SAC 623 Remote sensing and GIS techniques for soil and crop studies(2+1)

Lecture no. 1

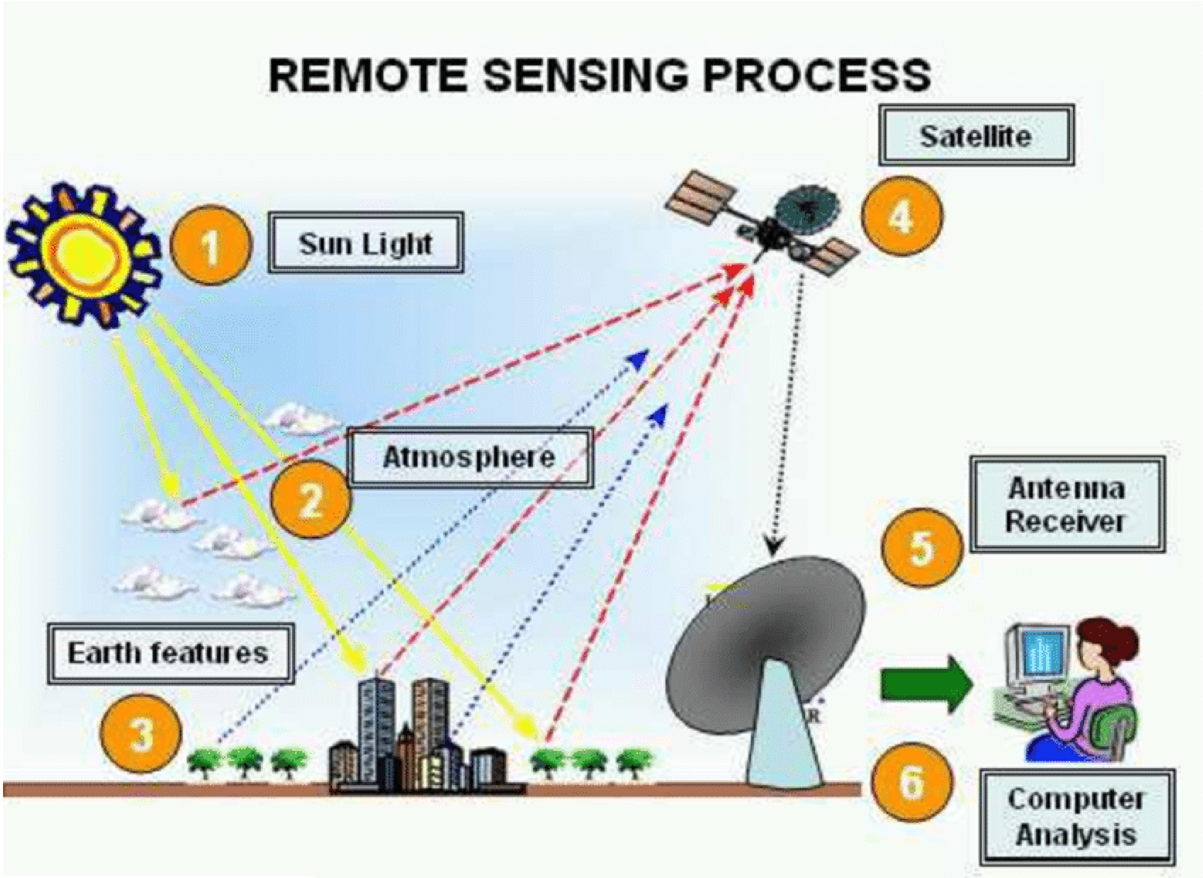
Principles

Electromagnetic energy refers to all energy that moves with the velocity of light in a harmonic wave pattern. The wave concept explains the propagation of electromagnetic energy, but this energy is detectable only in terms of its interaction with matter. 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 at the speed of light (C). A number of interactions are possible when electromagnetic energy encounters matter depending on its properties, whether solid, liquid or gas. Energy may be (i) transmitted, through the substance, (ii) absorbed by a substance, (iii) emitted by a substance, (iv) scattered, i.e., deflected in all directions and lost, and ultimately (v) reflected. If it is returned unchanged from the surface of a substance with the angle equal and opposite to the angle of incidence, it is termed specular reflectance (as in a mirror). If radiation is reflected equally in all directions, it is termed diffuse. Real materials lie somewhere in between. The science of remote sensing detects and records changes in electromagnetic radiation by magnitude, direction, wavelength, polarization and phase. The resulting images and data are interpreted remotely to identify the characteristics of the matter that produced the changes in the recorded electromagnetic radiation.

Basic Processes of Remote Sensing

Basic processes of remote sensing are depicted in pictorial form and are listed as follows:

- Energy source (sun or transmitter)
- Transmission of energy from source to object
- Energy interaction with object surface
- Transmission of energ y to sensor
- Scattering and absorption by atmosphere
- Detection, measurement and output by sensor
- Data acquisition, recording, pre-processing and analysis/interpretation



Types of Remote Sensing

Based on Source of Energy

Passive Remote Sensing: It makes use of sensors that detect the naturally reflected or emitted electromagnetic radiation and are called passive sensors.

Active Remote Sensing: It supplies its own source of energy which is directed at the object in order to detect reflected responses from objects, such as radar, airborne laser and are known as active sensors.

Based on Spectral Regions of Electromagnetic Radiation used

Visible and Reflective Infrared Remote Sensing: The energy source used in the visible and reflective infrared remote sensing is the sun. The sun radiates electro-magnetic energy with a peak wavelength of 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. Spectral range covered is 0.4 to 3 µm.

Thermal Infrared Remote Sensing: The source of radiant energy used in thermal infrared remote sensing is the object itself, because any object with a normal temperature (300 °K) will emit electro-magnetic radiation with a peak at about 10 µm.

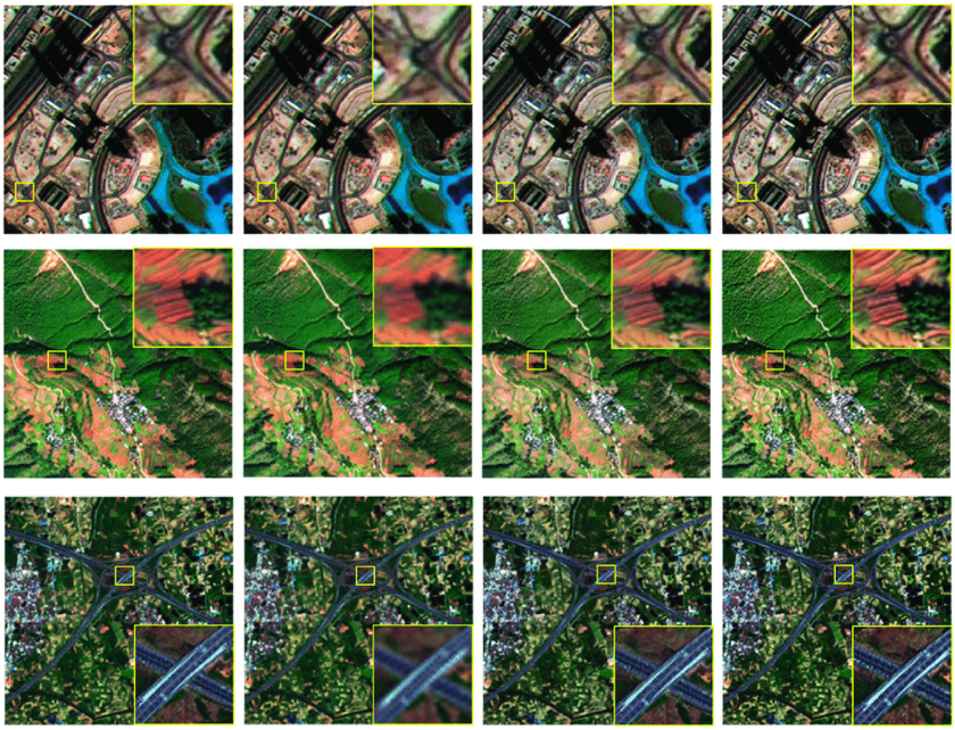
Therefore, in the wavelength region shorter than 3.0 µm, spectral reflectance is mainly observed, while in the region longer than 3.0 pm, thermal radiation is measured. Spectral range for thermal remote sensing is 3 to 14µm.

Microwave Remote Sensing: There are two types of microwave remote sensing, passive microwave remote sensing and active microwave remote sensing. In case of the former, the microwave radiation emitted from an object is detected, while the back scattering coefficient is detected in case of the latter. Microwave remote sensing covers spectral range of 0.1 to 100cm.

Lecture 2

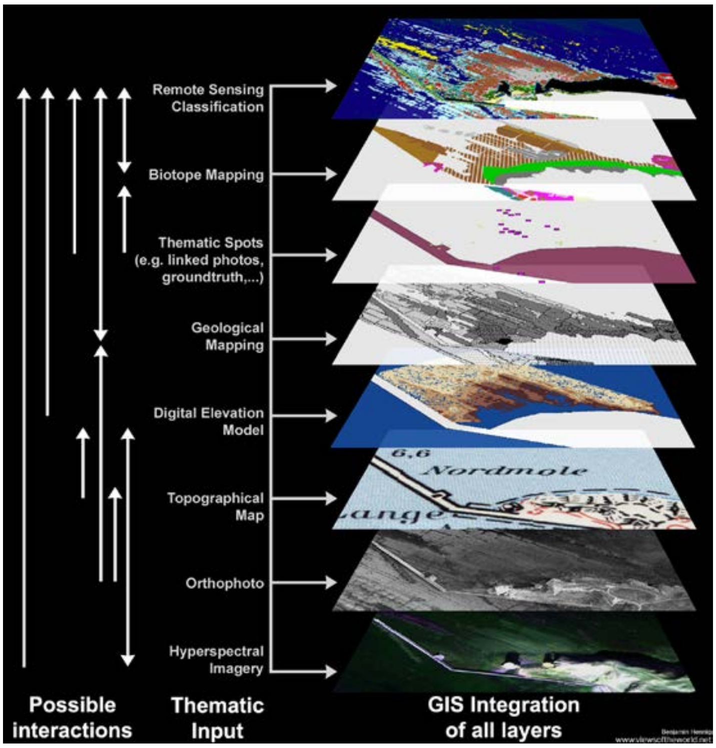
Based on Number of Spectral Bands used

Multispectral Remote Sensing: Bands (green, red, near infrared, shortwave infrared) of the multispectral sensors usually range between 3 and 10. IRS (Indian Remote Sensing) series satellites of India, Landsat of USA, and SPOT (Satellite Pour l'Observation de la Terre) satellite of France are well-known multispectral satellites.



Hyperspectral Remote Sensing: Hyperspectral sensors have narrower and as many as 200 (or more) contiguous spectral bands. The numerous narrow bands of hyperspectral sensors provide a continuous spectral measurement across the entire electromagnetic spectrum and therefore are more sensitive to subtle variations in reflected energy. For example, multispectral imagery can be used to cropped areas, while hyperspectral imagery can be used to map crop types within the cropped fields. Contiguous high-resolution spectrometry provides a new dimension in mapping capability because of the potential for quantitative measurement of surface biogeochemistry. Hyperion of E0-1 and AVIRIS (Airborne Visible and Infrared Imaging Spectrometer) of NASA is hyperspectral remote sensors on satellite and airborne platforms respectively.

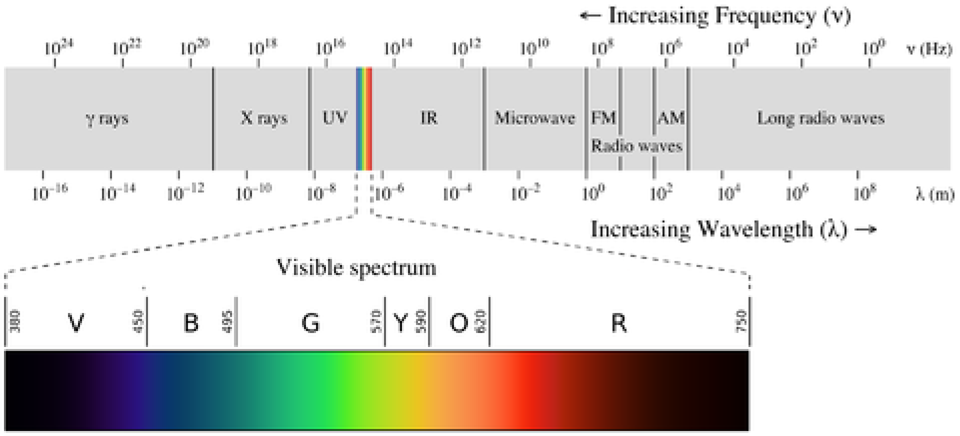
Out of all above listed remote sensing types, passive multispectral satellite remote sensing in optical and reflective infrared region is most commonly available and used worldwide.


Remote Sensing Classification
Biotope Mapping
Thematic Spots (e.g. linked photos, groundtruth,...)
Geological Mapping
Digital Elevation Model
Topographical Map
Orthophoto
Hyperspectral Imagery
6,6
Nordmole
Lange
Possible interactions
Thematic Input
GIS Integration of all layers
Benjamin Hennig
www.viewsoftheworld.net

Lecture 3

ELECTROMAGNETIC RADIATION

The energy from the natural source, sun is in the form of electromagnetic radiation (EMR), produced by nuclear reactions within the sun. The EMR consists of an electric field and magnetic field which are perpendiculars to each other moving in a-harmonic; wave pattern at: a constant speed of light (3 x 103 m/s) and perpendicular to the direction of motion.



Electromagnetic Wave

The electromagnetic wave displays three properties (Fig. 2.4) (i) Wavelength (ii) Frequency and (iii) Amplitude.

1. Wavelength. It is the length of a single wave that is from one wave peak to next. It is measured in the unit of length such as Angstrom (A 10^{-10} m) Nanometre (nm, 10^{-9} m), Micrometer (µm 10^{-6} m) or Centimetres (cm). It is represented by Greek letter, Lambda (λ).

2. Frequency. It is measured as number of wave peaks passing a fixed point in a given time. It is measured in Hertz which is equal to one cycle / second. It is denoted by v.

3. Amplitude. It is the height of each wave peak.

Lecture 4

LAWS OF RADIATION

The propagation of EME follows certain physical laws. All objects with temperatures above absolute zero have temperature and emit energy. The amount of energy and the wavelength at which it is emitted depend on the temperature of the object. As the temperature of the object increases, the total amount of energy emitted also increases, and the wavelength of maximum emission becomes shorter.

Stefan-Boltzman Law

The law states that the total radiation emitted from a black' body is proportional to the fourth power of the absolute temperature. It defined the relationship between total emitted radiation and temperature.

$$M = \sigma T^4$$

Where, M is energy of the body; σ is Stefan-Boltzman's constant. 5.67×10^{-8} w m^{-4}; T is the absolute temperature of the body.

This law states that hot bodies emit more energy per unit area than the cool bodies

Wein's Law

The wein's law states that, the dominant wavelength or Wavelength at which a blackbody radiation reaches a maximum (M5,) is related to its temperature.

$$\lambda \text{ max} = a/T$$

Where, 'a' is a constant with value of 2898 µ in °K; T is the absolute temperature of the blackbody in °K.

Thus, for a blackbody, the wavelength at which the maximum spectral radiation existence occurs varies inversely with its absolute temperature. The wavelength of maximum remittance shifts to shorter wavelength.

‘Kirchoff’s Law

Kirchoff’s law states that the ratio of emitted radiation to absorbed radiation is same for all blackbodies at the same temperature. This law forms the basis for definition of emisssivity (E), as the ratio between the emittance of a given object (M) and that a black body (Mb) at the same temperature

$$\text{Emissivity} = \frac{\text{Emittance of a body}}{\text{Emittance of a black body}} = \frac{M}{M_b}$$

The emissivity of a true blackbody is one and that of a perfect reflector (white body) is zero.

Blackbodies and white bodies are concepts in the laboratory under ideal conditions. In nature all objects have emisssivity that falls between zero and one are Gray bodies. For these bodies emissivity is a measure of their effectiveness as radiation of EM.

Planck’s Law

The spectral existence i.e. the total energy radiated in all directions by unit area in unit time in a spectral band for a blackbody is given by Planck’s law.

$$Q=hv$$

Where, h is Planck’s constant (6.6256 x 10^{-34} J/sec); V is frequency

The spectral existance of a blackbody is not the same at all wavelengths. The spectral existance is low for very short and very long wavelength. The law indicates that a blackbody at higher temperature emits more radiation than a blackbody at low temperature at all wavelengths.

In remote sensing we are interested in the following wavelength ranges.

1. Visible	0.4 0.7 µm
a) Blue	0.4 ~ 0.5 µm.
b) Green	0.5 0.6 µm
c) Red	0.6 0.7 µm

2. Infrared	0.7 30.0 µm
(a) Near infrared (NIR)	0.7 - 1.3 µm
b) Middle infrared‘(MIR)	1.3 3.0 µm
c) Far infrared (FIR)	3.0 30 µm
(thermal infrared)	
3. Microwaves	1 mm 1m

Most common sensing systems operate in one or several of the visible, IR or microwave portions of the spectrum.

In the infrared region, only the thermal infrared is directly related to the sensation of heat and near and middle infrared energy is not.

REMOTE SENSING MEASUREMENTS

In remote-sensing we measure the intensities of reflected and emitted radiations from target surfaces or objects. Due to characteristics interactions of different wave lengths of radiation with different materials we get characteristic variations in the measurement. Three important types of variations which form the basis of information about the object are:

1. Spectral variation: These are changes in the intensity of reflected/emitted radiations with wave length.

2. Spatial variation: These are changes in the intensity of reflected or emitted radiation with location due to variation in material composition or surface topography of the target.

3. Temporal variation: These are changes in the intensity of reflected or emitted radiations with time due to dynamic characteristics of target surface eg. Vegetation cover.

In order to derive information from the objects we have to measure these variations and relate them to the processes of known objects or phenomena.

INTERACTION OF EMR WITH ATMOSPHERE

Electromagnetic radiation (EMR) while travelling from the source to surface of the earth and then from there to the sensors on-board satellite comes in contact with the atmospheric constituents and interacts with them. The atmospheric constituents like dust particles, smoke particles and gases affect the incoming radiation. Hence, in the atmosphere, the interactions are caused mainly by scattering (Fig.3.1), absorption and refraction.

Scattering

Scattering is the redirection of EME in different directions. It occurs in presence of large dust particles and gas molecules in the atmosphere. The 'effect of scattering is to redirect the incoming radiation back to space as well as towards earth’s surface (Fig.3.2). There are three types of scattering depending on the size of particles in relation to wavelength.

1. Rayleigh scattering
2. Mie scattering
3. Non-selective scattering

l. Rayleigh Scattering

It occurs when particles are very small compared to the wavelength of radiation. These particles could be particles such as dust particles, nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths energy to be scattered more than longer wavelengths. It is the dominant scattering in upper atmosphere. The blue colour of the sky and red and orange colours at sunrise and sunset are due to Rayleigh scattering.

2. Mie Scattering

Mie scattering occurs when the atmospheric particles are about the same size of the wavelength of the radiation. These particles include dust, pollen, and smoke and water droplet. Mie scattering occurs mostly in the lower atmosphere (0-5 km) where larger particles are more abundant. It influences a broad range of wavelength in and near visible region.

3. Non-selective Scattering

Non-selective scattering occurs when the particle sizes are larger thin the wavelength of radiation. The particles may be dust and water droplets. This scattering does not depend on the wavelength of the radiation. This type of scattering causes fog and clouds to appear whitish appearance of sky.

Absorption

This phenomenon occurs when the atmospheric constituents absorb energy passing through the atmosphere. The gases like ozone (03), carbon dioxide (C02) and water vapour (H20) absorb radiation in the atmosphere. Ozone absorbs UV radiation, C02 absorbs radiation in the FIR portion of the spectrum and water vapour absorbs the incoming IR and microwave radiation.

Transmission or Atmospheric Window

Some radiations which are neither absorbed nor scattered are transmitted through the atmosphere. The transparency of atmosphere to such radiations is known as atmospheric window. Atmospheric windows are the regions in the EMS for which the atmosphere is transparent. i.e. these wavelengths are easily transmitted through the atmosphere. These are useful regions for remote sensing purposes. The major atmospheric windows available for remote sensing are given in Table: 3.1.

Refraction

Refraction is the bending of light rays at the surface of interaction. When the light enter into a different medium, it changes its direction or bends at the atmosphere as light passes through atmospheric layer of varying clarity, humidity and temperature. These variations influence the density of atmospheric layers, hence bending of light occurs when it changes the medium of higher density to lower density.

INTERACTlON OF EMR WITH EARTH SURFACE

The wave length of EMR that is useful for valuable in environmental remote sensing are

1 Reflected radiation in Visible, NIR, MIR and micro wave bands.

2. Emitted radiation in MIR and thermal IR wave bands.

These are three main components of remotely sensed scenes such as vegetation, soil and water. The processes involved in the interaction of EMR with earth's surface are reflection, scattering and transmission.

Radiation that is not absorbed or scattered in the atmosphere reaches and interacts with the earth's surface. According to the law of conservation of energy, energy cannot be created nor be destroyed; it can be converted or transformed to another form. Thus, the portion of incident radiation is reflected by the surface, transmitted in to the surface or absorbed by the surface (Fig.3.3). Different features on the earth's surface have different values of spectral reflectance, absorbance arid transmittance on the basis of which they can be identified. The sum of each proportion of the components is unity but the magnitude of each component depends on the nature of the surface and hence different.

$$I_\lambda = R_\lambda + T_\lambda + A_\lambda$$

Where I_λ is incident radiation; R_λ is reflected radiation; T_λ is transmitted radiation; A_λ is absorbed radiation

If the magnitude of the spectral radiance i.e. reflected, absorbed or transmitted is vary different for different surfaces on the earth surface than we can identified those features on the basis of their spectral properties.

Of all the interactions in the reflective regions "surface reflections" are the most useful in remote sensing applications.

It can be seen from the table that major principal windows lie in visible, infrared and micro wave regions.

Reflection

Reflection occurs when radiation is redirected from a nontransparent surface. Reflection depends on the roughness or smoothness of the surface, in relation to wavelength of radiation. According to Rayleigh criterion, if the surface height variations are less then $\lambda 8$, the surface height is considered to be smooth otherwise it is rough. Accordingly there are two types of reflections;

(i) Specular and (ii) Diffuse reflection

- Specular reflection: If the surface is smooth relative to the Wavelength, Specular reflection occurs which follow the law of reflection. They occur with surfaces such as mirror, metal and a calm water body. This type of reflections is undesirable in remote sensing.
- Diffuse reflection: Diffuse reflection occurs when the surface iS' rough in relation to wavelength. In these reflections energy is reflected almost uniformly in all directions. Diffuse reflections are useful in remote sensing. In nature mixed reflections occurs most frequently.

Absorption and Transmission

Absorption occurs when the object absorbs the radiation. Transmission occurs when the radiation passes through an object or target.

RESOLUTIONS

Resolution of a system refers to its ability to record and display fine details. The images are described in terms of its scale as well as in terms of its resolution. In remote sensing we need three different types of information such as spatial, spectral and radiometric (intensity) information. Accordingly the sensor system varies in principles of detection and construction. The types of sensor systems used to acquire different information.

Types of Resolution

In remote sensing there are four types of resolution

1. Spatial resolution

2. Spectral resolution

3. Radiometric resolution and

4. Temporal resolution

Spatial Resolution

Spatial resolution refers to the size of the smallest possible feature that can be detected. It is depended on the IFOV of the sensor. In many of the remote sensors, a small elemental area is observed at a time and such a field of view of the sensor is called the Instantaneous Field of View (IFOV). However, it should be noted that though the spatial resolution has a bearing on the IFOV, it does not entirely depend only on IFOV. There are various other factors such as satellite altitude, the relative motion between IFOV and the ground during the ‘dwell time’ (the time for which sensors looks over the elemental area), sampling frequency of the measurement, characteristics of all the subsystems of the sensing system, which contribute significantly to the overall spatial resolution of the system. Spatial resolution decides the smallest size of the observable picture element or pixel (under a given state of the art of detector technology). spatial resolution of remote sensing sensors is given in terms of the pixel size dimension. A pixel can be a square or rectangular shape.

Spectral Resolution

The radiation reaching the remote sensor from the earth’s Surface cover the entire electromagnetic spectrum. The spectral resolve the energy received in a given spectral bandwidth to characterize different constituents of earth’s surface. Thus the spectral resolution is defined by the spectral bandwidth of the filter and the sensitiveness of the detector. Thus, for example, onboard the Land sat satellite; the multispectral scanner system had the capability to resolve the earth’s surface features at 80 m spatial resolution using four spectral bands viz, 0.5-0.6 µm, 0.6-0.7 µm, 0.7-0.8 µm, and 0.8-1.1 µm. The last band has a bandwidth of 0.3 µm as opposed to 0.1 µm of the rest of the bands. As the incoming solar radiation in this year infrared spectral region is small as compared to other bands, one had to increase the bandwidth three times in order to maintain the spatial resolution at 80 m as well as the given the signal to noise ratio requirement. On the other hand if the spectral bandwidth of the fourth band is maintained at 0.1 pm, the spatial resolution would be much larger than 80 m in order to have the same signal to noise ratio.

The Thematic mapper (TM) of the Land sat satellite has seven spectral bands viz., 0.45-0.52 µm, 0.52-0.60 µm, 0.630.69 µm, 0.76-0.90 µm, 1.55-1.75µm, 10.4-12.5 µm and 2.082.35 µm. With the upgradation of technology that was used in the multi-spectral scanner design in the earlier satellites, the spatial resolution could be increased to 30 m even with the reduction in spectral bandwidth in the visible' and reflected infrared region of electromagnetic spectrum, i.e. the TM bands 1 to 5 and band 7. In case of TM thermal band (10.4 to 12.5 µm), the energy had to be integrated over 16 times larger area (i.e. 120 m) as well as over a bandwidth of 2.1 µm to provide an acceptable signal to noise ratio. This is because energy emitted by earth is small, the average surface temperature of earth being only 300 °K in comparison to the sun with its surface temperature of 6000 °K even when the differences in the distances are accounted for.

The Linear Imaging Self Scanning Sensor (LISS) onboard Indian Remote sensing Satellites (IRS-lA, 1B) has four spectral bands, viz., 0.45-0.52 µm, 0.52-0.59 µm, 0.62-0.68 µm and 0.77-0.86 µm.

In LISS system an array of 2048 element charge coupled devices (CCDs) is provided for each spectral band so that a separate detector collects signal from each pixel instead of through scanning mirror as in Land sat, to see different pixels along a scan line. Due to satellite velocity, the time, available to scan a line of say about 185 km (swath width of Land sat) is fixed, and this is shared by Viewing say 11 pixels in the scan line. In L188, 3 whole line is swept like the pushing broom on railway platform during cleaning operation where in each detector corresponding to a pixel gets the whole of the time available for scan line as dwell time (time during Which signal is integrated) and this improves the quality of signal from the pixel and also minimizes the geometric distortions caused due to non-uniform motion of mirror as in Land sat. More number of narrow spectral bands gives rise to greater ability to discriminate various features of the earth’s surface. Table 5.1 gives the sensor details and utility characteristics of various sensing systems onboard Land sat, IRS and the French SPOT satellites. Table 5.2 gives description of IRS-lC and Spot-4 satellites.

Radiometric Resolution

The ability to distinguish line variations in the radiance values of the different objects is characterized by the radiometric resolution.

In remote sensing, the reflected radiation from different objects generates an electrical signal (say, voltage) as output from the detector. This analogue voltage is digitized resulting into a digital number corresponding to the elemental area of the ground scene or pixel. The number of levels into which the output signal can be divided is dictated by the availability of data bandwidth and the signal to noise ratio. This is similar to the number of grey shades that can be seen in a black and white I photograph. -For example, the multi-spectral scanner onboard the Land sat satellites has a radiometric resolution of 1/64 in all the four spectral bands it uses. It means that 64 different values of radiance can be detected on the imagery obtained through the Land sat multi-spectral scanner. On the other hand, the thematic mapper flown on the Land sat 4 and 5 satellites had a radiometric resolution of 1/256 for all the seven bands in which it works. For comparison, the LISS I and II (Linear imaging self Scanner) on board the Indian Remote Sensing Satellite, IRS-l had a radiometric resolution of 1/128.

For radars operating in the microwave range, the radiometric resolution is given in terms of decibels representing the minimum signal level that can be detected with an acceptable signal to noise ratio. Decibel is one tenth of a bit, which is the logarithm of the ratio of the signal strength to a reference value. As an example, typical synthetic aperture radar has a radiometric resolution of about 1 to 2 decibels.

Temporal Resolution

Temporal resolution is specific to space borne sensors particularly to sun-synchronous satellites. These are polar orbiting satellites having 9-16 hours rotational period and cross the equator at the same local time (solar time) in each orbit. Such an orbit offers similar sun illumination conditions for all observations taken over different geographical locations along given latitude in sun-lit areas. By suitable selection of the spacecraft altitude and the inclination angle of the orbit, the spacecraft can be made to cover the same area on the earth at regular intervals For example, the Land sat 1, 2 and 3 had an orbiting altitude of 918 km, inclination of 99.114° and the repetition cycle of 18 days. For Land sat 4 and 5 with an altitude of 705 km and an inclination of 982°, the repetition cycle is 16 days. The Indian Remote Sensing satellite (IRS-lA and 1B) at an altitude of 904 km, with inclination of 99.02° and repeat cycle of 22 days. With proper placement of two satellites in orbit the repetition cycle could be reduced to half, say 11 days in case of IRS observation system. With such a repetitive coverage, a given area on earth can be observed at regular intervals and dynamic features such as vegetation and water resources can be very effectively studied and analyzed. This ability to have revisit over any given area by remote sensor at regular interval is defined as temporal resolution.

SCALE

Images can be described in terms of scale which is determined by the effective focal length of the lens of the remote sensing device, altitude of the platform and the magnification factor employed in reproducing the image.

Generally there are three type of scales such as small scale, intermediate scale and large scale. The quantitative range of the scale are given below:

Small scale	> 1:500,000	1 cm: >5 km
Intermediate	1: 50,000 to 1: 500,000	1 cm= 0.5 to 5 km
Large scale	<1: 50,000 ' '	1 cm: < 0.5 km

The large scale images provide more detailed information than the small scale images.

The following scales are used at different levels:

1 : 1,00,000	Intermediate scale	National level
1 : 2,50,000	Intermediate scale	State level
1 : 50,000	Intermediate scale	District level
<1 : 8,000	Large scale	Village level

Photo Scale

Photo scale of the 'aerial or satellite imageries .is computed as the ratio of the distance and the photo or map ((1) to actual distance on the ground (D) between any two known locations.

$$S = d/D$$

For the photographs taken in the vertical (Nadir) view, the photo scale is a function of the focal length of the camera (f), the flying height of the platform (H) and the magnification factor (M) i.e.

$$\text{Image scale} = Mf/H$$

In this type of scanner, the scan direction is along the track (direction of flight) and hence the name along track scanner (Fig.5.7). It is also called push broom scanner because the detectors are analogous to the bristles of a push broom sweeping a path on the floor.

Development of charge-coupled device (CCD) has contributed to the successful design of the along track scanner. In this the sensor elements consist of an array of silicon photodiodes arranged in a line. There are as many silicon photodiodes as there are ground resolution cells (corresponding to IFOV) accommodated within the restricted FOV of the sensor optics. Each silicon photodiode, in turn, is coupled to a tiny charge storage cell in an array of integrated circuit MOS (metal oxide semiconductor) device forming a charge coupled (1ng (CCD) (Fig.5.8). When light from a ground resolution cell strikes a photodiomm it generates a small current proportional to the intensity of light falling on it and the current charges the storage cell placed behind the diode. The charged cells formepart of an electronic shift register which can be activated to read out the charge stored in the cells in a sequential fashion. The output signals are correlated with the shift pulses, and digitized to reconstitute the image.

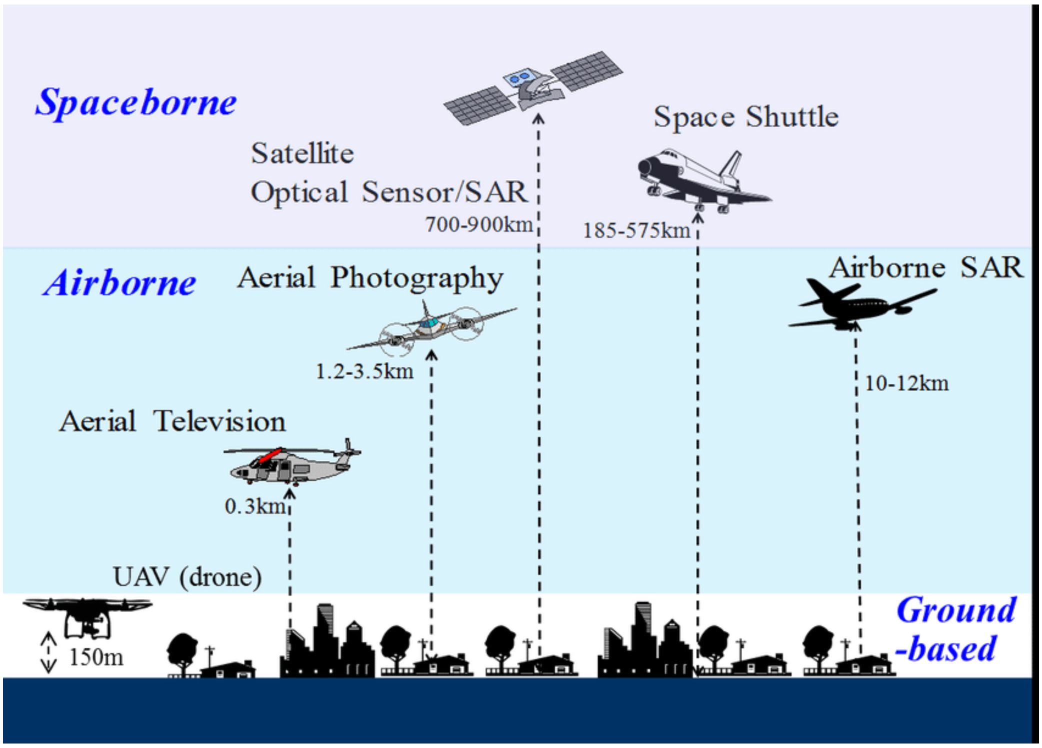
Lecture 5

Sensor Platform used

Ground based Remote Sensing: A wide variety of ground based platforms are used in remote sensing. Some of them are hand held spectroradiometer, and scatter meter.

Airborne Remote Sensing: Mostly used platforms for sensors are flight, unmanned aerial system (UAS) at desired height.

Satellite Remote Sensing: Carrier of the sensors is the satellite which may be placed in low earth orbit (LEO), at height earth ranging from 160 to 2000 km or geostationary earth orbit (GEO) at a height more than 30,000 km away from earth surface.



Lecture 6

Scanning Systems

Across Track Multispectral Scanner (MSS)

This form of imaging is used in Landsat series of satellite. The scanning system (Fig.5.6) employs a single detector per band of the multispectral signal. It has an electrical motor, to the axel of which is attached a solid metal cylinder whose free end is cut at 45 degrees to the axis of its rotation and highly polished to act as a scanning mirror. The field of view (FOV) is restricted by an aperture so that the mirror will receive signals in almost nadir view from 2000 ground resolution cells that makes one scan line. The signal received by the rotating scanning mirror from a ground resolution cell (corresponding to GIFOV) is a white one and contains spectral information in different bands. This white beam is reflected by the mirror in the flight direction (parallel to the ground) and is allowed to pass through a monochromator/spectroscope which splits the composite beam into its color components. The detectors with their designed apertures are so placed that they now receive the spectral information from the ground resolution cells in the Specified bandwidths of various color components of the white signal

The dwell time of the scanner is compared by the formula

Dwell Time = (Scan rate per line)/(Number of ground resolution cells per line).

The Spatial Resolution of the scanner

=ground resolution of the scanner

=GIFOV x Attitude of the scanner

Along track multispectral

Scanner/ Push Broom Scanner

In this type of scanner, the scan direction is along the track (direction of night) and hence the name along track scanner (Fig.5.7). It is also called push broom scanner because the detectors are analogous to the bristles of a push broom sweeping a path on the floor.

Development of charge-coupled device (CCD) has contributed to the successful design of the along track scanner. In this the sensor elements consist of an array of silicon photodiodes arranged in a line. There are as many silicon photodiodes as there are ground resolution cells (corresponding to IFOV) accommodated within the restricted FOV of the sensor optics. Each silicon photodiode, in turn, is coupled to a tiny charge storage cell in an array of integrated circuit MOS (metal oxide semiconductor) device forming a char e coupled device (CCD) (Fig.5 3). When light from a ground resolution cell strikes a photodiode in the array, it generates a small current proportional to the intensity of light falling on it and the current charges the storage cell placed behind the diode. The charged cells form part of an electronic shift register which can be activated to read out the charge stored in the cells in a sequential fashion. The output signals are correlated with the shift pulses, and digitized to reconstitute the image.

The spatial resolution of the sensor = ground resolution cell

=GIFOV x altitude of the scanner

The dwell time for the long track scanner is given by

Dwell time = (ground resolution cell dimension)/ (velocity of sensor platform)

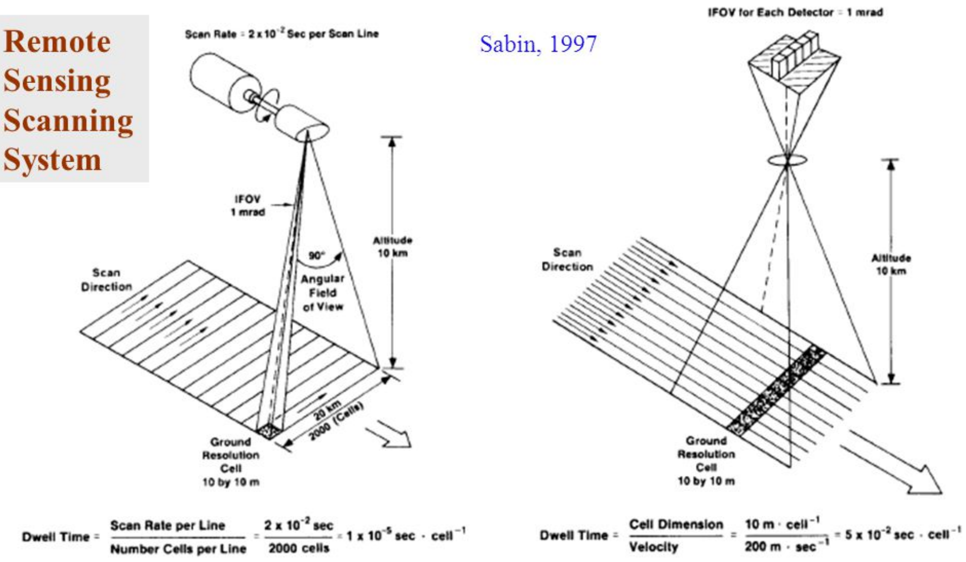
Side Viewing /Side Looking Scanner

The across track and along track scanners described above are used in passive remote sensing in visible, infrared and microwave regions of the electromagnetic spectrum. These scanners always receive signals in the nadir view. However if the user demands (on payment basis) to observe a dynamic scene frequently, then there is provision in SPOT and IRS satellites to steer the cameras to look off-nadir at the required scene, some days before to some days after the normal nadir viewing date (fig 5.9).

But scanners of active remote sensing, like the scanners used 'for radar remote sensing, in their normal mode of scanning look to the sides and not to the nadir for technical reasons which will be described later. Therefore such scanners are called side looking airborne radar (SLAR). The most sought after sophisticatedly designed synthetic aperture radar (SAR) belongs to the side looking scanner system.

Remote Sensing Scanning System

Sabin, 1997



$$\text{Dwell Time} = \frac{\text{Scan Rate per Line}}{\text{Number Cells per Line}} = \frac{2 \times 10^{-2}\ \text{sec}}{2000\ \text{cells}} = 1 \times 10^{-5}\ \text{sec} \cdot \text{cell}^{-1}$$

A. Cross-track scanner.

Wiskbroom

$$\text{Dwell Time} = \frac{\text{Cell Dimension}}{\text{Velocity}} = \frac{10\ \text{m} \cdot \text{cell}^{-1}}{200\ \text{m} \cdot \text{sec}^{-1}} = 5 \times 10^{-2}\ \text{sec} \cdot \text{cell}^{-1}$$

B. Along-track scanner.

Pushbroom

Field of View (FOV), Instantaneous Field of View (IFOV)
Dwell time is the time required for the detector IFOV to sweep across a ground cell. The longer dwell time allows more energy to impinge on the detector, which creates a stronger signal.

Lecture 7

Definition of Aerial Photograph

The aerial photography is defined as the science of making photographs from aircrafts for studying the earth's surface. Aerial photographs of the earth's surface are taken using a variety of platforms like balloons, rockets, aircrafts, satellites etc. Aria! photography was the first method of remote sensing and even today in the age of the satellite and electronic scanners, aerial photographs still remain the most widely used type of remotely sensed data. The popularity of aerial photographs is due to its six characteristics namely,

Characteristics of Good Aerial Photographs

1. Availability: Aerial photographs are readily available at a range of scales for much of the world.
2. Economy: Aerial photographs are Cheaper than field surveys and are often cheaper and more accurate than the maps for many countries of the world.
3. Synoptic viewpoint: Aerial photographs enable the detection of small-scale features and spatial relationships that would not be evident on the ground.
4. Time freezing ability: An aerial photograph is a record of the Earth' surface at one point in time and can therefore be used as a historical record.
5. Spectral and spatial resolution: Aerial photographs are sensitive to radiation in wavelengths that are outside of the spectral sensitivity range of the human eye, as they can sense both ultra violet (0.3-0.4 µm) and near infrared (0.7-0.9 µm) radiation. They can also be sensitive to objects outside the spatial resolving power of the human eye.
6. Three dimensional perspectives: A stereoscopic view of the Earth's surface can be created and measured both horizontally and vertically; a characteristic that is lacking for the majority of remotely sensed images.

Uses of Aerial Photographs

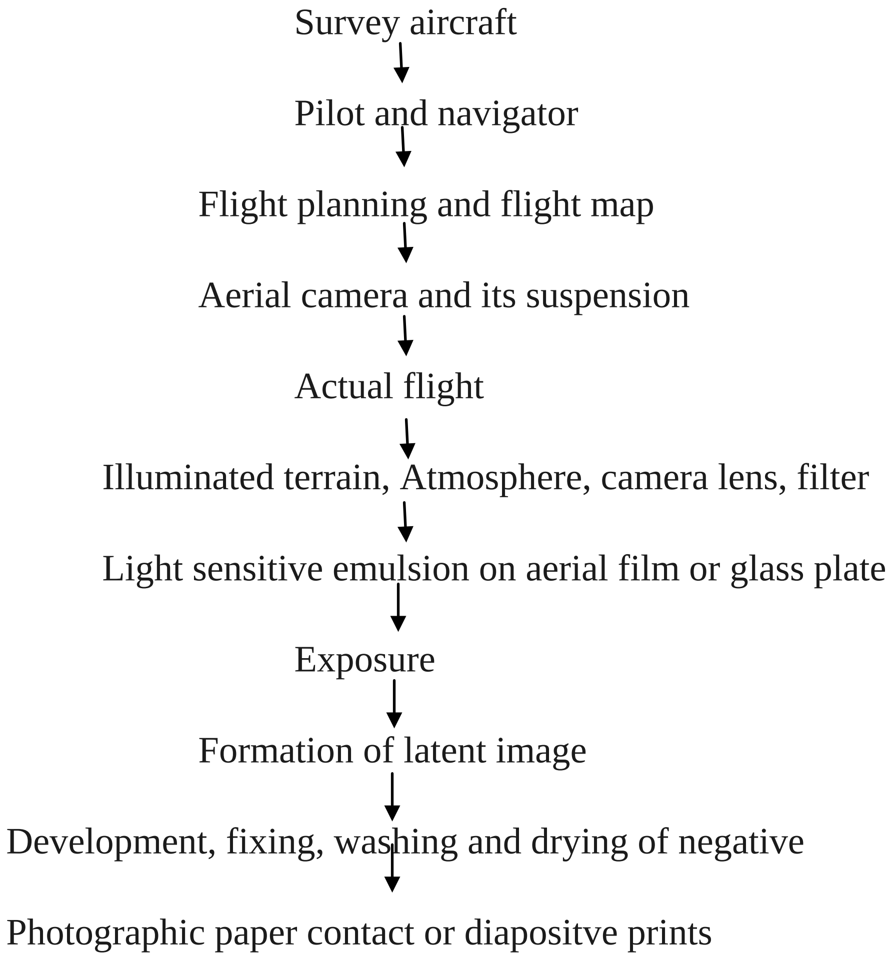
The main use of aerial photography is for pictorial representation i.e. mosaic photo-interpretation and photographic survey. In almost all natural resources studies air photographs are used as basic material and therefore, play an important role.

Aerial photography is valuable for faithful reproduction of terrain unbroken continuity of its tonal relationships and its meticulous minute detail. A good air photograph has to achieve a certain standard in the accuracy of its geometrical properties and tonal relationships with origin and must record details of the smallest size perceptible from camera station. The aerial photograph is the result of the combined scientific and productive effects of

1. Optical lens
2. Camera
3. Photographic materials
4. Aero plane
5. Navigator
6. Camera operator
7. Photo laboratory workers.

Stages of Aerial Photography

The various stages in aerial photography and production of photographic prints are illustrated below.



Aerial photography in India is controlled and co-coordinated by the Survey of India and flown by a flying agency, Once the scale and type of photography are indicated, the Survey of India designs the photographic specifications and places the order for photography one of three flying agencies viz., 1) The Indian Air force 2) M/ S Air Survey Company (Pvt) and 3) National Remote Sensing Agency, Hyderabad (NRSA).

Some of the factors, which influence the image quality of the photographs, are given below.

Factors	**Principal Characteristics**
Ground detail colour	Size, light distribution, shade,
Atmosphere	Haze
Aircraft window flatness	Light scattered and loss, optical
Aircraft enclosure	Temperature and pressure
Camera and its mounting	Vibration and steadiness
Aerial camera shutter and	Calibration and rigidity of lens, magazine assembly
Filter transmission,	Light scatter and loss, spectral optical flatness
Camera lens light loss and	Aperture, illumination, diffusion, scatter, distortion, and aberration
Camera shutter	Efficiency and mechanical shock
Focal plane	Flatness
Negative emulsion (film or glass plate)	Speed, contrast, spectral

sensitivity, diffusion	and exposure
Negative base (film or glass plate) to base	Spread of photographic image due reflection from negative
Processing dimensional	Contrast, speed, definition, and stability
Printing dimensional stability.	Definition contrast and

Visual Image Interpretation

When performed manually (visually) a human interpreter interprets the image. The image used in such analysis is in a pictorial form or photograph type or ANALOG image. Photographic sensors produce analog images and variations of reflected energy.

Remote sensing images are also represented in digital form. The digital processing and analysis is performed using a computer. A digital image is composed of mall areas known as picture element (PIXEL) arranged in a matrix form. Each pixel location is assigned a number known as Digital Number (DN), which represents the brightness of the small area on the earth’s surface.

When we view a two dimensional image, we cannot sense the depth of the scene. We are used to see the objects as horizontal view whereas the imagery are vertical view. The other difficulty is that we can see only the visible wavelength and the interpretation of imagery recorded outside the visible range is not interpreted.

Visual image interpretation techniques could be used on LAND SAT/airborne/RADAR images. This has the advantage of being relatively simple and inexpensive. Each LAND SAT scene which is near-orthographic and covers 3.5 million hectares give synoptic _view of soil association. The influence of climate, vegetation, topography and parent materials on soils can be observed distinctly on LAND SAT scenes.

Elements of Visual Interpretation

There are eight elements of visual interpretation to identify the objects. The factors involved in identifying an object are:

1. Tone or colour
2. Texture
3. Shape
4. Size
5. Pattern
6. Shadow
7. Association
8. Site

Tone

Tone refers to the relative brightness or colours of objects in an image. Since different objects reflect differently, they appear as light or dark colours on imagery. For example, two Fields with different crops will have different colours, depending on the reflectivity.

Texture

Texture refers to the arrangement .and frequency of colour changes in particular areas of an image. When the brightness values change abruptly in a small area, it is a rough texture, whereas smooth textured surfaces have very little colour variation. Smooth textures results from uniform or even surfaces like agricultural held and rough textures from irregular like forests.

Shape

Shape refers to the general form of the objects. Shape is the distinctive clue for identification of objects. Natural features are irregular in shape like mountains whereas manmade objects have regular shapes like a stadium and cricket fields.

Size

Size refers to the scale of an image. In order to quickly identify the size of the objects relative to other objects in a scene must be considered. For example, if an image has to suggest the use of buildings would suggest commercial factories and ware houses whereas small houses as residential houses.

Pattern

Pattern refers to the spatial arrangement of objects. It is an orderly repetition of similar colours and texture. For example, orchards have evenly spaced trees with roads in between, whereas urban areas have regularly spaced houses.

Shadow

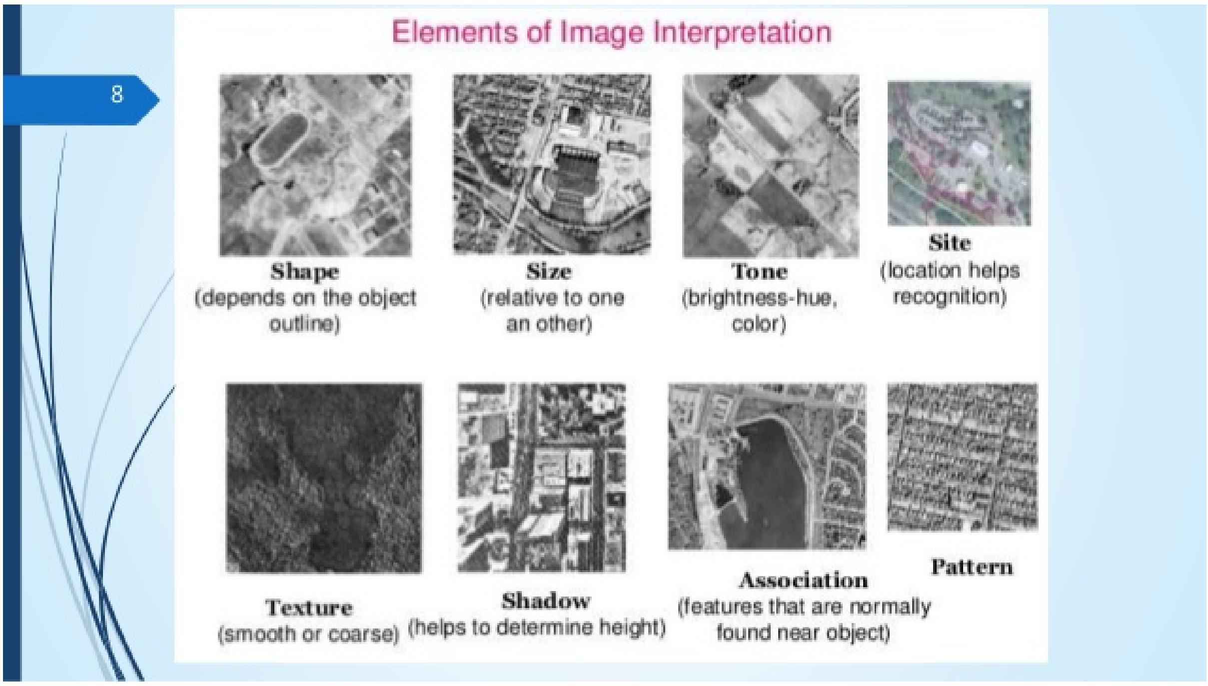
The shadow of tall object helps in interpretation. However, shadows also hinder the image interpretation because objects within shadows are not visible.

Site

Site refers to topographic or geographic location and is important in the identification of vegetation types. For example, certain tree species would be expected to occur on well drained upland sites whereas other trees on low land sites.

Association or location of objects

This refers to the relationship between the objects and their location. For example, factories can be associated with highways, whereas schools can be associated with residential areas.



Elements of Image Interpretation

Shape
(depends on the object outline)

Size
(relative to one an other)

Tone
(brightness-hue, color)

Site
(location helps recognition)

Texture
(smooth or coarse)

Shadow
(helps to determine height)

Association
(features that are normally found near object)

Pattern

Digital Image Analysis

Digital image processing involves manipulation and interpretation of digital images with the help of a computer. It includes geocoding and georeferencing with proper coordinate and projection system there are many advantages of digital image processing as compared to Visual interpretation, such as better visualization, easier cartographic facilities, flexibility in editing of data and area estimation. The digital image processing system is composed of two parts:

Hardware and Software

Hardware refers to the physical components that make up the system and software refers to the set of programmes written in a computer programming language for a particular application. Minimum hardware and some of the software's used for image processing and geophysical analysis is listed below:

Table 8.1: Hardware and software used for the study

Sr. No.	Hardware	Software Packages
1	Personal computer	ILWIS (integrated Land and water Information System)

2	Plotter	
3	Desk jet printer	Arc lnfo., Arc View, ERDAS
4	Geographical positioning system	IMAGIN, IDRSI, ENVI, GRASS, IDIMS, ELAS, GYPSY, ERIPS, SMIPS
5	Digitizer and scanner	EASI/PACE, IDRS for data procurement. GPS software, Arc pad

Georeferencing

Remotely sensed image in row format contain no reference to the location of the data. In order to integrate these data with other data in a 618, it is necessary to correct and adopt them geometrically.

Remote sensing data is affected b geometric distortion due to many factors such as sensor geometry, scanner and platform instabilities, earth rotation, earth curvature etc. These can be corrected by referencing the image to existing maps.

Geocoding

Transformation of an image which results in a new image with the pixels stored in a new line or Coolum geometry is known as geocoding. The geocoding is used to correct the geometry of the georeferenced image, so that a distortion free image can be obtained.

Digital Image Processing

The image processing can be categorized into three main functions.

1. Image processing

2. Image enhancement

3 image classification

Image processing

Image processing refers to the preliminary operation to the main analysis. It involves the removal of errors introduced in the imaging, so that the image resembles to the original scene. Processing operations are grouped into two:

1. Radiometric error correction

2. Geometric error correction

Radiometric error correction

Radiometric corrections are necessary to remove variations in scene illumination, atmospheric conditions and sensor noises and response.

- Variation in illumination and viewing geometry between images can be corrected by establishing the geometric relationship between the area imaged and the senor.
- Sensor noise may be introduced in an image due to irregularly that occurs in sensor or in data recording and transmission. Common forms of noises are banding and dropped lines. The correction to banding can be done by comparing with other lines of date. Dropped lines occurs due to 110 response from sensor and data is lost while transmission. They are corrected by replacing the line with pixel values in the line above or below or with the average of two.
- The atmospheric conditions change and reduce the illumination of the scene. The scattering reduces same of the energy illuminating the surface and from layer to the sensor.

The correction procedure is complex, because it involves the detailed modeling of atmospheric conditions during data acquisition.

Geometric error correction

Remote sensing data involves number of geometric distortion which occurs due to several reasons like rotation and curvature of earth motion of scanning system and satellite, satellite altitude and velocity. Image rectification or geometric registration is a process by which the geometry of an image is transformed to a known coordinate system.

The image rectification process (IRP) involves

1. Identification of ground control points and

2. Resampling.

Resampling procedure determines the digital values of new pixel location in the corrected image.

Image Enhancement

Image enhancement is a digital technique to improve the appearance o in image for human visual analyses and machine analysis.

The enhancement of an image is necessary because, in remote sensing, reflected or emitted energy from different earth surface materials is recorded. Under ideal conditions one material reflects large amount of energy at certain wavelength while another reflects very less energy in the same wavelength. Due to this the objects get high and low values from bright and dark areas. Again, different materials reflect different wavelength regions resulting in similar colour. This is known as low contrast image.

There are two contrast enhancement techniques

Linear contrast enhancement

In this technique the original values are expanded to make use of the range of output device. The lowest value in the input image is assigned to black (having a value of 0) and the highest value to white colour (having value of 255). All the intermediate values are linearly distributed between these two extremes.

Nonlinear contrast enhancement

In non linear contrast enhancement the input and output values are hot linearly related, they are transformed logarithmically.

Spatial filtering

Spatial filtering is a technique to highlight or suppress specific features in an image based on their spatial frequency. Spatial frequency is defined as the number of changes in “brightness” values per unit distance for any part of the image. An area having very few changes in brightness values is known as low frequency area and in a high frequency area brightness values change suddenly. Filtering is done through a procedure known as convolution.

Band rationing (vegetation indices)

Band rationing is a technique in which the difference from surface due to different seasons and illumination are reduced. Due to different seasons, topographic conditions and changes in sunlight, the brightness values of the same surface changes, causing problem in identifying the objects.

This technique also highlights variations in the response of different surfaces. For example, healthy vegetation reflects large amount of energy in the NIR portion of the EMS while it absorbs energy in RED wavelength region. Other surfaces like soil and water have almost similar reflectance in both NIR and RED portions. Therefore, a ratio of reflectance in IR by a ratio of reflectance in RED would result in variation and about 1.0 for soils and water. This differentiates the vegetation from other surfaces.

Also it becomes possible to identify the areas of unhealthy vegetation which will have lower ratio value than that for healthy vegetation.

Principal Component Analysis (PCA)

Principal component analysis (PCA) is a technique which reduces the number of bands in the data and compresses as much' information in the original band as possible into fewer bands. Interpretation and analysis of these bands of data is simpler and more accurate than trying to use all the bands of data. The compressed bands are called components; hence it is called as principal component analysis.

Image classification

False colour cnmposite (FCC)

This is the first step of image classification process. The spectral information stored in the separate bands can be integrated by combining them into a colour composite. The spectral information is combined by displaying each individual band in one of the three primary additive colours: blue, green and red. A specific combination of bands used to create a. colour composite image is called false colour composite. In a FCC, the red colour is assigned to the NIR, the green colour to the red, and the blue colour to the green band. For example, the green vegetation will appear reddish, the water will appear bluish and the bare soil in shades of brown and gray in an imagery.

The images generated by remote sensing measurements in blue, green and red bands are combined by superposing the transmission is known as True Colour composite (TCC), whereas the other possible combinations of colour filters and spectral band images are known as False Colour Composite (FCC). This is done to improve the visual perception by assigning BGR to observations in green, red and near infrared spectral bands respectively. Thus, in FCC the blue colour is assigned to green band, the green colour to the red band and the red colour to the NIR band.

- Vegetation in imageries appears red in FCC. The vegetation generally reflects predominantly in NIR region as compared to green and red. Hence vegetation appears red in FCC due to assignment of IR band to red colour.
- Water appears bluish in FCC. The sky blue or dark blue can be differentiated depending on the depth and concentration of sediments in water.
- The bare soil in shares appears brown or gray in FCC.
- The agriculture and forest appear pink to deep red depending on leaf greenness as the green band is assigned to the blue colour.
- The ice, snow and clouds appear white in FCC.
- The human settlements, cities would appear gray in FCC.

Methods of image classification

Image classification is very important and necessary step in processing of digital data. In this technique similar pixels are regrouped into “classes”. Without classification it is difficult to know about earth features accurately.

Actually we are used to categorize the objects by labels describing them as forest, agriculture field, river, residential building etc. we are not used to calling areas by numbers as is the case with digital images. Hence digital image classification is the process of assigning pixels to classes. Each pixel in a digital image is treated as an individual unit having different wavelength regions (spectral bands).

There are two methods of digital image classification

1. Supervised classification

2. Unsupervised classification

A coloured image is classihed into groups of colours called cluster and then after collecting ground information, it is used for supervised classification.

Supervised classification

Supervised classification is the process of using known identity that is using pixels which are already assigned to some informational class to classify pixels, whose identity is not known. There are six stages of the classification process

1. To define training 'sites

2. Extract signatures

3. Classify the image

4. In-process classification assessment (IPCA) 5. Generalization

6. Accuracy assessment

The description of these processes is very lengthy and out of the object of this book and hence not included.

Unsupervised classification

In this process there is no knowledge about thematic map, land cover class names such as town, village, road etc. this classification can be defined as identification of natural groups within the data. In this technique, computer is required to group pixels with similar characteristics.

A series of computer software's are used for the classification of ages which need spec1al expertise. This book deals with the theoretical aspects of the subject and hence safely excluded the description of this practical aspect.

Users of remote sensing techniques

The following groups and departments are engaged in the use of_ remote sensing techniques.

1. All India Soil and Land Use Survey (AISLS)
2. Central Ground Water Board (CGWB)

3. Geological Survey of India (GSI)
4. National Remote Sensing Agency (NRSA)
5. National Bureau of Soil Survey Land Use Planning (N BSSLP)
6. National Institute of Oceanography (NIO)
7. Oil and Natural Gas Commission (ONGC)
8. Space Application Centre (SAC)
9. Survey of India (SOI)

Lecture 8

Geographic Information System (GIS)

Geographic information system (GIS) is defined as a powerful set of computer-based tools for collecting storing, retrieving at will, and transforming and-displaying spatial him from the real world for a particular set of purposes. GIS consists of

(i) An extensive database of geographic information involving both positional data about land features and descriptive / non-locational data about these features at different points of time; and

(ii) Sets of programmes of applications, which enable the data to be input, assessed, manipulated, analyzed and reported.

The GIS history dates back 1960 where computer based GIS have been used and their manual procedures were in life 100 years earlier or so. On introduction of and spread of personal computers in 1980’s, exponential growth of GIS technology took place. However, potentiality of GIS is realized in the recent past and now it has become popular among many users for variety of applications. GIS is all about analysis of spatial data for extracting information, thereby it is called Geographic Information and is done through an integrated system comprised of four components: (i) hardware comprising of computer as processing unit, input (keyboard, digitizer, mouse, scanner) and output devices (monitor or display unit, plotter), (ii) designated software, (iii) data both spatial and non-spatial, and (iv) live ware i.e. people responsible as interface between software and data using specific methods and protocols for required output (Figure 5.11).

Objectives of GIS are:

- Maximizing the efficiency of planning and decision making
- Providing efficient means for data distribution and handling
- Elimination of redundant data base minimize duplication
- Capacity to integrate information from many sources, and

- Complex analysis/query involving geographical referenced data to generate new information.

For any application there are five generic questions a (GIS) can answer:

- Location what exists at a particular location?
- Condition Identify locations where certain conditions exist.
- Trends what has changed since?
- Patterns what spatial pattern exists?
- Modeling What if........... ?

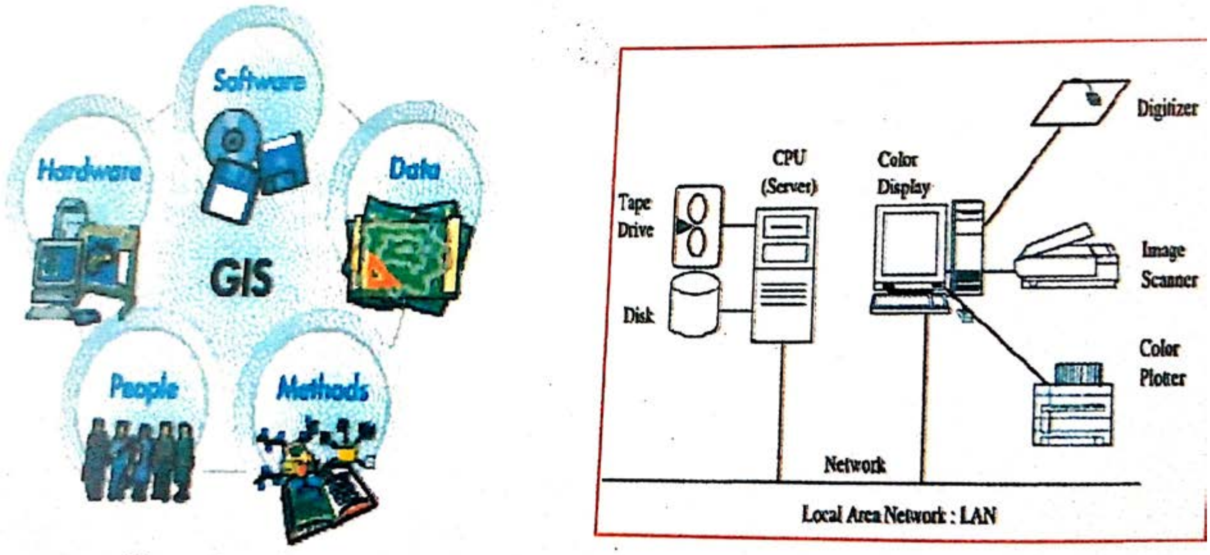
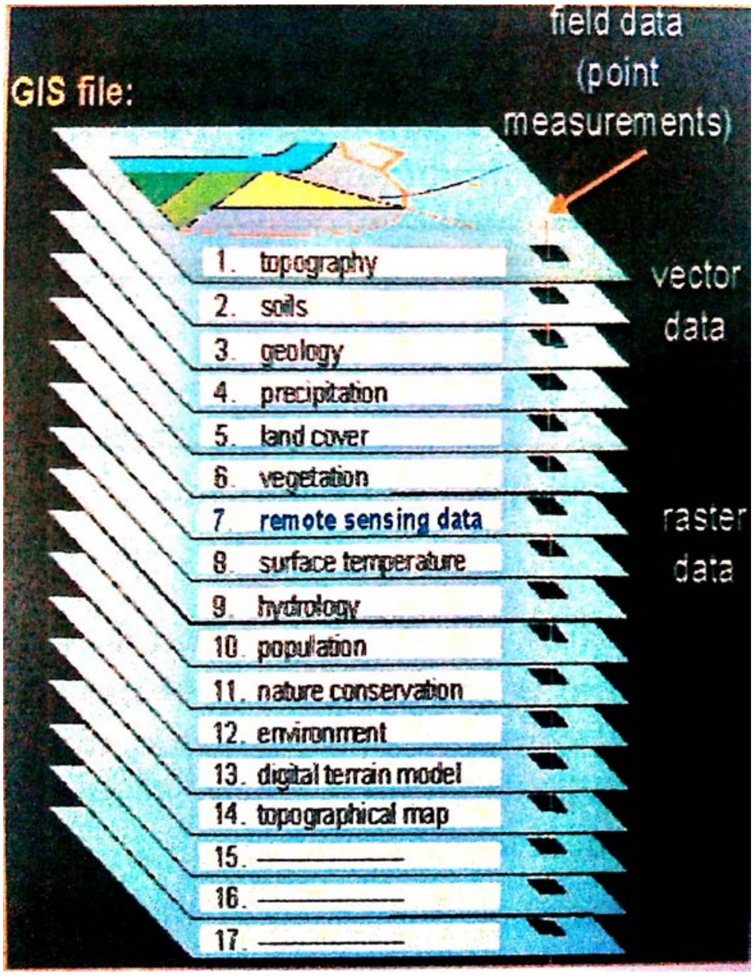


Figure 5.11. Components of GIS along with details hardware components

GIS differs from digital map due to features such as (i) it makes map dynamic, (ii) displays map information interactively, (iv) builds spatial relationship between features, and (V) analyze to answer real world problem.

Data in GIS

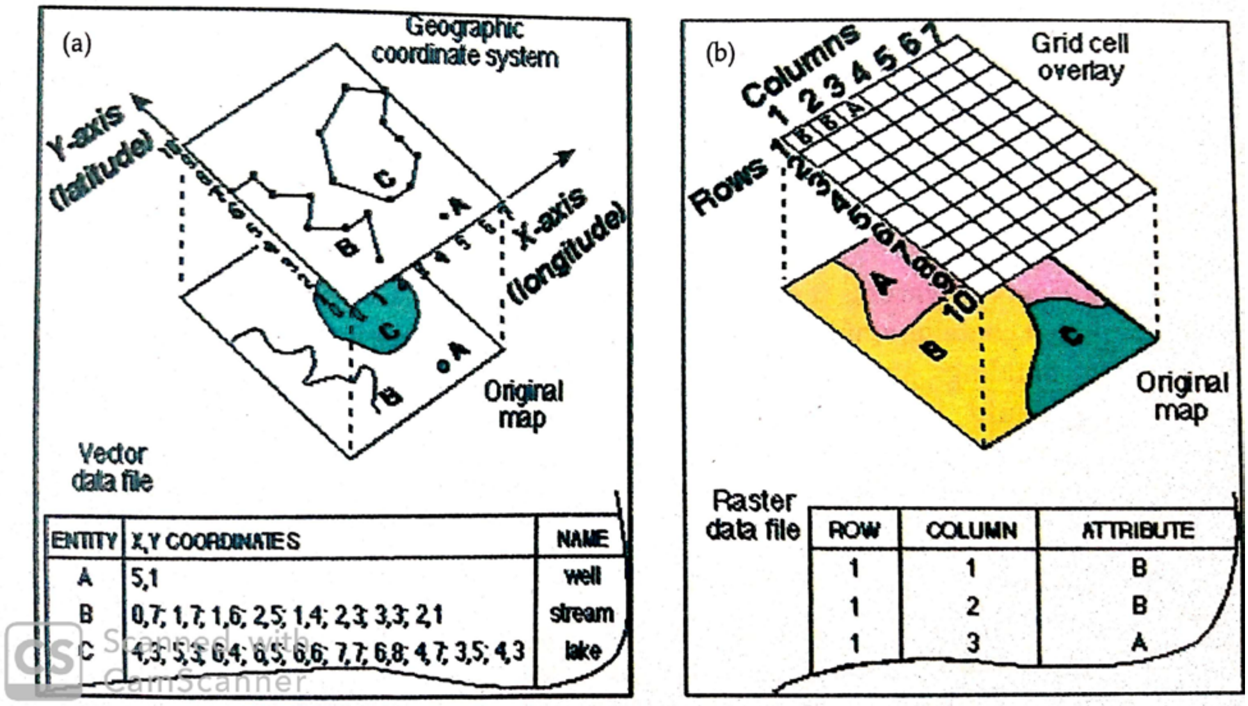
Most important part of GIS is the data. GIS stores information about the world as a Collection of layers on various themes that can be used together (Figure) a layer can be anything that contains similar features such as customers, buildings streets, lakes, or postal codes. This could be either an explicit geographic reference, such as a latitude and longitude called spatial data, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name called non-spatial data or attributes. Spatial data show where the feature is and attribute, provide information about the feature. These are linked by the software. Both spatial and attribute data in GIS allow the digital database to be exploited in many more ways than a conventional database making the maps dynamic and interactive. Therefore, GIS is more than all the functionalities of the DBMS and adds spatial functionality.



Spatial Data: Spatial data represent the location, size and shape of an object on planet Earth such au building lake, Mountain or township. Spatial data may also include attribute that provide more information about entity that is being represented. Geographic Information Systems (GIS) or other specialized software applications are to be used to access, Visualize, manipulate and analyze these data. Spatial data typically include various kinds of maps, ground survey data and remotely sensed imagery and can be represented by points, lines or polygons

Attribute Data: Attribute data refers to various types of administrative records, census, field sample records and collection of historical records. Attributes are either the qualitative characteristics of the spatial data or are descriptive information about the geographical location. Attributes are stored in the form of tables where each column of the table describes one attribute and each row of the table corresponds to a feature.

In raster type of representation of the geographical data, a set of cells located by coordinate is used; each cell is independently addressed with the value of an attribute. Each cell contains a single value and every location corresponds to a cell. One set of cell and associated value is a layer. Raster models are simple and spatial analysis is easier and faster. But it is voluminous. Vector data model uses line segments or points represented by their explicit x, y coordinates to identify locations. Discrete objects are formed by connecting line segments and its area is defined by set of line segments. Compared to raster, vector data models require less storage space, and are precise in estimating area/perimeter. Editing is faster and convenient. Spatial analysis is difficult. The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals. The raster model has evolved to model such continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture. Both the vector and raster models, storing geographic data, have unique advantages and disadvantages. Modern GIS packages are able to handle both these models.



ENTITY	X,Y COORDINATES	NAME
A	5,1	well
B	0,7; 1,7; 1,6; 2,5; 1,4; 2,3; 3,3; 2,1	stream
C	4,3; 5,3; 6,4; 6,5; 6,6; 7,7; 6,8; 4,7; 3,5; 4,3	lake

ROW	COLUMN	ATTRIBUTE
1	1	B
1	2	B
1	3	A

GIS Layers and Coverage

The common requirement to access data on the basis of one or more classes has resulted in several GIS employing organizational schemes in which all data of a particular level of classification, such as roads, rivers or vegetation types are grouped into so-called layers or coverages. The concept of layers is to be found in both vector and raster models. The layers can be combined with each other in various ways to create new layers that are a function of the individual ones (Figure 5.12). The characteristic of each layer within a layer-based GIS is that all locations with each layer may be said to belong to a single arial region or cell, whether it be a polygon bounded by lines in vector system, or a grid cell in a raster system. But it is possible for each region to have multiple attributes.

Lecture 10

Components of GIS data output functions

Geographic Information System Five Components.

1. Hardware:
2. Software:
3. Data:
4. People:
5. Methods**:**

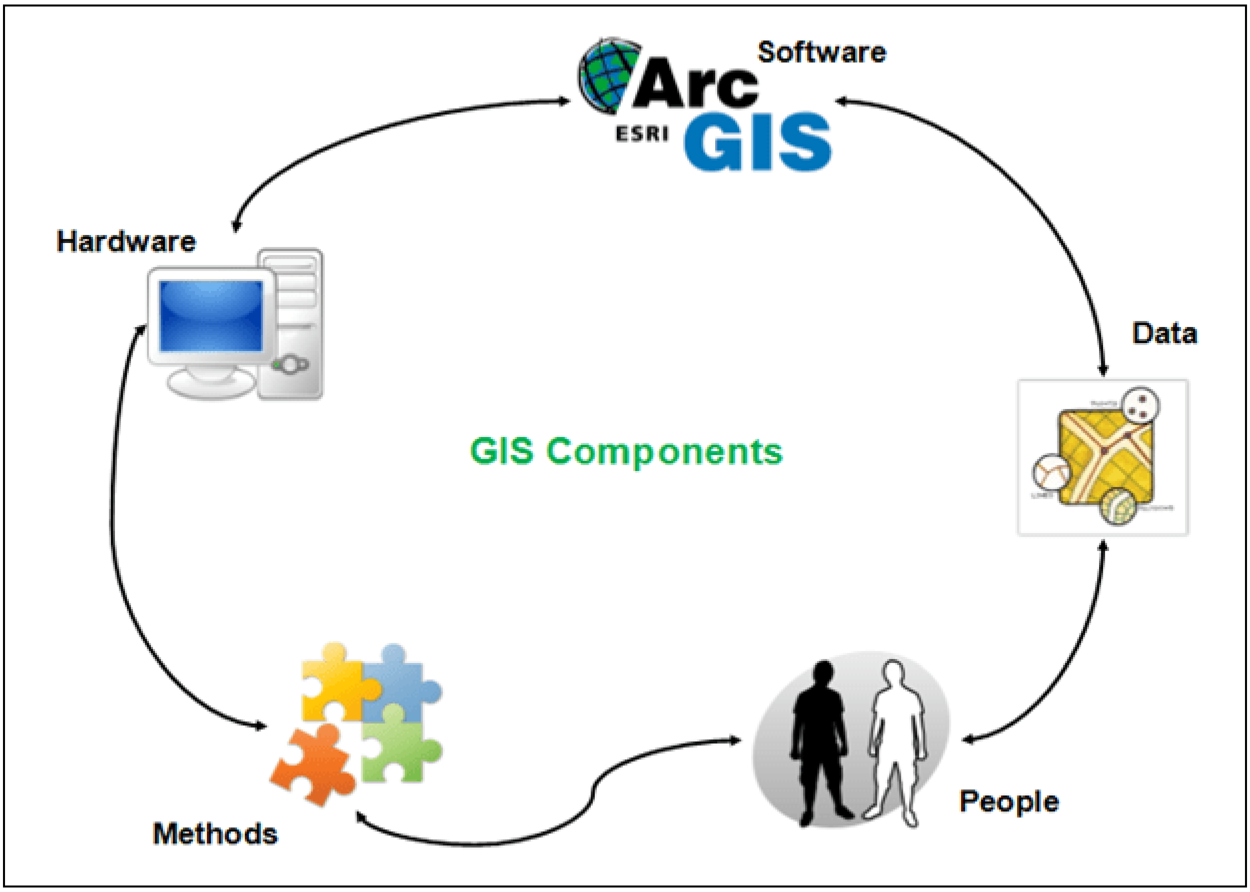


Figure: How GIS Components integrate with each other

Hardware: Hardware is Computer on which GIS software runs. Nowadays there are a different range of computer, it might be Desktop or server based. ArcGIS Server is server based computer where GIS software runs on network computer or cloud based. For computer to perform well all hardware component must have high capacity. Some of the hardware components are: Motherboard, Hard driver, processor, graphics card, printer and so on. These all component function together to run a GIS software smoothly.

Main Hardware Components:

1. **Motherboard:** It is board where major hardware parts are installed or It is a place where all components gets hooked up.
2. **Hard Drive:** It is also called hard disk, place to store data.
3. **Processor:** Processor is the major component in computer, it performs calculation. It is called as Central processing Unit (CPU).
4. **RAM:** Random Access Memory (RAM) where all running programs load temporarily.
5. **Printer:** It is output device and used to print image, map or document. There are various type of printer available in market.
6. **External Disk:** These are portable storage space such as USB drive, DVD, CD or external disk.
7. **Monitor:** It is a screen for displaying output information. Nowadays there are various type of monitor: CRT (cathode ray tube), LCD (Liquid Crystal Display), LED (Light Emitting Diodes) and more.

Software: Next component is GIS software which provide tools to run and edit spatial information. It helps to query, edit, run and display GIS data. It uses RDBMS (Relational Database Management System) to store the data. Few GIS software list: ArcGis, ArcView 3.2, QGIS, SAGA GIS.

Software Components:

1. **GIS Tools:** Key tools to support the browsing of the GIS data
2. **RDBMS:** Relational Database Management System to store GIS data. GIS Software retrieve from RDBMS or insert data into RDBMS.
3. **Query Tools:** Tools that work with database management system for querying, insertion, deletion and other SQL (Standard Query Language).
4. **GUI:** Graphical User Interface that helps user and Software to interact well.
5. **Layout:** Good layout window to design map.

Data: The most important and expensive component of the Geographic Information System is Data which is generally known as fuel for GIS. GIS data is combination of graphic and tabular data. Graphic can be vector or raster. Both type of data can be created in house using GIS software or can be purchased. The process of creating the GIS data from the analog data or paper format is called digitization. Digitization process involves registering of raster image using few GCP (ground control point) or known coordinates. This process is widely known as rubber sheeting or georefrencing. Polygon, lines and points are created by digitizing raster image. Raster image itself can be registered with coordinates which is widely known as rectifying the image. Registered image are mostly exported in TIFF format. As mentioned above, GIS data can be Raster or Vector.

GIS Data Types:

1. **Raster:** Raster image store information in a cell based manner. It can be aerial photo, satellite image, Digital Elevation Model (DEM). Raster images normally store continuous data.
2. **Vector:** Vector data are discrete. It store information in x, y coordinate format. There are three types of Vector data: Lines, Points and Area.

People: People are user of Geographic Information System. They run the GIS software. Hardware and software have seen tremendous development which made people easy to run the GIS software. Also computer are affordable so people are using for GIS task. These task may be creating simple map or performing advance GIS analysis. The people are main component for the successful GIS.

Lecture 11
Attribute Data Types for GIS

There are two components to GIS data: spatial information (coordinate and projection information for spatial features) and attribute data. Attribute data is information appended in tabular format to spatial features. The spatial data is the where and attribute data can contain information about the what, where, and why. Attribute data provides characteristics about spatial data.

Types of Attribute Data

Attribute data can be store as one of five different field types in a table or database: character, integer, floating, date, and BLOB.

Character Data

The character property (or string) is for text based values such as the name of a street or descriptive values such as the condition of a street. Character attribute data is stored as a series of alphanumeric symbols.

Aside from descriptors, character fields can contain other attribute values such as categories and ranks. For example, a character field may contain the categories for a street: avenue, boulevard, lane, or highway. A character field could also contain the rank, which is a relative ordering of features. For example, a ranking of the traffic load of the street with “1” being the street with the highest traffic.

Character data can be sorted in ascending (A to Z) and descending (Z to A) order. Since numbers are considered text in this field, those numbers will be sorted alphabetically which means that a number sequence of 1, 2, 9, 11, 13, 22 would be sorted in ascending order as 1, 11, 13, 2, 22, 9.

Because character data is not numeric, calculations (sum, average, median, etc.) can’t be performed on this type of field, even if the value stored in the field are numbers (to do that, the field type would need to be converted to a numeric field). Character fields can be summarized to produced counts (e.g. the number of features that have been categorized as “avenue”).

Numeric Data

Integer and floating are numerical values (see: the difference between floating and integer values). Within the integer type, the is a further division between short and long integer values. As would be expected, short integers store numeric values without fractional values for a shorter range than long integers. Floating point attribute values store numeric values with fractional values. Therefore, floating point values are for numeric values with decimal points (i.e numbers to the right of the decimal point as opposed to whole values).

Numeric values will be sorted in sequentially either in ascending (1 to 10) or descending (10 to 1) order.

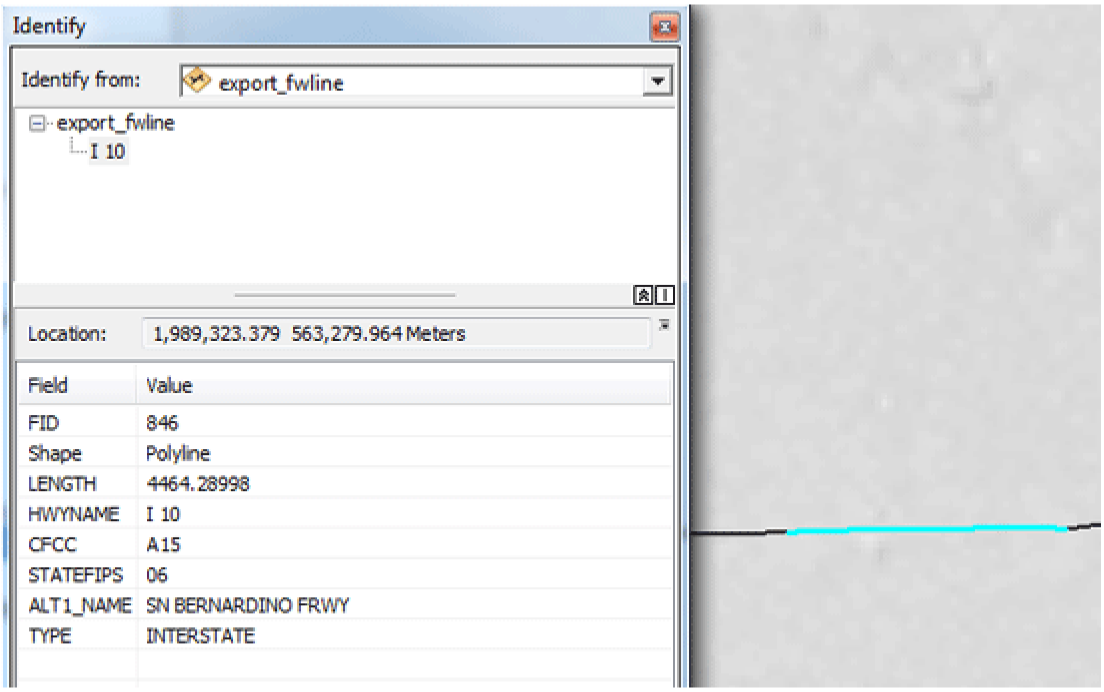
Numerical value fields can have operations performed such as calculating the sum or average value. Numerical field values can be a count (e.g. the total number of students at a school) or be a ratio (e.g. the percentage of students that are girls at a school).

Date/Time Data

Date fields contains date and time values.

BLOB Data

BLOB stands for binary large object and this attribute type is used for storing information such images, multimedia, or bits of code in a field. This field stores object linking and embedding (OLE) which are objects created in other applications such as images and multimedia and linked from the BLOB field



Identify from: export_fwline

export_fwline
- I 10

Location: 1,989,323.379 563,279.964 Meters

Field	Value
FID	846
Shape	Polyline
LENGTH	4464.28998
HWYNAME	I 10
CFCC	A15
STATEFIPS	06
ALT1_NAME	SN BERNARDINO FRWY
TYPE	INTERSTATE

Attribute data for a road in GIS.

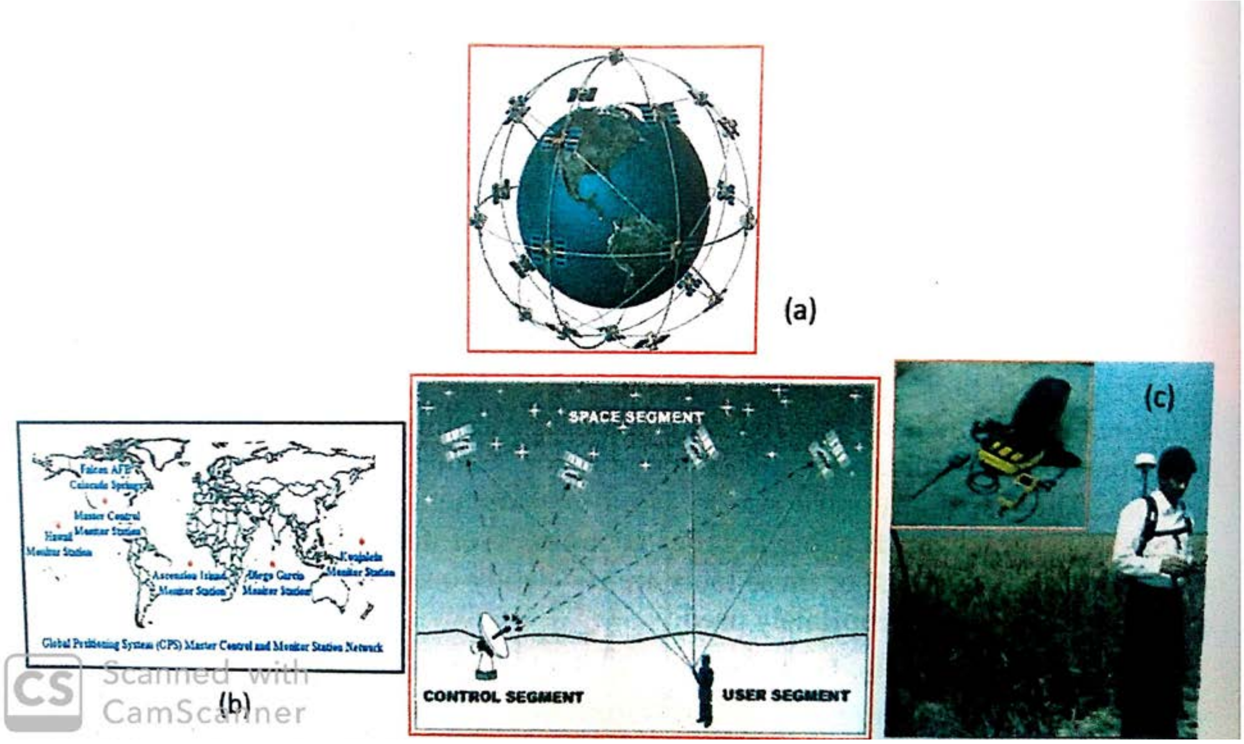
Lecture 12

Global Positioning System (GPS)

GPS is network of satellites (24 total - 21 in use, 3 spares) that continuously transmit coded information, which makes it possible to precisely identify locations on earth by measuring distance from the satellites. GPS provides continuous (round the clock), real time, 3-dimensional positioning, navigation and timing worldwide in any weather condition. It was originally intended for military applications, but in the 19805 it was made available for civilian use. There are no subscription fees or setup charges to use GPS. Any person With a GPS receiver can access the system, and it can be used for any application that requires location coordinates.

Components of GPS

The GPS system consists of three segments: 1) the segments: the GPS satellites themselves, 2) the control system, and 3) the user segment, which includes both military and civilian users and their CPS equipment (Figure 5.14). The space segment is composed of the GPS satellites that transmit signals from space based on which time and position of the user is measured. The whole set of satellite is called 'constallation' and also known as Global Navigation satellite system (GNSS). There are three globally known GNSS. These are NAVSTAR (NAVigation System using Timing and Ranging) of USA, GLONASS (Globalnaya Navigazionnaya Sputnikovaya Sistema, or Global Navigation satellite System) of Russia, and GALILEO of European Union. Indian Regional Navigation Satellite System (IRNSS) is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to user in India as well as in the region extending up to 1500 km from its boundary, which is its primary service area. The control segment consists of Monitor Stations, Ground Antennas and a Master Control station (MCS). The monitor stations passively track all satellites in view, accumulating ranging data. This information is processed at the MCS to determine satellite orbits and to update each satellite's navigation message Updated information is transmitted to each satellite via the Ground Antennas. The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert satellite signal into position, velocity, and time estimates. Four satellites are required to compute the four dimensions X, Y, Z (position) and time. GPS receivers are used for navigation, positioning, time dissemination, and other research. There are civilian applications for GPS in almost every field, from surveying to transportation to natural resource management to agriculture. Most civilian uses of GPS, however, fall into one of four categories: navigation, surveying, mapping and timing.



Working Principles of GPS

Each satellite transmits a message containing three pieces of information: the satellite number; its position in space, and the time at which the message was sent. The GPS receiver reads the message and saves the information. GPS receivers take this information and use triangulation (otherwise called trilateration) to calculate the user's exact location.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in View, the receiver can determine the user's 3D position unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

Lecture 13

Data Products from Indian Satellite

Overview

ISRO has a vibrant Indian Remote Sensing program since 1988 with a gamut of Indian Remote Sensing Missions (IRS) observing Earth with Optical, microwave and hyper-spectral instruments flown on-board to provide necessary data in various spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage.NRSC is the nodal centre for hosting Satellite Data Products from more than 13 IRS satellites right from the first IRS optical mission namely IRS-1A and SAR imaging missions. Satellites are primarily tasked to cover India and surroundings in a programmatic manner or on-demand as required by user as per mission capability. NRSC also acquires and archives data of global regions for disasters, calibrations and specific studies. Near real time data products from IRS weather sensors is delivered for climate and weather models for a global coverage. Georeferenced, Orthokit, Orthorectified products are provided in standard formats like Geotiff, HDF. Customized value added products are generated based on the requirements from the user for large AOI.NRSC Data archive is extensively utilized for Land use land cover monitoring, Ocean studies, weather applications and scientific research. The Government agencies, industries and academia is highly benefiting by the valuable huge data products archive and technology to meet their respective end objectives.

Optical High Resolution 2.5m and better

Sno	**Satellite**	**Sensor**	**Resolution**	**Data available from**
1	Cartosat-2 Series	Pan	0.65 m	01-Aug-2016
2	Cartosat-2 Series	MX	1.6 m	01-Aug-2016
3	CARTOSAT-2B	PAN	1 m	13-Jul-2010
4	CARTOSAT-2A	PAN	1 m	29-Apr-2008
5	CARTOSAT-2	PAN	1 m	14-Apr-2007

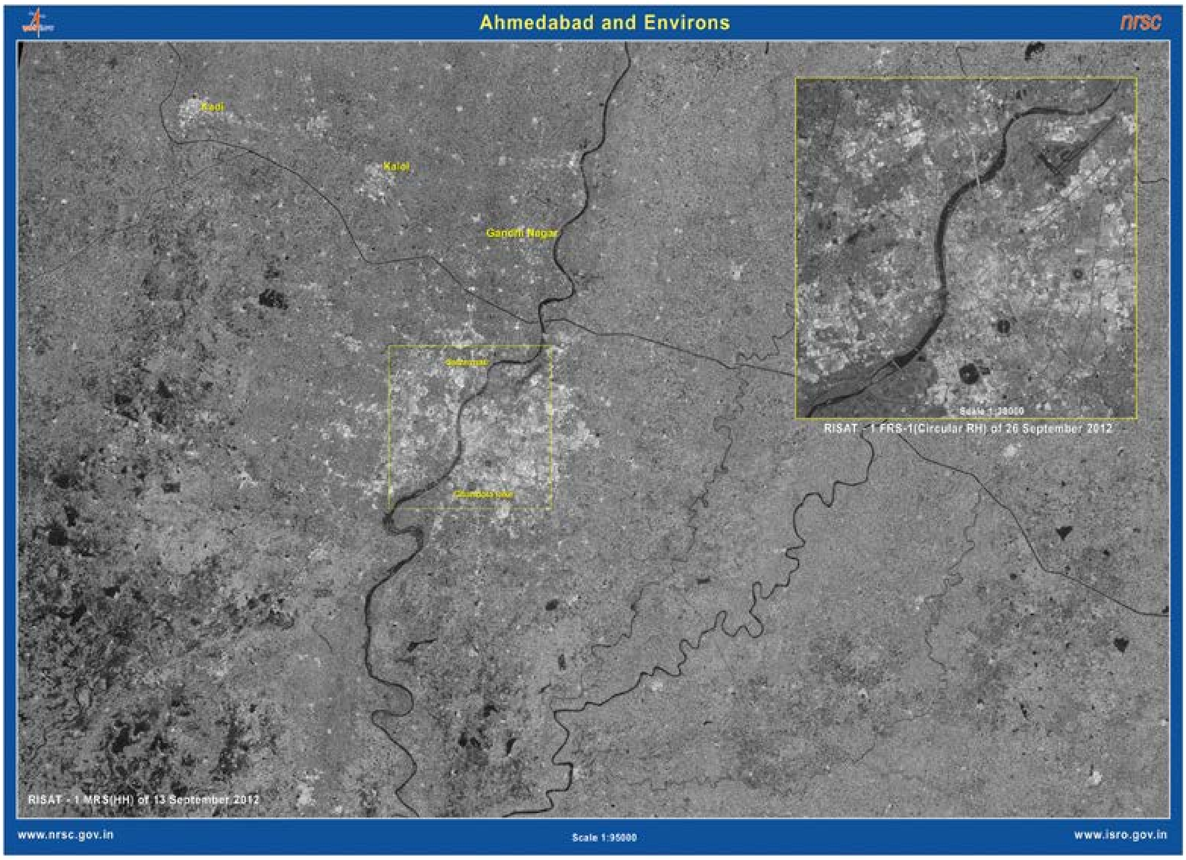
Sno	Satellite	Sensor	Resolution	Data available from
6	CARTOSAT-1	PAN-F	2.5 m	08-May-2005
7	CARTOSAT-1	PAN-A	2.5 m	08-May-2005
8	CARTOSAT-1	Stereo	2.5 m	08-May-2005
9	CARTOSAT-1	Widemono	2.5 m	27-May-2005

RS2A AWIFS, Gujarat

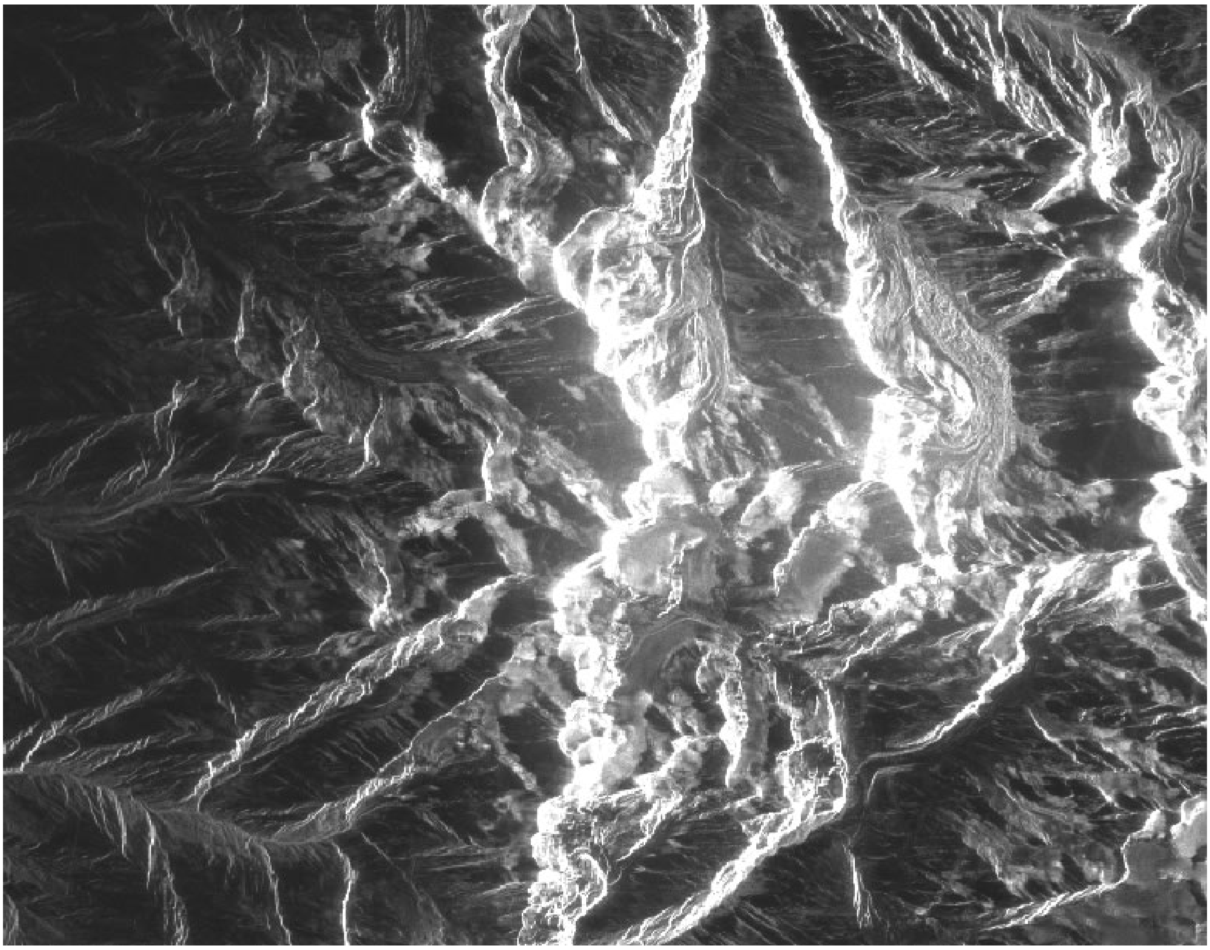
Microwave

Sno	Satellite	Sensor	Resolution	Data available from
1	RISAT-1	MRS, C-band	24 m	01-Jul-2012 to 17-Mar-2017
2	RISAT-1	CRS, C-band	48 m	01-Jul-2012 to 27-Feb-2017
3	RISAT-1	FRS-1, C-band	3 m	01-Jul-2012 to 13-Mar-2017

Sno	Satellite	Sensor	Resolution	Data available from
4	RISAT-1	FRS-2, C-band	9 m	01-Jul-2012 to 18-Sep-2016
5	RISAT-2	SPOT , X-band STRIPMAP,X-band SCANSAR, X-band	1-8 m	02-Jan-2009
6	OSCAT	Ku-band	50 km 25 km	09-Feb-2010 to 01-Mar-2014
7	SCATSAT-1	Ku band Scatterometer	50 km 25 km	26-May-2017
8	SARAL	ka-band radar altimeter		01-Nov-2014



Ahmedabad



Gangotri

Hyperspectral

Sno	Satellite	Sensor	Resolution	Data availability from
1	IMS-1	VNIR	500m	02-Jan-2009

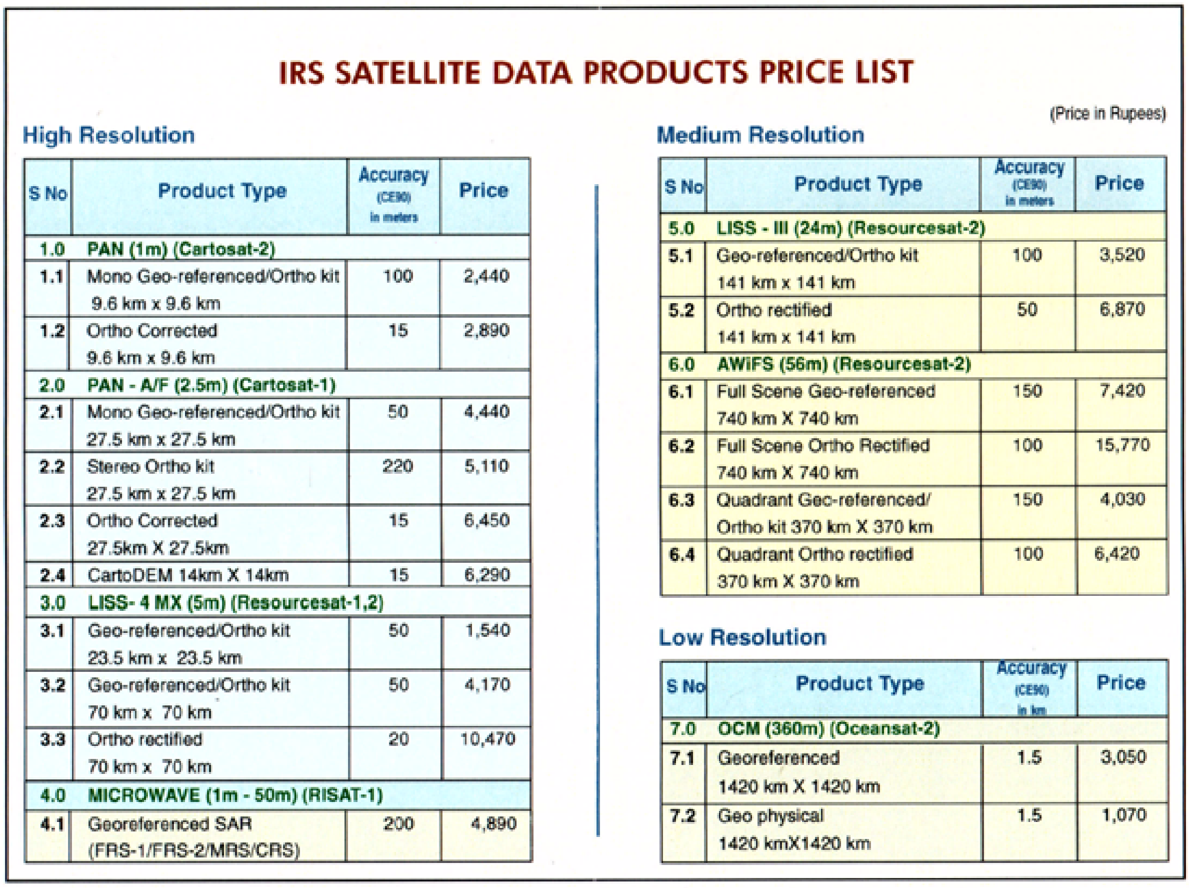
RS2A LISS3, Mumbai

Remote Sensing Data Policy (RSDP)

For operating a remote sensing satellite from India, license and/or permission of the Government, through the nodal agency, will be necessary. As a national commitment and as a “public good”, Government assures a continuous/improving observing/imaging capability from its own Indian Remote Sensing Satellites (IRS) programme. The Government of India, through the nodal agency, will be the sole and exclusive owner of all data collected/received from IRS. All users will be provided with only a license to use the said data and add value to the satellite data. Government reserves right to impose control over imaging tasks and distribution of data from IRS or any other Indian remote sensing satellite when it is of the opinion that national security and/or international obligations and/or foreign policies of the Government so require. For acquisition/distribution of remote sensing data within India, license/permission from the Government of India, through the nodal agency, will be necessary. Government reserves the right to select and permit agencies to acquire/distribute satellite remote sensing data in India. DOS shall be competent to decide about the procedure for granting license/permission for dissemination of such data and for the levy of necessary fees.

To cater to the developmental needs of the country, the National Remote Sensing Centre (NRSC) of the Indian Space Research Organization

(ISRO)/DOS is vested with the authority to acquire and disseminate all satellite remote sensing data in India, both from Indian and foreign satellites.



IRS SATELLITE DATA PRODUCTS PRICE LIST

(Price in Rupees)

High Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
1.0	PAN (1m) (Cartosat-2)		
1.1	Mono Geo-referenced/Ortho kit 9.6 km x 9.6 km	100	2,440
1.2	Ortho Corrected 9.6 km x 9.6 km	15	2,890
2.0	PAN - A/F (2.5m) (Cartosat-1)		
2.1	Mono Geo-referenced/Ortho kit 27.5 km x 27.5 km	50	4,440
2.2	Stereo Ortho kit 27.5 km x 27.5 km	220	5,110
2.3	Ortho Corrected 27.5km X 27.5km	15	6,450
2.4	CartoDEM 14km X 14km	15	6,290
3.0	LISS- 4 MX (5m) (Resourcesat-1,2)		
3.1	Geo-referenced/Ortho kit 23.5 km x 23.5 km	50	1,540
3.2	Geo-referenced/Ortho kit 70 km x 70 km	50	4,170
3.3	Ortho rectified 70 km x 70 km	20	10,470
4.0	MICROWAVE (1m - 50m) (RISAT-1)		
4.1	Georeferenced SAR (FRS-1/FRS-2/MRS/CRS)	200	4,890

Medium Resolution

S No	Product Type	Accuracy (CE90) in meters	Price
5.0	LISS - III (24m) (Resourcesat-2)		
5.1	Geo-referenced/Ortho kit 141 km x 141 km	100	3,520
5.2	Ortho rectified 141 km x 141 km	50	6,870
6.0	AWiFS (56m) (Resourcesat-2)		
6.1	Full Scene Geo-referenced 740 km X 740 km	150	7,420
6.2	Full Scene Ortho Rectified 740 km X 740 km	100	15,770
6.3	Quadrant Geo-referenced/ Ortho kit 370 km X 370 km	150	4,030
6.4	Quadrant Ortho rectified 370 km X 370 km	100	6,420

Low Resolution

S No	Product Type	Accuracy (CE90) in km	Price
7.0	OCM (360m) (Oceansat-2)		
7.1	Georeferenced 1420 km X 1420 km	1.5	3,050
7.2	Geo physical 1420 kmX1420 km	1.5	1,070

Data Dissemination Portals

- User Ordering Processing Service (UOPS)
- Bhuvan-Geoportal
- Scientific Application for Global Archive data(SAGAR)
- Meteorological & Oceanographic Satellite Data Archival Centre (MOSDAC)
- Indian Space Science Data Center (ISSDC)

Users

Satellite data is disseminated to various users viz. Central Ministries/Departments, State Ministries / departments, ISRO DOS Projects, Academia and Industry .

- **Central Departments / Ministries**
    - Several ministries / departments e.g. Rural Development RGNDWM, Ministry of Agriculture and Farmer Welfare, Department of Science & Technologies, Central Water Commission (CWC) / MoWRD-GR, Gas Authority of India Limited (GAIL)
    - Projects undertaken are e.g. Ground Water Prospects Mapping, Agricultural Drought Monitoring, India Water Resources Information System (India-WRIS), National Hydrology Project (NHP);
- **State Departments / Ministries**
    - All State Remote Sensing Applications Centres, Departments of State Water Resources, Agriculture, Forest, Urban and Rural development
- **ISRO / DOS Projects**
    - Natural Resources Census (NRC), Space based Information System for Decentralized Planning (SIS-DP),,National Database for Emergency Management (NDEM), Bhuvan Geoportal.
- **Academia and Industry**

Lecture 14

Soil information system for resource management – Tripura as a case study

The basic requirement to develop a soil information system (SIS) is to have large datasets. Such datasets are not generally available for all the states and Union Territories of the country. Tripura is one of the states for which relevant and pertinent datasets on natural resources are made available by the National Bureau of Soil Survey & Land Use Planning (NBSS&LUP; ICAR), Nagpur, during the past decade. While reviewing and interpreting the published data on the 1 : 50,000 scale, it was realized that a SIS can be developed which can serve as an example as to how such a system could be built for other States and Union Territories. Tripura was surveyed earlier by the All India Soil and Land Use Survey (AISLUS) and later by NBSS&LUP to develop soil datasets. Since the modern day information system of any natural resource requires its physical location in terms of space, exact referencing of natural resources has become necessary. The geographic information system (GIS) has been an important tool for geo-referencing the soil information system (GeoSIS). Soil information system elsewhere

Various countries have developed their own SIS1. The most widely used system is the Soil and Terrain Digital Database (SOTER; 1 : 1 m). It provides data for improved mapping, modelling and monitoring of changes of world soil and terrain resources. The SOTER methodology allows mapping and characterization of areas of land with a distinctive, often repetitive pattern of landform, lithology, surface form, slope, parent material and soils 2. The approach resembles physiographic or land systems mapping. The collated materials are stored in a SOTER database linked to the GIS, permitting a wide range of environmental applications3,4. The SOTER is applied5 at scales ranging from 1 : 250,000 to 1 : 5 M. The SOTER method used for studies on carbon stocks and their changes in the Indo-Gangetic Plains (IGP), led to the following, viz. (i) linkage between soil profile data and spatial component of a SOTER map for environmental applications requires generalizations of measured soil (profile) data by soil unit and depth zone, (ii) the set of soil parameter estimates for the IGP should be seen as best estimates, based on the currently available selection of profile data held in IGP–SOTER and World Inventory of Soil Emission Potential (WISE), and (iii) the primary and secondary datasets for IGP will be useful6 for agroecological zoning, land evaluation and modelling of carbon stocks and changes at a scale of 1 : 1 M.

Soil information system in India

Recently, the National Agricultural Innovative Project (NAIP) has sponsored a NBSS&LUP-led project of georeferenced soil information system (NAIP–GeoSIS) on the soils of the IGP and those of the black soil regions (BSR)7. Various research projects in the field of natural resource management funded by the World Bank, Department of Science and Technology (DST), New Delhi and the Indian Council of Agricultural Research, New Delhi have produced datasets on soils which lay the foundation

Usefulness of soil series information

Soil series provide first-hand information on soil resources of the state in terms of morphological, physical, chemical and mineralogical properties. As discussed earlier, such information helps understand the nature and extent of a particular soil under different categories of acidity, physiographic position and land use. This soil information can be systematically arranged according to the users' demand. The soil information developed for Tripura has helped include 15 soil series in the National Register maintained by NBSS&LUP.

Application of soil information system

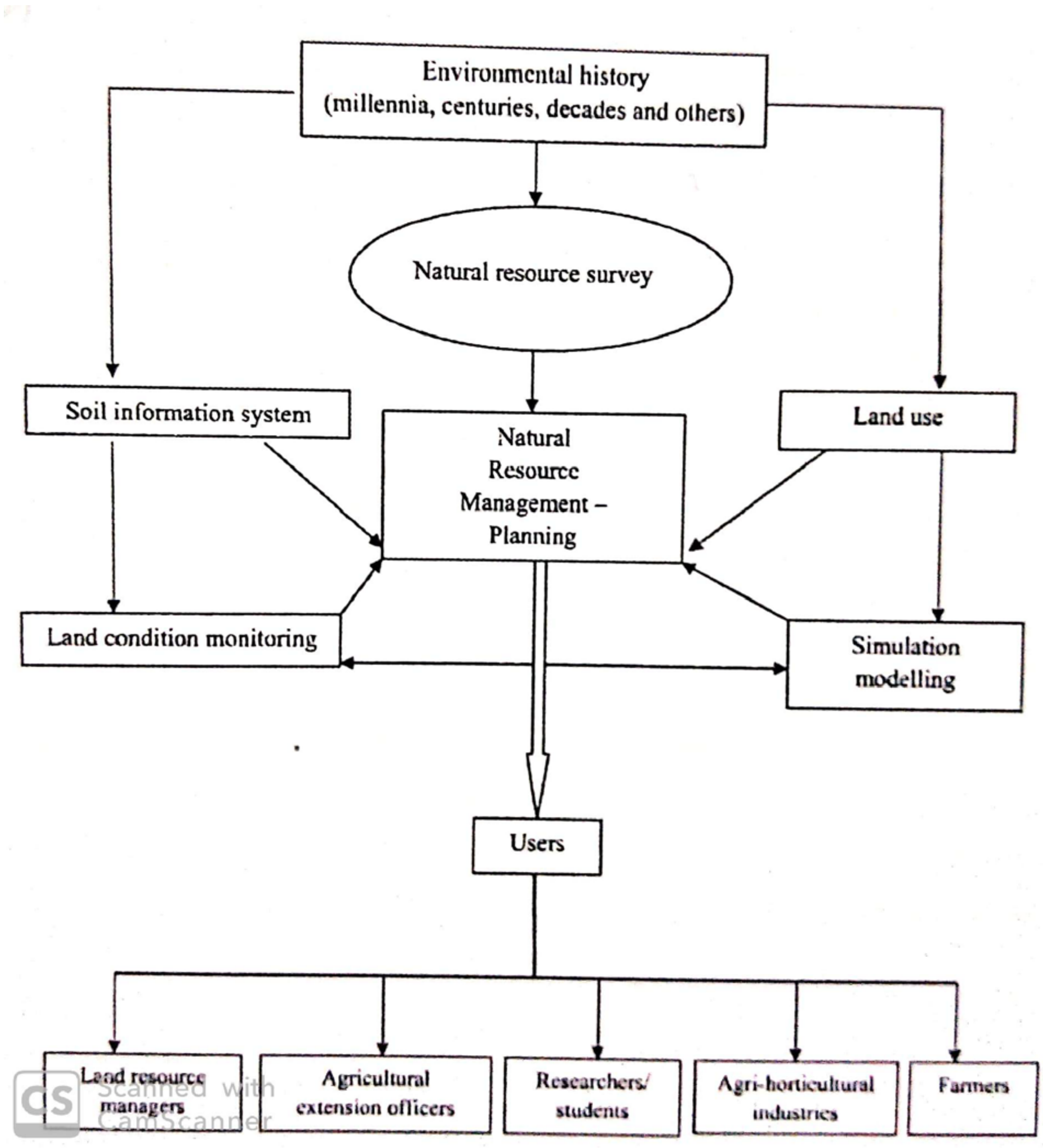
The SIS contains datasets on soil, landscape, land use, water and climate and as such provides a spatial framework for managing natural resources. The SIS of Tripura integrates outputs from various sources across the state and may be considered useful for monitoring natural resources, modeling soil physiographic relation, finding crop suitability, land-use options, estimating soil loss and conservation of natural resources. Modeling soil carbon and crop performances can also be a continuous exercise to comprehend the soil health and related changes in soils due to climate change. In isolation, each activity may not justify to provide appropriate information for natural resource management and planning, but in combination they provide a powerful tool to address the following issues for posterity.

Soil information system – soil degradation

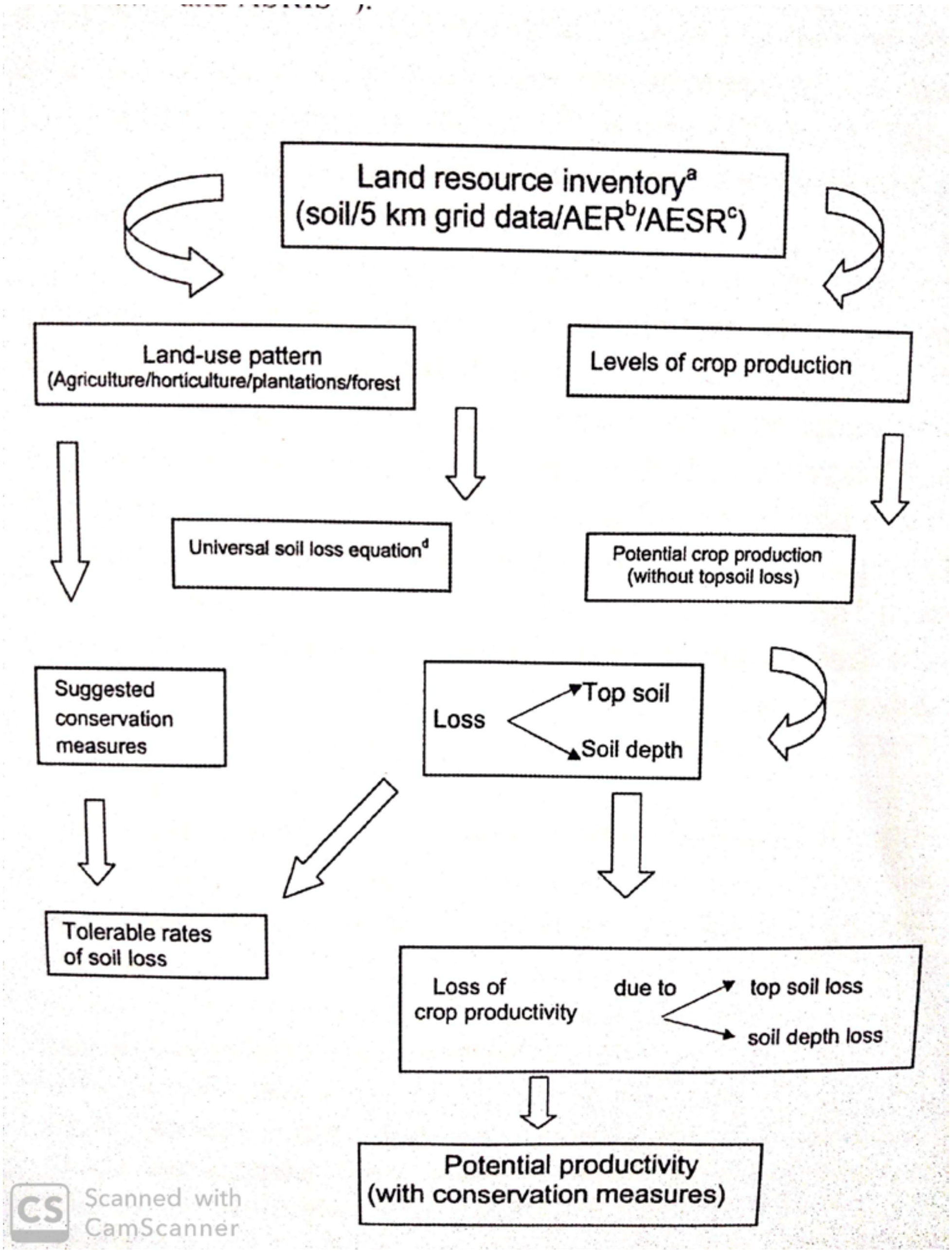
Two categories of soil degradation are recognized in Tripura. The first category deals with degradation by displacement of soil material, principally by water. The second one deals with the internal soil deterioration resulting from loss of nutrients (chemical deterioration) or through physical processes, including waterlogging and flooding (physical deterioration). SIS indicates that as much as 60% area of the state is under various types of degradation [8]. If slight and moderate degrees of degradation are ignored, the extent of degradation is nearly 21% area of the state.

Soil information system to develop soil loss and crop productivity model

Since soil erosion is the major reason for soil loss and imperative for the land-use managers and planners to adopt appropriate soil conservation measures. The soil loss and crop productivity model (Figure 2) explains the development of regional-level methodology for estimation of actual soil loss in Tripura using the 5 km grid 5 km points11,22 (Figure 3). Loss of crop yield due to loss of topsoil is compensated by the use of manure and fertilizer. At the same time, loss of topsoil by soil erosion is also compensated by the formation of fresh soil layers



through the process of pedogenesis. To calculate loss of topsoil it is necessary to take into account the amount of soil regenerated, keeping in view the difference in the rate of soil formation under different types of climatic conditions11. On the basis of available soil information8,11,14 and the rate of topsoil formation at each grid point, various soil loss limits were developed. The estimates of soil erosion sometimes appear exaggerated when factual information is scarce. To make the generated output more factual, SIS developed by NBSS&LUP was



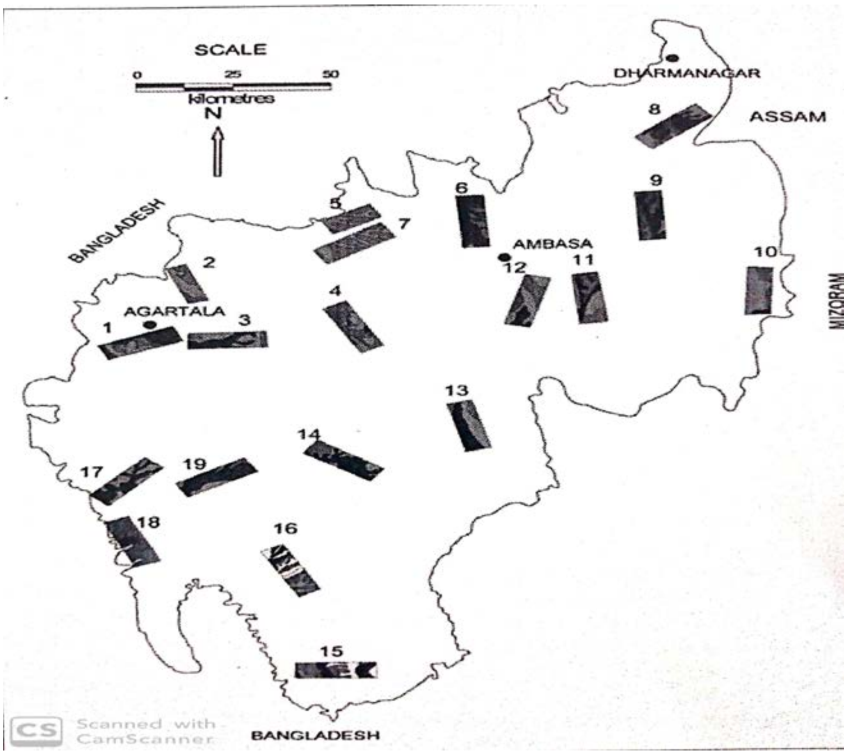
utilized 8–11,14. The SIS can thus generate soil erosion datasets to enrich it and also make it more useful for soil conservation. Totally seven classes of soil erosion were identified. Taking the medium values of the soil erosion range, the total soil lost under different erosion classes was estimated. For humid, tropical climate like Tripura, an annual addition of 29 tonnes soilwas estimated23. In view of this the soil erosion class indicating ≤ 29 t ha–1 yr–1 was not considered while computing the effective soil loss. The estimated annual loss of soil was nearly 15 million tonnes (mt) every year.

Soil information system vis-a-vis conservation measures

While applying the soil loss and crop productivity model (Figures 2 and 3), potential erosion losses for each desired land use may be evaluated assuming that no specific soil conservation measures are applied, which indicates that the protection factor (*P*) is one. These results could be compared with what are considered as acceptable rates of soil loss under various levels of inputs23, that are followed for estimation of the required conservation needs and their associated costs. Soil conservation need is estimated as the protection factor (*P*) when lands are not under any conservation programmes. The average rate of erosion covers both the cultivated and the uncultivated parts of the crop and fallow-period cycle. Estimation of conservation need showed that the required soil loss reduction was 48.5 t ha–1 (146–97.5 t ha–1). In land under cultivation, the total soil loss over 6 years was 130 t ha–1 (12 + 18 + 100 t ha–1). Therefore, the conservation need (*P* factor) required to achieve this is 48.5/130 = 0.37. Soil conservation helps achieve three types of benefit, viz. (i) long-term reduction in checking the decline of agricultural production; (ii) gradual increase in agricultural production, and (iii) other non-agricultural benefits such as improved flow to the river during summer, reduction in periodicity and severity of flooding, reduction in siltation of reservoirs, reduction in damage of various costly infrastructure and low harmful impacts on farm lands. In Tripura many areas in the higher and middle elevations are under forest (58% TGA)8. The tilla lands and the lower foothills are used for plantation of rubber and/or for agricultural and horticultural crops. These lands are highly susceptible to soil erosion, and therefore require soil conservation measures such as benchterracing. Most of the areas showing nearly 15 mt soil erosion every year occupy the degraded uplands and forest areas used for jhumming. In rainfed areas like Tripura, terraces may be constructed on slopes ranging from 6% to 33%. The value of supporting conservation practice (*P* factor) using bench-terracing technique (0.5% longitudinal gradient, 2.5% inward gradient) is quite low (0.027) for very deep red soils in Ooty hills, with a slope of 25%. Judging by similar terrain conditions, such efforts could be recommended for Tripura. However, appropriate techniques could be evolved by the conservation experts. Tilla lands and part of the degraded lands with shrubs and bushes are now exposed to erosion due to lack of vegetation. These areas need proper afforestation programmes. Part of these areas may be recommended to be brought under rubber cultivation and other plantation and horticultural crops 8,9. Such practice will be doubly beneficial since it will save the loss of the most valuable natural resources like soil and would also generate income source among the local people.

Soil information system for suitability of different land uses

Eighteen model study areas and 390 grid-point observations were analysed in terms of 16 identified soil series vis-a-vis the suitability of land uses like horticulture and agriculture (Figures 3 and 4). Soil parameters vis-à-vis different selected crops indicated a general relationship of crop/land-use selection, elevation and KCl-extractable Al in the soils. Forest species predominate up to about 400 m elevation which includes oranges. The 400–250 m elevation could be ideal for plantations and horticultural crops, whereas 250–150 m may be ideal for upland paddy and other horticultural crops. Low lands (150 m) should be earmarked for lowland paddy and vegetables (Figure 5). It is interesting to note that the plantation and horticultural crops are suitable for those soils where KCl extractable Al is very high. Forest and upland paddy soils have a medium range of KCl–Al and the soils suitable for lowland paddy and vegetables contain very low amount of KCl-extractable Al (Figure).

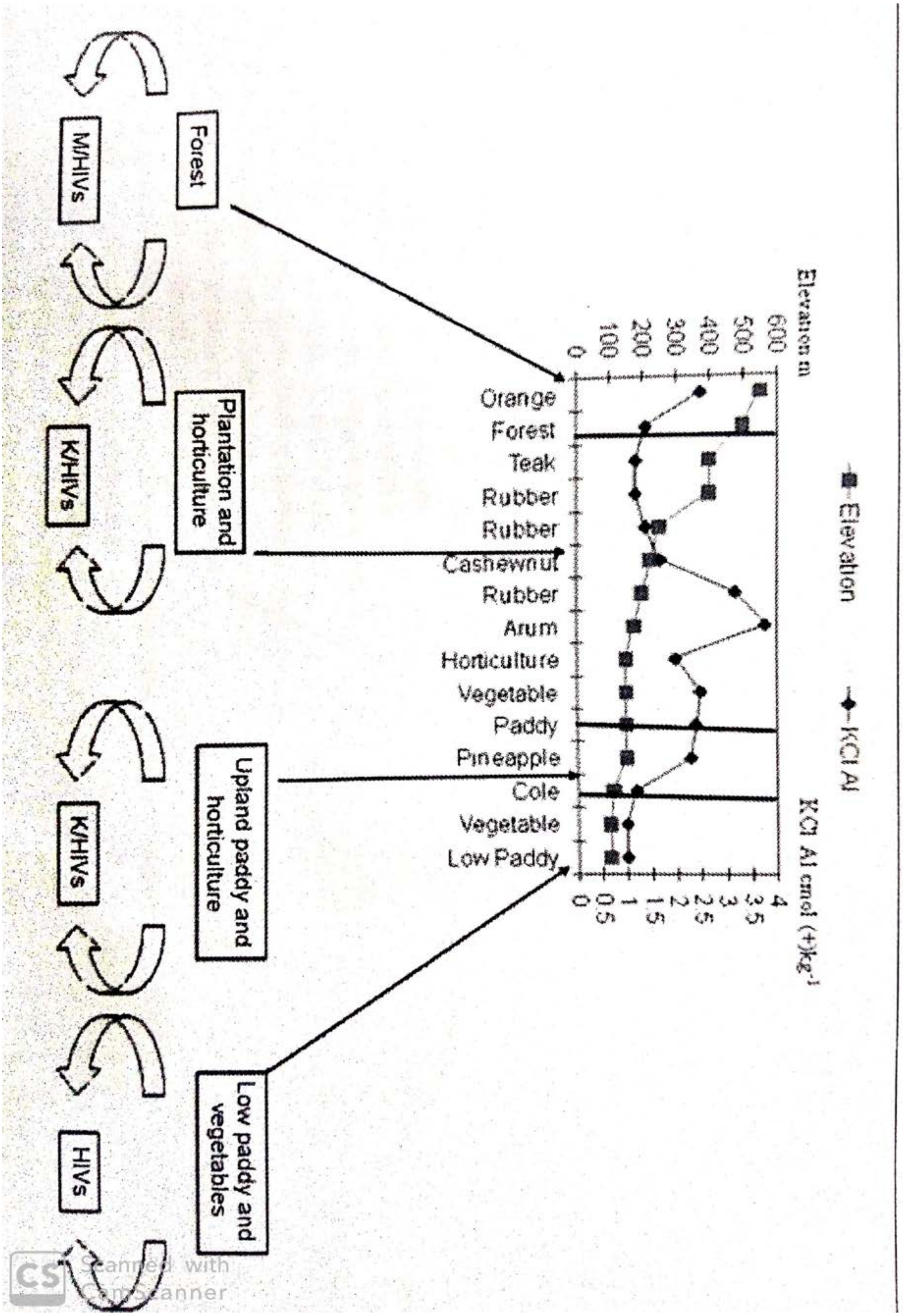


Soil information system for crop suitability

Each plant requires definite soil and climatic conditions for optimum growth. Since the availability of both water and plant nutrients is largely controlled by the physical and chemical properties and micro-environments of soils, the success and failure of any species in a particular area is governed by soil characteristics, which indicates the significance of SIS. SIS was extensively used for evaluating lands for suitability of different types of crops and plantation species. Suitability criteria for rubber plantations in Tripura showed most of the areas as moderately suitable in the undulating plains and uplands without forests. It should be mentioned that most of the horticultural crops have similar soil-site requirements, which naturally compete with the rubber growing areas. It was, therefore, recommended that the rubber might be restricted to the marginal areas with further higher slopes. Using SIS the probable expansible area for rubber plantation was estimated 8,10 as 5.11%.

Soil information system – clay minerals vis-à-vis crop suitability

The soil series association map (1 : 50,000 scale) was used as a base map to establish the relation between clay mineralogy and crop suitability. Clay samples (<2 μm) of the selected soil series were analysed using X-ray diffraction techniques to estimate clay mineral content. Soil parameters such as CEC, clay and organic matter content were used to correlate the mineral make-up in the clay fractions. Data on clay minerals for 48 soil series from Tripura were utilized to generate a clay mineral map for the state. The data indicated dominance of hydroxyl interlayered Kaolin interstratified with HIV. (Kl) in fine and total clay fractions. Presence of hydroxyl interlayered smectites (HIS) was also noticed. Interestingly, mica and kaolinite minerals are also present as interstratified minerals with HIV as M/HIV and Kl/HIV12, 24–26. On the basis of mineral make-up of different soil series, clay mineralogy maps of various combinations were generated. Tilla lands used mostly for rubber and horticultural crops, are dominated by soils with less than 10% HIS, high hills (forests) are dominated by soils with less than 10–20% HIS and inter-hill valleys (agricultural crops) are dominated by soils with more than 20% HIS. Tilla lands are also dominated by soils with less than 17% HIV, high hills with less than 17–20% HIV and inter-hill valleys with more than 20% HIV. Tilla lands, used mostly



for rubber and horticultural crops, are dominated by soils with less than 35% Kl/HIV; high hills covered under forests are dominated by soils with less than

35–50% Kl/HIV and inter-hill valleys growing paddy and other agricultural crops are dominated by soils with more than 50% Kl/HIV. In the humid tropical weathering environment of Tripura, the presence of vermiculite/low charge smectites is common. Minerals in clay fractions have not yet weathered to reach the stage of kaolinite. Thus the mineralogy class of these soils as mixed appears to be more appropriate. During humid tropical weathering, huge quantity of Al3+ ions are liberated to cause higher acidity (H+), which was estimated as 149 kg ha–1. It is interesting to note that vermiculites adsorb Al3+ ions as hydroxy-cations to form HIV/HIS. The vermiculite minerals thus act as a natural sink to sequester Al3+ ions. A representative acid soil of Tripura can sequester Al in the first 30 cm depth25,26 to the tune of 65 kg ha–1. This is the reason why Tripura soils show relatively higher proportion of hydroxy interlayered vermiculites effecting lower concentration of Al3+ ions in the soil solution. This fact may possibly help in removing a myth about Al-toxicity in acid soils in general and in acid soils of Tripura in particular.

Soil information system – soil health vis-à-vis organic carbon in soils

The SIS of Tripura helps to find out the soil health in terms of soil organic carbon (SOC). In Tripura, SOC content varies from 0.34% to 1.88%. Relatively high SOC isfound in deep to very deep, well to excessively drained loamy hill soils. The North Eastern Region (NER) in India has been declared as a green belt. Earlier SOC level of 1.0% was shown as a threshold limit for soils with good health21,27,28. SIS of Tripura helps estimate SOC stock. The data show that nearly 58% area in Tripura hasmore than 45 kg ha–1 SOC stock in the first 30 cm depth of soils. The SOC stock of Tripura in various soil depths is shown in. Total estimated SOC stock in India and Tripura is 9.55 Pg and 0.05 Pg, respectively23. It shows that SOC stock in Tripura is maintained at 0.046 Pg ha–1 compared to the all-India average of0.029 Pg ha–1. Earlier, using the 14 agro-climatic zones (ACZs) of the Planning Commission, ACZ 2, representing the entire NER was found to store organic carbon @0.064 Pg/m ha of soils29. Such threshold values of SOC stock ranging from 0.05 to 0.06 Pg/m ha should, therefore, be maintained in areas declared as the green belt to protect natural ecosystems.

Lecture 15

Application of geo information in soil resource studies

Land Information System: GIS based land acquisition management system will provide complete information about the land. Land acquisition managements is being used for the past 3 or 4 years only. It would help in assessment, payments for private land with owner details, tracking of land allotments and possessions identification and timely resolution of land acquisition related issues.

Soil Mapping : Soil mapping provides resource information about an area. It helps in understanding soil suitability for various land use activities. It is essential for preventing environmental deterioration associated with misuse of land. GIS Helps to identify soil types in an area and to delineate soil boundaries. It is used for the identification and classification of soil. Soil map is widely used by the farmers in developed countries to retain soil nutrients and earn maximum yield.

Natural Resources Management: By the help of GIS technology the agricultural, water and forest resources can be well maintain and manage. Foresters can easily monitor forest condition. Agricultural land includes managing crop yield, monitoring crop rotation, and more. Water is one of the most essential constituents of the environment. GIS is used to analyze geographic distribution of water resources. They are interrelated, i.e. forest cover reduces the storm water runoff and tree canopy stores approximately 215,000 tons carbon. GIS is also used in afforestation.

Determine land use/land cover changes: Land cover means the feature that is covering the barren surface .Land use means the area in the surface utilized for particular use. The role of GIS technology in land use and land cover applications is that we can determine land use/land cover changes in the different areas. Also it can detect and estimate the changes in the land use/ land cover pattern within time. It enables to find out sudden changes in land use and land cover either by natural forces or by other activities like deforestation.

Agricultural Applications: GIS can be used to create more effective and efficient farming techniques. It can also analyze soil data and to determine: what are the best crop to plant?, where they should go? how to maintain nutrition levels to best benefit crop to plant?. It is fully integrated and widely accepted for helping government agencies to manage programs that support farmers and protect the environment. This could increase food production in different parts of the world so the world food crisis could be avoided.

Pedonwise soil database

Soil information of Tripura contains the soil database as detailed soil series information showing 30 parameters of site information, 17 morphological properties, 3 physical characteristics and 6 chemical properties12,14. It also shows details of mineralogical properties of various particle size fractions and soil groupings.

Concluding remarks

This article projects the need of relevant and pertinent datasets to develop a SIS for a state. In view of the global changing scenario the need of the hour is to produce a fresh group of earth scientists with specialization in soil and crop science, geology and geography with appreciable knowledge in GIS and other information technology software. They will be equipped to deal with data storage, and retrieval in a user-friendly mode for management recommendations, so that issues like land degradation, biodiversity, food security and climate change can be addressed adequately. In view of the global changing scenario with the developments of GIS and other web technologies, dissemination of spatial information is getting a paradigm shift. Natural resource information is an essential pre-requisite for monitoring and predicting global environmental change with special reference to climate. This article may not only serve as a ‘handbook’ for development purposes for the state, but may also encourage specialists in the subject to document natural resource information in a similar way.

Pedotransfer Functions for Estimation of K_s

The term pedotransfer function (PTF), coined by Bouma (1989), refers to statistical regression equations used to express relationships between soil properties. In K_s context, PTFs are used to develop relationships between Ks and more easily measured soil properties. Terminology is new, but concept is old. Many decades-old methods for Ks estimation can be considered PTFs.

Primary benefit of PTF concept?

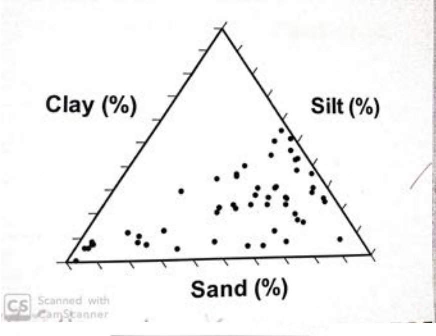
Renewed interest in estimation of hydraulic properties, Focusing of effort in soil science community, Strong interest in PTFs mainly a result of new methods and tools for PTF development: Statistical regression techniques, Artificial neural networks, Group method of data handling, Regression tree modeling.

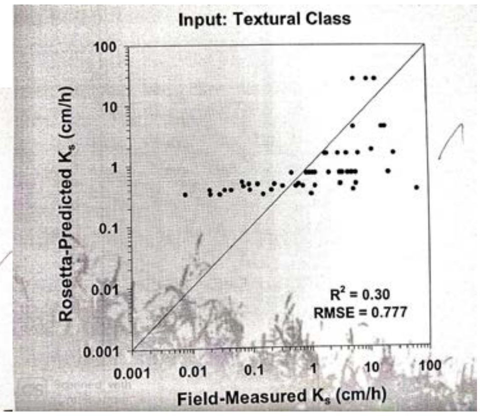
Considerable interest in neural network PTF of Schaap et al. (1998) for K_s estimation.Interest driven, in part, by availability of a graphical user interface (Rosetta) for implementing method.

Evaluation of PTFs for Estimating Ks

Methods

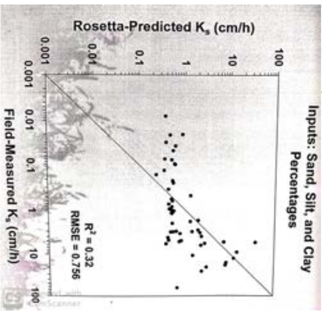
Pit excavated at each site and soil described by NRCS soil scientist. Samples from each horizon sent to NSSC Soil Survey Laboratory for physical property analysis. Field measurements of Ks obtained using constant-head well permeameter method (Amoozemeter) with five replicates per horizon. Where appropriate, horizons less than 15-cm thick were grouped to satisfy constraints of CHWP method. The 16 sites yielded 53 samples including 14 A horizons, 29 B horizons, and 10 C horizons. Relatively uniform distribution of textures with the exception of sandy clay. Estimation of Ks from physical property done using Rosetta (Schaap et al., 2001), and the methods of Ahuja et al. (1989) and Saxton et al. (1986).

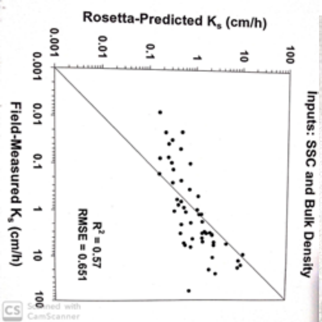


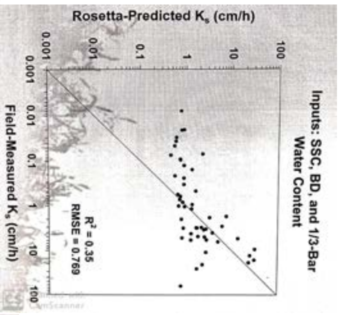


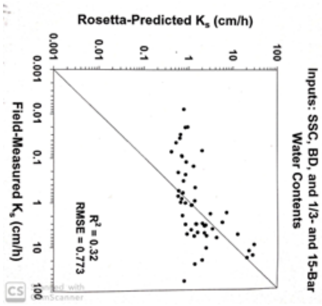
$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}[\log(K_s)-\log(K_s')]^2}$$

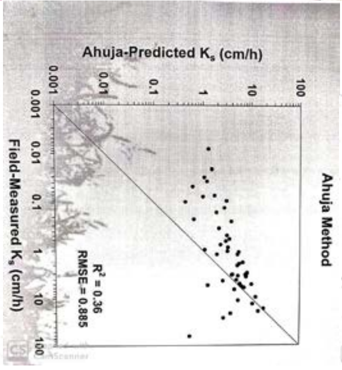
RMSE quantifies deviation from 1:1 line due to both scatter and bias (rotation & translation).

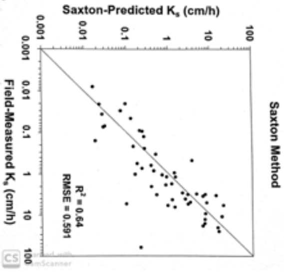

Rosetta-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Inputs: Sand, Silt, and Clay Percentages
R^2 = 0.32
RMSE = 0.756
0.001
0.01
0.1
1
10
100


Rosetta-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Inputs: SSC and Bulk Density
R^2 = 0.57
RMSE = 0.651
0.001
0.01
0.1
1
10
100


Rosetta-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Inputs: SSC, BD, and 1/3-Bar Water Content
R^2 = 0.35
RMSE = 0.769
0.001
0.01
0.1
1
10
100


Rosetta-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Inputs: SSC, BD, and 1/3- and 15-Bar Water Contents
R^2 = 0.32
RMSE = 0.773
0.001
0.01
0.1
1
10
100


Ahuja-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Ahuja Method
R^2 = 0.36
RMSE = 0.885
0.001
0.01
0.1
1
10
100


Saxton-Predicted K_s (cm/h)
Field-Measured K_s (cm/h)
Saxton Method
R^2 = 0.64
RMSE = 0.591
0.001
0.01
0.1
1
10
100


20
40

Rosetta allows for five hierarchical levels of input data:

Textural class

Sand, silt and clay (SSC) percentages

SSC and bulk density (BD)

SSC, BD, and 33-kPa water content

SSC, BD, and 33- and 1500-kPa water contents

Method of Ahuja et al. (1989) uses effective porosity.

Method of Saxton et al. (1986) uses sand and clay percentages and total porosity

Results – Estimation using Rosetta

Results show only modest correlation between measured and Rosetta-predicted saturated hydraulic conductivity. Best estimation achieved with combination of sand, silt and clay percentages and bulk density. The use of 33- and 1500-kPa water contents did not enhance predictive ability over SSC and bulk density. Rosetta estimates were biased (rotational) towards overestimation at low Ks and underestimation at high Ks. Bias and modest correlation likely a result of the data set used for calibration of Rosetta.

Evaluation of PTFs for Estimating Ks

Results – Ks from Ahuja and Saxton Methods

Ahuja Method

Rotational bias in Ks estimates similar to that for Rosetta. Did not perform as well as Rosetta (larger RMSE) due to translational bias.

Saxton Method

Best of the three PTFs examined (lowest RMSE) due to minimal bias in Ks estimates.

Conclusions

A high-quality data set has been assembled for evaluating pedotransfer functions for Ks estimation. The results suggest that Rosetta is not well suited for estimating Ks due to modest correlation with measured values and substantial bias. Of the PTFs evaluated, the Saxton method proved to be the most effective for estimating Ks. Problems with bias in Ks estimation were most likely a result of the data sets used for PTF calibration.

Lecture 16

YIELD MONITORING SYSTEM

Crop yield estimation using Remote sensing and forecasting

Remote sensing technology has been proved as a useful application for natural resources evaluation and management. Spectral data acquired via satellite have been extensively utilized for crop yield modelling in various parts of the world. The important assumption in use of remote sensing data for crop modelling is that the spectral data is strongly related with canopy parameters which related to final yield at a critical stage of the crop growth. In the satellite data at the time of maximum flowering/heading of the crop area into vegetation vigour classes like high vegetation , average vegetation, poor vegetation.

Estimation procedure based on use of crop yield survey data along with satellite spectral data

The factors like different soil types, agricultural inputs, adoption of improved technology, etc affect the crop yield and hence cause a lot of variability in the yield even with a stratum. The spectral reflectance is a manisfestation of all important factors affecting the crop, hence a stratification of crop area on the basis of crop vigour as reflected by the spectral data is expected to result in a greater efficiency of the crop yield estimation. For identifying the villages selected for crop surveys on the FCC, topographic maps of scale of 1:50000 which contain information on identifiable features like roads, canals, water bodies etc. were used. The GPS was taken to the plots and location of the plots in terms of longitudes and latitudes were recorded. These locations then identified on the FCC’s. The coordinates of each plot in terms of scan line and column number were recorded to identify these plots on the Normalized Difference Vegetation Index (NDVI).NDVI is defined as the ratio of (IR-R) to (IR-R) and RVI is defined as ratio of IR to R where Ir and R denote the radiance in infra red (band-4) and red (band3) respectively. The concept of density slicing technique was used to divide the NDVI and RVI imageries into different identifiable classes which provided three classes named as 1. Non vegetation class ii. Average vegetation class and iii. The High vegetation class. To obtain the strata weights for the two vegetation classes, the number of pixels falling into these classes were obtained and since the pixel size is fixed, hence the area of the classes were obtained and since the pixel size is fixed , hence the area of the classes were obtained which were used as strata weights.

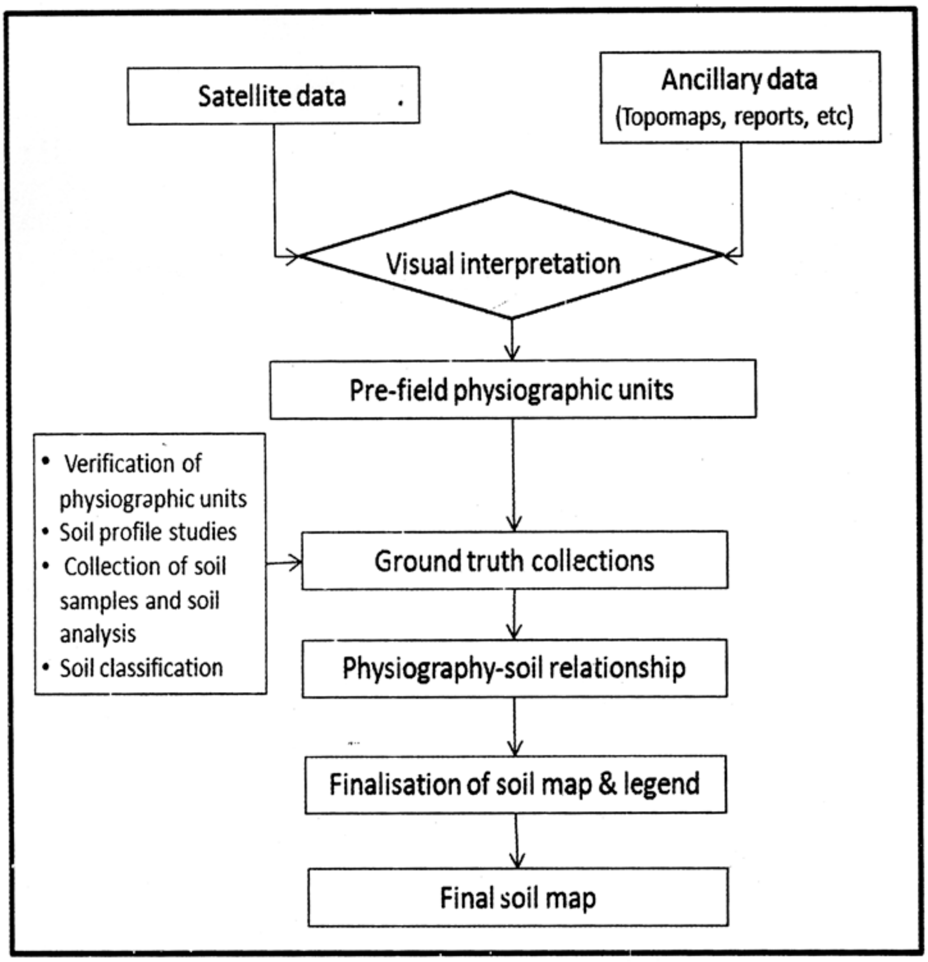
Small area estimation of crop yield at block level

Issue of small area estimation has gained importance in view of growing needs of micro level planning. Most of the small area estimation techniques in the early stages were developed in the context of demographic studies. In order to develop crop yield estimates at tehsil level from general crop yield estimation surveys based on crop cutting experiments we propose two estimators *viz.*, i. The Direct estimator and ii. The synthetic estimator. These estimators make use of available information on crop yield and also the information of crop acreage for all the post srata which ovelap the tehsil.

SOIL SURVEY METHODOLOGY

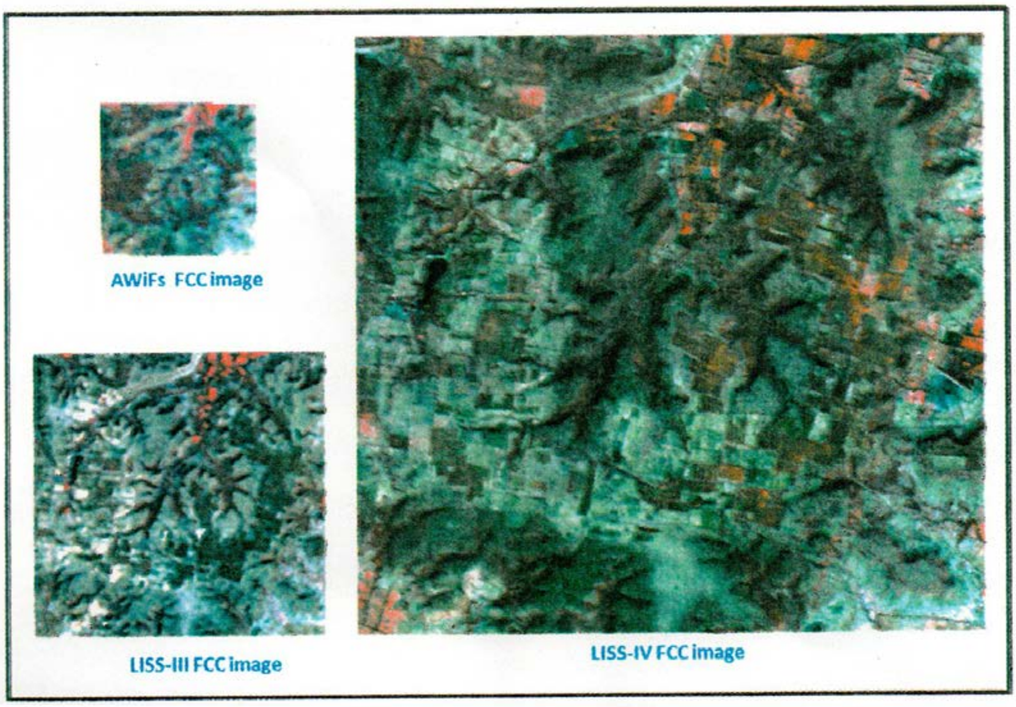
Soil surveyors consider the physiographic variation (keeping other soil forming factors constant) as a base for depicting the soil variability on a map. The general methodology of soil survey comprises pre-field interpretation using cadastral map, survey of India toposheets, aerial photograph and satellite data (depending upon their availability) for delination of various physiographic units, ground-truthing for verification or physiographic units, soil profile study, developing physiography-soil relationship and extrapolation of this relationship to other similar areas. Topographical maps are generally published on the scale of 1:25,000, 1:50,000 and 1:250,000. These map show not only physical, features but also contain topograhical details in the form of contours and elevation. Black and white or pan-chromatic aerial photographs contain 50-65% per cent overlap for a stereoscopic viewing. The flow chart showing the general methodology used for soil mapping using remote sensing data is shown in Figure.

Among the two methods of remote sensing data interpretation *viz.*, visual and digital, the former approach is pre-dominantly used in soil mapping. Visual interpretation of satellite imagery is done based on shape, size, tone, shadow, pattern, site and association. This has the advantage of being relatively simple and inexpensive. In digital interpretation, the computer-aided techniques utilize the spectral variations for classification. The pattern recognition in remote sensing assists in identification of homogenous area, which can be used as a base for carrying out detailed field investigations.



Flow chart depicting general methodology for soil mapping

Spatial and spectral resolution of remote sensing data plays an important role in determining the scale of mapping. The coarse resolution data from IRS LISS-I, WiFS, AwiFs and LANDST-MSS sensors have been used by NBSS & LUP, Nagpur to prepare soil maps on 1:250,000 scale or smaller. To map soils on 1:50,000 scale, medium resolution remote sensing data from LANDSAT-TM, IRS LISS-II/LISS-III and SPOT-MLA are mostly employed. Satellite data from IRS-P6 (LISS-IV sensor), Cartosal-1 and Cartosat-2 and IKONOS are now being employed for detailed characterization of soils on 1:10,000 scale and larger (Figure).



IRS-P6 FCCs of part of Darwha tehsil of Yavatmal district, Maharashtra acquired by AWiFs, LISS-III and LISS-IV sensors

Precision Farming

Advancement of geoinformatics technology in 20th century led to the development of the concept of precision farming which relies on the integration of these technologies into a single system that can be operated at farm level with sustainable effort. Precision Farming (PF) which is otherwise known as site-specific farming involves matching resource application and agronomic practices with soil properties and crop requirements as they vary across a site. PF has three requirements viz. (i) ability to identify each field location, (ii) ability to capture, interpret and analyse agronomic data at an appropriate scale and frequency, and (iii) ability to adjust input use and farming practices to maximize benefits from each field location. However, modern geospatial tools such as Remote Sensing, GPS and GIS meet these requirements, thereby recognized as potential component of precision farming.

Recently farmers have gained access to site-specific technology through GPS, which is important to find out the exact location in the field to assess the spatial variability and site-specific application of the inputs. GPS operating in differential mode are capable of providing location accuracy of 1 m. The most common use of GPS in agriculture is for yield mapping and variable rate fertilizer/pesticide applicator, the availability of GPS approaches to farming will allow all field-based variables to be tied together. This tool has proven to be the unifying connection among field variables such as weeds, crop yield, soil moisture, and remote sensing data.

Remote sensing holds great promise for precision agriculture because of its potential for monitoring spatial variability over time at high resolution. Various workers have shown the advantages of using remote sensing technology to obtain spatially and temporally variable information for precision farming. Keeping in view the agricultural scenario in developing countries, the requirement for a marketable RS technology for precision agriculture is the delivery of information with the characteristics like low turnaround time (24-48 hrs), low data Cost (~ Rs 100/acre/season), high Spatial Resolution (at least 2 m multi-spectral), high Spectral Resolution (<25 nm), high temporal Resolution (at least 5-6 data per season) and delivery of analytical products in simpler format.

GIS can integrate all types of information and interface with other decision support tools. It displays analysed information in maps that allow (a) better understanding of interactions among yield, fertility, pests, weeds and other factors, and (b) decision-making based on such spatial relationships. Many types of GIS software with varying functionality and price are now available. A comprehensive farm GIS contains base maps such as topography, soil type, N, P, K and other nutrient levels, soil moisture, pH, etc. Data on crop rotations, tillage, nutrient and pesticide applications, yields, etc. can also be stored. GIS is useful to create fertility, weed and pest intensity maps, which can then be used for making maps that show recommended application rates of nutrients or pesticides.

Variable rate technology in PP is key component Which is done for site specific input management and it is done in two ways The first method, map-based, includes the following steps: grid sampling a field, performing laboratory analyses of the soil samples, generating a site-specific map of the properties through geostatistical technique and finally using this map to control a variable-rate applicator. During the sampling and application steps, GPS is used to identify the current location in the field. The second method, sensor based, utilizes real-time sensors and feedback control to measure the desired properties on-the-go, usually soil properties or crop characteristics, and immediately use this signal to control the variable-rate applicator Precision Farming thus calls for the use of appropriate tools and techniques, within a set of the framework as mentioned, to address the micro-level variations between crop requirements and applications of agricultural inputs. Inevitably, it integrates a significant amount of data from different sources; information and knowledge about the crops, soils, ecology and economy but higher levels of control require a more sophisticated systems approach. It is not simply the ability to apply treatments that are varied at the local level but the ability to precisely monitor and assess the agricultural systems at a local and farm level. This essentially requires sufficient understanding of the processes involved for applying inputs to achieve a particular goal not necessarily maximum yield but to maximize financial advantage while operating within environmental constraints.

Lecture 17

CROP HEALTH ANALYSIS

Crop health monitoring

Remote Sensing based Crop Health Monitoring

NDVI based Crop Health Monitoring

Remote Sensing Based Crop Health Monitoring

Introduction

Remote sensing techniques can play quite an important role in land cover survey and as a source of information relating to land resource condition. Besides, remote sensing techniques of the satellite imageries are also useful whenever there are rapid changes of landscape due to introduction of large scale development specially in the field of agriculture. Remote sensing data are capable of capturing changes in plant phenology (growth) throughout the growing season, whether relating to changes in chlorophyll content or structural changes. Satellite and airborne images are used as mapping tools to classify crops, examine their health and viability, and monitor farming practices. Identifying and mapping crop is important for a number of reasons. The main objective is to prepare an inventory of what was grown in certain areas and when. Key activities include identifying the crop types and delineating their extent (often measured in acres). Traditional methods of obtaining this information are census and ground surveying. In order to standardize measurements however, particularly for multinational agencies and consortiums, remote sensing can provide common data collection and information extraction strategies.

Spectral Reflectance, Vegetation and Normalized Difference Vegetation Index (NDVI)

Spectral vegetation index measurement derived from remotely sensed observations shows great promise as a means to improve knowledge of vegetation pattern. Different band ratios are possible given the number of spectral bands of the satellite image. Various mathematical combinations of satellite bands have been found to be sensitive indicators of the presence and condition of green vegetation. These band combinations are thus referred to as vegetation indices. The dominant method for vegetation area identification and change detection using remotely sensed data is through vegetation indices. Vegetation indices are algorithms aimed at simplifying data from multiple reflectance bands to a single value correlating to physical vegetation parameters (such as biomass, productivity, leaf area index, or percent vegetation ground cover). These vegetation indices are based on the well-documented unique spectral characteristics of healthy green vegetation over the visible to infrared wavelengths.

A green healthy leaf has typical spectral features, which differ in function of the three main optical spectral domains. In the visible bands (400-700 nm), light absorption by pigments dominates the reflectance spectrum of the leaf and leads to generally lower reflectances (15% maximum). There are two main absorption bands, in blue (450 nm) and in red (670 nm), due to the absorption of the two main leaf pigments: the chlorophyll a and b, which account for 65% of the total leaf pigments of superior plants. These strong absorption bands induce a reflectance peck in the yellow-green (550 nm) band. For this reason, chlorophyll is called the green pigment. Other leaf pigments also have an important effect of the visible spectrum. For example, the yellow to orange-red pigment, the carotene, has a strong absorption in the 350-500 nm range and is responsible for the color of some flowers and fruits as well as of leaves without chlorophyll. The red and blue pigment, the xanthophylls, has a strong absorption in the 350-500 nm range and is responsible for the leaf color in fall. In the near infrared spectrum domain (700-1300 nm), leaf structure explains the optical properties. Leaf pigment and cellulose are transparent to near-infrared wavelengths and therefore leaf absorption is very small (10% maximum), but not the leaf reflectance and transmittance, which can reach 50%. In this region, there is typically a reflectance plateau in the leaf spectrum. The level of this plateau is dependent on the internal leaf structure as well as on the space amount in the mesophyll that determines interfaces with different reflection indices (air or water- cells). Leaf reflectance increases for more heterogeneous cell shapes and contents as well as with increasing number of cell layers, number of inter cell spaces and cell size. This reflectance is therefore depending on the relative thickness of the mesophyll. In order to minimize the effect, on the canopy radiometric response of factors like optical properties of the soil background, illumination and view geometric as well as meteorological factors (wind, cloud), single band reflectances are combined into a vegetation index. An ideal vegetation index must be sensitive to the plant canopy (the green part) and not to the soil. Most of the ratio-based vegetation indices use, as spectral band, the red one, which is related to the chlorophyll light absorption and the near infrared one, which is related to the green vegetation density, because this band contain more than 90% of the information on a plant canopy. So, Photosynthetically active plant components, primarily leaves, produce a stepped reflectance pattern with low reflectance in the visible and high reflectance in the near infrared. This green vegetation spectral reflectance pattern results from strong absorption of visible light by chlorophylls and related pigments and scattering, because of leaf structural properties, but minimal absorption of light in the near infrared. A number of spectral vegetation indices premised on the contrasts in spectral reflectance between green vegetation and background materials. The normalized difference vegetation index (NDVI) is representative of the various spectral vegetation indices. NDVI is the traditional vegetation index used by researchers for extracting vegetation abundance from remotely sensed data. It divides the difference between reflectance values in the visible red and near-infrared wavelengths by the overall reflectance in those wavelengths to give an estimate of green vegetation abundance. In essence, the algorithm isolates the dramatic increase in reflectance over the visible red to near infrared wavelengths, and normalizes it by dividing by the overall brightness of each pixel in those wavelengths. 1t is computed;

$$NDVI = (NIR-RED)/(NIR + RED)$$

where

NIR = reflectance in the near infrared band

RED = reflectance in the red (visible) band

In theory NDVI measurements range between -1.0 and +1.0. However, in practice the measurements generally range between -0.1 and +0.7. Clouds, water, snow and ice give negative NDVI values. Bare soils and other background materials produce NDVI values between -0.1 and + 0.1. Larger NDVI values occur as the amount of green vegetation in the observed area increases.

Methodology for Crop Health Monitoring

The timing and amount of rainfall is very critical for crop yield. Factors like temperature, bright sunshine hours, wind speed; sources of seed, timely use and quantity of fertilizers are the other important factors affecting the crop vigor and ultimately the yield of the crop. It is possible to assess the crop vigor using appropriate sets of satellite images during the critical stage of crop growth. Each crop type has its own growth cycle and hence has a standard trend of crop vigor variation. Crop vigor in the form of NDVI is calculated for the crop at different stages of plant growth and is compared with the standard trend of NDVI values of a particular crop. The NDVI values are also compared with corresponding period of NDVI values of a crop during a Normal year. Any major reduction in the value of NDVI from standard values, pin points the areas of concern, and is verified at field. This data, when analyzed in conjunction with administrative boundaries in a GIS environment, can help assessing the real ground conditions prevailing in the area concerned with a relatively good accuracy. This study will be done by using low resolution satellite imageries because its repetivity like NOAA or MODIS having repetition is once or twice in a day and also the drawback is its resolution and the resolution for NOAA is around 1Km and for MODIS resolution is 250M. Whereas medium resolution images are best for crop health monitoring like AWiFS and the repetivity is 5 days of 80% area. The AWiFS satellite images ground resolution is 56M and overage of area is 370 km x 370 km.

CROP MODELING

Crop modeling: A tool for agricultural research

Changing markets, technological innovation and organizational progress in recent years have increased the intensity and scale of agricultural land use. Producer deal with very broad and rapidly expanding range of technology, in areas such as weed control, direct seeding and varieties selection, all of which are required to optimize productivity, protect the environment and maintain or improve the profitability. However, intensification in agriculture follows a pattern of declining marginal productivity and increasing complexity. In the past the main focus of agronomic research has been on crop production only but recently , profitable crop production, the quality of the environment has become an important issue that agricultural producer must address. So the agricultural manager requires strategies for optimize the profitability of the crop production while maintaining soil quality and minimizing environmental degradation.

Solution of these new challenges requires consideration of how numerous components interact to effect plant growth. To achieve this goal, future agriculture research will require considerably with more effort and resource than present research activity.

Efficient crop production technology is based on a right decision at right time in a right way. Traditionally a crop production functions that are used in agricultural decision making were derived from conventional experienced base agronomic research, in which crop yield were related to some defined variable based on correlation and regression or regression analysis. Crop yield were expressed as polynomial or exponential mathematical function of the defined variables, with regression coefficient. The application of correlation and regression analysis has provided some qualitative understanding of the variable and their interactions that were involved in cropping system and has contributed to the progress of agricultural sciences. However the quantitative information obtained from this type of analysis is very site specific. The information obtained can only be reliably applied to other site where climate, important .soil parameters and crop management are similar to those used in developing the original functions. Thus the quantitative application of regression crop based model for decision-making is severely limited.

Agriculture models are, however, only crude representations of the real systems because of the incomplete knowledge resulting from the inherent complexity of the systems. Judicious use of such model is possible only if the user has a sound understanding of model structure, scope and limitation. Crop modeling is a new discipline and back ground literature is scarce. So the purpose of this article is provide to some basic information about crop modeling.

MODELLING IN AGRICULTURAL SYSTEMS

Complexity of agricultural systems

Agricultural systems are characterized by having many organizational levels. From the individual components within a single plant , through constituent plants, to farms or a whole agricultural region or nation, lies a whole range of agricultural systems. Since the core of agriculture is concerned with plants, the level that is of main interest to the agricultural modeller is the plant.

Reactions and interactions at the level of tissues and organs are combined to form a picture of the plant that is then extrapolated to the crop and their output.

Models in agriculture

Agricultural models are mathematical equations that represent the reactions that occur within the plant and the interactions between the plant and its environment. Owing to the complexity of the system and the incomplete status of present knowledge, it becomes impossible to completely represent the system in mathematical terms and hence, agricultural models images of the reality . Unlike in the fields of physics and engineering, universal models do not exist within the agricultural sector. Models are built for specific purposes and the level of complexity is accordingly adopted. Inevitably, different models are built for different subsystems and several models may be built to simulate a particular crop or a particular aspect of the production system.

Features of crop models

The main aim of constructing crop models is to obtain an estimate of the harvestable (economic) yield. According to the amount of data and knowledge that is available within a particular field, models with different levels of complexity are developed. The most pertinent aspects of crop models are described below.

Empirical model

Empirical models are direct descriptions of observed data and are generally expressed as regression equations (with one or a few factors) and are used to estimate the final yield. Examples of such models include the response of crop yield to fertiliser application, the relationship between leaf area and leaf size in a given plant species. The limitation of this model site specific, it can not use universally.

Mechanistic model

A mechanistic model is one that describes the behaviour of the system in terms of lower-level attributes. Hence, there is some mechanism, understanding or explanation at the lower levels. These models have the ability to mimic relevant physical, chemical or biological processes and to describe how and why a particular response results.

Static and dynamic models

A static model is one that does not contain time as a variable even if the end-products of cropping systems are accumulated over time, e.g., the empirical models. In contrast dynamic models explicitly incorporate time as a variable and most dynamic models are first expressed as differential equations:

Deterministic and stochastic models

A deterministic model is one that makes definite predictions for quantities (e.g., animal live weight, crop yield or rainfall) without any associated probability distribution, variance, or random element. However, variations due to inaccuracies in recorded data and to heterogeneity in the material being dealt with, are inherent to biological and agricultural systems. In certain cases, deterministic models may be adequate despite these inherent variations but in others they might prove to be unsatisfactory e.g. in rainfall prediction. The greater the uncertainty in the system, the more inadequate deterministic models becomes and in contrast to this stochastic models appears.

Simulation and optimizing models

Simulation models form a group of models that is designed for the purpose of imitating the behaviour of a system. They are mechanistic and in the majority of cases they are deterministic. Since they are designed to mimic the system at short time intervals (daily time-step), the aspect of variability related to daily change in weather and soil conditions is integrated. The short simulation time-step demands that a large amount of input data (climate parameters, soil characteristics and crop parameters) be available for the model to run. These models usually offer the possibility of specifying management options and they can be used to investigate a wide range of management strategies at low costs. Most crop models that are used to estimate crop yield fall within this category.

Optimizing models have the specific objective of devising the best option in terms of management inputs for practical operation of the system. For deriving solutions, they use decision rules that are consistent with some optimising algorithm. This forces some rigidity into their structure resulting in restrictions in representing stochastic and dynamic aspects of agricultural systems. Linear and non-linear programming were used initially at farm level for enterprise selection and resource allocation. Later, applications to assess long-term adjustments in agriculture, regional competition, transportation studies, integrated production and distribution systems as well as policy issues in the adoption of technology, industry re-structuring and natural resources have been developed. Optimising models do not allow the incorporation of many biological details and may be poor representations of reality. Using the simulation approach to identify a restricted set of management options that are then evaluated with the optimising models has been reported as a useful option.

Some crop models reported in recent literature

Software	**Details**
SLAM II	Forage harvesting operation
SPICE	Whole plant water flow
REALSOY	Soyabean
MODVEX	Model development and validation system
IRRIGATE	Irrigation scheduling model
COTTAM	Cotton
APSIM	Modelling framework for a range of crops
GWM	General weed model in row crops
MPTGro	Acacia spp.and Leucaena Spp.
GOSSYM-COMAX	Cotton

CropSyst	Wheat & other crops
SIMCOM	Crop (CERES crop modules) & economics
LUPINMOD	Lupin
TUBERPRO	Potato & disease
SIMPOTATO	Potato
WOFOST	Wheat & maize, Water and nutrient
WAVE	Water and agrochemicals
SUCROS	Crop models
ORYZA1	Rice, water
SIMRIW	Rice, water
SIMCOY	Corn
CERES-Rice	Rice, water
GRAZPLAN	Pasture, water, lamb
EPIC	Erosion Productivity Impact Calculator
CERES	Series of crop simulation models
DSSAT	Framework of crop simulation models including

	modules of CERES, CROPGRO and CROPSIM
PERFECT QCANE	Sugarcane, potential conditions
AUSCANE	Sugarcane, potential & water stress conds., erosion
CANEGRO	Sugarcane, potential & water stress conds
APSIM-Sugarcane	Sugarcane, potential growth, water and nitrogen stress
NTKenaf	Kenaf, potential growth, water stress

MODEL DEVELOPMENT

Strength

The strengths of models in general include the abilities to:

- Provide a framework for understanding a system and for investigating how manipulating it affects its various components
- Evaluate long-term impact of particular interventions
- Provide an analysis of the risks involved in adopting a particular strategy
- Provide answers quicker and more cheaply than is possible with traditional experimentation

Model calibration

Calibration is adjustment of the system parameters so that simulation results reach a predetermined level, usually that of an observation. In many instances, even if a model is based on observed data, simulated values do not exactly comply with the observed data and minor adjustments have to be made for some parameters.

Model validation

The model validation stage involves the confirmation that the calibrated model closely represents the real situation. The procedure consists of a comparison of simulated output and observed data that have not been previously used in the calibration stage. Ideally, all mechanistic models should be validated both at the level of overall system output and at the level of internal components and processes. The latter is an important aspect because due to the occurrence of feedback loops in biological systems, good prediction of system's overall output could be attributed to compensating internal errors. However, validation of all the components is not possible due to lack of detailed datasets and the option of validating only the determinant ones is adopted. For example, in a soil-water-crop model, it is important to validate the extractable water and leaf area components since biomass accumulated is heavily dependent on these.

The methodology of model validation is still rudimentary. The main reason is that, unlike the case of disciplinary experiments, a large set of hypotheses is being tested simultaneously in a model. Furthermore, biological and agricultural models are reflections of systems for which the behavior of some components is not fully understood and differences between model output and real systems cannot be fully accounted for.

The validation of system simulation models at present is further complicated by the fact that field data are rarely so definite that validation can be conclusive. This results from the fact that model parameters and driving variables are derived from site-specific situations that ideally should be measurable and available. However, in practice, plant, soil and meteorological data are rarely precise and may come from nearby sites. At times, parameters that were not routinely measured may turn out to be important and they are then arbitrarily estimated. Measured parameters also vary due to inherent soil heterogeneity over relatively small distances and to variations arising from the effects of husbandry practices on soil properties. Crop data reflect soil heterogeneity as well as variation in environmental factors over the growing period. Finally, sampling errors also contribute to inaccuracies in the observed data. Validation procedures involve both qualitative and quantitative comparisons. Before starting the quantitative tests, it is advisable to qualitatively assess time-trends of simulated and observed data for both internal variables and systems outputs.

Inadequate predictions of model outputs may require "re-fitting" of the regression curves or fine-tuning of one or more internal variables. This exercise should be undertaken with care because arbitrary changes may lead to changes in model structure that may limit the use of the model as a predictive tool. In some cases, it is best to seek more reliable data through further experimentation than embarking on extensive modification of model parameters to achieve an acceptable fit to doubtful data. This decision relies on the modeller's expertise and rigour as well as on human resources and time available to invest in fine-tuning model predictions.

MODEL USES AND LIMITATIONS

Models are developed by agricultural scientists but the user-group includes the latter as well as breeders, agronomists, extension workers, policy-makers and farmers. As different users possess varying degrees of expertise in the modelling field, misuse of models may occur. Since crop models are not universal, the user has to choose the most appropriate model according to his objectives. Even when a judicious choice is made, it is important that aspects of model limitations be borne in mind such that modelling studies are put in the proper perspective and successful applications are achieved.

Misperceptions and limitations of models

Agricultural systems are characterised by high levels of interaction between the components that are not completely understood. Models are, therefore, crude representations of reality. Wherever knowledge is lacking, the modeller usually adopts a simplified equation to describe an extensive subsystem. Simplifications are adopted according to the model purpose and / or the developer's views, and therefore constitute some degree of subjectivity. Models that do not result from strong interdisciplinary collaboration are often good in the area of the developer's expertise but are weak in other areas. Model quality is related to the quality of scientific data used in model development, calibration and validation.

When a model is applied in a new situation (e.g., switching a new variety), the calibration and validation steps are crucial for correct simulations. The need for model verification arises because all processes are not fully understood and even the best mechanistic model still contains some empirism making parameter adjustments vital in a new situation. Model performance is limited to the quality of input data. It is common in cropping systems to have large volumes of data relating to the above-ground crop growth and development, but data relating to root growth and soil characteristics are generally not as extensive. Using approximations may lead to erroneous results.

Most simulation models require that meteorological data be reliable and complete. Meteorological sites may not fully represent the weather at a chosen location. In some cases, data may be available for only one (usually rainfall) or a few (rainfall and temperature) parameters but data for solar radiation, which is important in the estimation of photosynthesis and biomass accumulation, may not be available. In such cases, the user would rely on generated data. At times, records may be incomplete and gaps have to be filled. Using approximations would have an impact on model performance.

Model users need to understand the structure of the chosen model, its assumptions, its limitations and its requirements before any application is initiated, *e.g,* using a model like QCANE, developed for cane growth under non-limiting conditions, would lead to erroneous output and analysis if it is used to simulate under water or nitrogen stress conditions. At times, model developers may raise the expectations of model users beyond model capabilities. Users, therefore, need to judiciously assess model capabilities and limitations before it is adopted for application and decision-making purposes. Generally, crop models are developed by crop scientists and if interdisciplinary collaboration is not strong, the coding may not be well-structured and model documentation may be poor. This makes alteration and adaptation to simulate new situations difficult, specially for users with limited expertise. Finally, using a model for an objective for which it had not been designed or using a model in a situation that is drastically different from that for which it had been developed would lead to model failure.

Model uses

The above points may give the impression that crop modelling has a bleak future but recent literature confirms the contrary. Simulation modelling is increasingly being applied in research, teaching, farm and resource management, policy analysis and production forecasts. These model can be applied into three areas, namely, research tools, crop system management tools, and policy analysis tools. A summary of some specific applications within the different groups follows:

As research tools

Research understanding: Model development ensures the integration of research understanding acquired through discreet disciplinary research and allows the identification of the major factors that drive the system and can highlight areas where knowledge is insufficient. Thus, adopting a modelling approach could contribute towards more targeted and efficient research planning. For example, changing the plant density in a sugar beet model resulted in model failure. This failure stimulated studies that gave additional information concerning biomass partitioning in the sugar beet.

Integration of knowledge across disciplines: Adoption of a modular approach in model coding allows the scientist to pursue his discipline-oriented research in an independent manner and at a later stage to integrate the acquired knowledge into a model. For example, the modular aspect of the APSIM software allows the integration of knowledge across crops as well as across disciplines for a particular crop. Adoption of a modular framework also allows for the integration of basic research that is carried out in different regions, countries and continents. This ensures a reduction of research costs (e.g., through a reduction in duplication of research) as well as the collaboration between researchers at an international level.

Improvement in experiment documentation and data organization: Simulation model development, testing and application demand the use of a large amount of technical and observational data supplied in given units and in a particular order. Data handling forces the modeller to resort to formal data organisation and database systems. The systematic organisation of data enhances the efficiency of data manipulation in other research areas (e.g., productivity analysis, change in soil fertility status over time)

Genetic improvement: As simulation models become more detailed and mechanistic, they can mimic the system more closely. More precise information can be obtained regarding the impact of different genetic traits on economic yields and these can be integrated in genetic improvement programs, e.g., the NTKenaf model. Researchers used the modelling approach to design crop ideotypes for specific environments.

Yield analysis: When a model with a sound physiological background is adopted, it is possible to extrapolate to other environments. The use of several simulation models to assess climatically-determined yield in various crops . The CANEGRO model has been used along the same lines in the South African sugar industry. Through the modelling approach, quantification of yield reductions caused by non-climatic causes (e.g., delayed sowing, soil fertility, pests and diseases) becomes possible. Almost all simulation models have been used for such purposes. Simulation models have also been reported as useful in separating yield gain into components due to changing weather trends, genetic improvements and improved technology.

As crop system management tools

Cultural and input management: Management decisions regarding cultural practices and inputs have a major impact on yield. Simulation models, that allow the specification of management options, offer a relatively inexpensive means of evaluating a large number of strategies that would rapidly become too expensive if the traditional experimentation approach were to be adopted. Many publications are available describing the use of simulation models with respect to cultural management (planting and harvest date, irrigation, spacing, selection of variety type) and input application (water and fertiliser).

Risks assessment and investment support: Using a combination of simulated yields and gross margins, economic risks and weather-related variability can be assessed. These data can then be used as an investment decision support tool.

Site-specific farming: Profit maximisation may be achieved by managing farms as sets of sub-units and providing the required inputs at the optimum level to match variation in soil properties across the farm. Such an endeavour is attainable by coupling simulation models with geographic information systems (GIS) to produce maps of predicted yield over the farm. But, one of the prerequisites is a systematic characterisation of units that may prove costly.

As policy analysis tools

Best management practices: Models having chemical leaching or erosion components can be used to determine the best practices over the long-term. The EPIC model has been used to evaluate erosion risks due to cropping practices and tillage.

Yield forecasting: Yield forecasting for industries over large areas is important to the producer (harvesting and transport), the processing agent (milling period) as well as the marketing agency. The technique uses weather records together with forecast data to estimate yield across the industry.

Introduction of a new crop: Agricultural research is linked to the prevailing cropping system in a particular region. Hence, data concerning the growth and development of a new crop in that region would be lacking. Developing a simulation model based on scientific data collected elsewhere and a few datasets collected in the new environment helps in the assessment of temporal variability in yield using long-term climatic data. Running the simulations with meteorological data in a balanced network of locations also helps in locating the industry.

Global climate change and crop production: Increased levels of CO_2 and other greenhouse gases are contributing to global warming with associated changes in rainfall pattern. Assessing the effects of these changes on crop yield is important at the producer as well as at the government level for planning purposes.

CONCLUSION

Crop/soil simulation models basically applied in three sections (1) tools for research, (2) tools for decision-making, and (3) tools for education, training and technology-transfer. The greatest use of crop/soil models so far has been by the research community, as models are primarily tools for organizing knowledge gained in experimentation. However, there is an urgent need to make the use of models in research more relevant to problems in the real world, and find effective means of dissemination of results from work using models to potential beneficiaries. Nevertheless, crop models can be used for a wide range of applications. As research tools, model development and application can contribute to identify gaps in our knowledge, thus enabling more efficient and targeted research planning. Models that are based on sound physiological data are capable of supporting extrapolation to alternative cropping cycles and locations, thus permitting the quantification of temporal and spatial variability. Over a relatively short time span and at comparatively low costs, the modeller can investigate a large number of management strategies that would not be possible using traditional methodologies. Despite some limitations, the modelling approach remains the best means of assessing the effects of future global climate change, thus helping in the formulation of national policies for mitigation purposes. Other policy issues, like yield forecasting, industry planning, operations management, consequences of management decisions on environmental issues, are also well supported by modelling.

LAND SUITABILITY CLASSIFICATION FOR DIFFERENT CROPS

Each plant species requires definite soil and site conditions for its optimum growth. Although some plants may be found to grow under different soils and extreme agro-ecological conditions, yet not all plants can grow on the same soil and under the same environment. The conspicuous absence of Pinus species in inter-tropical and of eucalyptus in the temperate (cold) regions are examples. Since the availability of both water and plant nutrients is largely controlled by the physicon chemical and micro environment of soils, the success and/or failure of any plant species, in a particular area, is largely determined by these factors. The deep rooted forest or orchard plantations respond differently to soil depth and soil texture(Mishra and Sahu,1991) than the shallow-rooted arable crops such as rice, wheat, green gram, black gram, pigeon-pea, groundnut etc.

Several soil-site studies for different plant species have been reported in the literature. These illustrate how soil depth, (sub) soil texture, salinity and drainage conditions are related to soil-site quality. The objective of various soil-site evaluation studies has been to predict and classify land for plant growth (Sehgal,1996). Observations on growth inhibiting factors for certain species and tolerance of others to extremely adverse conditions have been evaluated by many scientists.

Suitability Criteria

Most of the plant species need well drained, moderately fine to medium texture soils, free of salinity and having optimum physical environment. Soil resource maps based on several parameters, can aid in predicting the behaviour and suitability of soils for growing field crops, horticultural crops, forest species and other plantation crops once the suitability criteria is established. Within limits, it may also find application in transfer of technology to other areas with comparable soil-site characteristics.

Several systems of land evaluation have been proposed for use in different regions, the important being that of Storie(1954) and Ricquier *et al.* (1970).

The FAO land suitability classification system has four different categories: Orders, Classes, Subclasses and Units.

There are two orders(S and N) which reflect the kind of suitability (S for suitable and N for unsuitable land).

Order "S" -Suitable land

Land on which sustained use for the defined purpose in the defined manner is expected to yield benefits that will justify required recurrent inputs without unacceptable risk to land resources.

Order "N"-Unsuitable land

Land having characteristics which appear to preclude its sustained use for the defined purpose in the defined manner or which would create production, upkeep and/or conservation problems requiring a level of recurrent inputs unacceptable at the time of interpretation.

Land Suitability Classes:

The framework at its origin permits complete freedom in determining the number of classes within each order. However, it has been recommended to use only 3 classes within order S and 2 classes within order N. The class will be indicated by an Arabic number in sequence of decreasing suitability within the order and therefore reflects degrees of suitability within the orders.

Examples:

S1 : Suitable

S2 : Moderately suitable S3 : Marginally suitable

N1 : Actually unsuitable but potentially suitable N2 : Actually and potentially unsuitable

No firm criteria are given for defining the classes; this permits complete freedom in choice of the criteria in order to elaborate the degrees of suitability within the orders. For each specific case a specific method is to be suggested. Appraisal can be done according to an evaluation of land limitations

Land Suitability Subclasses:

The sub classes reflect kinds of limitations or main kinds of improvement measures required within classes. They are indicated in the symbol using lower case letters.

c : Climatic conditions

t : Topographic limitations w : Wetness limitations

n : Salinity (and/or alkalinity) limitations

f : Soil fertility limitations not readily to be corrected

s: Physical soil limitations (influencing soil / water relationship and management).

Land suitability units

This grouping is used to identify land development units having minor differences in management requirements. This can indicate the relative importance of land development works. It is indicated by Arabic numerals, enclosed in parenthesis, following the subclass symbol.

Example of total unit

The whole unit is indicated by a symbol; for example : S2w(2). Here "S" represents Order (Suitable); the number 2 after the letter S represents Class 2 (moderately suitable); "w" represents Subclass w(wetness limitation); and (2) represents Unit 2.

Sys and Verheye (1975) proposed the following capability index (Ci) based on nine parameters for crop production in the arid and semi-arid regions.

$$Ci = A.B.C.D.E.F.G.H.I.$$

Where,

A = rating for soil texture(Taken as 100 for best texture, say loam)

B = rating for calcium carbonate(Taken as fraction of 1(one)

C = rating for gypsum (as above) D = rating for salinity (as above)

E = rating for sodium saturation (as above) F = rating for drainage (as above)

G = rating for soil depth (as above)

H = rating for epipedon and weathering stage (as above)

I = rating for profile development (as above).

For example a soil has loam texture, has 5 to 10 percent calcium carbonate, 2.5 percent of gypsum, 4.8(dS/m) of salinity content, low in sodium saturation, is well drained, very deep, has well defined epipedon and matured soil horizons. The Capability index(Ci) of the soil as per the scheme will work out to be

$$100 \times 0.8 \times 0.8 \times 0.9 \times 1.0 \times 1.0 \times 1.0 \times 1.0 \times 1.0 = 57.6$$

The Capability index of the above soil is 57.6.It comes under the Ci range of 45 to 60;so the soil has moderate limitation for economic production of crops.

Sys (1976) proposed the following scheme for evaluating the degree of limitation ranging from 0(suggesting no limitation and having Ci of 80 or more) to 4 (suggesting very severe limitation with Ci of 30 or less.

No (0): The characteristics (quality) are optimal for plant growth (Ci 80 or more).

Limitation Slight (1): The characteristics are nearly optimal for the land utilization type and Limitation affect productivity for not more than 20 per cent with regard to optimal Yield (Ci 60 to 80).

Moderate (3): The characteristics have moderate influence on crop yield decline; Limitation however, benefits can still be made and the yield remain economical. (Ci 45 to 60).

Severe (4): Such limitations will not only decrease the yields below the Limitation profitable level, but may inhibit the use of the soil for the considered land utilization(Ci less than 30).

The limitation approach has been successfully used to provide a qualitative land evaluation based on general characteristics which are made available after a quality soil survey and general study of other soil resources in the area.

The soil-site parameters considered for the purpose of evaluating land for agriculture, forestry and for plantation crops and for defining suitability classes are:

Soil-Site Characteristics Related Land Quality

Climate - Available moisture

Topography and Landscape(t) - Resistance to erosion Wetness(w) conditions

- Available moisture
- Drainage
- Flooding

Physical conditions(s) of soil

- Texture
- Water availability
- Gravels/Stoniness
- Availability of foot-hold for

(Surface and subsoil) root development

- Depth
- Availability of foot-hold for plant growth
- Calcium carbonate
- Nutrient availability
- Gypsum
- Source of nutrient sulphur

Soil fertility(f) (Not readily correctable):

- Organic matter
- Cation Exchange Capacity (CEC)

- Base Saturation
- Nutrient availability

Salinity and Alkalinity(n):

- Salinity
- Groundwater depth and its quality
- Alkalinity/Sodicity