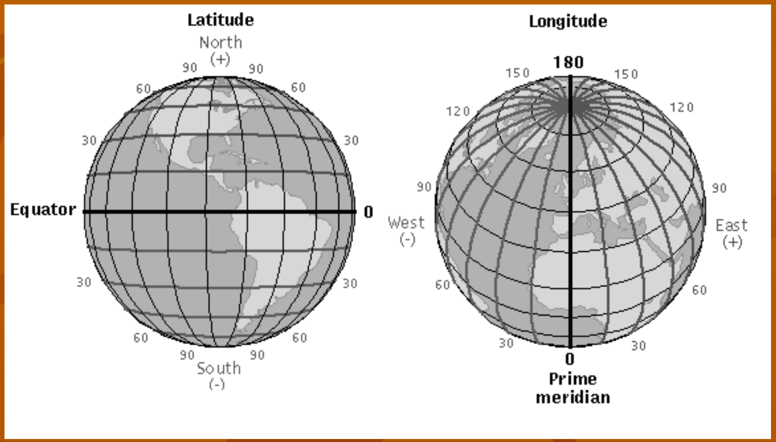


Figure 2. Geographic grid and coordinate systems of the globe

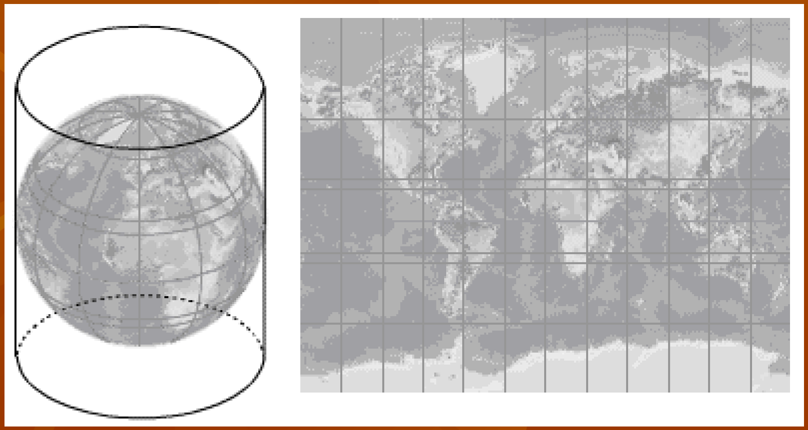


Figure 3. Cylindrical projection

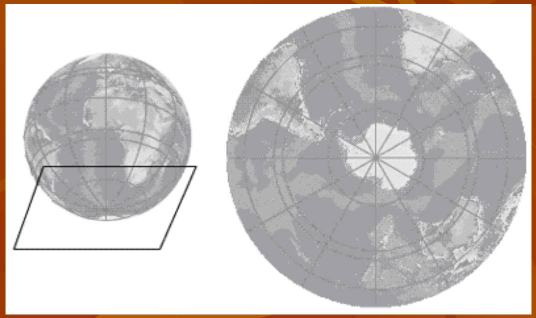


Figure 4. Azimuthal Projection

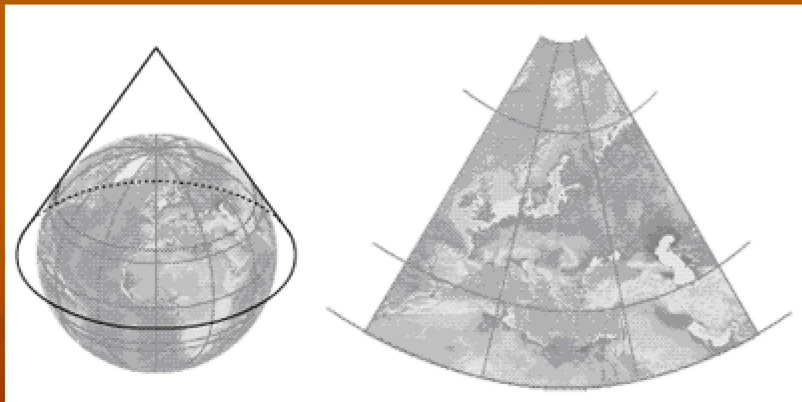


Figure 5. Conic Projection

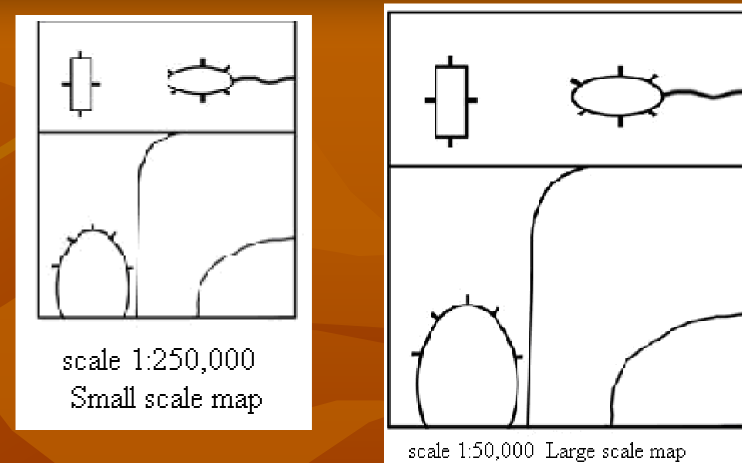


Figure 6. Effect of Map scale on earth features

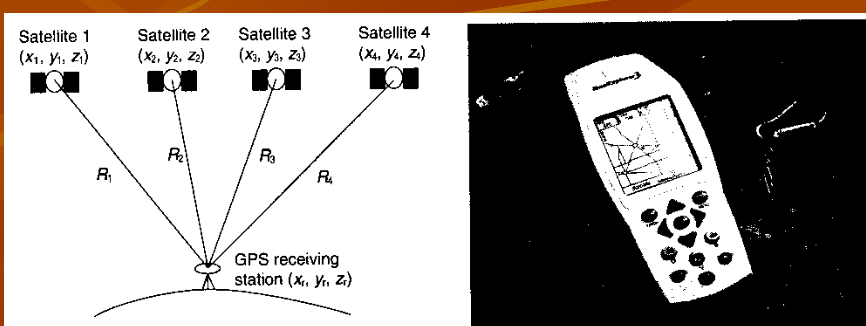
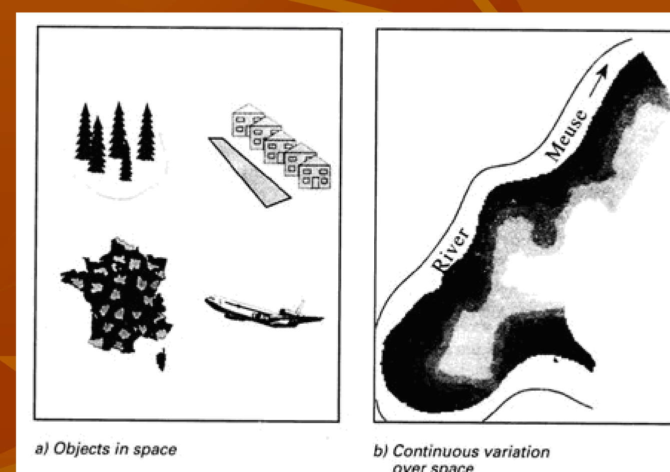


Figure 7. A Portable GPS Receiver



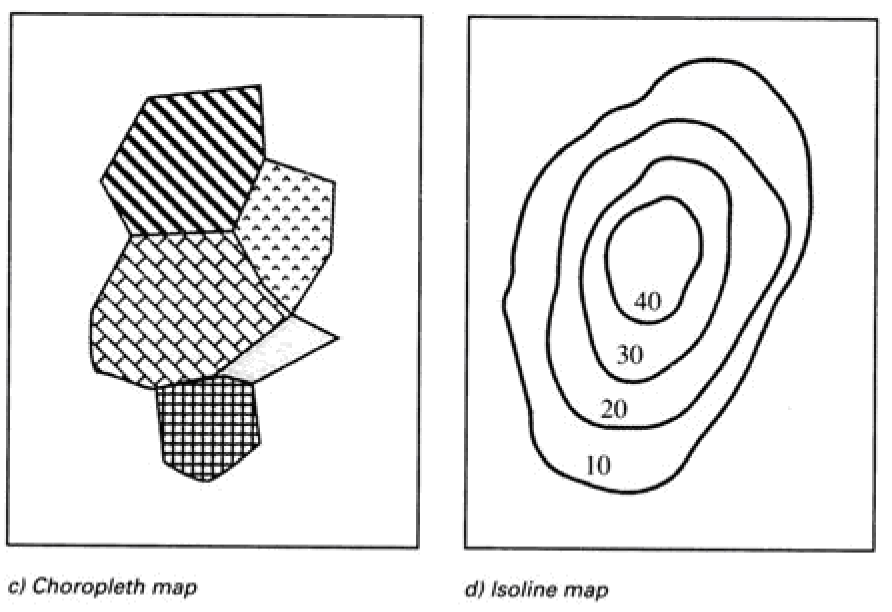


Figure 8. Conceptual models and representation of spatial phenomena

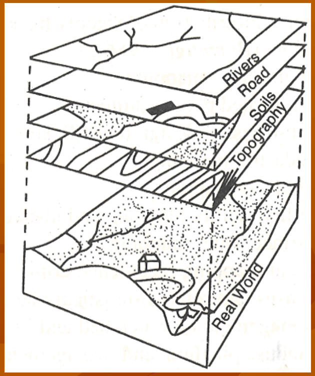


Figure 9. The overlay concept of the real world

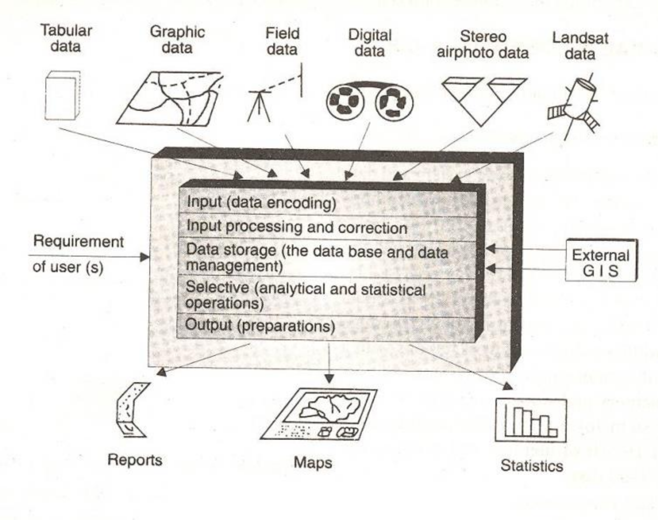


Figure 10. Various sub-systems of a GIS

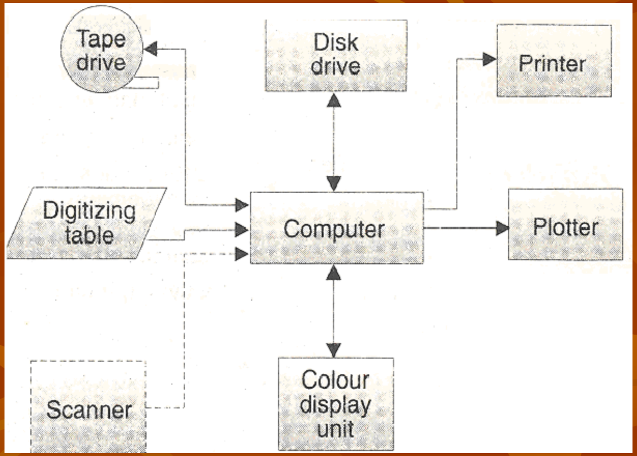


Figure 11. Major hardware components of a GIS

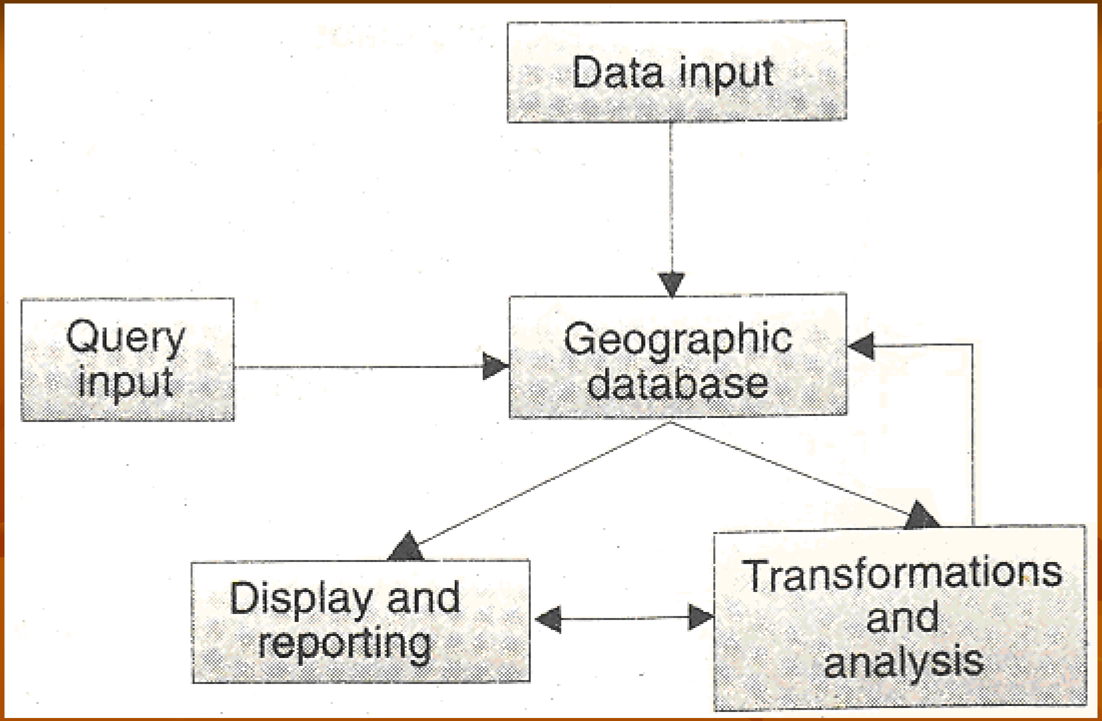


Figure 12. Major software components of a GIS

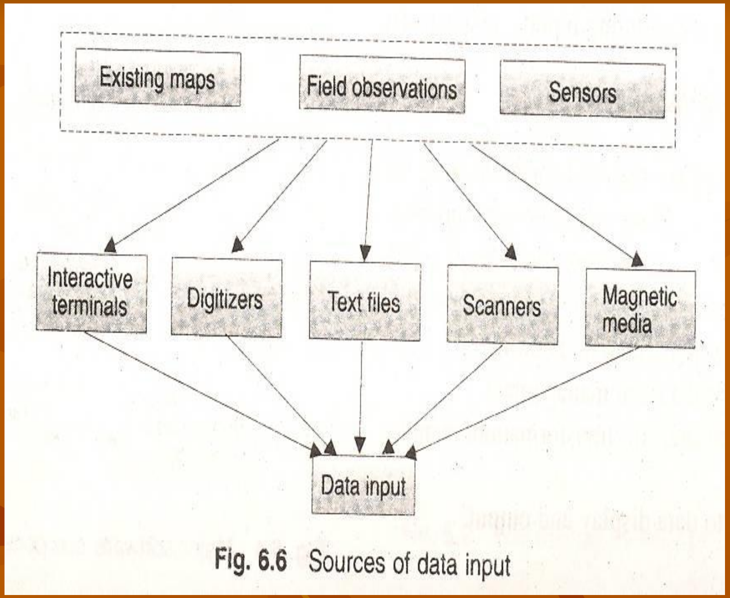


Figure 13. Sources of Input data

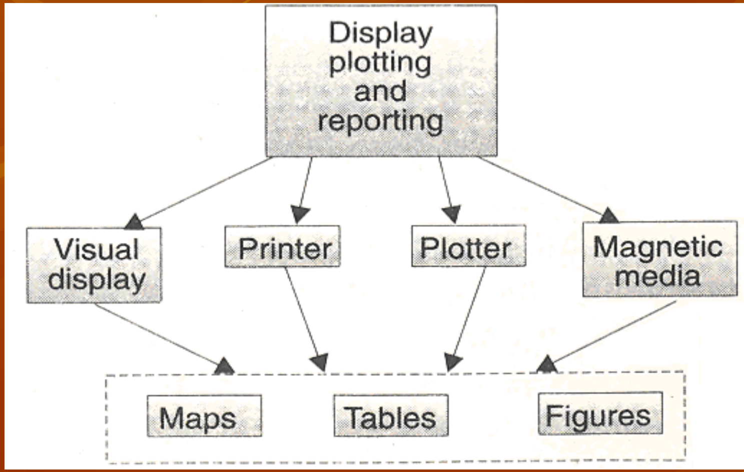


Figure 14. Output and presentation of data

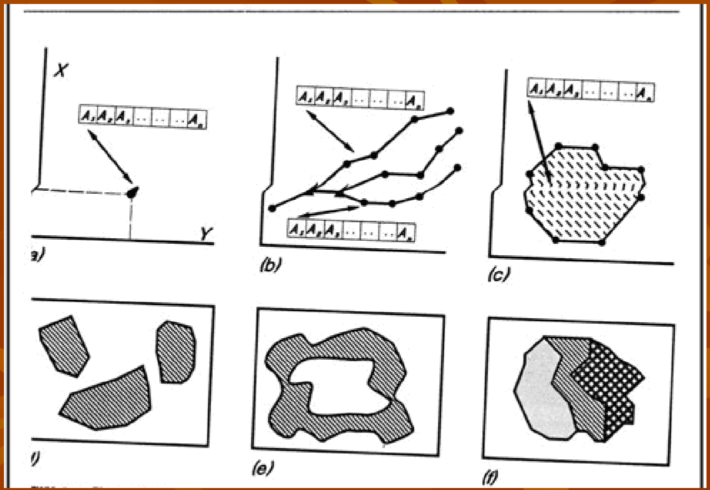


Figure 15. Fundamental geographical primitives of points, lines and polygons

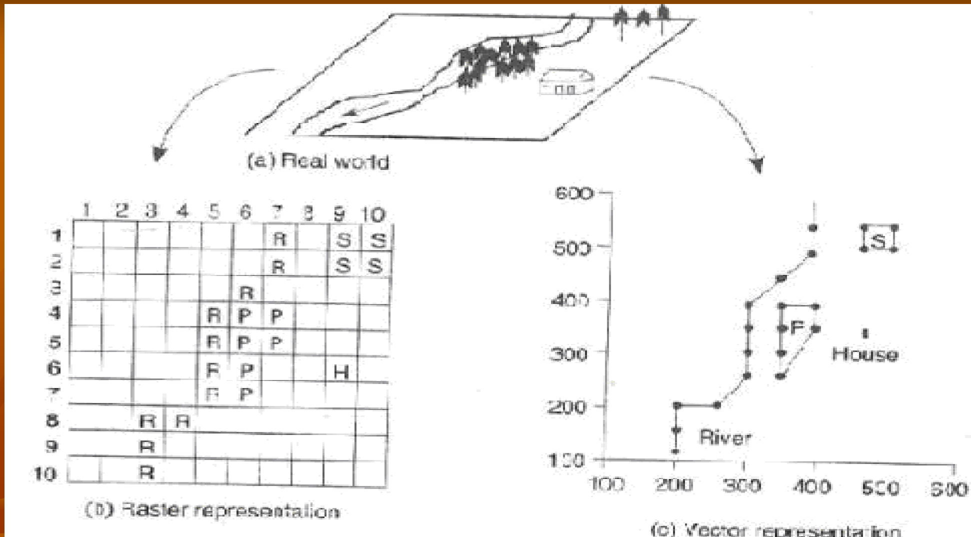


Figure 16. Representation of point, line and aerial data in raster and rector form

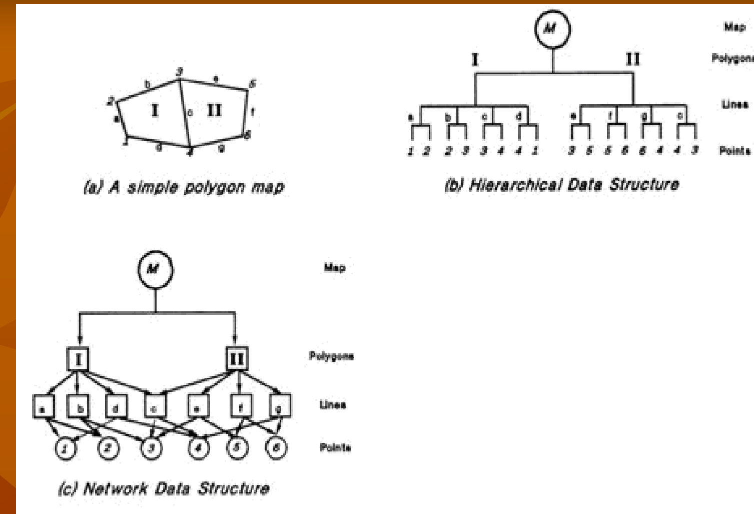


Figure 17.Network data structures for simple polygons

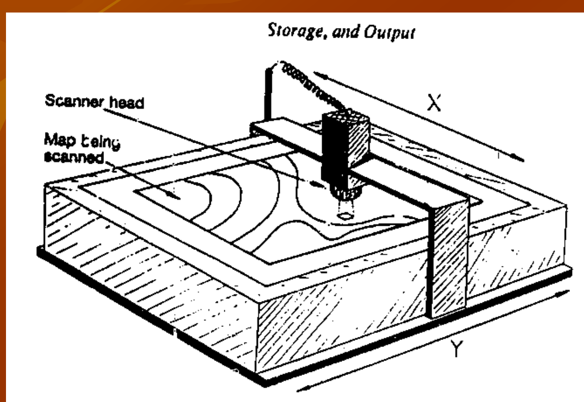


Figure 18. Flat bed optical scanner

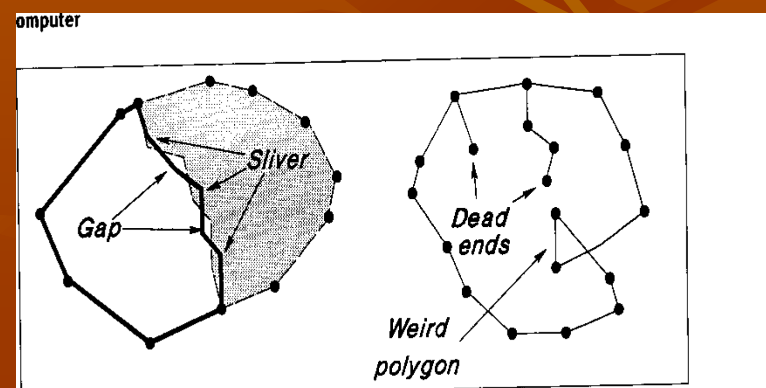
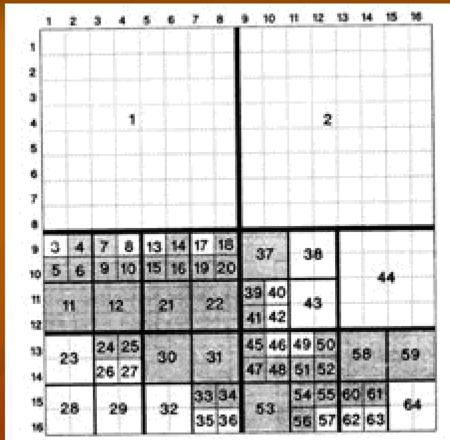
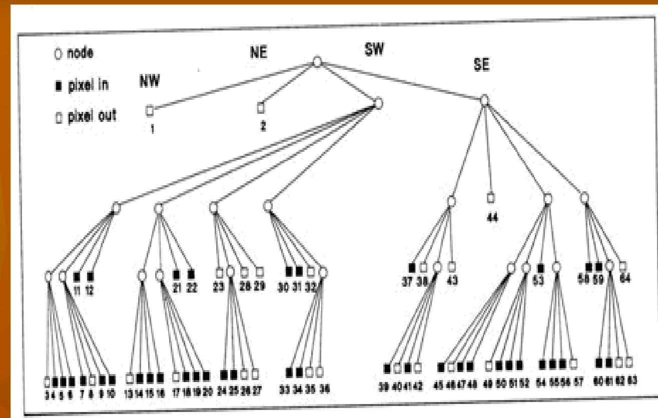


Figure 19. Simple polygon structure with topological errors





(a) (b)

Figure 20. Quadtree structure of the simple region

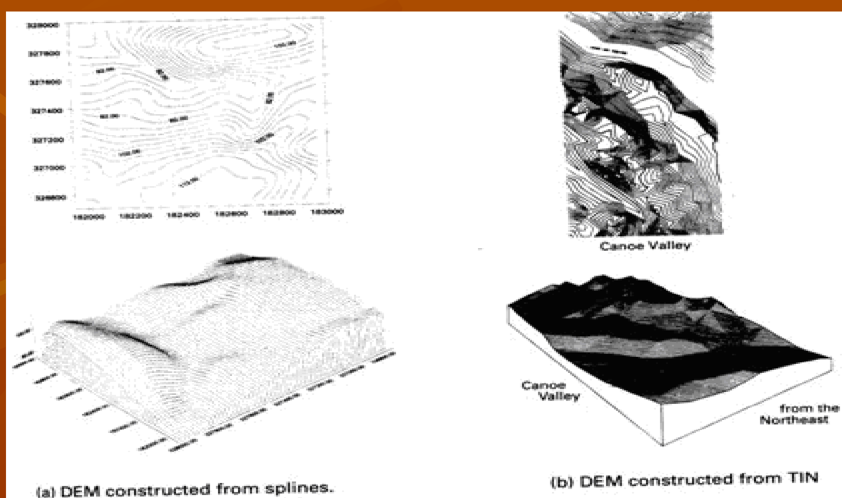


Figure 21. Digital elevation models

Figure 22. Mini watershed wise runoff potential map

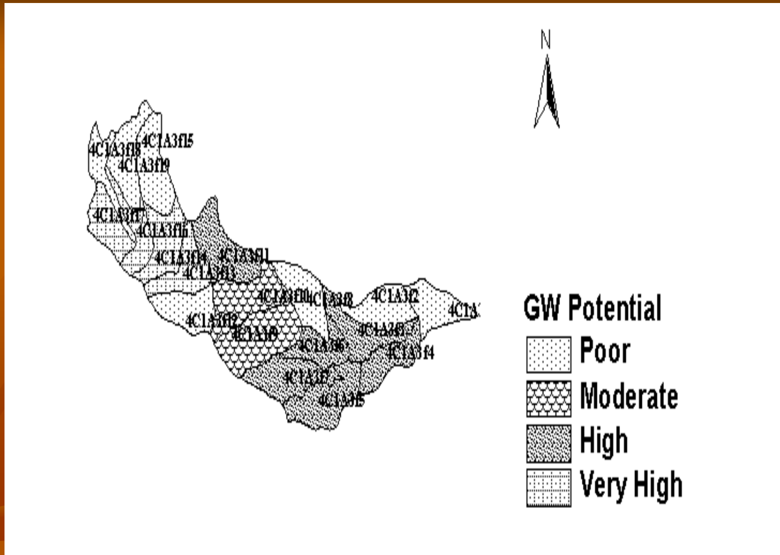


Figure 23. Mini watershed wise groundwater potential map

Figure 24. Land capability classification map

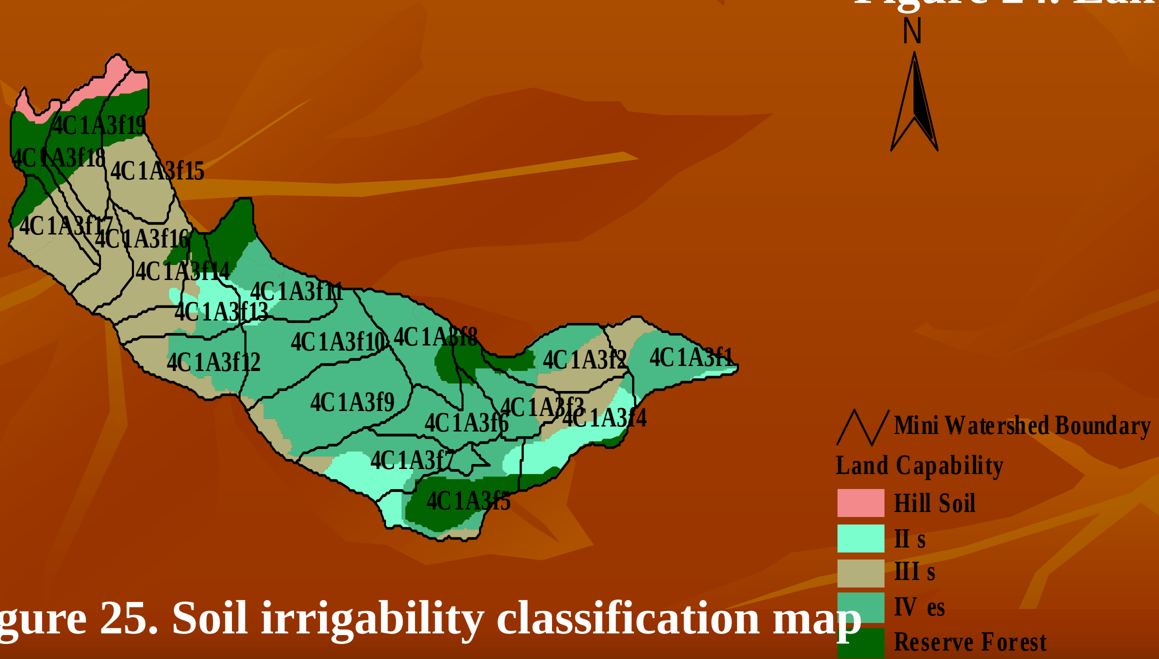
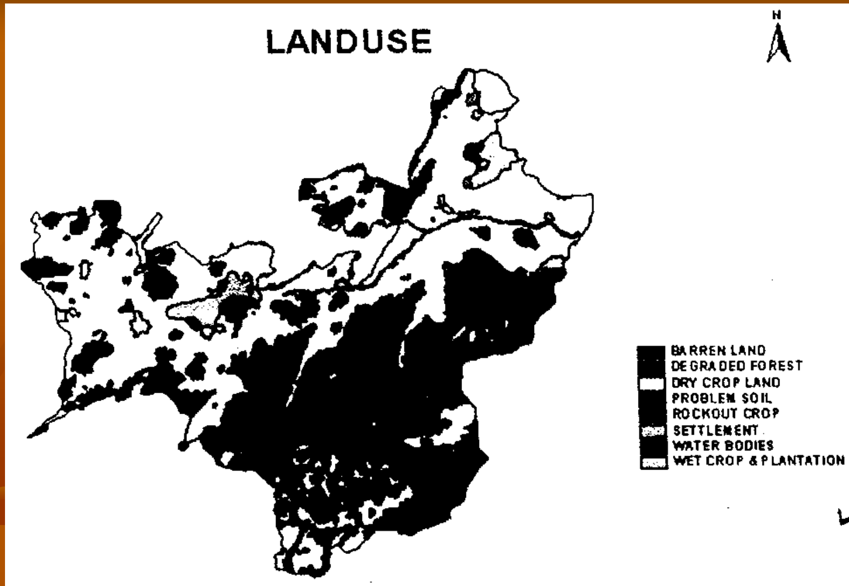


Figure 25. Soil irrigability classification map



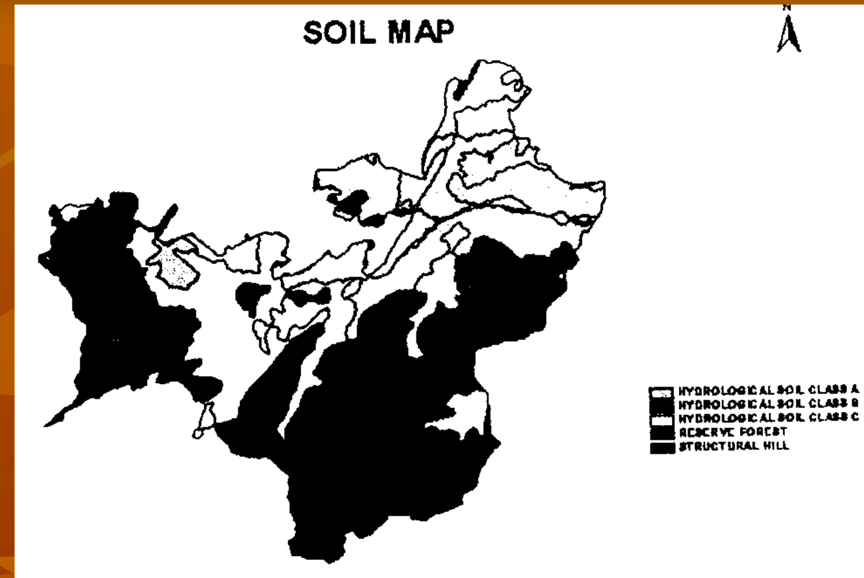
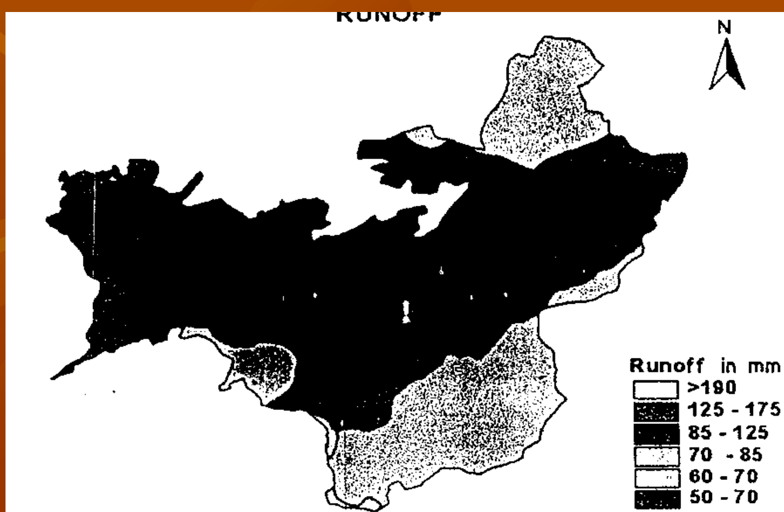


Figure 26. Typical Thematic Maps



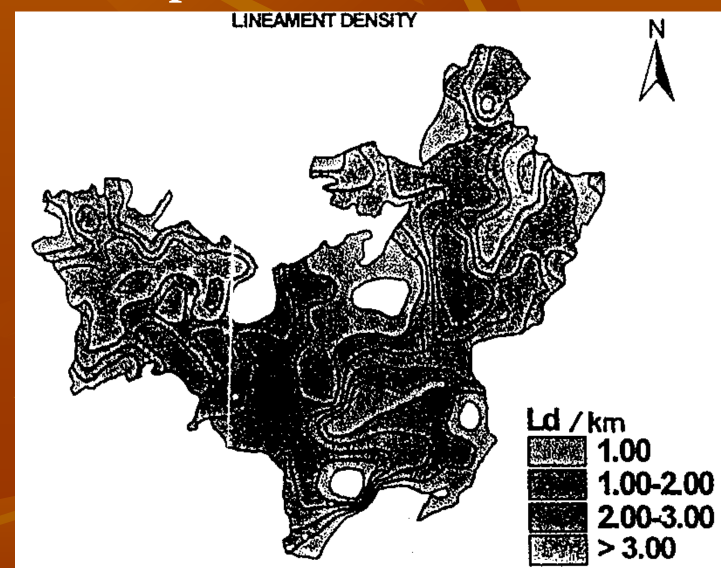


Figure 27. Typical derived Maps

PLANCK'S LAW explains the photoelectric effect.
It defines the spectral existance of a black body (Henderson, 1970)

$$M_\lambda = C_1 / \lambda^5 [\exp(C_2/\lambda T) - 1]$$

Where M_λ = Spectral existance / unit wavelength

$C_1 = 3.742 \times 10^{-16}$ watts per m^2

$C_2 = 1.4388 \times 10^{-2}$ m °K

λ = Wavelength in μm

T = Temperature °K

Note 1: The longer the wavelength, the low is the energy content.

Note 2: Black body Radiation.

Digital data products are available on CD-ROMs or DVDs, magnetic tapes, multiple floppy disks, or any other digital storage device. Use of CD-ROM is most common due to low cost and reliability. In case of photographic outputs, the scale of products is another important matter to consider.

Based on the project requirement, the data or combination of data should be collected to interpret and analyse.

9.4 BORDER OR MARGINAL INFORMATION

To assess the utility of a particular image data, the analyst must know its spatial extents, how it was captured, when and how it was developed, the resolution of data, the accuracy of the data, band combination used, scale of the data, date and time of capturing for temporal analysis like change detection, etc. These data are also important because there is no 'local' knowledge about the conditions under which the data were produced. The information required to assess the fitness of a dataset in the context of a particular problem is printed at the margins or borders of photographic products. From a thorough reading of this information, an individual should be able to determine what types of interactions are needed for analysis. The photographic products generally contain these details annotated on the image margins. First we shall consider a satellite image and then an airphoto to understand the marginal/border information.

Figure 9.1 shows photographic printout of a satellite image from Resourcesat-1 (LISS-IV sensor), prepared by NRSC. This image may be considered to understand what the marginal information supplied in a photographic product and how they are arranged or how they look like. All the information may not be required in every cases. In Fig. 9.1, annotation lines include the following information (*Courtesy*: NRSC):

ANNOTATION LINE NUMBER 1 (TOP)

IRS-P6	STD	FIXED	FULL	PLD	B:234	G:332	PATHBASED	POL	CC
A	B	C	D	E	F	G	H	I	J

where

A → Satellite_id

B → Product type (other options are geocoded/merged/stereo)

C → Other option is float

D → Other options are India/Geo

E → This space will be left blank if the product is not an OBSSR product

F → Band number details/band combination

G → Gain settings

H → Other options are stereo pair (1/2)/merged/ orthoimage /point based/mapsheet number

I → Type of projection (POL [polyconic]/SOM/UTM/PS/LCC)

J → Type of resampling

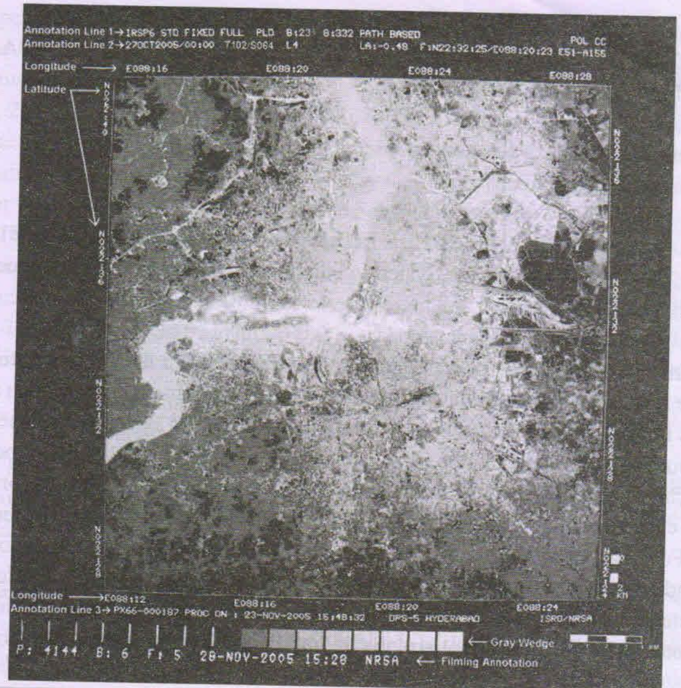


Fig. 9.1 Typical photographic product supplied by NRSC (*see also Plate 4*)

			ANNOTATAION LINE NUMBER 2 (TOP)				
27OCT2005/ 10:00	**T102/ S064**	**L4**	**A0**	**QU:12**	**LA0:48**	**FN:22:32:25/ E88:20:23**	**E:51- A155**
A	B	C	D	E	F	G	H

where

A → Date of acquisition with time

B → Path–row details or strip-scene details for LISS-IV

C → Sensor details (like L3, L4, AW, PN etc. for LISS-III, LISS-IV, AWiFS, PAN, respectively)

D → Subscene details, which may left blank (applicable in case of LISS-IV and AWiFS products)

E → Quadrant number, which may left blank (other option is percentage of shift)

F → Look angle in degrees

G → Corrected scene centre lat/long coordinates (Deg-Min-Sec)

H → Sun elevation and azimuth (Deg)

Note Annotation line number 2 (top) will be repeated as annotation line number 3 (top), in case there is more than one scene and annotation line 3 will become line number 4.

ANNOTATION LINE NUMBER 3 (BOTTOM)

PX66-000187	PROC.ON:23-NOV-2005/15:48:32	NOLUT	DPS-5	HYDERABAD	ISRO/NRSA
A	B	C	D	E	F

where

- A Generation_id
- B Date & time of generation
- C Enhancement (NOLUT/CLUT/HLUT/EQLUT), which may be left blank
- D DPS (Data Processing System) chain at which the product was generated
- E Place of generation
- F Data generation agency

In case of airphoto, the border information is different than that of satellite imagery. The instrument panel (or data block) is affixed to the camera body in such a manner that it is imaged along an edge of the airphoto negative at the same instant when the scene is exposed and recorded on the film. The panel holds 4–6 dial or digital type instruments. Each instrument records a particular data such as time, altitude, attitude (orientation) etc. for each airphoto. Figure 9.2(b) shows these data at the right margin of the photograph.

For larger areas (e.g., a district or a state), a very large number of airphotos need to be handled and stored in an organized and systematic manner. Different countries use different systems to maintain this information; however, they are very similar. In India, aerial photography and aerial photographs are highly restricted by the Central Government. All

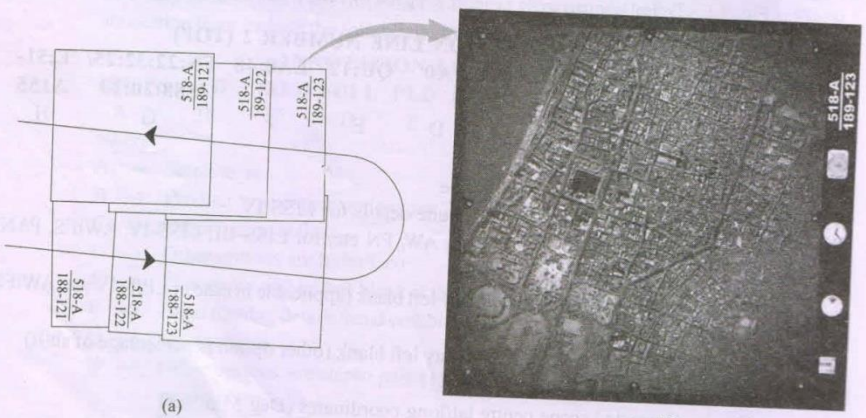


Fig. 9.2 (a) A mosaic of air photos showing the numbering system; (b) an airphoto with border information (not the original data)