RANVEER DESAI

APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING TECHNIQUES

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Table of Contents

Chapter 1	Introduction to Remote Sensing, Sensors and Platforms	**1**
Chapter 2	Image Analysis	**27**
Chapter 3	Geographic Information System, Data Entry and Preparation	**40**
Chapter 4	Spatial Data Analysis	**67**
Chapter 5	RS and GIS Applications General	**85**
Chapter 6	Application to Hydrology and Water Resources	**100**

1

INTRODUCTION TO REMOTE SENSING,SENSORS AND PLATFORMS

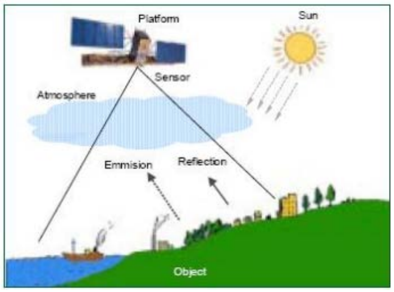
Introduction to remote sensing: Basic concepts of remote sensing, electromagnetic radiation, electromagnetic spectrum, interaction with atmosphere, energy interaction with the earth surfaces characteristics of remote sensing systems.

Sensors and platforms: Introduction, types of sensors, airborne remote sensing, spaceborne remote sensing, image data characteristics, digital image data formats-band interleaved by pixel, band interleaved by line, band sequential, IRS, LANDSAT, SPOT.

1.1 Introduction to remote sensing: Basic concepts of remote sensing

Remote sensing is an art and science of obtaining the information about an object or its feature without physically coming in contact with that object or feature. Humans apply remote sensing in their day-to-day business, through vision, hearing and sense of smell. The data collected can be of many forms: variations in force distributions (e.g., gravity meter), variations in acoustic wave distributions (e.g., sonar), variations in electromagnetic energy distributions (e.g., eye) etc. These remotely collected data through various sensors may be analyzed to obtain information about the objects or features under investigation.

Thus, the remote sensing is a process of inferring the surface parameters from measurements of the electromagnetic radiation (EMR) from the Earth's surface. This EMR can either be emitted or reflected from the Earth's surface. In other words, remote sensing is detecting and measuring electromagnetic energy emanating or reflected from distant objects made of various materials, so that we can identify and categorize these objects by class or type, substance and spatial distribution [American Society of Photogrammetry, 1975].



Schematic representation of remote sensing technique

Remote sensing provides a means of observing large areas at finer spatial and temporal frequencies. It finds extensive applications in civil engineering including watershed studies, hydrological modeling, hydrological states and fluxes simulation, disaster management services such as drought warning, flood and and monitoring, damage assessment in case of natural calamities, environmental monitoring, urban planning etc.

Principles of Remote Sensing

Different objects reflect or emit different amounts of energy in different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both the incident energy and the material. Detection and discrimination of objects or surface features is done through the uniqueness of the reflected or emitted electromagnetic radiation from the object.

A device to detect this reflected or emitted electro-magnetic radiation from an object is called a “sensor” (e.g., cameras and scanners). A vehicle used to carry the sensor is called a “platform” (e.g., air crafts and satellites).

Main stages in remote sensing are the following.

A. Emission of electromagnetic radiation

• The Sun or an EMR source located on the platform

B. Transmission of energy from the source to the object

• Absorption and the scattering of the EMR while transmission

C. Interaction of EMR with the object and the subsequent reflection and emission

D. Transmission of energy from the object to the sensor

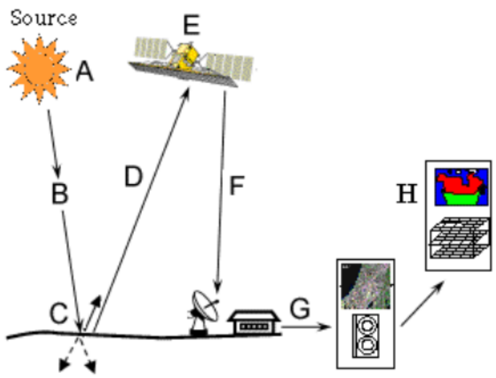
E. Recording of energy by the sensor

• Photographic or non-photographic sensors

F. Transmission of the recorded information to the ground station

G. Processing of the data into the digital or hard copy image

H. Analysis of data



Important stages in remote sensing

Advantages and Disadvantages of Remote Sensing

Advantages of remote sensing are:

a) Provides data of large areas.

b) Provides the data of very remote and inaccessible regions.

c) Able to obtain imagery of any area over a continuous period of time through which the any anthropogenic or natural changes in the landscape can be analyzed.

d) Easy and rapid collection of data.

e) Relatively inexpensive when compared to employing a team of surveyors.

f) Rapid production of maps for interpretation.

Disadvantages of remote sensing are:

a) The interpretation of imagery requires a certain skill level.

b) Needs cross verification with ground (field) survey data.

c) Data from multiple sources may create confusion.

d) Objects could be misclassified or confused.

e) Distortions may occur in an image due to the relative motion of sensor and source.

1.1.1 Electromagnetic radiation, electromagnetic spectrum

Electromagnetic radiation

Electromagnetic energy or electromagnetic radiation (EMR) is the energy propagated in the form of an advancing interaction between electric and magnetic fields (Sabbins, 1978). It travels with the velocity of light. Visible light, ultraviolet rays, heat, infrared rays, radio waves, X-rays all are different forms of electro-magnetic energy.

Electro-magnetic energy (E) can be expressed either in terms of the frequency (f) or wave length (λ) of radiation as

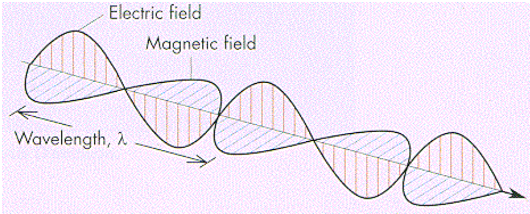
$E = hcf$ or hc / λ ___________________(1)

Where h is Planck's constant (6.626×10^{-34} Joules-sec), c is a constant that expresses the celerity or speed of light (3×10^{8} m/sec), f is frequency expressed in Hertz and λ is the wavelength expressed in micro meters ($1\mu m = 10^{-6}$ m).

As can be observed from equation (1), shorter wavelengths have higher energy content and longer wavelengths have lower energy content.

Electromagnetic radiation is energy that is propagated through the free space or through a material medium in the form of the electromagnetic waves, such as radio waves, visible light and gamma rays. Term also refers to the emission and transmission of such radiant energy.

Scottish physicist James Clerk Maxwell was the first to predict the existence of the electromagnetic waves. In 1864 he set forth his electromagnetic theory, proposing that light--including the various other forms of the radiant energy--is an electromagnetic disturbance in the form of the waves. In 1887 Heinrich Hertz, a German physicist, provided experimental confirmation by producing the first man-made electromagnetic waves and investigating their properties. The subsequent studies resulted in a broader understanding of the nature and the origin of radiant energy.



It has been established that the time-varying electric fields can induce magnetic fields and that time-varying magnetic fields can induce electric fields. Because such electric and the magnetic fields generate each other, they occur jointly and together they propagate as electromagnetic waves.

An electromagnetic wave is a transverse wave in that electric field and magnetic field at any point and time in wave are perpendicular to each other as well as to the direction of propagation. In free space (i.e., a space that is absolutely devoid of matter and that experiences no intrusion from the other fields or forces), electromagnetic waves always propagate with same speed--that of light (299,792,458 m per second or 186,282 miles per second)--independent of the speed of the observer or of the source of the waves.

Electromagnetic radiation has properties in common with the other forms of waves such as reflection, diffraction, refraction, and interference. Moreover, it might be characterized by frequency with which it varies over time or by its wavelength. Electromagnetic radiation, though, has particle-like properties in addition to those associated with the wave motion. It is quantized in that for a given frequency, its energy occurs as an integer times h, in which h is a fundamental constant of the nature known as Planck's constant. A quantum of the electromagnetic energy is called a photon. The visible light and other forms of electromagnetic radiation may be thought of as a stream of photons, with photon energy directly proportional to the frequency.

Electromagnetic radiation spans an enormous range of the frequencies or wavelengths, as is shown by electromagnetic spectrum. Customarily, it is designated by fields, waves and particles in increasing magnitude of frequencies--radio waves, microwaves, infrared rays, visible light, ultraviolet light, X rays and gamma rays. Corresponding wavelengths are inversely proportional and both the frequency and wavelength scales are logarithmic.

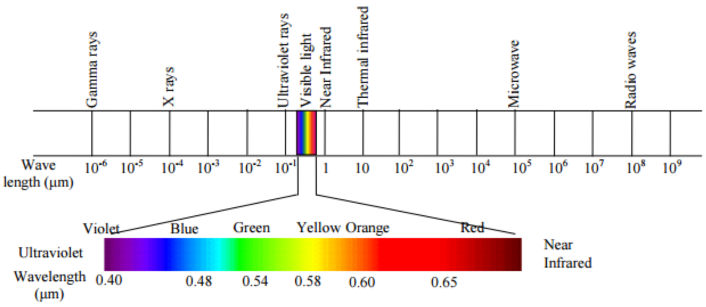
Electromagnetic radiation of different frequencies interacts with matter differently. A vacuum is the only perfectly transparent medium and all the material media absorb strongly some regions of the electromagnetic spectrum. Example, molecular oxygen (O_2), ozone (O_3) and molecular nitrogen (N_2) in the Earth's atmosphere are almost perfectly transparent to infrared rays of all frequencies, but they strongly absorb ultraviolet light, X rays and gamma rays.

The frequency of X rays is substantially higher than that of visible light and so X rays are able to penetrate many materials which do not transmit light. Moreover, absorption of X rays by a molecular system can cause chemical reactions to occur. When X rays are absorbed in a gas, for instance, they eject photoelectrons from the gas, which in turn ionize the molecules.

If these processes occur in living tissue, the photoelectrons emitted from the organic molecules destroy the cells of the tissue. Gamma rays, though generally of somewhat higher frequency than X rays, have basically same nature. When energy of gamma rays is absorbed in matter, its effect is virtually indistinguishable from the effect produced by X rays.

There are several sources of electromagnetic radiation, both natural and man-made. Radio waves, for example, are produced by the cosmic objects such as pulsars and quasars and by electronic circuits. Sources of the ultraviolet radiation include mercury vapour lamps and high-intensity lights, as well as the Sun. The latter also generates X rays, as do certain types of the particle accelerators and electronic devices.

Distribution of the continuum of energy can be plotted as a function of wavelength (or frequency) and is known as the EMR spectrum.



Electromagnetic radiation spectrum

In the remote sensing terminology, electromagnetic energy is generally expressed in terms of wavelength, λ.

All matters reflect, emit or radiate a range of the electromagnetic energy, depending upon the material characteristics. In remote sensing, it is the measurement of electromagnetic radiation reflected or emitted from an object, is the used to identify the target and to infer its properties.

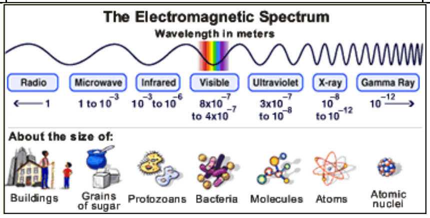
Electromagnetic spectrum

The electromagnetic spectrum consists of all the different wavelengths of electromagnetic radiation including light, radio waves and X-rays. We name the regions of the spectrum rather arbitrarily, but the names give us the general sense of the energy of the radiation. For example, ultraviolet light has the shorter wavelengths than radio light. The only region in the entire electromagnetic spectrum that our eyes are sensitive to is the visible region.

Band designations for microwave frequency ranges

Old	**New**	**Frequency ranges (GHz)**
Ka	K	26.5 - 40
K	K	20 - 26.5
K	J	18 - 20

Ku	J	12.4 - 18
X	J	10 - 12.4
X	I	8 - 10
C	H	6 - 8
C	G	4 - 6
S	F	3 - 4
S	E	2 - 3
L	D	1 - 2
UHF	C	0.5 - 1



Gamma rays have the shortest wavelengths, < 0.01 nanometers. This is the highest frequency and most energetic region of the electromagnetic spectrum. Gamma rays can result from nuclear reactions and from processes taking place in objects such as pulsars, quasars and black holes.

X-rays range in wavelength from 0.01 to 10 nm. They are generated, for example, by the super-heated gas from exploding stars and quasars, where temperatures are near a million to ten million degrees.

Ultraviolet radiation has wavelengths of 10 to 310 nm. Young, hot stars produce a lot of ultraviolet light and the bathe interstellar space with this energetic light.

Visible light covers the range of wavelengths from 400 to 700 nm (from the size of a molecule to a protozoan). Our sun emits the most of its radiation in the visible range, which our eyes perceive as the colors of the rainbow. Our eyes are sensitive only to this small portion of the electromagnetic spectrum.

Infrared wavelengths span from 710 nm to 1 millimeter (from the width of a pinpoint to the size of small plant seeds). At a temperature of 37 degrees C, our bodies give off infrared wavelengths with a peak intensity near 900 nm.

Radio waves are longer than 1 mm. Since these are the longest waves, they have the lowest energy and are associated with the lowest temperatures.

Radio wavelengths are found everywhere in the background radiation of the universe, in interstellar clouds and in the cool remnants of supernova explosions, to name a few. Radio stations uses the radio wavelengths of electromagnetic radiation to send the signals that our radios then translate into sound.

Radio stations transmits the electromagnetic radiation, not sound. The radio station encodes the pattern on the electromagnetic radiation it transmits and then our radios receive the electromagnetic radiation, decode the pattern and then translates the pattern into sound.

1.2 Interaction with atmosphere

Irrespective of its source, all radiation detected by remote sensors passes through some distance or path length, of atmosphere. The path length involved can vary widely. For example, space photography results from sunlight that passes through the full thickness of the earth's atmosphere twice on its journey from source to sensor. On the other hand, an airborne thermal sensor detects the energy emitted directly from objects on the earth, so a single, relatively short atmospheric path length is involved. Net effect of the atmosphere varies with these differences in path length and also varies with magnitude of the energy signal being sensed, the atmospheric conditions present and the wavelengths involved.

Because of the varied nature of atmospheric effects, we treat this subject on a sensor-by-sensor. The atmosphere could have a profound effect on, among other things, the intensity and spectral composition of radiation available to any sensing system. These effects are caused principally through the mechanisms of atmospheric scattering and absorption.

Scattering

Atmospheric scattering is unpredictable diffusion of radiation by particles in the atmosphere. Rayleigh scattering is common when radiation interacts with atmospheric molecules and other tiny particles that are much smaller in diameter than wavelength of the interacting radiation. The effect of Rayleigh scatter is inversely proportional to fourth power of wavelength. Hence, there is a much stronger tendency for short wavelengths to be scattered by this scattering mechanism than the long wavelengths.

A "blue" sky is a manifestation of Rayleigh scatter. In the absence of scatter, sky would appear black. But, as sunlight interacts with the earth's atmosphere, it scatters the shorter (blue) wavelengths more dominantly than the other visible wavelengths. Consequently, we see a blue sky. At sunrise and sunset, though, the sun's rays travel through longer atmospheric path than during mid-day. With the longer path, the scatter of short wavelengths is so complete that we see only less-scattered, longer wavelengths of orange and red.

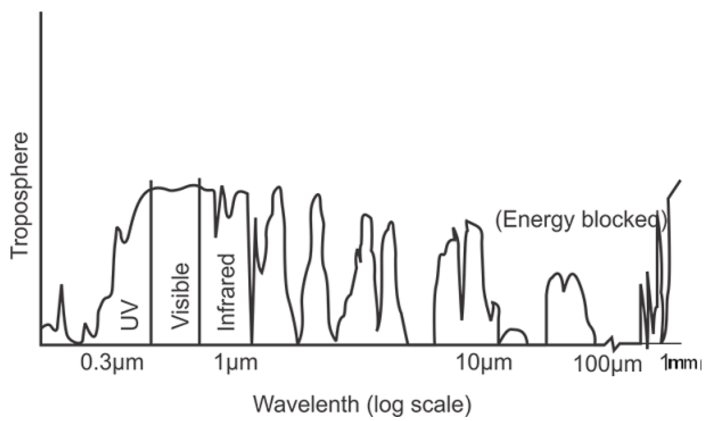
Rayleigh scatter is one of the primary cause of "haze" in imagery. Visually, the haze diminishes the "crispness," on an image. In the colour photography, it results in a bluish-grey cast to an image, particularly when taken from high altitude. Haze could often be eliminated or at least minimized, in the photography by introducing, in front of the camera lens, a filter that does not transmit short wavelengths.

Another type of scatter is Mie scatter, which exists when atmospheric particle diameters approximately equal the energy wavelengths which is being sensed. Water vapour and dust are major causes of Mie scatter. This type of scatter tends to influences longer wavelengths compared to Rayleigh scatter. Although Rayleigh scatter tends to dominate under the most atmospheric conditions, Mie scatter is significant in slightly overcast ones.

A more bothersome phenomenon is nonselective scatter, which comes about when the diameters of the particles causing scatter are much larger than the energy wavelengths being sensed. Water droplets, for example, cause such scatter. They commonly have a diameter in the 5 to 100 µm range and scatter all visible and reflected IR wavelengths about equally. Consequently, this scattering is "nonselective" with respect to wavelength. In the visible wavelengths, equal quantities of blue, green and red light are scattered, making fog and clouds appear white.

Absorption

In contrast to scatter, atmospheric absorption results in the effective loss of energy to atmospheric constituents. This normally involves absorption of energy at a given wavelength. The most efficient absorbers of solar radiation in this regard are water vapour, carbon dioxide and ozone. Because these gasses tend to absorb electromagnetic energy in specific wavelength bands, they strongly influence "where we look" spectrally with any given remote sensing system. The wavelength ranges in which the atmosphere is particularly transmissive of energy are referred to as atmospheric windows.



Spectral characteristics of Atmospheric transmittance

Figure shows the atmospheric absorption characteristics of electromagnetic energy. The most common sources of energy is solar energy and the energy emitted from earth. In above figure, spectral regions in which the atmosphere blocks energy are shown. Remote sensing data acquisition is limited to the non blocked spectral regions, called "atmospheric w i n dows". The spectral sensitivity range of the eye (the "visible" range) coincides both with an atmospheric window and the peak level of energy from t he sun. Emitted "heat" energy from the earth, is sensed through the windows at 3 to 5µm and 8 to 14µm using such devices as the thermal scanners. Multispectral scanners sense simultaneously through multiple, narrow wavelength ranges that could be located at various points in the visible through the thermal spectral region. Radar and passive microwave systems operate through a window in the 1 mm to 1 m region.

The important point to note from above figure is the interaction and interdependence between the primary sources of electromagnetic energy, the atmospheric windows through which source energy might be transmitted to and from the earth surface features and the spectral sensitivity of the sensors available to detect and record the energy. One cannot select sensor to be used in any given remote sensing task arbitrarily; one must instead consider:

1) The presence or absence of atmospheric windows in the spectral range (s) in which one wishes to sense,

2) The source, magnitude and spectral composition of the energy available in the these ranges, and

3) The spectral sensitivity of the sensors available.

Ultimately, however, the choice of spectral range of the sensor must be based on the manner in which energy interacts with the features under investigation. It is to this last, very important, element that we now turn our attention.

1.2.1 Energy interaction with the earth surfaces characteristics of remote sensing systems

When electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible. This is illustrated in figure below for an element of the volume of a water body. Various fractions of energy incident on the element are reflected, absorbed and/ or transmitted. The amount of radiant energy onto, off of or through surface per unit time is called radiant flux (Φ) and is measured in watts (W).

Applying the principle of conservation of energy, the inter-relationship between these three energy interactions can be expressed as,

$E_1 (\lambda) = E_R (\lambda) + E_A (\lambda) + E_T (\lambda)$

Where,

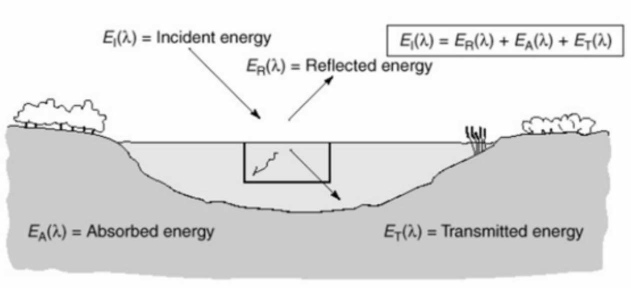
E_1 = Incident energy

E_R = Reflected energy

E_A = Absorbed energy

E_T = Transmitted energy

All energy components are function of wavelength λ.



Basic interactions between electromagnetic energy and an earth surface

In above equation two points concerning this relationship should be noted. First, the proportions of energy reflected, absorbed and transmitted will vary for different earth features, depending on their material type and the condition. These differences permit us to distinguish different features on an image. Second, wavelength dependency means that, even within a given feature type, the proportion of reflected, absorbed and transmitted energy would vary at different wavelengths. Thus, two features may be indistinguishable in one spectral range and be very different in an another wavelength band.

In remote sensing the radiation reflected from targets. We refer to two types of reflection is measured reflection from a target: can be specular reflection and diffuse reflection. For a smooth surface specular or the mirror-like reflection occurs where all (or almost all) of the energy is directed away from surface in a single direction.

Diffuse reflection occurs when the surface is rough and the energy is reflected almost uniformly in all the directions. Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Figure below illustrate specular and diffused reflection. Whether a particular target reflects specularly or diffusely or somewhere in between, depends on the surface roughness of the feature in comparison to the wavelength of incoming radiation. If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, the diffuse reflection will dominate. For example, fine-grained sand would appear fairly smooth to the long wavelength microwaves but will appear quite rough to the visible wavelengths.

(a) Specular Reflection and (b) Diffuse Reflection

Diffuse reflections contain spectral information on the “color” of the reflecting surface, whereas specular reflections do not. Hence, in remote sensing, we are most often interested in measuring diffuse reflectance properties of terrain features.

This is measured as a function of wavelength and is called spectral reflectance, ρ(λ).

It is can be expressed as,

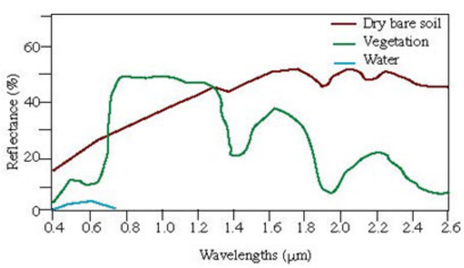
$$\rho_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)}$$

$$= \frac{\text{Energy of wavelength } \lambda \text{ reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident upon the object}} \times 100$$

Where ρ(λ) is expressed as a percentage.

The spectral response of objects could be built from the measured reflected energy for different wavelengths. The spectral response of a material to different wavelengths of EMR can be represented graphically as a Spectral Reflectance Curve.

The comparison of the spectral reflectance curves of different objects one can distinguish between them. For example, water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Figure below shows the typical spectral reflectance curves for three basic types of earth features: healthy green vegetation, dry bare soil and the clear lake water. These curves indicate how much incident energy would be reflected from the surface and subsequently recorded by a remote sensing instrument. At a given wavelength, the higher the reflectance, the brighter the object appears in an image.



Spectral reflectance curve

Note that vegetation reflects much more energy in the near-infrared (0.8 to 1.4 microns) than it does in visible light (0.4 to 0.7 microns). The amount of energy that vegetation reflects is related to the internal structure of the plant and the amount of moisture in the plant. A surface like astro-turf, which is colored green, would appear dark in the near infrared, because it doesn't have the internal structure of living vegetation. Another feature to notice is that clear water reflects visible light only, so it will appear dark in infrared images.

Thus, to utilize remote sensing data effectively, one must know and understand the spectral characteristics of the particular features under investigation in any given application.

1.3 Sensors and platforms: Introduction, types of sensors

Introduction:

A platform is the vehicle or carrier for remote sensors for which they are borne. In Meteorology platforms are used to house sensors which obtain data for remote sensing purposes and are classified according to their heights and events to be monitored.

Platforms used for remote sensing:

They are classified into three categories.

• Ground-based

• Airborne

• Space-borne

Ground-Based Platforms

Mobile Hydraulic Platforms

• Carried on vehicles

• Extendable to a height of 15m above the surface.

• At the top of the platform there are:

• Spectral reflectance meters

• Photographic systems

• IR or Microwave scanners

• Linked to data loggers in the vans.

Limitation:

Vehicles limited to roads and the range is confined to the small area along or around the road.

Portable Masts

• Used to support cameras and scanners.

Example. a Land Rover fitted with an extending aerial.

• **Limitation:** Very unstable in windy conditions.

Towers

• Can be dismantled and moved from one place to another.

• Offer greater rigidity than masts but are less mobile and require more time to erect.

Weather Surveillance Radar

• A Weather Surveillance Radar is of the long range type which detects and tracks typhoons and cloud masses at distance of 400 kilometers or less.

• This radar has a rotating antenna disk preferably mounted on top of a building free from any physical obstruction.

• Radio energy emitted by the transmitter and focused by the antenna shoots outward through atmosphere in a narrow beam.

• The cloud mass, whether it is part of a typhoon or not, reflects a small fraction of the energy back to the antenna.

• This reflected energy is amplified and displayed visually on a radar scope.

• Distance or slant range of the target from the radar is determined through the elapsed time the signal is transmitted and then received as an echo.

• Direction is determined by the direction at which the focused beam is pointing at instant the echo is received.

• The radar is a useful tool in tracking and monitoring tropical cyclones.

The ground based platforms could also be classified according to operational range

• **Short range systems**

Operate at ranges of 50-100m with panoramic scanning and are often used to map building interiors or small objects

• **Medium range systems**

Operate at a distance of 150-250m, also achieving millimeter accuracies in high definition surveying in 3D modelling applications example, bridge and dam monitoring

• **Long range systems**

Can measure at distances of up to 1km and are frequently used in the open-pit mining and topographic survey applications.

1.4 Digital image data formats-band interleaved by pixel, band interleaved by line, band sequential, IRS, LANDSAT, SPOT

Introduction

In order to properly process the remotely sensed data, the analyst must know how the data is organized and stored on digital tapes and how the data is processed by computers and software. Understanding existing digital data formats is essential before the data could be processed. There are many different data formats used for storing digital remotely sensed data. Many commercial data suppliers such as EOSAT and SPOT, provide radiometrically corrected data in a customer specified format. There are four major data formats used by government and commercial data suppliers:

1. Band Interleaved by Pixel (BIP) Format

2. Band Interleaved by Line (BIL) Format

3. Band Sequential (BSQ) Format

4. Run-Length Encoding Format

Most digital data are stored on the nine-track tape (800, 1600 and 6250 bpi), 4- or 8-mm tape or on optical disks. The nine-track and 4- or 8-mm tapes should be read serially while it is possible to randomly select areas of interest from within the optical disk. This may result in significant savings of time when unloading remote sensor data. The 4- and 8-mm tape and compact disks are very efficient storage mediums, as opposed to the large number of nine-track tapes required to store most images.

Band Interleaved By Pixel Format (BIP)

One of the earliest digital formats used for satellite data is band interleaved by pixel (BIP) format. This format treats pixels as the separate storage unit. Brightness values for each pixel are stored one after another. It is practical to use if all bands in an image are to be used. Figure below shows the logic of how the data is recorded to the computer tape in sequential values for a four band image in BIP format.

Line 1	Pixel **1**	Band 1	Line 1	Pixel **2**	Band 1	Line 1	Pixel **3**	Band 1
Line 1	Pixel **1**	Band 2	Line 1	Pixel **2**	Band 2	Line 1	Pixel **3**	Band 2
Line 1	Pixel **1**	Band 3	Line 1	Pixel **2**	Band 3	Line 1	Pixel **3**	Band 3
Line 1	Pixel **1**	Band 4	Line 1	Pixel **2**	Band 4	Line 1	Pixel **3**	Band 4

All four bands are written to the tape before values for the next pixel are represented. Any given pixel located on the tape contains values for all four bands written directly in sequence. This format may be awkward to use if only certain bands of imagery are needed. Often data in BIP format is organized into four separate panels or tiles, consisting of the vertical strips each 840 lines wide in the x direction and 2,342 lines long in the y direction. In order to read all four bands of the image, all four panels must be pieced together to form the entire scene.

Band Interleaved By Line Format (BIL)

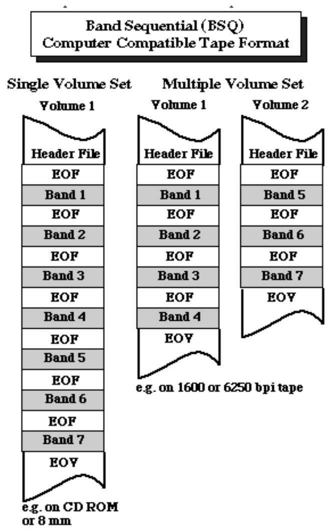
Just as the BIP format treats each pixel of data as the separate unit, the band interleaved by line (BIL) format is stored by lines. Figure below shows the logic of how the data is recorded to the computer tape in the sequential values for a four band image in BIL format.

Line **1**	Band 1	Line **1**	Band 2	Line **1**	Band 3	Line **1**	Band 4			
	Line **2**	Band 1	Line **2**	Band 2	Line **2**	Band 3	Line **2**	Band 4		
		Line **3**	Band 1	Line **3**	Band 2	Line **3**	Band 3	Line **3**	Band 4	
			Line **4**	Band 1	Line **4**	Band 2	Line **4**	Band 3	Line **4**	Band 4

Each line is represented in all four bands before the next line is recorded. Like the BIP format, it is a useful to use if all bands of the imagery are to be used in the analysis. If some bands are not of interest, the format is inefficient if the data are on tape, since it is necessary to read serially past the unwanted data.

Band Sequential Format

The band sequential format requires that all data for a single band covering the entire scene be written as one file. Thus, if an analyst wanted to extract the area in the center of a scene in four bands, it would be necessary to read into this location in four separate files to extract the desired information. Several researchers like this format because it is not necessary to read serially past unwanted information if the certain bands are of no value, especially when the data are on a number of different tapes. Random-access optical disk technology, though, makes this serial argument obsolete.



LANDSAT SATELLITE PROGRAMME

National Aeronautics and Space Administration (NASA) of USA with the cooperation of the U.S. Department of Interior planned the launching of a series of the Earth Resources Technology Satellites (ERTS). ERTS-1 was launched by a ThorDelta rocket on July 23, 1972 and it operated until January 6,1978. It represented the first unmanned satellite designed to acquire data about the earth resources on a systematic, medium resolution, repetitive, multispectral basis. Subsequently, NASA renamed the ERTS programme as "Landsat" programme to distinguish it from the series of meteorological and oceanographic satellites that the USA launched later.

ERTS-1 was retrospectively named Landsat-1. Five Landsat satellites have been launched so far and the experimental programme has evolved into an operational global resource monitoring programme. Three different types of sensors have been flown in various combinations on the five missions. These are Return Beam Vidicon (RBV) camera system, the Multispectral Scanner (MSS) system and the Thematic Mapper (TM).

Characteristics of Landsat Satellites and Their Sensors:

Satellite Capabilities :		
Particulars	**Landsat - 1 to 3**	**Landsat - 4 & 5**
Altitude	919 Km	705 Km
Orbit	Near-Polar Sun-Synchronous	Near-Polar Sun-Synchronous

Inclination	99.09 Degree	98.2 Degrees
Equatorial crossing time	0930 Hours	0945 Hours
Period	103 minutes	99 minutes
Repeat Cycle	18 Days	16 Days
Swath Width	185 Km	185 Km
Data rate	15.06 Mbps	84.9 Mbps

Sensor Capabilities :

Sensor	**Mission**	**Channel**	**Spectral Spatial Resolution (Microns)**	**Spatial Resolution**	**Radiometric Resolution**
RBV	Landsat1 to 3	1 2 3 4	0.475-0.575 0.580-0.680 0.690-0.830 0.505-0.750	80 m 80 m 80 m 80 m	6 bits (127 levels)
MSS	Landsat 1 to 5	1 2 3 4 5	0.5-0.6 0.6-0.7 0.7-0.8 0.8-1.1 10.4-12.6	79/82 m* 79/82 m* 79/82 m* 79/82 m* 240 m	6 bits (127 levels)

TM	Landsat 4 & 5	1 2 3 4 5 6 7	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75 2.08-2.35 10.4-12.5	30 m 30 m 30 m 30 m 30 m 30 m 120 m	8 bits (255 levels)
* The Spatial Resolution is 79 m for Landsat-1, 2 & 3. It is 82 m for Landsat 4 & 5.					

SPOT SATELLITE PROGRAMME

France, Sweden and Belgium joined together and pooled up their resources to develop the System Pourl' Observation dela Terre (SPOT), an earth observation satellite programme. First satellite of the series, SPOT-1 was launched from Kourou Launch Range in French Guiana on February 21,1986 aboard an Ariance Launch vehicle (AIV).

This is the first earth resource satellite system to include a linear array sensor employing push broom scanning technique. This enables side-to-side oft-nadir viewing capabilities and affords a full scene stereoscopic imaging from two different viewing points of the same area. The high resolution data obtained from the SPOT sensors, namely,Thematic Mapper (TM) and High Resolution Visible (HRV), have been extensively used for urban planning, urban growth assessment, transportation planning, besides the conventional applications related to natural resources.

Characteristics of SPOT Satellite and HRV Sensor Satellite

SPOT Satellite	
Orbit	Near-polar Sun-synchronous
Altitude	832 km
Inclination	98.7 Degrees

Equatorial Crossing Time	10.30 Hours
Repeat Cycle	26 Days
HRV Sensor	
Channel	**Waveband (Microns) Multispectral**
1	0.50-0.59
2	0.61-0.68
3	0.79-0.89
Panchromatic	
1	0.51-0.73
Spatial resolution	20-m (Multispectral) (at nadir) 10 m (panchromatic)
Radiometric resolution	8 bits (Multispectral) 6 bits (Panchromatic)
Swath Width	117 Km (60 km per HRV, 3 Km overlap)
Angular field of view	4.13 Degrees
Off-nadir viewing	± 27° in 45 steps of 0.6° (= ± Km from nadir)

INDIAN REMOTE SENSING SATELLITE (IRS)

The IRS mission envisages the planning and implementation of a satellite based remote sensing system for evaluating the natural resources. The principal components of the mission are: a three axis stabilized polar sun synchronous satellite with multispectral sensors, a ground based data reception, recording and processing systems for the multispectral data, ground systems for the in-orbit satellite control including the tracking network with the associated supporting systems and hardware and software elements for the generation of user oriented data products, the data analysis and archival.

The principal aim of the IRS mission is to use the satellite data in conjunction with supplementary/complementary information from other sources for survey and management of natural resources in important areas, like the agriculture,geology and hydrology in association with the user agencies. IR$ series of satellites are IRS lA, IRS IB, IRS IC, IRS ID and IRS P4 apart from other satellites which were launched by the Government of India. The orbital and sensor characteristics of IRS IA and IB are the same and IRS IC and IRS ID have almost similar characteristics.

IRSP4is an oceanographic satellite. IRS has application potential in a wide range of disciplines such as management of agricultural resources, inventory of forest resources, geological mapping, estimation of water resources, study of the coastal hydrodynamics and water quality surveying.

The sensor payload system consists of two push broom cameras (LiSS-II) of36.25 m resolution and one camera. (LlSS-I) of 72.5 m resolution employing linear Charge Coupled Device (CCD) arrays as detectors. Each camera system images in four spectral bands in the visible and near IR region. The camera system consists of collecting optics, imaging detectors, in flight calibration equipment and processing devices. The orbital characteristics of the IRS-1A, 1 B satellites and the sensor capabilities are given in Table below. As IRS-1 D satellite is the latest satellite of the series and hence the system overview of IRS - 1 D is provided.

The IRS-1 D is a three-axes body stabilized satellite, similar to IRS-1 C. Since IRS-1 C and 1 D are similar in orbital characteristics and sensor capabilities. It will have an operational life of three years in a near polar sun synchronous orbit at a mean altitude of 780 Km.The payload consists of three sensors, namely, Panchromatic camera (PAN), linear imaging and self-scanning sensor (LiSSIII) and the wide Field sensor (WiFs). The satellite is equipped with an On-Board Tape Recorder (OBTR) capable of recording a limited amount of specified sensor data. Operation of each of the sensors can be programmed.

The payload operation sequence for whole day can be loaded daily on to the on- board command memory when the satellite is within visibility range. The ground segment consists of a Telemetry Tracking and Command (TTC) segment comprising a TTC network and an Image segment comprising data acquisition, data processing and product generation system along with data dissemination centre.

The overview of IRS-1 D mission is to provide optimum satellite operation and a mission control centre for mission management, spacecraft operations and scheduling. The three sensors on board IRS-1 D and IRS-1 C are as described below.

The panchromatic camera provides data with a spatial resolution of 5.2-5.8 m(at nadir) and a ground swath between 63 Km -70 Km (at nadir). It operates in the0.50 - 0.75 microns spectral band. This camera can be steered up to ± 26 deg.storable up to ±398 Km across the track from nadir, which in turn increases the revisit capability to 3 days for most part of the cycle and 7 days in some extreme cases.

<table>
<tr><td colspan="3">Characteristics of Satellite</td></tr>
<tr><td>Orbit</td><td colspan="2">Near-polar, Sun-synchronous</td></tr>
<tr><td>Altitude</td><td colspan="2">904 Km</td></tr>
<tr><td>Inclination</td><td colspan="2">99.03 Degrees</td></tr>
<tr><td>Equatorial Crossing Time</td><td colspan="2">10.00 Hours</td></tr>
<tr><td>Repeat Cycle</td><td colspan="2">22 days</td></tr>
<tr><td>Eccentricity</td><td colspan="2">0.002</td></tr>
<tr><td>Period</td><td colspan="2">103 minutes</td></tr>
<tr><td colspan="3">Sensor Capabilities
Linear Image Scanning System : LISS</td></tr>
<tr><td>No. of LISS Cameras</td><td>LRC (One)*</td><td>MRC (two)**</td></tr>
<tr><td>No. of Spectral Bands</td><td>4</td><td>4</td></tr>
</table>

IFOV (Microrad)	80	40
Geometric Resolution	72.5	36.25
Swath Width	148 Km	74 Km
Radiometric Resolution	7 bits	7 bits
Band-to-Band	0.5	0.5
* Low Resolution Camera ** Medium Resolution Camera		

2

IMAGE ANALYSIS

Image analysis: Introduction, elements of visual interpretations, digital image processing- image preprocessing, image enhancement, image classification, supervised classification, unsupervised classification.

2.1 Image analysis: Introduction

Image analysis plays an important role in the scientific field due to its wide range of applications in the quantitative measurements. Visualization and image analysis methods are critical for understanding various features of the cell biology, molecular biology and neuroscience. With the development of fluorescent probes and application of high-resolution microscopes biological image processing techniques became more reliable with a profound impact on research in biological sciences.

One of the most important and frequently overlooked aspects of cell imaging is image quantification and analysis. In the past, microscopic techniques were applied to study the structural details, but recent advances in research, demands on determination of the number of cells, its area, perimeter, concentration, localization, densitometry analysis, etc.,. for molecular level studies.

Biologists are increasingly interested in using image analysis protocols to convert the microscopic images into more relatively quantitative measurements.

The difficulties in the visual interpretation such as counting of the cell and quantification of specific molecules of interest in research application, can be overcome by implementing automated methods in these fields. Computerized image analysis has a lot of applications over visual analysis, including reproducibility, rapidity, adaptability and the ability to simultaneously measure several features in the image. The goal of image analysis techniques is to combine results of the wet laboratory techniques with image analysis software, thereby providing more quantitative information.

A large number of the image analysis software packages have been developed for biological applications due to their usability in the biological sciences. These software packages help to extract useful information from the specimens (image) of interest. In fact, most of this software is expensive and often requires high performance computers to function. Throughout this lab, Image is referred as standard image analysis software, since it is freely available, platform independent and is applicable to the biological researchers to quantify the results obtained in the laboratory techniques.

Image processing is a method to convert an image into the digital form and perform some operations on it, in order to get an enhanced image or to extract some of the useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. Generally Image Processing system includes treating images as two dimensional signals while applying already set signal processing methods to them.

It is among rapidly growing technologies today, with its applications in various aspects of a business. The image Processing forms core research area within engineering and computer science disciplines too.

Image processing generally includes the following three steps.

• Importing the image with optical scanner or by digital photography.

• Analyzing and manipulating image which includes data compression and image enhancement and spotting patterns which are not to human eyes like satellite photographs.

• Output is the last stage in which result can be altered image or report that is based on the image analysis.

Purpose of Image processing

The purpose of image processing is divided into 5 groups. They are:

1. Measurement of pattern – Measures various objects in an image.

2. Image sharpening and restoration - To create a better image.

3. Image Recognition – Distinguish the objects in an image.

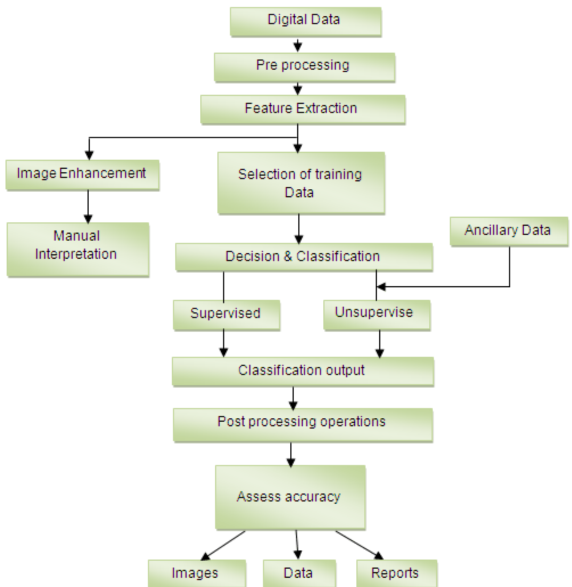
4. Image retrieval - Seek for the image of interest.

5. Visualization - Observe the objects that are not visible.

Types

The two types of methods used for Image Processing are Analog and Digital Image Processing. Analog or visual techniques of image processing can be used for the hard copies like printouts and photographs. Image analysts use various fundamentals of interpretation while using these visual techniques. Image processing is not just confined to area that has to be studied but on knowledge of analyst. Association is another important tool in image processing through visual techniques. So analysts apply a combination of personal knowledge and collateral data to image processing.

Digital Processing techniques help in manipulation of digital images by using computers. As raw data from imaging sensors from satellite platform contains deficiencies. To get over such flaws and to get originality of information, it has to undergo various phases of processing. The three general phases that all types of data have to undergo while using digital technique are Pre- processing, enhancement and display, information extraction.



2.1.1 Elements of visual interpretations

Visual interpretation of satellite imagery is essentially a three-step process of detection, categorization and identification.

Detection

Detection is the process of spotting objects, irrespective of whether they are recognizable or not. Detection makes it possible to separate an object (entity) from its background (surroundings). Detection depends mainly on visual sensation rather than on cognizant factors. The simplest case of detection is the contrast detection between an object's contour and the surroundings. This kind of detection might be named "boundary detection."

It plays an important role in image analysis and will lead to the possibilities of delineation of homogeneous or quasi-homogeneous zones which, when correctly selected, correspond to the object to be mapped and identified.

Categorization

Categorization is the act of sorting by designating the set membership of elements of a population. Categorization is possible if the image elements have distinctive and detectable properties that allow determination of their set membership. Categorization of subsets of the image can be done on a descriptive basis, listing characteristic features in terms of tone, texture, pattern, shape, orientation, association and others of each category.

Thus, if subsets of the image consist of "structured fields", each having distinctive characteristics, then it will be possible to partition the data space into mutually exclusive subspaces and to label each subspace according to the category it belongs to. At this stage, a map can be produced showing the spatial distribution of the different categories. In this map each category represents a unit to be identified. A categorized image contains a number of discrete and non-overlapping units delineated and labeled according to their set membership, but not identified yet.

Identification

Identification is assigning proper names to the categories, essentially, identification is an act of recognition. Basically there are three, modes of operation in the identification process, viz., spontaneous recognition, logical inference and ground-truth acquisition. In spontaneous recognition the interpreter resorts to his memory trained by experience and he recognizes the objects as he "sees" them. If spontaneous recognition fails, the interpreter may be able to make a decision on the basis of logical inference; by inductive and deductive reasoning he may come to a logically sound decision about the object's identity.

The third method of identification, here loosely referred to as "ground truth", actually embraces more than field- checking alone, since it includes also the use of all other external information, such as are obtainable from existing maps, reports and other sources. In practice each interpretation is carried out in such a way that all three identification methods are applied in combination and emphasis is shifted from one method to the other depending upon the interpreter's ability, the nature of problems involved, type and amount of available external information and terrain accessibility.

Satellite images may be interpreted in much the same manner as small-scale aerial photographs and images acquired by aircraft and manned satellites. The terminology employed by most of the concerned disciplines is adequate for describing features on satellite images. However, there are certain advantages of satellite images e.g. in interpretation of lineaments or circular features and that should be emphasized.

Lineament

Lineament is defined as a mappable simple or composite linear feature of a surface, whose parts are aligned in a straight or slightly curving relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon.The surface features making up a lineament may be geomorphic (caused by relief) or tonal (caused by contrast differences).

The surface features may be landforms, the linear boundaries between different types of terrain or breaks within a uniform terrain. Straight stream valleys and aligned segments of valleys are typical geomorphic expressions of lineaments. Tonal lineament may be a straight boundary between areas of contrasting tones.

Lineaments may be continuous or discontinuous. In discontinuous lineaments the separate features are aligned in a consistent direction and are relatively closely spaced. Lineaments may be simple or composite. Simple lineaments are formed by a single type of feature, such as a linear stream valley or aligned topographic escarpment. Composite lineaments are defined by more than one type of feature, such as an alignment of linear tonal features, stream segments and ridges.

Although many lineaments are controlled at least in part by faults, however, structural displacement (faulting) is not a requirement in the definition of a lineament. Linear features newly discovered on images may initially be called lineaments. If field checking establishes the presence of structural offset, they can then be designated as faults. No minimum length is proposed here as a requirement for lineaments, but significant crustal features are typically measured in tens of kilometers. An arbitrary categorization of lineaments may be made on the basis of their extent into: Lineament, up to 100 km, Mega Lineament, between 100 to 3(X) km and Super Lineament for those extending more than 300 km.

Lineaments also may be recognized on topographic, gravity, magnetic and seismic contour maps by aligned highs and lows, steep contour gradients and aligned offset trends. Lineaments are well expressed on satellite images because of the oblique illumination, suppression of distracting spatial details and the regional coverage.

The lineaments may be plotted on a radial diagram to obtain the major direction of faults and fractures. Studies have shown that a close coincidence exists of between the pattern of previously mapped faults/fractures and lineaments deciphered from satellite imagery of the same area. The intersection of lineaments and their densities can also be plotted and density contours drawn. It has been observed that high-density lineament intersection show preferred orientation which are useful in locating groundwater and mineralization zones.

Circular Feature

Rowan and Wetlaufer (1975) recognized 50 circular and elliptical features on the Landsat mosaic of Nevada that is presumed to be centers of igneous activity. Similar circular/oval features in a basement gneissic complex have been observed and have been correlated with mantle domes. Attempts have been made to correlate the circular features with aeromagnetic maps and it was noticed that the features coincide with the aeromagnetic anomalies, denoting probably the surface expressions of centers of igneous activity, emplacement of granitic bosses or diapiric intrusions at deeper levels. Occurrence of circular features in parts of Thar desert of Rajasthan, India was studied by Bakliwal and Ramasamy (1985).

2.1.2 Digital image processing- image preprocessing

Elements of digital image processing

Interpretation and analysis of remote sensing data involves the identification and measurement of various targets in an image in order to extract useful information about them. There are two main methods can be use to interpret and extract information of interpretation from images:

Visual interpretation of images, which is based on feature tone (color), pattern, shape, texture, shadow and association. The identification of targets performed by a human interpreter digital processing and analysis may be performed using a computer (without manual intervention by a human interpreter). This method can be used to enhance data, to correct or restore the image, to automatically identify targets and extract information and to delineate different areas in an image into thematic classes.

In many case digital processing and analysis is carried out as a complete replacement for manual interpretation. Often, it is done to supplement and assist the human analyst. Applying a mix of both methods we can use manual and digital techniques advantages.

Digital processing and analysis

The most common image processing functions can be placed into the following four categories:

1. Preprocessing

2. Image Enhancement

3. Image Transformation

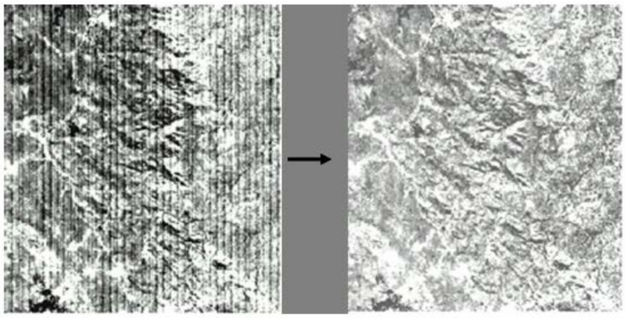
4. Image Classification and Analysis

Preprocessing

Preprocessing functions involve those operations that are normally required prior to the main data analysis and extraction of information and are generally grouped as radiometric or geometric corrections. Some standard correction procedures may be carried out in the ground station before the data is delivered to the user. These procedures include the radiometric correction to correct for uneven sensor response over the whole image and the geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions.

Radiometric corrections

Radiometric correction is a preprocessing method to reconstruct physically calibrated values by correcting spectral errors and distortions caused by sensors, sun angle, topography and the atmosphere. Figure below shows a typical systems errors which result in missing or defective data along a scan line. Dropped lines are normally corrected by replacing line with the pixel values in the line above or below or with the average of the two.



De-striping: Correction of line dropout.

Geometric corrections

Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations and conversion of the data to real world coordinates on the Earth's surface. The systematic or predictable distortions can be corrected by accurate modeling of the sensor and platform motion and the geometric relationship of the platform with the Earth. Hence, to correct other unsystematic or random errors we have to perform geometric registration of the imagery to a known ground coordinate system.

Geometric registration process can be made in two steps:

Identifying the image coordinates of several clearly discernible points, called ground control points, in the distorted image and then matching them to their true positions in ground coordinates. Polynomial equations are used to convert source coordinates to rectified coordinates, using 1st and 2nd order transformation. The coefficients of the polynomial are calculated by least square regression method, that will help in relating any point in the map to its corresponding point in image.

Resampling: this process is used to determine the digital values to place in the new pixel locations of corrected output image. There are three common methods for resampling: nearest neighbour, bilinear interpolation and cubic convolution.

2.2 Image enhancement

Image enhancement techniques improve the quality of an image as perceived by a human. The techniques are most useful because many satellite images when examined on a colour display gives an inadequate information for image interpretation. There is no conscious effort to improve the fidelity of image with regard to some ideal form of the image. There exists a wide variety of techniques for improving image quality. Contrast stretch, density slicing, edge enhancement and spatial filtering are the more commonly used techniques. The image enhancement is attempted after the image is corrected for geometric and radiometric distortions. The image enhancement methods are applied separately to each band of a multispectral image. Digital techniques have been found to be most satisfactory than the photographic technique for image enhancement, because of the precision and the wide variety of digital processes.

Contrast

Contrast generally refers to the difference in luminance or grey level values in an image and is an important characteristic. It can be defined as the ratio of the maximum intensity to minimum intensity over an image.

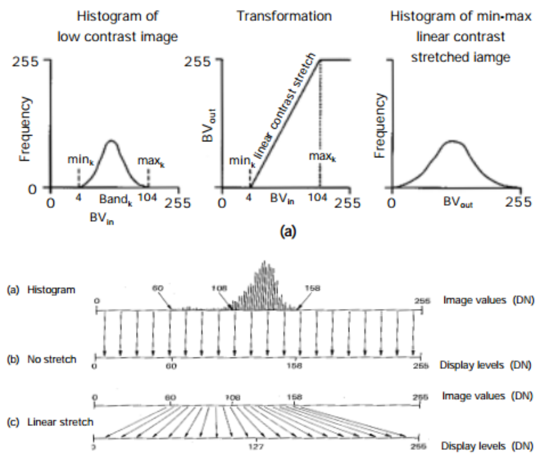
Contrast ratio has a strong bearing on the resolving power and detectability of an image. Larger this ratio, it is more easy to interpret the image. Satellite images lack adequate contrast and require contrast improvement.

Contrast Enhancement

The contrast enhancement techniques expand the range of brightness values in an image so that the image can be efficiently displayed in a manner desired by the analyst. The density values in a scene are literally pulled farther apart, that is, expanded over a greater range. The effect is to increase the visual contrast between the two areas of different uniform densities. This enables the analyst to discriminate easily between areas initially having a small difference in density.

Linear Contrast Stretch

This is the simplest contrast stretch algorithm. The grey values in the original image and modified image follow a linear relation in this algorithm. A density number in the low range of the original histogram is assigned to extremely black and a value at the high end is assigned to extremely white. The remaining pixel values are distributed linearly between these extremes. The features or details that were obscure on the original image will be clear in contrast stretched image. Linear contrast stretch operation can be represented graphically as shown in figure below. To provide optimal contrast and colour variation in colour composites the small range of grey values in each band is stretched to the full brightness range of the output or display unit.



Linear Contrast Stretch

Non-Linear Contrast Enhancement

In these methods, the input and output data values follow a non-linear transformation. General form of the non-linear contrast enhancement is defined by y = f (x), where x is the input data value and y is the output data value. The non-linear contrast enhancement techniques have been found to be useful for enhancing colour contrast between the nearly classes and subclasses of a main class.

A type of non linear contrast stretch involves scaling the input data logarithmically. This enhancement has greatest impact on the brightness values found in the darker part of histogram. It could be reversed to enhance values in brighter part of histogram by scaling input data using an inverse log function.

Histogram equalization is another non-linear contrast enhancement technique. In this technique, histogram of the original image is redistributed to produce a uniform population density. This is obtained by grouping certain adjacent grey values. Thus the number of grey levels in the enhanced image is less than number of grey levels in the original image.

2.3 Image classification

Digital image classification techniques group pixels to represent land cover features. Land cover could be forested, urban, agricultural and the other types of features. There are three main image classification techniques.

Image Classification Techniques in Remote Sensing:

• Unsupervised image classification

• Supervised image classification

• Object-based image analysis

Pixels are smallest unit represented in an image. Image classification uses the reflectance statistics for individual pixels. Unsupervised and supervised image classification techniques are the two most common approaches. However, object-based classification has been breaking more ground as of late.

General procedures in the image classification

Classification is the most popularly used information extraction techniques in digital remote sensing. In the image space I, a classification unit is defined as the image segment on which a classification decision is based. A classification unit can be a pixel, a group of neighbouring pixels or the whole image. Conventional multispectral classification techniques perform the class assignments based only on the spectral signatures of a classification unit. Contextual classification refers to use of spatial, temporal and other related information, in addition to the spectral information of a classification unit in classification of an image. Usually, it is the pixel that is used as the classification unit.

The general image classification procedures include (Gong and Howarth 1990b):

(1) Design image classification scheme: they are generally information classes such as urban, agriculture, forest areas, etc. Conduct field studies and collect the ground information and other ancillary data of the study area.

(2) Preprocessing of the image, including radiometric, atmospheric, geometric and the topographic corrections, image enhancement and initial image clustering.

(3) Select representative areas on the image and analyze initial clustering results or generate training signatures.

(4) Image classification

Supervised mode: Using the training signature

Unsupervised mode: Image clustering and cluster grouping

(5) Post-processing: Complete the geometric correction & filtering and classification decorating.

(6) Accuracy assessment: Compare classification results with field studies.

The following diagram shows the major steps in two types of image classification:

Supervised

Image → Supervised Training → Pixel Labelling → Accuracy Assessment

Unsupervised

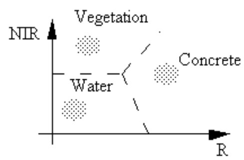
Image → Clustering & Cluster Analysis → Clustering & Cluster Grouping → Accuracy Assessment

In order to describe the differences between the supervised and unsupervised classification, we will introduce two concepts: information class and spectral class:

Information class: a class specified by an image analyst. It refers to information to be extracted.

Spectral class: a class which includes similar grey-level vectors in the multispectral space.

In an ideal information extraction task, we can directly associate a spectral class in the multispectral space with an information class. Example, we have in a two dimensional space three classes: water, vegetation and concrete surface.



By defining boundaries among the three groups of grey-level vectors in the two-dimensional space, we can separate the three classes.

One of the differences between a supervised classification and an unsupervised one is ways of associating each spectral class to an information class. For supervised classification, we first start with specifying an information class on image. An algorithm is then used to summarize multispectral information from the specified areas on image to form class signatures. This process is called supervised training. For the unsupervised case,however, an algorithm is first applied to the image and some spectral classes (also called clusters) are formed. Image analyst then try to assign a spectral class to the desirable information class.

2.3.1 Supervised classification

User selects representative samples for each land cover class in the digital image. These sample land cover classes are called "training sites". The image classification software uses the training sites to identify the land cover classes in the entire image.

The classification of land cover is based on the spectral signature defined in the training set. Digital image classification software determines each class on what it resembles most in the training set.

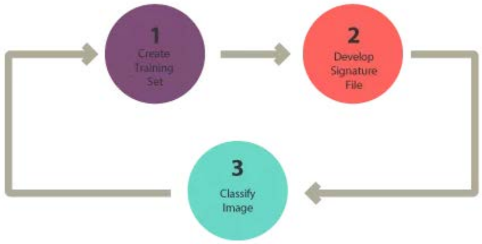
The common supervised classification algorithms are maximum likelihood and minimum-distance classification.

Supervised Classification Steps:

• Select the training areas

• Generate signature file

• Classify



Supervised Classification Diagram

2.3.2 Unsupervised classification

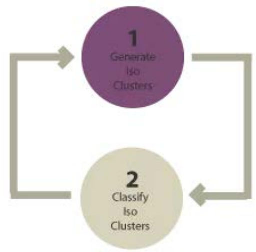
Pixels are grouped based on the reflectance properties of pixels. These groupings are known as “clusters”. The user identifies the number of clusters to generate and which bands to use. With this information, image classification software generates clusters. There are different image clustering algorithms such as K-means and ISODATA.

The user manually identifies each cluster with land cover classes. It’s often the case that multiple clusters represent a single land cover class. User merges clusters into a land cover type. The unsupervised classification image classification technique is commonly used when there is no sample sites.

Unsupervised Classification Steps:

• Generate clusters

• Assign classes



Unsupervised Classification Diagram

3

GEOGRAPHIC INFORMATION SYSTEM,DATA ENTRY AND PREPARATION

Geographic Information System: Introduction, key components, application areas of GIS, map projections.

Data entry and preparation: spatial data input, raster data models, vector data models.

3.1 Geographic Information System: Introduction

Geographic information (i.e.., land information, spatial information) is information which can be associated with a place name, a street address, section/township, a zip code or coordinates of latitude and longitude.
A multitude of the government functions require geographic information; at least 70 percent of all information used by the local governments is geographically referenced. For example, property records and assessment, planning and zoning, natural resource management, permit tracking, infrastructure and transportation management, economic development planning and health and the public safety.
All of these applications consider the location of certain features on the landscape in relation to the other features. For instance, in assessment, the location of soil types relative to property parcels is considered, whereas in planning and zoning, the location of animal confinement facilities relative to residential areas may be relevant. A geographic information system (GIS) allows the user to examine and visualize these relationships.

A "geographic information system" (GIS) is a computer-based tool that allows us to create, manipulate, analyze, store and display the information based on its location. GIS makes it possible to integrate different kinds of geographic information, like the aerial photographs, digital maps, satellite images and global positioning system data (GPS), along with associated tabular database information (example, 'attributes' or characteristics about geographic features).
Using GIS, we can incorporate all of this information into a single system and execute common database operations. For example, GIS allows us to perform statistical analysis or spatial queries, to explore 'what-if' scenarios and to create predictive models.

A geographic information system (GIS) is a computer system for capturing, storing, checking and displaying data related to positions on Earth's surface. GIS could show many different kinds of data on one map. This enables people to more easily see, analyze and understand patterns and relationships.

With GIS technology, people could compare locations of different things in order to find how they relate to each other. For example, using GIS, the same map could include sites that produce pollution, such as gas stations and sites that are sensitive to pollution, like wetlands. Such a map would help people decide which wetlands are most at risk.

GIS can use any information that includes location. The location can be expressed in many different ways, such as latitude and longitude, address or ZIP code. Many different types of information can be compared and contrasted using GIS. The system could include data about people, such as population, income or education level. It can include information about the land, like the location of streams, different kinds of vegetation and the different kinds of soil. It can include information about the sites of factories, farms and schools or storm drains, roads and electric power lines.

Data and GIS

Data in several different forms can be entered into GIS. Data which are already in map form can be included in GIS. This includes such information as the location of rivers and roads, hills and valleys. Digital or computerized, data can also be entered into the GIS. An example of this kind of information is data collected by satellites that show land use—the location of farms, towns or forests. GIS can also include data in table form, such as population information. GIS technology allows all these different types of information, no matter their source or the original format, to be overlaid on top of one another on a single map.

Putting the information into GIS is called data capture. Data that are already in digital form, such as images taken by satellites and most tables, can simply be uploaded into GIS. Maps must be scanned or converted into the digital information.

GIS must make the information from all different maps and sources align, so they fit together. One reason this is necessary is because maps have different scales. A scale is the relationship between the distance on a map and the actual distance on Earth. GIS combines information from different sources in such a way that it all has same scale.

Often, GIS must also manipulate the data because different maps have different projections. A projection is the method of transferring information from Earth's curved surface to a flat piece of paper or the computer screen. No projection can copy the reality of Earth's curved surface perfectly. Different types of projections accomplish this task in different ways, but all result in some distortion. To transfer a curved, three-dimensional shape onto a flat surface inevitably needs stretching some parts and squeezing other parts. A world map can show either correct sizes of countries or their correct shapes, but it can't do both. GIS takes data from maps that were made using different projections and combines them so all the information can be displayed using one common projection.

GIS Maps

Once all the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. For instance, using GIS technology, many kinds of information can be shown about a single city. Maps can be produced that relate such information as average income, book sales and voting patterns. Any GIS data layer can be added or subtracted to the same map.

GIS maps can be used to show information about the number and density. For example, GIS can be used to show how many doctors there are in different areas compared with the population. They can also show what is near what, such as which homes and businesses are in areas prone to flooding.

With GIS technology, researchers can also look at change over time. They can use satellite data to study topics like how much of the polar regions is covered in ice. A police department can study changes in crime data to help determine where to assign officers.

GIS often contains a large variety of data that do not appear in an onscreen or printed map. GIS technology sometimes allows users to access this information. A person can point to a spot on computerized map to find the other information stored in the GIS about that location. For example, a user might click on a school to find the number of students enrolled, how many students there are per teacher or what sports facilities the school has.

GIS systems are often used to produce the three-dimensional images. This is useful, for example, to geologists studying faults.

The GIS technology makes updating maps much easier. Updated data can simply be added to the existing GIS program. A new map could then be printed or displayed on screen. This skips the traditional process of drawing a map, which can be time-consuming and expensive.

People working in many different fields use GIS technology. Many businesses use GIS to help them decide where to locate a new store. Biologists use GIS to track animal migration patterns. City officials use GIS to help plan their response in the case of a natural disaster such as an earthquake or hurricane. The GIS maps could show these officials what neighborhoods are most in danger, where to locate shelters and what routes people should take to reach safety. Scientists use GIS to compare population growth to resources such as drinking water or to try to decide a region’s future needs for public services like parking, roads and electricity. There is no limit to the kind of information that can be analyzed using GIS technology.

Components of GIS

The next step in understanding GIS is to look at each area and how they work together. These components are:

- Hardware
- Software
- Data
- People

Hardware

The hardware comprises the equipment needed to support the many activities needed for geospatial analysis ranging from data collection to data analysis. The central piece of equipment is the workstation, which runs the GIS software and is attachment point for ancillary equipment. Data collection efforts can also require the use of a digitizer for conversion of hard copy data to digital data and a GPS data logger to collect data in the field. The use of handheld field technology is also becoming an important data collection tool in GIS. With the advent of web mapping, web servers have also become an important piece of the equipment.

Software

Different types of software are important. Central to this is GIS application package. Such software is essential for creating, editing and analyzing spatial and attribute data, therefore these packages contain a myriad of geospatial functions inherent to them. Extensions or add-ons are software which extends the capabilities of the GIS software package. Component GIS software is the opposite of application software. Component GIS seeks to build software applications that meet a specific purpose and thus are limited in their spatial analysis capabilities. Utilities are stand-alone programs that perform a specific function. For example, a file format utility which converts from on type of GIS file to another. There is also web GIS software that helps serve data and interactive maps through Internet browsers.

Data

Data is the core of any GIS. There are two primary types of data that are used in GIS: vector and raster data. A geo database is a database that is in some way referenced to locations on the earth. The geo databases are grouped into two different types: vector and raster. Vector data is spatial data represented as points, lines and polygons. Raster data is cell-based data such as aerial imagery and digital elevation models. Coupled with this data is generally data known as attribute data. Attribute data usually defined as additional information about each spatial feature housed in the tabular format. Documentation of GIS datasets is known as metadata. The Metadata contains such information as the coordinate system, when the data was created, when it was last updated, who created it and how to contact them and the definitions for any of the code attribute data.

People

The well-trained GIS professionals knowledgeable in spatial analysis and skilled in using GIS software are essential to the GIS process. There are three factors to the people component: education, career path and networking. The right education is key; taking the right combination of classes. Selecting right type of GIS job is important. A person highly skilled in GIS analysis should not seek a job as a GIS developer if they haven’t taken the necessary programming classes. Finally, continuous networking with the other GIS professionals is essential for the exchange of ideas as well as a support community.

Uses of GIS

There are numerous ways in which this technology can be used. The most common ones are:

1. Planning of locations and management of assets
2. Management of resources
3. An Impact assessment of the environment
4. Archaeological uses
5. Investigations of the earth's surface that is scientific in nature
6. Analysis with regards to engineering
7. Urban & regional planning
8. Studies of the demographics of an area plus its population
9. Criminology matters
10. The assessment and eventual development of infrastructure

Some of the common instances where we will find the GIS in use include:

1. Emergency response teams normally use GIS when they want to collect logistics with regards to how they will move in times of natural disasters.

2. System also comes in handy when authorities want to discover any potential wetlands that need to be protected from harmful effects brought about by pollution.

3. Companies also take advantage of the GIS so that they may be able to choose a strategic market location that has not yet been saturated by other competitors in the particular niche industry.

4. Management personnel use this system also so that they can be able to locate areas that are bound to suffer from catastrophes with regards to the infrastructure that is in place there.

5. Any potential spread of diseases and other such like pandemic are usually limited by the use of the GIS since the patterns of their occurrence is predicted in sufficient time.

3.1.1 Key components

1. Management support, leadership and vision

2. Data conversion and maintenance

3. Hardware and software

4. User training

5. Data communications

6. Software customization

7. User support

8. Funding

Thriving GIS programs have adequate resources in all of these areas. Ineffective, faltering or disappointing GIS programs are lacking in one or more of these key areas. One GIS has great hardware and software and great people managing it, but is restricted to one project or department, rather than serving the entire organization, because top management does not support it. In another organization, top management is really enthusiastic about GIS, but the program never achieves its potential because of turnover among the GIS staff. Yet another GIS program has all the right tools, personnel and management support, but lacks the funds to move ahead. GIS programs succeed to varying degrees depending on their effectiveness in each of these areas.

Management Support, Leadership and Vision

Establishing and maintaining a GIS requires a significant expenditure of time and money. Therefore, it most often needs approval by the top decision makers in an organization. Although this is true of many other capital improvement programs, a GIS is different in that the top-level decision makers are usually not familiar with GIS technology. Some may understand the basics of computer technology, but few are familiar with mapping concepts in general and computer mapping in particular.

In many cases, the initial support and enthusiasm for a GIS develops among mid-level managers, technicians and professionals who hear about it from peers in other organizations, read about it in trade publications or learn about it at industry conferences. They must then interest top management. If top management is not fully convinced of the justification for a GIS, they might grant only tentative or partial approval of the program.

This poses a real danger. Without management's total sup-port and full commitment to a GIS, sometimes, for example, only portions of land records are automated or only portions of the GIS are implemented. This generally means that the system will not reach its full potential. Moreover, if the project runs into technical problems or cost overruns, top-management support is critical to keep it afloat. Obtaining top management's full support may delay the start of a GIS project, but in view of the benefits that could result as the GIS project proceeds, it is well worth the effort and the delay.

A GIS program also needs a clear vision of objectives. This vision may serve as the foundation of the system's implementation plan. Some GIS programs are too ambitious, trying to do too much too fast. Others have a scope that falls short of the technology's potential, often creating a "stovepipe" operation that only serves one department's needs and neglects those of other departments. Likewise, good leader-ship is needed to keep the vision in full view of the GIS team, offer encouragement organize and manage the GIS operation, make course corrections and answer to top management.

Hardware and Software

Computer hardware and software are the tools employees will use to input, analyze, manipulate and present GIS data Obviously, the choice of tools will have a major impact on the success of the GIS program. The principal consideration is selecting tools that will best satisfy the needs of the organization and its users, which is not always the most advanced or most popular system.

User Training

GIS introduces a great number of employees to a very different way of doing work. Typically, they have little exposure to computer systems in general and none to GIS in particular. Most employees sincerely want to do well in their work. However, to do well in their jobs, they need to feel confident about what they are doing and they need to have the knowledge and skills necessary. Trying to work with a new technologies such as GIS can destroy employee confidence and morale. This can only be overcome through a comprehensive, planned training program.

Initial training following system installation can almost always be purchased from the vendor or from a local authorized training center. Subsequent training can also be purchased, but many organizations set up in-house training programs run by employees with previous experience. The important point here is that some ongoing program is needed to train new users. They will replace employees lost through attrition and all users will need to learn to operate new equipment added as system usage expands and needs change.

The training program should recognize that the learning curve to full proficiency is three to six months. Moreover, the training program should make a realistic assess-ment of employee turnover. In fact, it should assume that turnover will be greater among GIS users because their new skills will be in grater demand than their previous ones. A basic GIS user training program will usually require about 40 hours of the employee's time. This may be spread over a number of sessions.

For instance, the employee could participate in two half-day training sessions per week over a five-week period. System managers may require one to two weeks of additional training to learn system management, network management, user account management and more advanced GIS and database functions the avenge user will not need.

Data Communications

Few organizations that use a GIS will confine its use to one department. Most often there are numerous departments that need access to the database. Distributing the GIS data is the key to making this data available to them. A data communications network is the most commonly used vehicle for GIS data distribution, so the timing of the GIS implementation plan is often tied to the installation of the network.

A local area network (LAN) is used most often, but there are other options for distributing GIS data. Some organizations distribute vector GIS files over the network, but use CD-ROM disks to distribute more voluminous types of raster data, such as aerial photography and satellite imagery. Whereas vector data may be updated on a daily basis, raster data sets rarely change, often only once a year or so. GIS data can also be transmitted by modem over a telephone line, but because the data files are relatively large, this process can be too slow to be practical.

The Internet is also used to distribute GIS data. This is most often done to make the information available to the public. Obviously there will be security considerations and some data may not be made available to Internet users. In some cases, access to certain types of data can be password-protected so that only authorized users can have access to it. A related technique is use of an intranet, which basically refers to the idea of accessing data using a web browser over an organization's internal LAN.

Software Customization

GIS vendors normally design their software to meet the needs of the largest possible number of users. They incorporate general capabilities suitable for many types of applications. For this reason, a GIS package will not provide optimal use of the technology unless it is customized for a particular user's needs.

The best way to get maximum use of a GIS is to customize the software. The GIS vendor typically offers a macro command language. This enables a user to string several commonly repeated operations together under one command. The vendor also usually offers a means of customizing the user interface; namely, the tablet menus and screen menus that provide access to the GIS commands. These two features can save a tremendous amount of time. This software development work is usually done by a GIS programmer.

It is important to find a programmer familiar with both the GIS programming language and the application. It is also important to encourage good communication between the programmer and users. This will ensure that the programming meets their needs.

User Support

GIS is a complex technology, making it relatively difficult to implement and man-age. One way to greatly increase the chances of a successful GIS implementation is to involve an experienced GIS manager and/or system support technician. Even if an experienced person is not hired into the organization, it is possible to obtain this experience from a contractor. This may be the GIS vendor or a qualified consultant. The length of the support contract may vary, but two months would seem to be a reasonable minimum.

In situations in which an organization is unable to ensure that an experienced employee will always be available, GIS support can be contracted for on a long-term basis. Although GIS vendors invariably offer extensive telephone support, having experienced help on site is far more effective. Personal experience suggests that, without exception, the most successful GIS programs either hired an experienced GIS manager or system engineer or obtained this support through a longterm contract.

Funding

A complete GIS program for a municipality, utility or military installation can cost hundreds of thousands to millions of dollars to implement and tens to hundreds of thousands to maintain each year. Obviously, adequate funding for the program is vitally important. Although there are many factors that affect the availability of funding, the lack of financial justification need not be one of them.

We once helped a very large suburban water and sewer utility develop a financial analysis for their proposed GIS program. We showed that the GIS would produce substantial cost savings. This analysis was reviewed by internal financial officers. A phased implementation program was presented to the utility commission, which approved it.

During the following year's budget process, every information technology (IT) bud-get was cut back except that of the GIS program. In fact, when the utility commission remembered the cost savings that had been documented and convincingly supported and after receiving assurance that the program was proceeding according to plan, they decided to increase its budget above the requested amount. 'Me sooner we implement this system, the sooner these savings will begin: was the essence of their reasoning. Needless to say, the GIS program manager was pleasantly surprised.

3.2 Application areas of GIS

Local Government

- Public works/infrastructure management (roads, water, sewer)
- Planning and environmental management
- **P**roperty records and appraisal

Real Estate and Marketing

- Retail site selection, site evaluation

Public safety and defense

- Crime analysis, fire prevention, emergency management, military/defense

Natural resource exploration/extraction

- Petroleum, minerals, quarrying

Transportation

- The airline route planning, transportation planning/modeling

Health Management (Health Systems, Health Centers, Management Beds)

Public health and epidemiology

The Geo-spatial Industry

- Data development, application development, programming

Urban Planning, Management & Policy

- Zoning, subdivision planning
- Land acquisition
- Economic development
- Code enforcement
- Housing renovation programs

- Emergency response
- Crime analysis
- Tax assessment

Environmental Sciences

- Monitoring environmental risk
- Modeling storm water runoff
- Environmental Impact Analysis
- Management of watersheds, floodplains, wetlands, forests, aquifers
- Groundwater modeling and contamination tracking
- Hazardous or toxic facility siting

Health Care

- Epidemiology
- Service Inventory
- Needs Analysis

Political Science

- Redistricting
- Analysis of election results
- Predictive modeling

Civil Engineering/Utility

- Designing alignment for the freeways, transit
- Coordination of infrastructure maintenance
- Locating underground facilities

Business

- Market Penetration/ Share Analysis

- Demographic Analysis
- Site Selection

Real Estate

- Neighborhood land prices
- Determination of Highest and Best Use
- Traffic Impact Analysis

Education Administration

- Enrollment Projections
- Attendance Area Maintenance
- School Bus Routing

GIS IN EDUCATION

- Meteorology
- Geography
- Law Enforcement
- Oceanography
- Public Health
- Sociology
- Geology
- History
- Urban/Regional Planning

AGRICULTURE

- Yield prediction
- Farm management
- Crop monitoring

• Pest/Disease tracking

• Soil analysis

PLANNING AND ECONOMIC DEVELOPMENT

• Market Analysis

• Property Tax Assessment

• Land Use/Zoning

• Population Forecast

• Emergency Preparedness

• Transportation

NATURAL RESOURCE MANAGEMENT

• Forestry

• Mining

• Ecology

• Petroleum

• Water Resources

Geographic Information Technologies

Global Positioning Systems (GPS)

A system of earth-orbiting satellites which can provide precise (100 meter to sub-cm.) location on the earth’s surface (in lat/long coordinates or equiv.)

Remote Sensing (RS)

Use of satellites or aircraft to capture information about earth’s surface

Digital ortho images a key product (map accurate digital photos)

Geographic Information Systems (GIS)

The software systems with capability for input, storage, manipulation/analysis and output/display of geographic (spatial) information

GPS and RS are sources of input data for a GIS

A GIS provides for storing and manipulating GPS and the RS data.

How Does GIS Provide Benefit?

• GIS improves efficiency

• GIS improves decisions by providing needed tools and data

• GIS identifies opportunities

BENEFITS OF GIS

• Better management of resources

• Adding new value-added services

• Ability for complex analysis

• Multiple scenario in planning can be performed easily

• Perform analysis on spatial and non spatial components

• Improves/enhances the effects of physical/environmental growth

• Display of information in a different light/view

• Fast recall of data

• Recalling of non spatial data through object location

3.2.1 Map projections

A map projection is a system in which the locations on the curved surface of the earth are displayed on a flat sheet or surface according to some set of rules. Mathematically, the projection is a process of transforming the global location (j,l) to a planar position (x,y) or (r,q)

Example:

The transformations for Mercator projection are:

x = l

y = loge tan(p/4 + j/2)

Relevance to GIS

Maps are the common source of input data for a GIS. It is often that the input maps will be in different projections, requiring transformation of one or all maps to make coordinates compatible. Therefore, the mathematical functions of projections are needed in a GIS. Often, GIS are used for projects of global or regional scales so consideration of the effect of the earth's curvature is necessary. Monitor screens are analogous to a flat sheet of paper. Hence, it is a need to provide the transformations from the curved surface to the plane for displaying data.

Distortion Properties

Angles, directions, areas, shapes and distances become distorted when it is transformed from a curved surface to a plane. All these properties cannot be kept undistorted in a single projection. Usually the distortion in one property will be kept to a minimum while other properties become very distorted.

Tissot's Indicatrix

Tissot's Indicatrix is a convenient way of showing the distortion. Imagine a tiny circle drawn on the surface of the globe. On the distorted map, circle will become an ellipse, squashed or stretched by the projection. The size and the shape of the Indicatrix will vary from one part of the map to another. We can use the Indicatrix to display the distorting effects of projections.

Conformal

A projection is conformal **(Orthomorphic)** if the angles in the original features are preserved. Over small areas, the shapes of objects will be preserved. The preservation of shape does not hold with large regions. A line drawn with constant orientation will be straight on a conformal projection, is termed as a rhumb line or loxodrome. The parallels and meridians cross each other at right angles. Tissot Indicatrix is a circle everywhere, but its size varies. The conformal projections cannot have equal area properties, so some areas are enlarged. Usually, areas near margins have a larger scale than areas near the center.

Equal area (Equivalent)

The representation of areas is preserved so that all regions on the projection will be represented in correct relative size. The equal area maps cannot be conformal, so most earth angles are deformed and shapes are strongly distorted. Indicatrix has the same area everywhere, but is always elliptical, never a circle.

Equidistant

It cannot make a single projection over which all distances are maintained. Thus, equidistant projections maintain relative distances from one or two points only. i.e., in a conic projection, all the distances from the center are represented at the same scale.

Figure Of The Earth

Figure of the earth is a geometrical model used to generate the projections. A compromise between the desire for mathematical simplicity and the need for accurate approximation of the earth's shape.

Types:

1. Plane

Assume that the earth is flat (use no projection). It is used for maps only intended to depict general relationships or for maps of small areas. At scales larger than 1:10,000 planar representation has little effect on accuracy. The planar projections are usually assumed when working with air photos.

2. Sphere

Assume that the earth is perfectly spherical. It does not truly represent the earth's shape.

3. Spheroid or ellipsoid of rotation

The spheroid models the fact that the earth's diameter at the equator is greater than the distance between poles, by about 0.3%. At global scales, the difference between the sphere and spheroid are small, about equal to the topographic variation on the earth's surface. With a line width of 0.5mm, the earth would have to be drawn with radius of 15cm before the two models would deviate. The difference is unlikely to affect mapping of the globe at scales smaller than 1:10,000,000.

Accuracy of figures used

The spheroid is still an approximation to the actual shape. Earth is actually slightly pear shaped, slightly larger in the southern hemisphere and has other smaller bulges. Thus, different spheroids are used in different regions, each chosen to fit the observed datum of each region.

Accurate conversion between latitude and longitude and projected coordinates requires knowledge of the specific figures of the earth that have been used. Actual shape of the earth can now be determined quite accurately by observing the satellite orbits. Satellite systems such as GPS, can determine latitude and longitude at any point on the earth's surface to accuracies of fractions of a second. Hence, it is now possible to observe. Otherwise unapparent errors introduced by the use of an approximate figure for map projections.

Geometric Analogy

Developable surfaces

The most common methods of the projection can be conceptually described by imagining the developable surface, which is a surface that can be made flat by cutting it along certain lines and unfolding or unrolling it. The points or lines where a developable surface touches the globe in projecting from globe are called standard points and lines or points and lines of zero distortion. At these points and lines, scale is constant and equal to that of the globe, no linear distortion is present. If developable surface touches the globe, the projection is called tangent.

If the surface cuts into the globe, it is called secant:

• Where surface and the globe intersect, there is no distortion

• Where the surface is outside globe, objects appear bigger than in reality - scales are greater than 1.

• Where the surface is inside the globe, objects appear smaller than in reality and the scales are less than 1.

Symbols used in the following:

l - Longitude

j - Latitude

c - Colatitude (90 - lat)

h - Distortion introduced along lines of longitude

k - Distortion introduced along lines of latitude

(h and k are the lengths of the minor and major axes of the Indicatrix)

Commonly used developable surfaces are:

1. Azimuthal or Planar

A flat sheet is placed in contact with a globe and points are projected from the globe to the sheet. Mathematically, the projection is easily expressed as mappings from latitude and longitude to polar coordinates with the origin located at the point of contact with the paper.

The formulas used for stereographic projection are as follows:

r = 2 tan(c / 2)

q = l

h = k = sec2(c / 2)

2. Conic

The transformation is made to the surface of a cone tangent at a small circle (tangent case) or intersecting at two small circles (secant case) on a globe. Mathematically, this projection is also expressed as mappings from latitude and longitude to polar coordinates, but with the origin located at the apex of the cone. Formulas for equidistant conical projection with one standard parallel (j0 , colatitude c0) are as follows:

r = tan(c0) + tan(c - c0)

q = n l

n = cos(c0)

h = 1.0

k = n r / sin(c)

3. Cylindrical

It is developed by transforming the spherical surface to a tangent or secant cylinder. Mathematically, a cylinder wrapped around the equator is expressed with x equal to longitude and the y coordinates some function of latitude. The formulas used for the cylindrical equal area projection are:

x = l

y = sin(j)

k = sec(j)

h = cos(j)

Mercator Projection characteristics

- Straight lines are lines of constant bearing - projection is useful for navigation.
- Meridians and parallels intersect at right angles.
- Great circles appear as curves.

4. Non-Geometric (Mathematical) projections

Some projections cannot be expressed geometrically. They have only mathematical descriptions.

Universal Transverse Mercator (UTM)

UTM is the first of the two projection based coordinate systems to be examined. UTM provides the geo-referencing at high levels of precision for the entire globe. It is established in 1936 by the International Union of Geodesy and Geophysics. It is adopted by the US Army in 1947. It is also adopted by many national and international mapping agencies, including NATO. It is commonly used in topographic and thematic mapping, for referencing satellite imagery and as a basis for widely distributed spatial databases.

Transverse Mercator Projection

Transverse Mercator Projection results from wrapping the cylinder around the poles rather than around the equator. Central meridian is the meridian where cylinder touches the sphere:

- Theoretically, central meridian is line of zero distortion.
- By rotating the cylinder around the poles
- The central meridian can be moved around earth

For North American data, the projection uses a spheroid of the approximate dimensions:

- 6378 km in the equatorial plane
- 6356 km in the polar plane

Zone System

In order to reduce distortion the globe is divided into 60 zones, 6 degrees of longitude wide. The zones are numbered eastward, 1 to 60, beginning at 180 degrees (W long). The system is only used from 84 degrees N to 80 degrees south as distortion at poles is too great with this projection. At the poles, a Universal Polar Stereographic projection (UPS) is used. Each zone is divided further into strips of 8 degrees latitude. They are beginning at 80 degrees S, are assigned letters C through X, where O and I are omitted.

Distortion

To reduce the distortion across the area covered by each zone, scale along the central meridian is reduced to 0.9996. This produces two parallel lines of zero distortion 180 km approximately away from the central meridian. The scale at zone boundary is approximately 1.0003 at US latitudes.

Coordinates

Coordinates are expressed in meters.

• Eastings (x) are displacements eastward.

• Northings (y) express displacement northward.

The central meridian is given an easting of 500,000 m. Northing for the equator varies depending on the hemisphere. When calculating the coordinates for locations in the northern hemisphere, equator has a northing of 0 m. In the southern hemisphere, the equator has a northing of 10,000,000 m

Advantages

• UTM is a universal approach to accurate geo referencing.

• It is consistent for the globe.

• UTM is frequently used.

Disadvantages

• Rectangular grid superimposed on zones defined by meridians causes axes on adjacent zones to be skewed with respect to each other.

• Full geo-reference requires the zone number, easting and northing.

• No simple mathematical relationship exists between coordinates of one zone and an adjacent zone

• Problems arise in working across zone boundaries.

State Plane Coordinates (SPC)

SPCs are individual coordinate systems adopted by U.S. state agencies. Each state's shape determines which projection is chosen to represent that state. E.g., a state extended N/S may use a Transverse Mercator projection while a state extended E/W may use a Lambert Conformal Conic projection. Projections are chosen to minimize the distortion over the state. A state may have 2 or more overlapping zones, each with its own projection system and grid. Its units are generally in feet.

Advantages

SPC coordinates may be simpler than those of UTM.

SPC may give a better representation than the UTM system for a state's area.

Disadvantages

Problems may arise at the boundaries of projections.

SPC are not universal from state to state.

Uses in GIS

Many GIS have catalogues of SPC projections listed by state which can be used to choose the appropriate projection for a given state.

3.3 Data entry and preparation: spatial data input

Spatial data can be obtained from various sources. It can be collected from scratch, using direct spatial data acquisition techniques or indirectly, by making use of existing spatial data collected by others. Under the first heading we could include field survey data and remotely sensed images. Under the second fall paper maps and existing digital data sets.

It seeks to prepare users of spatial data by drawing attention to issues concerning data accuracy and quality.

Direct spatial data capture

One way to obtain spatial data is by direct observation of the relevant geographic phenomena. This can be done through ground-based field surveys or by using remote sensors in satellites or airplanes . Many Earth sciences Primary data have developed their own survey techniques, as ground-based techniques re-main the most important source for reliable data in many cases.

Data which is captured directly from the environment is known as primary data. With primary data the core concern in knowing its properties is to know the process by which it was captured, the parameters of any instruments used and the with which quality requirements were observed.

Remotely sensed imagery is usually not fit for immediate use, as various sources of error and distortion may have been present and the imagery should first be freed from these. An image refers to raw data produced by an electronic sensor, which are not pictorial, but arrays of digital numbers related to some property of an objector scene, such as the amount of reflected light. For an image, no interpretation of reflectance values as thematic or geographic characteristics has taken place. When the reflectance values have been translated into some ‘thematic’ variable, we refer to it as a raster. more detail on rasters.

It is interesting to note that we refer to image pixels but to raster cells, although both are stored in a GIS in the same way. In practice, it is not always feasible to obtain spatial data by direct spatial data capture. Factors of cost and available time may be a hindrance or previous projects sometimes have acquired data that may fit the current project’s purpose

Indirect spatial data capture

In contrast to direct methods of data capture described above, spatial data can also be sourced indirectly. This includes data derived from existing paper maps through scanning, data digitized from a satellite image, processed data pur-chased from data capture firms or international agencies and so on. This type of data is known as secondary data: Any data which is not captured directly from the environment is known as secondary data.

Spatial Data Input

The functions for capturing data are closely related to the disciplines of surveying engineering, photogrammetry, remote sensing and the processes of digitizing, i.e. the conversion of analogue data into digital representations. Remote sensing, in particular, is the field that provides photographs and images as the raw base data from which spatial data sets are derived. Surveys of the study area often need to be conducted for data that cannot be obtained with remote sensing techniques or to validate data thus obtained.

Traditional techniques for obtaining spatial data, typically from paper sources,included manual digitizing and scanning. Table lists the main methods and de-vices used for data capture. In recent years there has been a significant increase in the availability and sharing of digital (geo spatial) data. Various media and computer networks play an important role in the dissemination of this data, particularly the internet.

The data, once obtained in some digital format, may not be quite ready for use in the system. This may be because the format obtained from the capturing process is not quite the format required for storage and further use, which means that some type of data conversion is required. In part, this problem may also arise when the captured data represents only raw base data, out of which the real data objects of interest to the system still need to be constructed. For example, semi-automatic digitizing may produce line segments, while the application's require-ments are that non-overlapping polygons are needed. A build-and-verification phase would then be needed to obtain these from the captured lines.

Table: Spatial data in-put methods and devices used

Method	**Device**
Manual digitizing	Coordinate entry via keyboard Digitizing tablet with cursor Mouse cursor on the computer Monitor (heads-up digitizing) (digital) photogrammetry
Automatic digitizing	Scanner
Semi-automatic digitizing	Line following software

Input of available digital data	CD-ROM or DVD-ROM Via computer network or internet (including geo-web-services

3.3.1 Raster data models

Raster data structures are generally made up of what can be considered grid cells or pixels, that are organized and referenced by their tow and column position in a database file. Raster data structures attempt to divide up and represent the landscape through the use of regular shapes (Wolf and Ghilani 2002). The shape that is almost exclusively used is the square figure(a). An other shapes, such as triangles, hexagons and octagons, can also cover the Earth completely and regularly. Some common raster GIS databases are those related to satellite imagery, digital elevation models, digital ortho-photographs and digital raster graphs.

Satellite Imagery

Satellite imagery is a term used to describe a wide ar-ray of products generated by remote sensors contained within satellites.

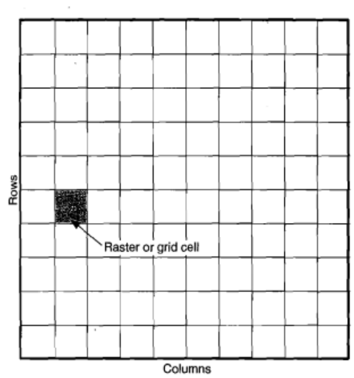


Figure 2.11 Generic raster data structure.

Generic raster data structure

Satellites either are positioned stationary above a location on the Earth or circumnavigate the Earth using a fixed orbit. Although satellites have been sent into deep space and have re-turned imagery to Earth, natural resource management is generally concerned only with imagery that provides information about the Earth and its natural resources.

Digital Elevation Models

When viewing satellite imagery of the Earth, it may seem as if there is no relief associated with the land-scape, since the images were collected from a very high elevation (100+ miles); however, one can associate elevation data with raster images and, subsequently, view them in three dimensions. A digital elevation model (DEM) is a database that contains in-formation about the topography of a landscape. The grid cells in these databases contain measurements of elevation across a landscape (figure (b). One can de-rive terrain models from DEMs that represent aspect, ground slope classes and shaded relief maps. One can also perform a wide variety of terrain-based analyses, such as landscape visualization or watershed analysis. Elevation data can be collected by a variety of means, including sensors located on satellite or aerial plat-forms and photogrammetric techniques that use aerial photography in conjunction with GPS data. Elevation data may also be collected from the bottom of water bodies, such as oceans, lakes or streams, through the use of sonar and acoustical sensors operated from boats or submersible water craft.

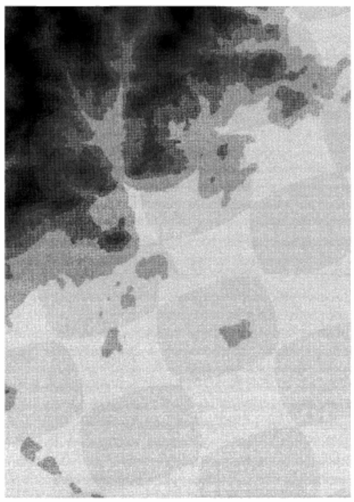


Figure 2.13 Digital elevation model (DEM).

Digital elevation model (DEM)

Digital Ortho-photographs

A **digital ortho-photograph** is essentially a digital aerial photograph (or an aerial photograph that has been scanned) that has been registered to a coordinate system. The displacement common to aerial photo-graphs is greatly reduced through the use of precise positional data, DEMs and information about the plat-form sensor (e.g., the camera system used). Most of the United States has been represented by digital ortho-photography, created through a mapping program sponsored by the U.S. Geological Survey (USGS). Digital ortho-photographs are generally made available in portions that match the extent of USGS 7.5 Minute Series Quadrangle maps and are often referred to as digital ortho-photo quadrangles (DOQs). Since the USGS Quadrangle maps cover large ground areas (7.5 minutes of longitude and latitude), digital ortho-photographs have been developed to cover portions of Quadrangle maps as well and are abbreviated DOQQ (digital ortho quarter quadrangle). Many counties in the United States have also commissioned more de-tailed digital ortho-photographs, as have private companies. Digital ortho-photographs provide a data source for those interested in obtaining a relatively fine scale image of landscape or in obtaining a base data layer for digitizing landscape features (figure(C)).

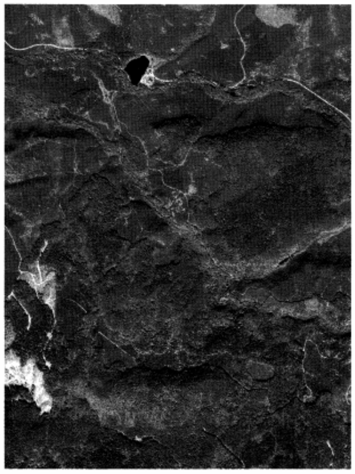


Figure 2.14 Digital orthophoto quadrangle (DOQ).

DIGITAL ortho-photo quadrangle

One of the strengths of digital ortho-photographs is that each image is geo referenced to a coordinate and projection system; thus, GIS users can employ desktop GIS software programs to digitize and create GIS data-bases using "heads-up" digitizing. The term heads-up digitizing indicates that the person doing the digitizing is looking at a computer screen (i.e., his or her head is up), rather than a digitizing table (which requires the person to look down), when digitizing landscape features. With heads-up digitizing, one can quickly create a GIS database from a digital ortho-photograph image on a computer screen.

3.3.2 Vector data models

Vector Data Structure

Vector data, as compared with raster data, are generally considered "irregular." This is not a comment on the quality or usefulness of vector data structures but, rather, a characterization of the type of data they rep-resent. Vector data are generally grouped into three categories: **points, lines or polygons**. Almost any landscape feature on the Earth can be described using one of these three shapes or a combination of the shapes.

Points are the most basic of the shapes but define the essence of all three forms. A line is a set of connected points. A polygon is a collection of lines that forms a closed loop. Point, line and polygon vector features can be referenced by almost any coordinate system. To represent a point, a single measure from each x- (east-west) and y- (north-south) axis is needed to describe the location of the point within a coordinate system. With lines and polygons, pairs of connected points are used to de-scribe these features. Most GIS software programs store location information (X, Y coordinates that describe the landscape features) in separate GIS databases for each theme of interest. For example, the coordinates that are used to describe a roads GIS database are separate from the coordinates that describe a streams GIS database. Al-though most of the location information that defines vector features will be transparent to users of desktop GIS software programs, it is vital in establishing and maintaining **topology**. Topology describes the spatial relationships between (or among) points, lines and polygons and is a very important consideration when conducting spatial analyses. Topology allows one to determine such things as the distance between points, whether lines intersect or whether a point (or a line) is located within the boundary of a polygon. Topology can be defined in a number of ways, but the most common definitions involve aspects of adjacency, connectivity and containment. **Adjacency** is used to describe a landscape feature's neighbors. One might use adjacency relationships to describe polygons that share borders (e.g., in support of green-up requirements in a forest management con-text) or to identify the lines that make up a polygon (area). Connectivity is typically used to describe linear **networks**, such as a network of culverts that might be connected by drainage ditches. Connectivity would al-low one to trace the flow of water through a stream system. One can also incorporate direction into a description of connectivity.

Based on the topography of a landscape in which a culvert system is situated, one could determine the overland flow paths of water through the system, given that water flows downhill. Containment allows one to describe which landscape features are located within or intersect, the boundary of polygons. One could use containment information to describe the well locations (points) or the power lines (lines) that are located within a proposed urban growth boundary, for example. In order for topology to exist, a system for coding topology that can be understood and manipulated by a computer must also exist. With GIS databases containing point features, there is little need for anything more than a file of coordinate pairs (**X, Y coordinates**), since all points are ideally separated from one another and, thus, there are no issues of adjacency, connectivity and containment to resolve. However, more detail is needed in describing feature locations and linkages when using GIS databases containing line and polygon features.

The spatial integrity of lines and polygons is maintained by managing the nodes, vertices and links of each feature. A **node** is the starting and ending point of a line and may represent the intersection of two or more lines . A **vertex** is any point that is not a node but specifies a location or creates a directional change in a line. A **link**, sometimes called an **arc**, is a line that connects points as defined by nodes and vertices. Nodes, vertices and links are usu-ally numbered and maintained in a GIS database file to maintain topology. In a network of lines and polygons , this would involve using numeric codes for network pieces (nodes and links) to identify the node locations, the nodes that are attached to each link and the polygons that may form on either side of each link.

4

SPATIAL DATA ANALYSIS

Spatial data analysis: Introduction, overlay function-vector overlay operations, raster overlay operations, arithmetic operators, comparison and logical operators, conditional expressions, overlay using a decision table, network analysis-optimal path finding, network allocation, network tracing.

4.1 Spatial data analysis: Introduction

Spatial analysis the crux of GIS because it includes all of the transformations, manipulations and methods which can be applied to geographic data to add value to them, to support decisions and to reveal patterns and the anomalies that are not immediately obvious

Spatial analysis is the process by which we turn raw data into useful information, Term analytical cartography is sometimes used to refer to methods of analysis that can be applied to maps to make them more informative and useful.

A devoted to spatial modeling, a loosely defined term that covers a diversity of more advanced and more complex techniques and includes the use of GIS to analyze and simulate dynamic processes, in addition to analyzing static patterns.

The human eye and brain are also very sophisticated processors of geographic data and excellent detectors of the patterns and anomalies in maps and images. So the approach taken here is to regard spatial analysis as spread out along a continuum of sophistication, ranging from the simplest types that occur very quickly and intuitively when eye and brain look at a map, to the types that require complex software and sophisticated mathematical understanding.

Spatial analysis is a set of methods whose results change when the locations of objects being analyzed or the frame used to analyze them, changes.

In general, observations for which absolute location and/or the relative positioning (spatial arrangement) is taken into account can be referred to as spatial data. It can be subdivided into the two major categories representing discrete and continuous phenomena. Based on the former classification, which has also been called the entity view, spatial phenomena are described using zero dimensional objects such as points, one dimensional objects such as lines or two dimensional objects such as areas. If space is described using continuous phenomena, such as in case of temperature or topography, this has also been described as field view. In practice, the latter is usually measured based on sampling discrete entities such as locations in space.

The entity view allows spatial objects to have attributes. The spatial analysis is typically aimed at the spatial arrangement of the observational units, but could also take into account attribute information. An analysis conducted only on the basis of the attributes of the observational units ignoring the spatial relationships is not considered a spatial data analysis.

Spatial Data Analysis

The methods used in spatial data analysis can be broadly categorized in those concerned with visualizing data, those for exploratory data analysis and methods for development of statistical models. During most analyses, a combination of techniques will be used with the data first being displayed visually, followed by exploration of possible patterns and possibly modeling.

Data visualization

One of the first steps in any data analysis should be an inspection of the data. Visual displays of the information using plots or maps will provide the epidemiologist with the basis for generating hypotheses and, if required, an assessment of the fit or predictive ability of models. Over the last couple of years the interactive computer packages have been developed which allow dynamic displays of the data. Geographic information systems can be used to produce maps and they allow the exploration of spatial patterns in an interactive fashion.

Exploratory data analysis

The data exploration is aimed at developing hypotheses and makes extensive use of graphical views of the data such as maps or scatter plots. Exploratory data analysis makes few assumptions about the data and should be robust to extreme data values. The simple analytical models can also be used in this analysis phase.

Models of spatial data

For this type of spatial data analysis specific hypotheses are formally tested or predictions are made using statistical models of the data. Modeling of the spatial phenomena has to incorporate the possibility of spatial dependence in order to provide a true representation of the existing effects. Such spatial effects can be either large scale trends or local effects. The first is also known as a first order effect and it describes overall variation in the mean value of a parameter such as rainfall. The second which is named a second order effect is produced by spatial dependence and represents the tendency of the neighboring values to follow each other in terms of their deviation from the mean. This can for example be the case with the incidence of an infectious animal disease affecting animals on farm properties. First order effects can be readily modeled by standard regression models. The presence of second order effects violates the independence assumption of the standard statistical analysis techniques and appropriate analysis techniques will have to take account of covariance structure in the data giving rise to these local effects.

Often spatial data are modeled as stationary spatial processes which assumes that while there may be dependence between neighboring observations, it is independent from the absolute location. A spatial process is isotropic, if in a stationary process the covariance between observations at different locations depends only on the distance but not on direction. Non- stationary data is almost impossible to the model as most locations will require different parameter sets. Hence, most spatial modeling procedures begin with first identifying a trend in the mean value and then modeling the residuals from this trend as a stationary process.

With any of these models it has to be kept in mind that they are abstractions of the reality and first or second order effects are artifacts of the modeler.

Problems in Spatial Data Analysis

A major factor influencing spatial data analysis is the geographical scale at which the data is being analyzed. It might be possible to identify specific non-random patterns at a local level which when looked at from a national level turn into random variations. Another problem can be which many spatial data sets are based on irregularly shaped area units or there might be directional effects. The proximity or neighborhood also may be more difficult to clearly define than for example in time-series analysis. Any type of spatial analysis will be subject to some degree of the edge effect where area units on the map boundary do have neighbours only in one direction. Many data analyses have to be conducted with the observations based on information summarized at a particular spatial aggregation level such as at the veterinary district. The inferences from such analyses may only be correct if used at the same level of aggregation. This situation has also been called the modifiable area unit problem.

Methods of Spatial Data Analysis

Methods used in spatial data analysis could be divided according to the three main categories of data to be analyzed. They are point patterns, the spatially continuous and area data.

Point patterns

Spatial point patterns are based on the coordinates of events such as locations of outbreaks of a disease. It is also possible that they include attribute information such as time of outbreak occurrence. Data on point patterns can be based on a complete map of all point events or a sampled point pattern. Basic interest of a spatial point pattern analysis will be to detect whether it is distributed at random or represents a clustered or the regular pattern. It is important to recognize that the stochastic process studied relates to the locations where events are occurring. A spatial point pattern can be quantified in terms of the intensity of the process using its first order properties, measured as the mean number of events per unit area. Second order properties or the spatial dependency are analyzed on the basis of the relationship between pairs of points or areas. The latter is typically interpreted as the analysis for clustering.

Spatially continuous data

The point pattern analyses assessed characteristics of the spatial distributions of points, but made only limited use of attribute information. With spatially continuous and also area data the analysis focus shifts towards use of the attribute information, in order to describe their pattern in space. The spatially continuous data is also often referred to as geostatistical data. The data is generally collected by sampling at fixed points in space. The main objective of the analysis will be to describe the spatial variation in an attribute value, using data collected at the sampled points. The spatial variation can be modeled as the first and second order spatial processes.

Area data

Attribute data which does have values within fixed polygonal zones within study area is referred to as area data or lattice data. The areal units can constitute a regular lattice or grid or consist of the irregular units. It is usually not required to estimate values as they should be present for all areas. The main emphasis with area data is on detection and explanation of spatial patterns or trends possibly extended to take account of covariates.

4.1.1 Overlay function-vector overlay operations

Overlay function

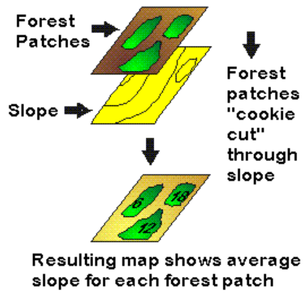
Overlay is a GIS operation in which layers with a common, registered map base are joined on the basis of their occupation of space.

The overlay function creates composite maps by combining diverse data sets. The overlay function can perform simple operations such as laying a road map over a map of the local wetlands or more sophisticated operations such as multiplying and adding map attributes of different value to determine the averages and co-occurrences.

Raster and vector models differ significantly in way overlay operations are implemented. Overlay operations are usually performed more efficiently in raster-based systems. In many GISs a hybrid approach is used that takes advantage of the capabilities of both data models. A vector-based system might implement some functions in the raster domain by performing a vector-to-raster conversion on the input data, doing the processing as a raster operation and converting the raster result back to a vector file.

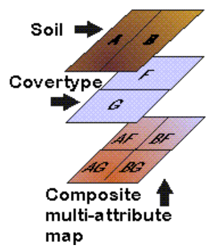
Region Wide Overlay: "Cookie Cutter Approach"

The region wide or "cookie cutter," approach to overlay analysis allows natural features, such as a forest stand boundaries or soil polygons, to become the spatial area(s) which will be analyzed on another map.



For example (see figures above): given two data sets, forest patches and slope, what is the area-weighted average slope within each separate patch of forest? To answer this question, the GIS overlays each patch of the forest from the forest patch data set onto the slope map and then calculates the area-weighted average slope for the each individual forest patch.

Topological Overlay:



Co-Occurrence mapping in a vector GIS is accomplished by topological overlaying. Any number of maps may be over layed to show features occurring at the same location. To accomplish this, the GIS first stacks maps on top of one another and finds all new intersecting lines. Second, new nodes (point features where the three or more arcs or lines, come together) are set at these new intersections. Lastly, the topologic structure of the data is rebuilt and the multifactor attributes are attached to the new area features.

Neighborhood Function

The Neighborhood Function analyzes the relationship between an object and similar surrounding objects. For example, in a certain area, analysis of a kind of land use is next to what kinds of land use can be done by using this function. This type of analysis is often used in the image processing. A new map is created by computing the value assigned to a location as a function of independent values surrounding that location. Neighborhood functions are particularly valuable in evaluating the character of a local area.

Point-in-Polygon and Line-In-Polygon

Point-in-Polygon is a topological overlay procedure that determines the spatial coincidence of points and polygons. Points are assigned the attributes of the polygons within which they fall. For example, this function can be used to analyze an address and find out if it (point) is located within certain zip code area (polygon).

Line-in-Polygon is a spatial operation in which lines in one coverage are overlaid with polygons of another coverage to determine which lines or portions of lines, are contained within the polygons. Polygon attributes are associated with corresponding lines in the resulting line coverage. For example, this function can be used to find out who will be affected when putting in a new power line in an area.

In a vector-based GIS, the identification of points and lines contained within a polygon area is a specialized search function. In a raster-based GIS, it is essentially an overlay operation, with the polygons in one data layer and the points and or lines in a second data layer.

Topographic Functions

Topography refers to the surface characteristics with the continuously changing value over an area such as elevations, aeromagnetics, noise levels, income levels and pollution levels. The topography of a land surface can be represented in a GIS by digital elevation data. An alternative form of the representation is the Triangulated Irregular Network or TIN used in vector-based systems. Topographic functions are used to calculate values that describe the topography at a specific geographic location or in the vicinity of the location. Two most commonly used terrain parameters are the slope and aspect, which are calculated using the elevation data of the neighbouring points. Slope is the measure of change in surface value over distance, expressed in degrees or as a percentage. Example, a rise of 2 meters over a distance of 100 meters describes a 2% slope with an angle of 1.15. Mathematically, slope is referred to as the first derivative of the surface. The maximum slope is termed the gradient.

In a raster format DEM, an another grid where each cell is the slope at a certain position could be created, then the maximum difference can be found and the gradient can be determined. Aspect is the direction that a surface faces. Aspect is defined by the horizontal and vertical angles that the surface faces. In a raster format DEM, another grid can be created for aspect and a number can be assigned to a specific direction.

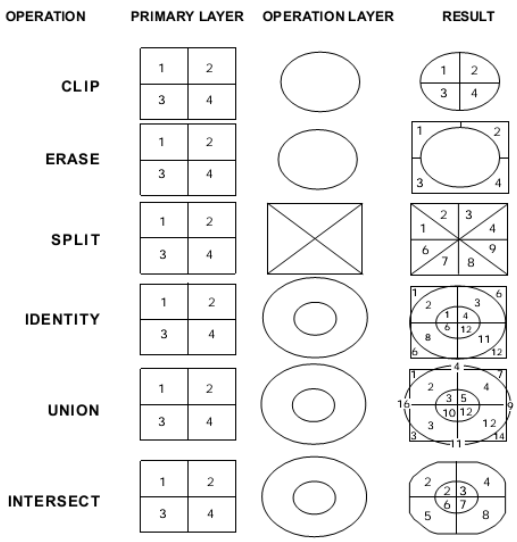
Sun intensity is the combination of slope and aspect. Illumination portrays the effect of shining a light onto a 3-dimensional surface.

Thiessen Polygons

Thiessen or voronoi polygons define the individual areas of influence around each of a set of points. Thiessen polygons are polygons whose boundaries define the area that is closest to each point relative to all other points. Thiessen polygons are generated from a set of points. They are mathematically defined by the perpendicular bisectors of the lines between all points. A tin structure is used to create Thiessen polygons.

VECTOR OVERLAY OPERATIONS

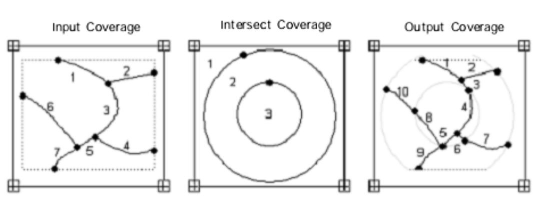
The Figure shows different types of vector overlay operations and gives flexibility for geographic data manipulation and analysis. In polygon overlay, features from two map coverages are geometrically intersected to produce a new set of information.



Overlay operations

Attributes for these new features are derived from the attributes of both the original coverages, thereby contain new spatial and attribute data relationships.

One of the overlay operation is AND (or INTERSECT) in vector layer operations, in which two coverages are combined. Only those features in the area common to both are preserved. Feature attributes from both coverages are joined in the output coverage



INPUT COVERAGE	
#	ATTRIBUTE
1	A
2	B
3	A
4	C
5	A
6	D
7	A

INTERSECT COVERAGE	
#	ATTRIBUTE
1	
2	102
3	103

OUTPUT COVERAGE	INPUT COVERAGE		INTERSECT COVERAGE	
#	#	ATTRIBUTE	#	ATTRIBUTE
1	1	A	2	102
2	2	B	2	102
3	3	A	2	102
4	3	A	3	103
5	5	A	3	103
6	4	C	3	103
7	4	C	2	102
8	6	D	3	103
9	7	A	2	102
10	6	D	2	102

4.2 Raster overlay operations -Arithmetic operators

The overlay raster into GIS may be accomplished automatically if there are known the layers and mathematical functions. This is important because into some models there are combined several maps by using different mathematical functions or conditional operators. Mathematical operators apply one or more mathematical operations on one or more raster maps; the mathematical functions apply a mathematical function on values of a single raster map.

There are three groups of mathematical operators into Map Calculator:

The Arithmetic, Boolean and Relational.

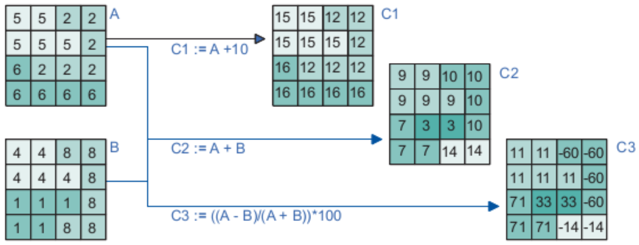
Arithmetic Operators (*, /, -, +) allows operations of sum, SCADERE, multiplying or dividing of two raster map or number or a combination of them.

Various arithmetic operators are supported. The standard ones are multiplication (x), division (/), subtraction (-) and addition (+). Obviously, these arithmetic operators should only be used on appropriate data values and for in-stance, not on classification values.

Other arithmetic operators might include modulo division (MOD) and integer di-vision (DIV). Modulo division returns remainder of division: for instance,

10 MOD 3 will return 1 as 10-3 x 3 = 1. Similarly, 10 DIV 3 will return 3.

More operators are goniometric: sine (sin), cosine (cos), tangent (tan) and their inverse functions asin , acos and atan , which return radian angles as real values.



Examples of arithmetic map algebra ex-pressions

Some simple map algebra assignments are illustrated in Figure. The assignment:

C 1 := A + 10

will add a constant factor of 10 to all cell values of raster A and store the result as output raster C 1. The assignment:

C 2 := A + B

will add the values of A and B cell by cell and store the result as raster C 2. Finally, the assignment

C 3 := (A B)=(A + B) 100

will create output raster C 3, as the result of the subtraction (cell by cell, as usual) of B cell values from A cell values, divided by their sum. The result is multi-plied by 100. This expression, when carried out on AVHRR channel 1 (red) and AVHRR channel 2 (near infrared) of NOAA satellite imagery, is known as the NDVI (Normalized Difference Vegetation Index). It has proven to be good indicator of the presence of green vegetation

Boolean Operators (And, Not, Or and Xor) use Boolean logics (TRUE or FALSE) on the input values. The output values with the value TRUE are represented with 1 and FALSE with 0.

Relational Operators (<, <=, <>, =, > and >=) evaluates the specific relational conditions. If the condition is available (TRUE), the output value will be 1, if the condition is FALSE, the value will be 0. Some raster layers used as input data may have a different ponder into the wanted result. Due to this a simple sum of the values for the input data is not enough.

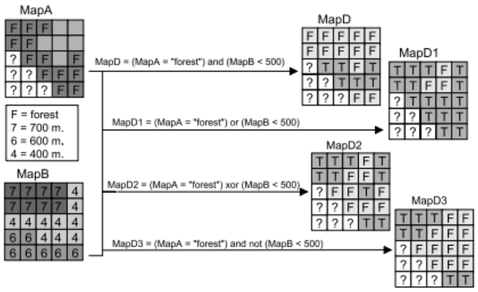
4.2.1 Comparison and logical operators

Logical operators used in MapCalc. They can be used on maps, with all types of domains

Syntax	Operation	Example
AND OR XO	Returns true if both expressions a and b are true. Returns true if one or both of the expressions a and b is true. Returns true if only one of the	AND (b) (a) OR (b)

	expressions a and b is true.	OXR (b)
NOT	Returns true if expression b is false	NOT (b)

Logical operators (see Table) compare two expressions and check if both are true (AND), at least one is true (OR), only one is true (XOR) or one is not true (NOT).



Examples of logical operations in ILWIS. Map A has the domain type class and MapB has domain type value. The output is either True (1), False (0) or undefined (?).

These operators are also called Boolean operators. Examples of Boolean operators (AND, OR, XOR, NOT) are presented in figure .

MapD = (MapA="Forest") AND (MapB<500)

When a pixel in MapA has class name Forest and at the same time this pixel in MapB has a value less than 500, assign value True (1) to this pixel in the output map (MapD). Assign value False (0) to all other pixels.

MapD1 = (MapA="Forest") OR (MapB<500)

The expression is true if only 1 of the expressions is true or both of 2 expressions are true:

If a pixel in mapA has class name Forest and in MapB not smaller than 500.

If that pixel in mapB has a value <500 and in MapA not Forest.

If a pixel in mapA is Forest and if that pixel in MapB <500.

Otherwise the whole expression is false.

MapD2 = (MapA="Forest") XOR (MapB<500) The expression is true if only 1 of the 2 expressions is true:

If a pixel in MapA is Forest and in MapB not smaller than 500.

If a pixel in MapB <500 and in MapA not Forest. Otherwise the whole expression is false. This statement is called exclusive OR.

MapD3 = (MapA="Forest") AND NOT (MapB<500) When a pixel in MapA has class name Forest and at the same time this pixel in MapB does not have a value less than 500, assign True (1) to this pixel in the output map (return True (1) if the first condition is true and the second is false). Assign False (0) for all pixels where this is not the case.

4.2.2 Conditional expressions

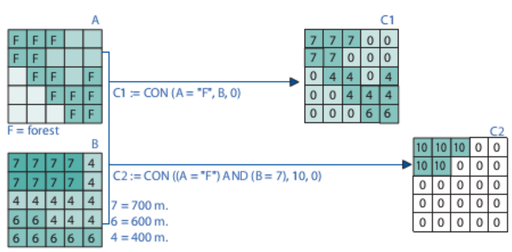
The above comparison and logical operators produce rasters with the truth values true and false. In practice, we often need conditional expression with them that allows us to test whether a condition is fulfilled.

The general format is Output raster := CON (condition , then expression, else expression):

Here, condition is the tested condition, then the expression is evaluated if condition holds and else expression is evaluated if it does not hold.

This means that an expression like CON (A = "forest",10; 0) will evaluate to 10 for each cell in the output raster where the same cell in A is classified as for-est. In each cell where this is not true, the else expression is evaluated, resulting in 0 . Another example is provided in figure showing that values for the then expression and the else expression can be some integer (possibly derived from another calculation) or values derived from other rasters.

In this example, the output raster C 1 is assigned the values of input raster B wherever the cells of input raster A contain forest. The cells in output raster C 2 are assigned 10 wherever the elevation (B) is equal to 7 and the groundcover (A) is forest.



Examples of conditional expressions in map algebra. Here A is a classified raster holding land use data and B is an elevation value raster.

4.2.3 Overlay using a decision table

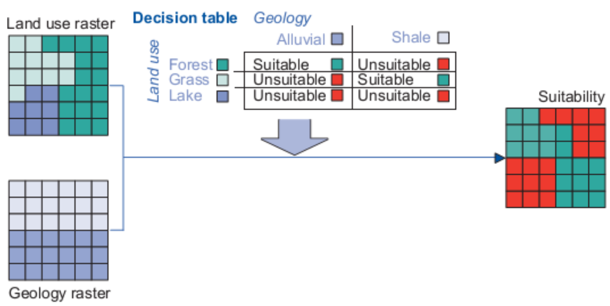
Conditional expressions are powerful tools in cases where multiple criteria must be taken into account. A small size example may illustrate this. Consider a suitability study in which a land use classification and a geological classification must be used. The respective rasters are illustrated in figure. on the left. Do- Domain expertise main expertise dictates that some combinations of land use and geology result in suitable areas, whereas other combinations do not. In our example, forests on alluvial terrain and grassland on shale are considered suitable combinations, while the others are not.

We could produce the output raster of figure, with a map algebra expression such as:

$$\begin{aligned}\text{Suitability} \;:=\; & CON((Landuse = \text{“}Forest\text{”}\ AND\ Geology = \text{“}Alluvial\text{”})\ OR \\ & (Landuse = \text{“}Grass\text{”}\ AND\ Geology = \text{“}Shale\text{”}), \\ & \text{“Suitable”}, \text{“Unsuitable”})\end{aligned}$$

And consider ourselves lucky that there are only two ‘suitable’ cases. In practice, many more cases must usually be covered and then writing up a complex CON expression is not an easy task.

To this end, some GISs accommodate setting up a separate decision table that will guide the raster overlay process. This extra table carries domain expertise,



The use of a decision table in raster overlay.

The overlay is computed in a suitability study, in which land use and geology are important factors. The meaning of values in both input rasters, as well as the out-put raster can be under-stood from the decision table. and dictates which combinations of input raster cell values would produce which output raster cell value.

This gives us a raster overlay operator using a decision table, as illustrated in figure. The GIS will have supporting functions to generate the additional table from the input rasters and to enter appropriate values in the table.

4.3 Network analysis-optimal path finding

A completely different set of analytical functions in GIS consists of computations on networks. A network is a connected set of lines, representing some geographic phenomenon, typically of transportation type. The 'goods' transported can be almost anything: people, cars and other vehicles along a road network, commercial goods along a logistic network, phone calls along a telephone network or water pollution along a stream or river network.

Network analysis can be performed on either raster or vector data layers, but they are more commonly done in the latter, as line features can be associated with a network and hence can be assigned typical transportation characteristics such as capacity and cost per unit. Fundamental characteristic of any network is whether the network lines are considered directed or not. Directed networks associate with each line a direction of transportation; undirected networks do not.

In the latter, the 'goods' could be transported along a line in both directions. We assume that the network is a set of connected line features that intersect only at the lines' nodes, not at internal vertices. (But we do mention under- and overpasses.)

For many applications of the network analysis, a planar network, i.e. one that can be embedded in a two-dimensional plane, will do the job. Many networks are naturally planar, like stream or river networks. A large-scale traffic network, on other end, is not planar: motorways have multi-level crossings and are constructed with underpasses and overpasses. Planar networks are easier to deal with the computationally, as they have simpler topological rules.

Not all GISs accommodate non-planar networks or can do so only using 'tricks'.

These may involve the splitting of overpassing lines at the intersection vertex and the creation of four lines out of the two original lines. Without further attention, the network will then allow one to make a turn onto another line at this new intersection node, which in reality would be impossible. In some GISs we Overpasses can allocate a cost with turning at a node on turning costs below and that cost, in the case of the overpass, can be made infinite to en-sure it is prohibited. But, as mentioned, this is a workaround to fit a non-planar situation into a data layer that presumes planarity.

The above is a good illustration of geometry not fully determining the network's behaviour. Additional application-specific rules are usually required to define what can and cannot happen in network. Most GISs provide rule-based tools that allow the definition of these extra application rules.

Various classical spatial analysis functions on the networks are supported by GIS software packages. The most important ones are:

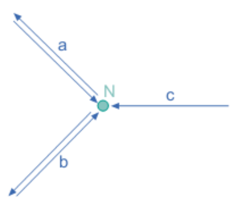
1. Optimal path finding which generates a least cost-path on a network be-tween a pair of predefined locations using both geometric and attribute data.

2. Network partitioning which assigns network elements (nodes or line segments) to different locations using predefined criteria.

OPTIMAL PATH FINDING

Optimal path finding techniques are used when a least-cost path between the two nodes in a network must be found. The two nodes are called origin and destination, respectively. The aim is to find a sequence of connected lines to traverse from the origin to the destination at the lowest possible cost.

The cost function can be simple: for instance, it can be defined as the total length of all lines on the path. The cost function could also be more elaborate and take into account not only length of the lines, but also their capacity, the maximum transmission (travel) rate and other line characteristics, for instance to obtain a reasonable approximation of travel time. There can even be cases in which the nodes visited add to the cost of the path as well. These might be called turning costs, which are defined in a separate turning cost table for each node, indicating cost of turning at the node when entering from one line and continuing on another. This is illustrated in figure(a).

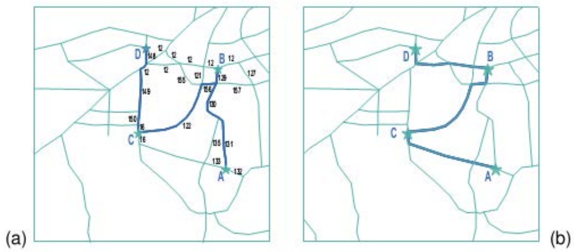


from	onto	cost
a	a	□
a	b	□
b	a	8
b	b	15
c	a	3
c	b	6

(a) The network neighbour-hood of node N with associated turning costs at N . Turning at N onto c is prohibited because of direction, so no costs are mentioned for turning onto c. A turning cost of infinity (∞) means that it is also prohibited.

The attentive reader will notice that it is possible to travel on line b in figure. then take a U-turn at node N and return along a to where one came from. The question is whether doing this makes sense in optimal path finding. After all, to go back to where one comes from will only increase the total cost. In fact, there are situations where it is optimal to do so. Suppose it is node M that is connected by line b with node N and that we actually wanted to travel to the another node L from M . The turn at M towards node L coming via another line may be prohibitively expensive, whereas turning towards L at M returning to M along b may not be so expensive.

Problems related to optimal path finding are ordered optimal path finding and unordered optimal path finding. Both have an extra requirement that a number of additional nodes needs to be visited along the path. In ordered optimal path finding, the sequence in which these extra nodes are visited matters; in Ordered and unordered path finding unordered optimal path finding it does not. An illustration of both types is provided in figure(b) Here, a path is found from node A to node D, visiting nodes B and C . Obviously, the length of the path found under non-ordered requirements is at most as long as the one found under ordered requirements. Some GISs provide the support for these more complicated path finding problems.



Ordered (a) and unordered (b) optimal path finding. In both cases, a path had to be found from A to D, in (a) by visiting B and then C, in (b) both nodes also but in arbitrary order.

4.3.1 Network allocation

Network allocation In network allocation, we have a number of target loca-tions that function as resource centres and the problem is which part of the net-work to exclusively assign to which service centre. This might sound like a simple allocation problem, in which a service centre is assigned those line (segments) to which it is nearest, but usually the problem statement is more complicated.

These further complications stem from the requirements to take into account

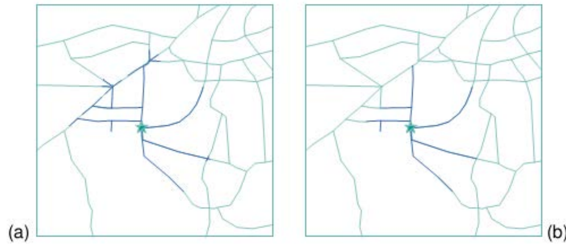
• The capacity with which a centre can produce the resources (whether they Are medical operations, school pupil positions, kilowatts or bottles of milk)

• The consumption of the resources, which may vary amongst lines or line segments. After all, some streets have more accidents, more children who live there, just more thirsty workers or more industry in high demand of electricity.

Network partitioning

In network partitioning, purpose is to assign lines and/or nodes of the net-work, in a mutually exclusive way, to a number of target locations. Typically, the target locations play the role of service centre for the network.

This may be any type of service: medical treatment, education, water supply. This type of network partitioning is known as a network allocation problem. Another problem is the trace analysis. Here, one wants to determine that part of the network that is upstream (or downstream) from a given target location. Such problems exist in pollution tracing along river or stream systems, but also in the network failure chasing in energy distribution networks



Network al-location on a pupil/ school assignment problem. In (a), the street segments within 2 km of the school are identified; in (b), the selection of (a) is further restricted to accommodate school's capacity for the new year

The service area of any centre is a subset of distribution network, in fact, a connected part of the network. Various techniques exist to assign network lines or their segments, to a centre. In figure(a), the green star indicates a primary school and the GIS has been used to assign streets and the street segments to the closest school within 2 km distance, along the network.

Then, using demographic figures of pupils living along the streets, it was determined that too many potential pupils lived in the area for the school's capacity. So in part (b), the already selected part of the network was reduced to accommodate precisely the school's pupil capacity for new year.

4.3.2 Network tracing

Trace analysis is performed when we want to understand which part of the network is 'conditionally connected' to a chosen node on the network, known as the trace origin. For a node or line to be conditionally connected, it means that a path exists from the node/line to the trace origin and that connecting path fulfills the conditions set. What these conditions are depends on the application and they may involve direction of the path, capacity, length or resource consumption along it.

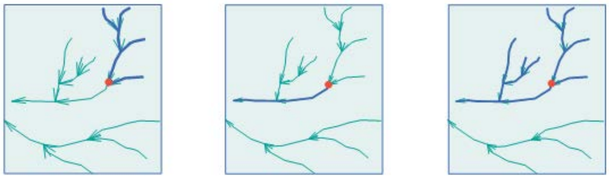
The condition typically is a logical expression, as we have seen before, for instance:

• The path must be directed from the node or line to the trace origin,

• Its capacity (defined as the minimum capacity of the lines that constitute the path) must be above a given threshold.

• The path's length must not exceed a given maximum length.

Tracing is the computation that the GIS performs to find the paths from trace origin that obey the tracing conditions. It is a rather useful function for many network-related problems.



(a) (b) (c)

Tracing functions on a network:

(a) Tracing upstream,

(b) Tracing downstream,

(c) Tracing without conditions on direction.

In figure, we trace origin is indicated in red. In part (a), the tracing conditions were set to trace all the way upstream; part (b) traces all the way down-stream and in part (c) there are no conditions on direction of the path, thereby tracing all connected lines from the trace origin. More complex conditions are certainly possible in tracing.

5

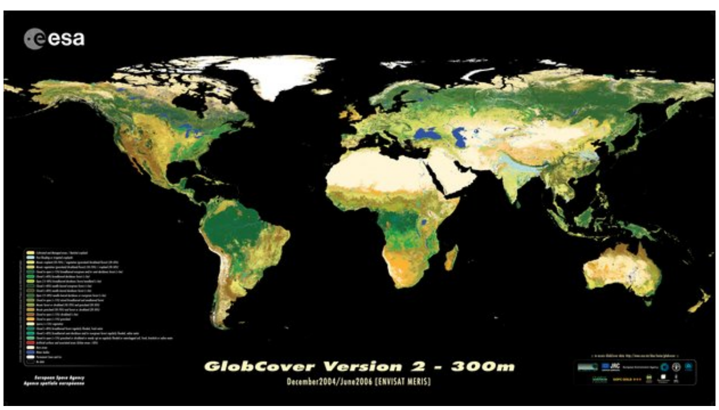
RS AND GIS APPLICATIONS GENERAL

RS and GIS applications General: Land cover and land use, agriculture, forestry, geology, geomorphology, urban applications.

5.1 RS and GIS applications General: Land cover and land use

Land use and land cover classification detailed land use and land cover map is another important input that remote sensing can yield for hydrologic analysis. Land cover classification using the multispectral remote sensing data is one of the earliest and well established remote sensing applications in water resources studies. With the capability of the remote sensing systems to provide frequent temporal sampling and the fine spatial resolution, it is possible to analyze the dynamics of land use land cover pattern and also its impact on the hydrologic processes.

Use of hyper-spectral imageries helps to achieve further improvement in the land use land cover classification , wherein spectral reflectance values recorded in the narrow contiguous bands are used to differentiate, different land use classes that shows close resemblance with each other. Identification of crop types using hyper spectral data is an example. With the help of satellite remote sensing, land use land cover maps at near global scale are available today for the hydrological applications. European Space Agency (ESA) has released a global land cover map of 300 m resolution, with 22 land cover classes at 73% accuracy.



Although the terms land cover and land use are often used interchangeably, the actual meanings are quite distinct. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for the global monitoring studies, resource management and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed and provides the ground cover information for the baseline thematic maps.

Land use refers to the purpose the land serves, for example, recreation, wildlife habitat or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what the current quantity of land is in what type of use and to identify the land use changes from year to year. This knowledge will help develop strategies to balance conservation, conflicting uses and developmental pressures. Issues driving the land use studies include the removal or disturbance of productive land, the urban encroachment and depletion of forests.

It is important to distinguish this difference between land cover and land use and the information that could be ascertained from each. The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred, particularly with ancillary data or a prior knowledge.

Land cover / use studies are multidisciplinary in the nature and therefore the participants involved in such work are numerous and varied, ranging from the international wildlife and conservation foundations, to government researchers and forestry companies. Regional government agencies have an operational need for land cover inventory and land use monitoring, as it is within their mandate to manage the natural resources of their respective regions. In addition to facilitating sustainable management of land, land cover and use information may be used for planning, monitoring and evaluation of development, industrial activity or reclamation. Detection of long term changes in land cover may reveal a response to a shift in the local or the regional climatic conditions, the basis of terrestrial global monitoring.

Ongoing negotiations of the aboriginal land claims have generated a need for more stringent knowledge of land information in those areas, ranging from the cartographic to thematic information.

The resource managers involved in parks, oil, timber and mining companies, are concerned with the both land use and land cover, as are local resource inventory or natural resource agencies. Changes in land cover will be examined by the environmental monitoring researchers, conservation authorities and departments of municipal affairs, with interests varying from tax assessment to reconnaissance vegetation mapping. Governments are also concerned with the general protection of the national resources and become involved in publicly sensitive activities involving land use conflicts.

The Land use applications of remote sensing include the following:

- Wildlife habitat protection
- Natural resource management

- Urban expansion / encroachment
- Baseline mapping for the GIS input
- Damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- Target detection - identification of landing strips, roads, clearings, bridges, land/water interface
- Routing and logistics planning for seismic / exploration / resource extraction activities
- Legal boundaries for tax and property evaluation

5.1.1 Agriculture

Agricultural Land may be defined broadly as land used primarily for production of food and fiber. On high-altitude imagery, the chief indications of agricultural activity would be distinctive geometric field and road patterns on landscape and the traces produced by livestock or the mechanized equipment. However, pasture and other lands where such equipment is used infrequently may not show as well defined shapes as other areas. These distinctive geometric patterns are also characteristic of Urban or Built-up Lands because of street layout and development by blocks.

Distinguishing between the Agricultural and Urban or Built-up Lands ordinarily should be possible on the basis of urban-activity indicators and the associated concentration of population. Number of building complexes is smaller and the density of the road and highway network is much lower in Agricultural Land than in Urban or Built-up Land. Some urban land uses, such as parks and the large cemeteries, however, might be mistaken for the Agricultural Land, especially when they occur on the periphery of the urban areas.

The interface of Agricultural Land with other categories of land use may sometimes be a transition zone in which there is an intermixture of land uses at first and second levels of categorization. Where farming activities are limited by the wetness, the exact boundary also might be difficult to locate and Agricultural Land may grade into Wetland. When the production of agricultural crops is not hindered by the wetland conditions, such cropland should be included in the Agricultural category. This latter stipulation also includes those cases in which the agricultural crop production depends on the wetland conditions, such as flooding of rice fields or the development of cranberry bogs.

When lands produce the economic commodities as a function of their wild state such as wild rice, cattails or certain forest products commonly associated with the wetland, however, they should be included in the Wetland category. Similarly, when the wetlands are drained for agricultural purposes, they should be included in the Agricultural Land category. When such drainage enterprises fall into the disuse and if wetland vegetation is reestablished, the land reverts to the Wetland category.

The Level II categories of Agricultural Land are:

Cropland and Pasture; Orchards, Groves, Vineyards, Nurseries and the Ornamental Horticultural Areas; Confined Feeding Operations and Other Agricultural Land.

Agriculture plays an important role in the economies of countries. The production of food is important to everyone and producing food in a cost-effective manner is goal of every farmer and an agricultural agency. The satellites has an ability to image individual fields, regions and counties on a frequent revisit cycle. Customers can receive field-based information including the crop identification, crop area determination and the crop condition monitoring (health and viability). Satellite data are employed in the precision agriculture to manage and monitor the farming practices at different levels. The data can be used to farm optimization and spatially-enable management of technical operations. The images can help determine the location and extent of crop stress and then could be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. The major agricultural applications of the remote sensing include the following:

Vegetation

• Crop condition assessment

• Crop type classification

• Crop yield estimation

Soil

• Mapping of soil characteristics

• Mapping of soil type

• Soil moisture

• Soil erosion

• Mapping of soil management practices

• Compliance monitoring

Crop type classification

Remote sensing technology can be used to prepare maps of crop type and delineating their extent. The traditional methods of obtaining this information are census and ground surveying. The use of satellites is advantageous as it can generate a systematic and repetitive coverage of a large area and provide information about health of the vegetation. Data of crop is needed for agricultural agencies to prepare an inventory of what was grown in certain areas and when. This information serves to predict the grain crop yield, collecting crop production statistics, facilitating the crop rotation records, mapping soil productivity, identification of factors influencing crop stress, assessment of crop damage and monitoring farming activity.

Crop monitoring and damage assessment

Remote sensing has a number of attributes that lend themselves to monitoring the health of crops. The optical (VIR) sensing advantage is that it could see the infrared, where wavelengths are highly sensitive to crop vigor as well as crop stress and crop damage. Remote sensing imagery also gives required spatial overview of the land. Remote sensing can aid in identifying crops affected by conditions that are too dry or wet, affected by insect, weed or fungal infestations or weather related damage. Images could be obtained throughout growing season to not only detect problems, but also to monitor the success of the treatment. Detecting damage and monitoring the crop health requires high-resolution, multi-spectral imagery and the multi-temporal imaging capabilities. The most critical factors in making imagery useful to farmers is a quick turnaround time from the data acquisition to distribution of crop information.

Soil mapping

The disturbance of soil by land use impacts on the quality of our environment. Salinity, soil acidification and erosion are some of the problems. Remote sensing is a good method for the mapping and prediction of the soil degradation. Soil layers that rise to the surface during erosion have different color, tone and structure than non eroded soils thus the eroded parts of soil can be easily identify on the images. Using multi-temporal images we can study and map dynamical features - the expansion of erosion, soil moisture. Attempts to study land degradation processes and necessity of degradation prediction have resulted in the creation of the erosion models. The necessary information (parameters of models; Universal Soil Loss Equation (USLE) to modeling can be often derived from satellite images. The vegetative cover is a major factor of soil erosion.

5.1.2 Forestry

To meet the various information requirements in the forest management different data sources, like field survey, aerial photography and satellite imagery is used, depending on the level of the detail required and the extension of the area under study. Before aerial photography was used for forest management purposes, information was generally obtained by means of the field surveys, identifying and measuring the forest types and stands.

This is still by far the most accurate and detailed way of measurement, although the lack of geographical positioning systems did not allow accurate location of the forests classified. The method is, though very elaborate, time consuming and expensive and it is nowadays used predominantly for purpose of research and for intensive sustainable production purposes. The traditional aerial photograph resulting from the different film types was and still is an important remote sensing tool.

The knowledge of photogrammetry and photography is essential for its proper use. For many decades use of aerial photographic data has been accepted by several forest institutions as a tool in various forest activities, such as planning, mapping, inventory, harvesting, area determination, road lay-out, registration of the declined and dead trees etc. on a local, regional or national scale. For the purpose of consistently and repeatedly monitor forests over larger areas, it is preferable to use remote sensing data and the automated image analysis techniques. Several types of remote sensing data, including multi-spectral scanner (MSS), aerial photography, Lidar (Light Detection and Ranging) laser, radar (Radio Detection and Ranging) and Videography data have been used by forest agencies to detect, identify, classify, evaluate and measure various forest cover types and their changes.

Over past decades tremendous progress has been made in demonstrating the potentials and limitations for identifying and mapping several earth surface features using optical remote sensing data. For large areas, satellite imagery has been shown effective for forest classification and consequently mapping. It is emphasized that one of the advantages of the use of remote sensing in forest survey is relative short time in which most of the required information can be obtained.

Gradually other types of the remote sensing tools were developed with which forest object properties were registered from the air or from space. New technologies, integrating satellite imagery, analytical photogrammetry and geo information systems (GIS) offer new possibilities, especially for the general interpretation and mapping and will be a challenge for future research and application. Analogue photographic data of aerial photographs as well as the satellite scanning data can be digitized and used for the multi-spectral or multi-temporal classification and corrections, geometrical or radio metrical. Scanning techniques are also applicable in airplanes.

Now the products of this aerospace technology are considered to be superior to and a replacement of the "old fashioned" analogue aerial photography. However, this technology is additional and complementary to aerial photography. Sometimes the products are used alone, but in most cases a combination with aerial photographs is applied. Also fieldwork is and remains essential when applying remote sensing techniques. Various factors could be mentioned to explain why in managed forests the operational application of remote sensing in the estimation of a number of the stand parameters, is relatively low. Foresters are in general conservative, in the beginning they were reserved in applying the aerial photography and nowadays other remote sensing techniques are not embraced whole heartily. There is a hesitation to take risks when departing from traditional data sources. Lack of knowledge of access to data of the specialized technology is and other reason for the limited application.

a. Forest cover types

b. Identify individual species

c. Species composition

d. Forest fire detection

e. Forest fire hazard

f. Detecting forest trees health (vigor and stress)

g. forest trees diseases and insects infestation

h. forest trees under air, soil and water pollution

i. Assessment of wind damage and other sever climatic condition

j. Detecting deforestation and forest degradation

k. Forest monitoring

l. Timber harvesting planning

Applications of remote sensing and GIS to forestry

The use of remote sensing by forest managers has steadily increased, promoted in large part by better integration of imagery with GIS technology and databases, as well as implementations of technology that better suit the information needs of forest managers. The most important forest information obtained from the remotely sensed data can be broadly classified in the following categories:

• Broad area monitoring of forest health and natural disturbances.

• Detailed forest inventory data (e.g., within-stand attributes).

• Assessment of forest structure in support of sustainable forest management.

Detailed forest inventory data

Forest inventory databases are based primarily on stand boundaries derived from the manual interpretation of aerial photographs. Stand boundaries are vector-based depictions of homogeneous units of forest characteristics. These stand polygons are described by a set of attributes that typically includes species composition, stand height, stand age and crown closure. Digital remotely sensed data can be used to update the inventory database with change (e.g., harvest) information for quality control, audit and bias detection. It can also add additional attribute information and identify biases in the forest inventory databases due to vintage, map sheet boundaries or interpreter preferences.

The objective of managing forests sustainably for multiple timber and non-timber values has required the collection of more detailed tree and stand data, as well as additional data such as gap size and distribution. Detailed within-stand forest inventory information can be obtained from high-spatial-resolution remote sensing data such as large-scale aerial photography and airborne digital imagery. Two methods of obtaining this information are polygon decomposition and individual tree crown recognition.

Polygon decomposition analyzes the multiple pixels representing a forest polygon on a remotely sensed image to generate new information that is then added to the forest inventory database. For example, a change detection analysis of multidate Landsat. Thematic Mapper satellite images can identify the areal extent and proportion of pixels where conditions have changed.

Individual tree crown recognition is based on analyzing high-spatial-resolution images from which characteristics such as crown area, stand density and volume may be derived.

5.2 Geology

Remote sensing is used as a tool to extract information about the land surface structure, composition or subsurface, but is often combined with other data sources providing complementary measurements.

Remote sensing is not limited to direct geology applications it is also used to support the logistics, such as route planning for access into a mining area, reclamation monitoring and generating the base maps upon which geological data can be referenced or superimposed.

Geological applications of the remote sensing include the following:

a. Surficial deposit / bedrock mapping

b. Lithological mapping

c. Structural mapping

d. Sand and gravel (aggregate) exploration/ exploitation

e. Mineral exploration

f. Hydrocarbon exploration

g. Environmental geology

h. Geobotany

i. Baseline infrastructure

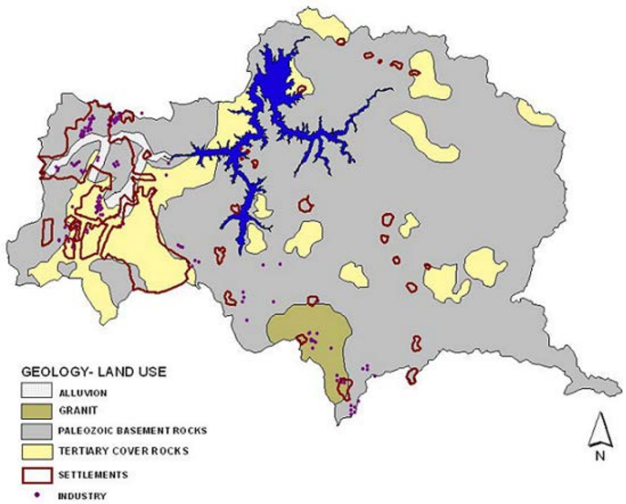
j. Sedimentation mapping and monitoring

k. Event mapping and monitoring

l. Geo-hazard mapping and planetary mapping

Geo environmental research can help to identify the causes of these events, point the way to rehabilitation measures and lend support for early warning systems

Remote sensing adds considerably to this research by providing a wide variety of sensors operated from airborne and satellite platforms.



5.2.2 Geomorphology

Remote sensing is the observation of the surfaces or objects while not being in direct contact with them. By this definition, cameras are remote sensors, observing the environment around us but not requiring us to touch the objects photographed; our eyes fall into this category. The more commonly accepted example of remote sensing is the use of satellites in orbit around the earth to observe the surface for the purpose of monitoring. Since the development of Google Earth, access to such data has become available to everyone for free. However, remote sensing for environmental monitoring is more involved than simply looking at one's neighbour hood from above: it has the capability to provide wide-scale observations of all geomorphological features on the Earth's surface. We are able to monitor the changing shape of Earth's surface, assess processes occurring and identify landforms in the remote regions that might otherwise be inaccessible.

In its most simple application, we could take a remotely sensed image of the Earth's surface and interpret what we see to produce a geomorphological map. This allows us to map the regions rapidly that might otherwise take many weeks of manual exploration and cartography. Such mapping processes could even be automated, to a certain extent. One constraint that we have, however, relates to spatial resolution of particular sensors, such as the smallest area on Earth's surface that a sensor can distinguish. For the continental-scale features like the mountain ranges, sensors with a coarser resolution may be sufficient (example, the NASA sensor, MODIS, which at best has a pixel size of 250 m). For smaller scale features, such as mountain glaciers or even sand dunes. the use of higher spatial resolution sensors will be necessary. For example,Worldview II is a new satellite launched in 2009 with a sub-metre spatial resolution.

What is also useful with regard to the today's remote sensors is the availability of the hyper spectral imagery, that is, imagery viewing the surface not just in the visible bands to produce what may look like a photograph, but imagery viewing the surface in different bands of the electromagnetic spectrum. This allows detection of certain materials which often reflect differences in the geomorphology. For example, we can distinguish different rock and sediment types and can inspect for different minerals within rock we could assess vegetation cover and we can, to a certain extent, determine the moisture content of the surface.

Aside from actual images of the surface, remote sensing also has the geomorphological application of being able to provide three-dimensional representations of the surface in the production of digital elevation models . On a number of orbiting satellites (and also on some airplanes), radar systems actively beam electromagnetic radiation to Earth and detect these as they bounce off the surface and return to the corresponding sensor, the longer this process takes, the further reflecting surface must be from the sensor, thereby indicating the shape of the land below. Not only is this useful for an instantaneous representation of the topography but it is immensely useful for monitoring how this might change over time, perhaps due to subsidence or uplift of the surface or the movement of a glacier.
The utility of remote sensing for geomorphological studies is immense. It allows for the rapid assessment of large areas and for monitoring of changes to these areas things that would be impossible to do using field studies alone. This is not to say that remote sensing might one day completely replace the requirement for on the ground field work but it will continue to provide an additional source of information for geomorphological studies at all spatial scales.

5.2.3 Urban Applications

Digitization of planning base maps facilitated updating of base maps wherever changes have taken place in terms of land development etc. Superimposition of any two digital maps which are on two different scales is feasible.Superimposition of revenue maps on base maps with reasonable accuracy is great advantage compared to manually done jobs.

URBAN PLANNING - APPLICATIONS OF RS

In India, the complexity of urban development is so dramatic that it demands immediate attention and perspective physical planning of the cities and towns. It is necessary and fundamental for policy makers to integrate like remote sensing into urban planning and management. New approaches are required and new methods must be incorporated into current practice.

Until recently, maps and land survey records from the 1960's and 70's were used for urban studies, but now the trend has shifted to using digital, multispectral images acquired by EOS and other sensors. The trend towards using remotely sensed data in the urban studies began with first-generation satellite sensors such as Landsat MSS and WAS given impetus by a number of second generation satellites: Landsat TM, ETM+ and SPOT HRV. The recent advent of a third generation of very high spatial resolution satellite sensors is stimulating.

Advancement in the technology of remote sensing has brought miracle in the availability of the higher and higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 meter resolution in multispectral mode, IRS-1D Pan image with 5.8 meter resolution, Cartosat-I imagery of 2.5 meter resolution with the stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space

Imaging with 4 meter in multispectral mode and 1 meter in panchromatic mode, Quickbird imagery of Digital Globe with 61 cm resolution in panchromatic mode. These high resolutions of the sensors provide a new methodology.

Apart from Cartographic applications, P-6 data will be useful in cadastral mapping and updating terrain visualization, generation of a national topographic database, utilities planning. The satellite will provide cadastral level information up to a 1:5,000 scale and will be useful for making 2-5 meter contour map (NRSA 2005).

The output of a remote sensing system is usually an image representing the scene being observed. Since remote sensing may not provide all the information needed for a full-fledged assessment, several other spatial attributes from various sources are needed to be integrated with remote sensing data. This integration of spatial data and their combined analysis is performed through GIS technique. It is a computer assisted system for the capture, storage, retrieval, analysis and display of spatial data and non-spatial attribute data. The data can be derived from alternative sources such as survey data, geographical/topographical/aerial maps or archived data. Data could be in the form of locational data (such as latitudes/longitudes) or tabular (attribute) data.

Application of Remote Sensing technology can lead to innovation in the planning process in various ways:

1. Digitization of planning basemaps:

Digitization of planning basemaps has facilitated updating of basemaps wherever changes have taken place in terms of land development etc. Superimposition of any two digital maps which are on two different scales is feasible. Similarly superimposition of the revenue maps on the basemaps with reasonable accuracy is great advantage compared to manually done jobs.

2. Digital formate:

Correlating several layers of information about a feature from satellite imagery, planning maps and revenue maps is feasible with help of image processing software like ERDAS Imagine, ENVI and PCI Geomatica, ILWIS. Such super imposed maps in the GIS software like Map info, Geomedia, Arc View, Auto CAD Map and Arc GIS provide valuable information for planning, implementing and management in the urban areas.

List of Indian Remote Sensing Satellites

Serial Number	Satellite	Date of Launch	Launch Vehicle	Status
1	IRS 1A	17 March 1988	Vostok, USSR	Mission Completed
2	IRS 1B	29 August 1991	Vostok, USSR	Mission Completed

3	IRS P1 (also IE)	20 September 1993	PSLV-D1	Crashed, due to launch failure of PSLV
4	IRS P2	15 October 1994	PSLV-D2	Mission Completed
5	IRS 1C	28 December 1995	Molniya, Russia	Mission Completed
6	IRS P3	21 March 1996	PSLV-D3	Mission Completed
7	IRS 1D	29 September 1997	PSLV-C1	Mission Completed
8	IRS P4 (Oceansat-1)	27 May 1999	PSLV-C2	Mission Completed
9	Technology Experiment Satellite(TES)	22 October 2001	PSLV-C3	In Service
10	IRS P6 (Resourcesat-1)	17 October 2003	PSLV-C5	In Service
11	IRS P5 (Cartosat 1)	5 May 2005	PSLV-C6	In Service
12	Cartosat 2 (IRS P7)	10 January 2007	PSLV-C7	In Service
13	Cartosat 2A	28 April 2008	PSLV-C9	In Service
14	IMS 1	28 April 2008	PSLV-C9	In Service
15	Oceansat-2	23 September 2009	PSLV-C14	In Service
16	Cartosat-2B	12 July 2010	PSLV-C15	In Service

17	Resourcesat-2	20 April 2011	PSLV-C16	In Service
18	Megha-Tropiques	12 October 2011	PSLV-C18	In Service
19	RISAT-1	26 April 2012	PSLV-C19	In Service

• Study urban growth/sprawl and trend of growth

• Updating and monitoring using repetitive coverage

• Study of the urban morphology, population estimation

• Space use surveys in city centers

• Slum detection, monitoring and updating

• Study of the transportation system and important aspects both in static and dynamic mode

• Site suitability and catchments area analysis

• Study of the open/vacant space.

GIS can be applied to many types of problem. Among these are representatives of both the raster and vector data base structures, both simple and complex analytical models. Master planning applications are one of them.

Especially for area monitoring (both on a sectoral and integral basis), regional potential and feasibility analyses and site selection studies. For studies in which plan alternatives are generated, much more flexible design, the optimization and evaluation tools would be needed in order to give GIS a dominant position in the development process.

GIS can also be helpful for the documentation of spatial plans and in the approval process for the development, building and installation permits.

GIS applied to a wide range of land management and land use planning issues including the interpretation and the formulation of land use policy. Land-use policy can be interpreted within GIS using a modeling approach.

Output in the form of maps showing areas in which land-use changes are more likely to occur and statistics, graphs and tables summarizing this information according to a variety of specified spatial units.

The predicted land-use changes can also form input for GIS-based impact assessment.

GIS have become of increasing significance for the environmental planning and assessment in recent years. One reason for this, a great number of spatial data with their attributes is involved in environmental planning. GIS represents a highly efficient instrument for such planning tasks. The GIS can be used to develop natural and cultural resource inventory to identify contamination sources, to assess environmental constraints, selection of sites for land application of sewage waste. Suitability for various treatment techniques can be considered using soil, topographic and land use factors, integrated with information about the biological, chemical and physical properties of waste.

Wetland applications of GIS are another examples. The wetland issues have become a major source of interest to the professional and to the public.Unlike other environmental issues that are localized or found only in certain areas, wetlands are found almost everywhere. GIS and remote sensor technologies supply the information of a more general nature. In a regional inventory satellite and high altitude image data sets can provide a valuable resource or focal point for data analyses.

6

APPLICATION TO HYDROLOGY AND WATER RESOURCES

Application to Hydrology and Water Resources: Flood zoning and mapping, groundwater prospects and potential recharge zones, watershed management.

6.1 Application to Hydrology

The contrasting water bearing properties of different geological formations usually play an important role in the occurrence and movement of groundwater. The crystalline rocks of Archaean age occupy 93% of the total geographical areas. The narrow discontinuous patches of recent to sub recent alluvium along the major river courses occupy about376sq.km area in the district Hydro-geologically the weathered and fractured zones of the crystalline and the porous alluvium and coastal deposits constitute the main repository of ground water in the district. Depending upon water yielding properties of various formations, the district can be broadly grouped into three distinct hydrogeological units viz.Consolidated Formations, Semi consolidated Formations and Unconsolidated Formations.

Remote sensing has held a great deal of promise for the hydrology, but in spite of this promise, applied or engineering hydrology has been slow to embrace remote sensing as a useful source of data, presumably because existing techniques and data have been satisfactory for the limited applications. Most of the advances in using remote sensing for hydrology have come from new areas of the hydrological analysis; areas where existing methods were unsatisfactory or limiting and areas where sufficient data were sparse or nonexistent. These areas include General Circulation Model (GCM) land parameterizations, advances in the snow hydrology and measurements of soil moisture.

In spite of this somewhat cool acceptance, the impact of remote sensing on hydrology is likely to be great for several reasons. First, it has the ability to provide spatial data rather than point data. Second, it has potential to provide measurements of hydrological variables not available through traditional techniques such as soil moisture and snow water content. Third, it has the ability, through satellite sensors, to provide a long term, global-wide data, even for remote and generally inaccessible regions of the Earth.

The nature of remote sensing data

When considering how remote sensing data may be used in hydrology, it is necessary to consider the characteristics of remote sensing data and how these may be used to improve our understanding and capabilities in hydrology. There are four characteristics of remote sensing data that make it a potentially very powerful tool for advancing hydrological sciences. Each of these characteristics is given below:

Measuring system states

Thermal infrared and microwave remote sensing, because of their unique responses to surface properties important to hydrology such as surface temperature, soil moisture and snow water content, have the capability to measure these system states directly. However, using system-state data will require new models in which to incorporate the new data types. Such models would structurally resemble contemporary simulation models but would be more capable of accounting for spatial variability and changes. Also, the subprocess algorithms would be designed to use remote sensing data as well as the more traditional inputs.

Area vs point data

The use of data representing an area in which the spatial variabilities of specific parameters of the area have been integrated may help provide one of the keys to understanding scaling and scale interdependence in hydrological systems.

The capability to aggregate up in scale or disaggregate down in scale by electronic means may provide a perspective of scaling that may instill new insight to answering the scale questions that dominate scientific hydrology.

Temporal data

Remote sensing data from a satellite platform can provide unique time series data for hydrological use. The actual frequency of observation could vary from continuous to once every two weeks or so, depending upon the sensors and type of orbit. This approach is appealing because it may be a very cost effective method to monitor various hydrological states over very large areas as well as monitor the dynamic properties in hydrology. Temporal data may provide a means for imparting a hydrological interpretation to certain observations.

For example, observing the time changes in soil moisture may provide information on soil types and even hydraulic properties such as hydraulic conductivity. In fact the interpretation of soil properties as a remote sensing signature could be extremely useful for hydrology because it would represent an areal value rather than a point value determined in a laboratory or with a field measurement.

New data forms

Entirely new data types may be formed by merging several data sets of different wavelengths, polarizations, look angles, etc. to provide entirely new hydrological parameters that are developed from the unique characteristics of remote sensing. New data forms could also be considered to be combinations of remote sensing data combined with other spatial data (such as soil maps) and even point data through a data assimilation scheme or sophisticated GIS (Geographical Information System).

These and other ideas need to be explored through research that combines remote sensing and hydrological modelling. Each presents a unique opportunity for hydrologists to apply remote sensing in ways other than simple extensions of photogrammetry. Remote sensing can produce an integrated measurement that simultaneously observes several factors. It also gives a view that is uncommon to past thinking in that it looks at a relatively large area and somehow integrates information from the entire scene. A great deal of research is needed to learn how to interpret properly the complex response obtained from the various remote sensing instruments. To use these data effectively, there is a need to develop new concepts and to change the historical way of conceptualizing hydrological processes.

6.1.1 Water Resources: Flood zoning and mapping

Flood is a relatively high flow of water that overtops the natural and artificial banks in any of the reaches of a stream. When banks are overtopped, water spreads over flood plain and generally causes problem for inhabitants, crops and vegetation. During extreme flood event it is important to determine quickly the extent of flooding and land use under water. Flood map can be applied to develop comprehensive relief effort immediately after flooding. There are varieties of issues and uncertainties involved in flood mapping. Remotely senses data can be used to develop flood map in an efficient and effective way.

Data Requirement for Flood Mapping

Generally for flood mapping two sets of the remotely sensed data are required; one set consisting of data acquired before the flood event and the other acquired during the flood occurrence. The image before the flood usually used as the reference. Sometimes two reference images acquired for finding out the mean reference DN values of pre flood scenarios. However aerial photographs, DEM, water level measurements and the high water marks after flood events are required for the aid of analysis. The remote sensing data might be provided by the active or passive remote sensing system. In some of the studies a combination of active and passive remotely sensed data is used.

Difficulties

• Flood is a wave phenomenon and all satellites have their repeating intervals. So generally the time of acquisition of satellite data does not coincide with the time of flood peak that is related to the maximum inundation area.

• In most of the cases timely acquisition of flood data is prevented by obscuring cloud cover, especially in the monsoon countries where flooding occurs due to widespread precipitation over relatively long period of time. Usually passive remote sensing system as NOAA AVHRR, LandSat MSS, LandSat TM cannot receives the radiance from a cloud covered ground surface. So presence of cloud cover over the flooded area limits the usefulness of these data and the difficulties arises with the interpretation of whether a given area beneath cloud cover is dry or water.

• Due to lack of canopy penetration of Landsat TM data, flooded areas under dense canopies may not be detected by the classification of the TM data that results the underestimation of the flooded area.

• Active remote sensing system as SAR has capability of allowing delineation of flood boundary beneath cloud cover, vegetation canopies but actual application of SAR however frustrated due to a lack of regularly available data such as might be achieved using space borne SAR platforms. Aerial acquisition of SAR data also limited by the bad weather condition and the aerial extent.

Flood Mapping by Passive Remote Sensing System

Passive remote sensing data have been widely used for flood mapping used Landsat MSS data to delineate flood boundaries by monsoon rains in Bangladesh, Islam and Sado used NOAA AVHRR data for mapping the extent of flood and food hazard map of Bangladesh, used Landsat to delineate the maximum flood extent on a coastal flood plain of North Carolina, USA. The methodology applied by will be presented below as an example of the flood delineation using passive remote sensing data. The reasons of choosing this method are

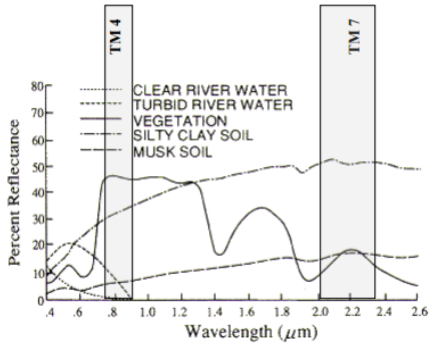
a) TM data are more appropriate than the AVHRR data for flood mapping because of coarser resolution of AVHRR.

b) The method is efficient and economic

c) It combines the DEM with the TM data to delineate flood boundary in forested region as TM data has the limitation in distinguishing the flooded area in forest canopies.

Methodology

Identifying water verses non water areas



Spectral reflectance of vegetation, soil and water

The first task of food mapping is identifying the water verses non water areas for the reference image and the flooded image. Two steps should be followed are:

i) Representation of the reflectance values of the water and non water feature

Here it should be noted that water has almost no reflectance in the infrared region. Referring to the figure above it is obvious that TM 4 (0.76-0.90 μm) is responsive to the amount of vegetation biomass where is water has almost no reflectance in this band. Hence TM 4 band is useful in identifying land and the water boundaries. But the confusion arises between the reflectance of water with asphalt areas i.e. road pavement and the rooftops of building as they reflect little back to the sensor and appeared black on the TM 4 image. It was found that on the TM 5 and TM 7 (2.08-2.35 μm) image the reflectance of water, paved roof surfaces and rooftops are different. But differences are slightly smaller in TM 5 than those are in TM 7. So the addition of TM 4 and TM 7 (TM 4+TM 7) will be useful for determining water verses non water area. So if the reflectance of a pixel is low in TM 4+TM 7 image the pixel is considered as water, otherwise it will be represented as non water

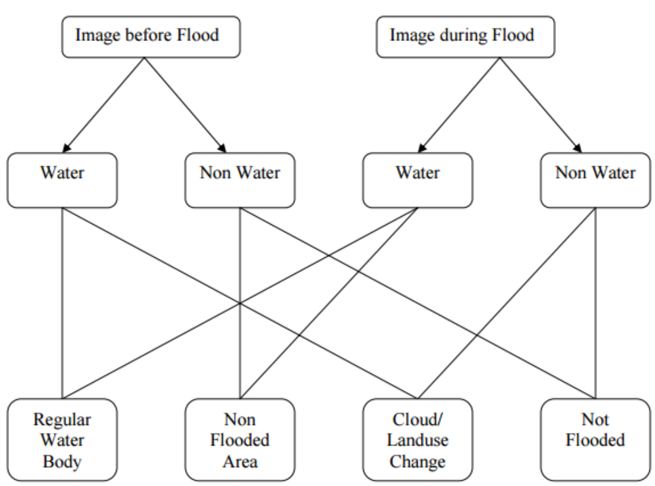
ii) Setup the cutoff value

After the representation of the reflectance of the water and the non water features, a cutoff value of DN has to be set to separate the water and non water features. Say this cutoff value is DN_c. So if a pixel's DN value is less than DN_c, the pixel will be categorized as water otherwise it would be assigned as non water. The selection of cutoff values might be done by ground truthing and by the histogram analysis of the (TM 4 + TM7) image.

Ground truthing involves taking observation directly form the field and through the analysis of aerial photos.

Determining flooded area during the flood event

After identifying water and non water area on before flood and during flood image the flood affected area could be made. Both of the images should be examined in a pixel to pixel basis.



Determination of flooded and non flooded area

There are four possible scenarios as shown in figure above:

i) Water-Water:

If a pixel is classified as water on the pre-flood image and water on the during flood image the pixel is not be considered as flooded, rather the pixel represents the regular water body as streams, lakes etc.

ii) Non Water-Water:

If a pixel is classified as non water on the pre-flood image and water on during flood image the pixel will be considered as Flooded.

iii) Non Water-Non Water:

If a pixel is classified as non water on both image, the pixel will be considered as Non flooded.

iv) Non Water-Water:

If a pixel is found that is classified as non water on the pre flood image but water on during flood image the pixel may be considered as changes in land use during period of image acquiring or cloud.

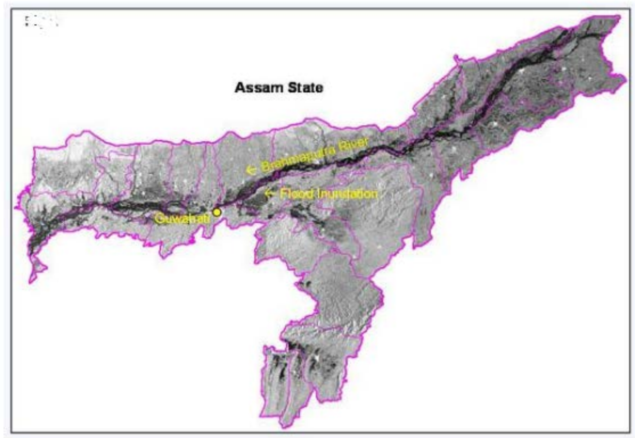
Remote sensing applications in flood analysis, the following areas of remote sensing data application in flood analysis are identified:

a. Flood mapping

b. Flood hazard mapping

A. Flood mapping

Mapping of the flooded areas using optical images is based on the fact that water absorbs or transmits most of the electromagnetic energy in the MR and MIR wavelengths, which results in the less reflection and in turn a dark color on FCCs. Optical remote sensing techniques, though provide very fine spatial resolution, are less capable of penetrating through the clouds, which limit their application in bad weather conditions. This is particularly a problem in flood monitoring. Use of microwave remote sensing techniques, with its all-weather capability greatly compliments the existing optical images to overcome this. Water surface provides the specular reflection of the microwave radiation and hence very little energy is scattered back compared to the other land features. The difference in the energy received back at the radar sensor is used for differentiating and to mark the boundaries of the water bodies. Radarsat mosaic of 4th and 7th July 2003 showing the Brahmaputra River flood affected areas in Assam is shown in figure.

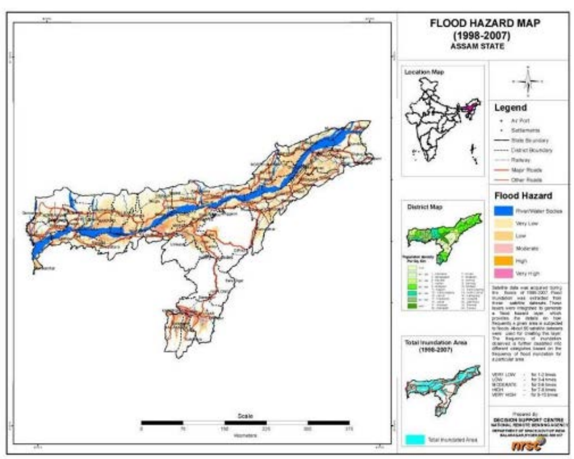


Radar sat image showing the Brahmaputra River flood affected areas in Assam

B. Flood hazard mapping

Flood hazard map of an area shows the areas likely to be inundated during floods of different magnitudes and with specific return periods. Such maps help to identify the area most vulnerable to frequent flood. Appropriate measures can be taken to regulate the development activities in such areas so as to minimize the damages in case of a flood.

Remote sensing data can be used to identify the flood affected areas continuously over a long period shown in figure. shows the flood hazard map prepared by the DSC, for the Brahmaputra River Basin in Assam Flood inundation information collected using the satellite remote sensing data for the period 1998-2007 was used for generating the map.



Flood hazard map prepared by the DSC, for the Brahmaputra River Basin in Assam

6.2 Groundwater Prospects And Potential Recharge Zones

Ground water controlling factors

Ground water is a part of the hydrological cycle and forms a dynamic system. It comes into existence with the process of infiltration at the surface. Then, it percolates into the ground, which comprises of different rock formations having different hydrogeological properties. The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. In other words, at a given location, the occurrence of ground water depends on the storage capacity and the rate of transmission. However, the hydrogeological properties of aquifer developed at the time of formation of the rocks with the initial geometric shape ranging from tabular to lenticular to cylindrical undergo different changes as a) The structural and erosional modifications change the thickness and lateral continuity of most major rock units, b) The hydrothermal alteration, contact metamorphism, digenesis and thermal-mechanical effects modify rock-hydraulic properties to differing degrees locally c) The fracturing alters permeability along fault / fracture zones. These changes bring significant variations in the hydrogeological properties within the rock type thereby changing the ground water storage and transmitting abilities both horizontally and vertically.

The framework in which the ground water occurs is as varied as that of rock types, as intricate as their structural deformation and geomorphic history and as complex as that of the balance among the lithologic, structural and geomorphic parameters. The entire column of subsurface acts as a three dimensional framework of groundwater conduits and aquifers and ground water barriers and confining units. Finally, the ground water prospects in the unit depend on the availability of the recharge which in turn depends on the prevailing hydrological conditions. Hence, the ground water regime can be defined as a combination of four factors, i.e.

1. Lithology

2. Landform

3. Structure

4. Recharge conditions.

The possible combinations of variety and intricacy are virtually infinite and the ground water conditions at a given site are unique.

b. Hydro geomorphological units

The combined units in which the Lithology, landform, structure and recharge conditions are unique are called ‘hydro geomorphic units’. They are considered as three dimensional homogenous entities with respect to hydrogeological properties and the recharge condition. In other words, they are treated as the aquifers. The ground water prospects are expected to be uniform in a hydro geomorphic unit.

However, some amount of heterogeneity may exist at micro level and it can be brought out only through large scale studies. It is basically depended on the scale of mapping. The degree of heterogeneity and the resultant variations in the ground water condition need to be accounted depending on the scale of study. In order to study the ground water prospects of a hydro geomorphic unit, inventory of the controlling factors i.e., rock type, landform, structure and recharge condition, by which the hydro geomorphic unit is made up of, has to be done and their hydrogeological characteristics need to be evaluated.

c. Relevance of Satellite Data

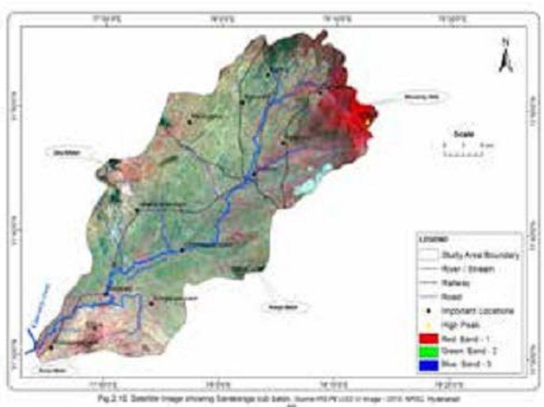
The hydro geomorphic unit is evolved from the original rock formation due to structural, geomorphological and hydrological processes. These processes and the resultant changes are manifested on the surface. Satellite imagery is the best data base where the information pertaining to all these parameters is available in an integrated environment. Based on the interpretation of satellite imagery in conjunction with limited ground truth information, the extraction and mapping of spatial distribution of the rock formations, landforms, structural network and hydrological conditions can be done accurately. They can be better studied and understood in association with each other. This is not possible through

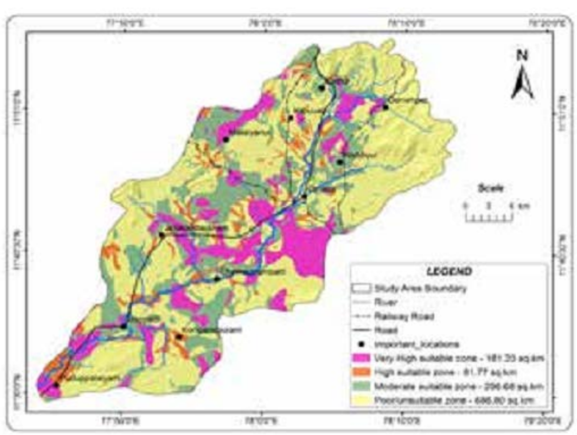
conventional ground surveys. Apart from this it takes lot of time and energy there by becoming the ground water survey costly. The geology maps showing rock types and major structures prepared by Geological Survey of India are being used for gross estimation of the resource and its distribution. Particularly, the data on the land forms, geological structures and recharge conditions are not at all available. For example, an area occupied by granite gneisses intruded by dolerite dykes and cut across by a number of faults and lineaments, it is possible to draw conclusions on – the dolerite dykes act as barrier for movement of groundwater, whereas the lineaments/faults which cut across them act as conduits for groundwater movement. The weathered zones within the granite gneisses contain limited quantities of groundwater. The water bodies (tanks) which are seen on the imagery as black patches not only provide irrigation facility in the area but also contribute for recharge to groundwater. Thus, by providing appropriate hydrogeological information the satellite data facilitate proper identification and mapping of prospective groundwater zones. The satellite data by providing spatial distribution of irrigated crop land as bright red patches are not only useful in calculating where and how much of groundwater is being tapped for irrigation but also in classifying the entire area into over-developed, under-developed, optimally developed and undeveloped zones, indicating the status of groundwater development. Analysis of multispectral high resolution data clearly depict minor faults and lineaments indicated by slips/offsets and gaps and in the dyke ridges. These faults/lineaments act as conduits for movement of water below the ground and form the prospective groundwater zone. With the help of field boundaries, cart tracks, stream courses and other reference points, these zones can be more accurately demarcated on the ground. In addition, some minor fractures originating from these major faults/lineaments and passing through water bodies (tanks) which also form potential sources for tapping drinking water to the nearby village could be delineated.

Potential Recharge Zones

The systematic analysis of AHP techniques on weighted parameters has produced a suitable groundwater recharge potential zone map in Arc GIS environment. As per the guidelines of CGWB, Government of India, the surface that has characteristics of deep soil depth with high permeability, slope and aquifer thickness associated with agricultural and settlements. It has been prepared from IRS P6 LISS IV satellite image procured from NRSA figure(a). Based on this concept, the normalized weighted raster was classified into high, moderate, low and unsuitable for groundwater recharge figure(b) . The result reveals that, around 181.20 sq.km of the total area has been identified as very high potential zone are covered central, southern and northwestern part were implement groundwater recharge zone. The high potential zones patches are noticed in groundwater recharge are covered 81.77 sq.km. The zones are comprised Fissile Hornblende Gneissic area moderate potential zones for groundwater recharge it's around 296.68 sq.km. The poor groundwater potential zones are covered 686.80 sq.km. Moreover, these landforms have the lineament density range between 0.5 to 2.0 m/km^2 .

The potential zones and its influencing characteristics for groundwater recharge are given in Table .





Geometric Mean Of Individual Parameters

Geomorphology	Geology	Slope (in %)	Soil type	Drainage density km/km²	Lineament density km/km²	Aquifer Thickness	Remarks
Valley Fill/ filled in valley buried Pediplain Shallow weathered shallow / Pediplain	Ultrabasic Syenite Carbonatite Complex Granitic/ Acidic rocks Ultramafic / Ultrabasic rocks	1-3%	Alfisols, Entisols	0-0.5	<0.5	>86	Very high suitable zone
Shallow Flood Plain Shallow Buried Pediment	Alkaline rocks Syenite Charnockite Fissile Hornblende Biotite Gneiss	3-10%	Entisols, Inceptisols	0.6-1.5	0.5-1.5	86-66	High suitable zone
Pediment/ Valley Floor	Fissile Hornblende Biotite Gneiss Charnockite	10-15%	Vertisols Miscellaneous Reserve	1.6-2.0	1.5-2	66-40	Moderate suitable zone
Dome type Residual Hills	Charnockite	15-30%	Forest	2.1-2.5	>2	<40	Poor/un suitable zone

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Dome type Residual Hills	Charnockite	15-30%	Forest	2.1-2.5	>2	<40	Poor/un suitable zone

6.2.1 Watershed management

Steps involved in watershed development:

1. Generation of drainage map

2. Delineation of watersheds

3. Characterization of watersheds on a smaller scale

4. Prioritization of watersheds/selection

5. Characterization of watersheds on a larger scale

6. Preparation of action plan

7. Implementation

8. Monitoring of developmental activities

9. Impact assessment

10. Post treatment management

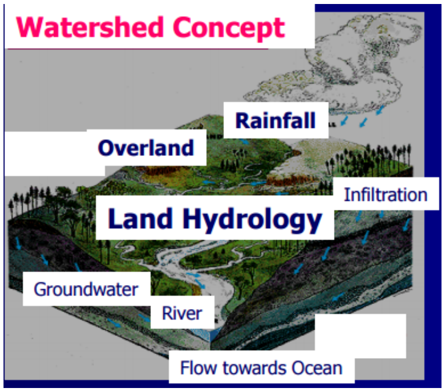
Watershed management is an adaptive, comprehensive, integrated multi-resource management planning process that seeks to balance healthy ecological, economic and cultural and social conditions within a watershed. Watershed management serves to integrate planning for land and water; it takes into account both ground and surface water flow, recognizing and planning for the interaction of water, plants, animals and human land use found within the physical boundaries of a watershed.

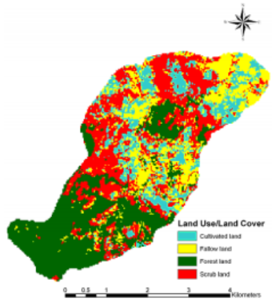
Watershed management provides a framework for integrated decision-making to help: assess the nature and status of the watershed; identify watershed issues; define and re-evaluate short and long-term objectives, actions and goals; assess benefits and costs; and implement and evaluate actions.

Adopting a watershed approach is founded on the basis that Alberta's water resources must be managed within the capacity of individual watersheds and that all Albertans recognize there are limits to the available water supply. What happens on the land and water in a watershed can affect the water supply that rivers provide. While land and water are closely linked, these resources have not historically been managed in a fully integrated manner. Focusing efforts at the watershed level provides a comprehensive understanding of local management needs and encourages locally led management decisions.

Concept of Watershed

Hydrosphere & hydrological cycle – gives better concept gives better concept about watershed





Hydrosphere – In physical geography - describes combined mass of waters found on, under and above the surface of the planet under and above the surface of the planet .

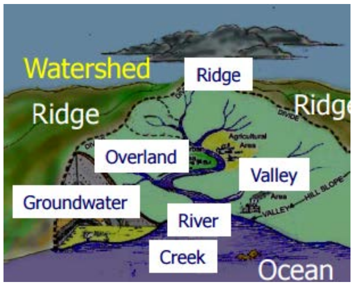
Hydrosphere consists waters of land (rivers and other water bodies, groundwater system etc.), oceans & atmosphere surrounding the land.

Hydrological Cycle Hydrological Cycle - Change in phase Change in phase of water in the hydrosphere

Watershed: Topographically delineated area delineated area that is drained by a stream system An area from which runoff resulting from precipitation flows past a single point into a stream, river, lake or an ocean.

Watershed Watershed - drains from surrounding drains from surrounding ridges to the common point such a leke of stream

Share boundaries with neighboring watersheds



Watershed Characteristics:

• Size

• Shape

• Physiography

• Climate

• Drainage

• Land use

• Vegetation

• Geology and Soils

• Hydrology

• Hydrogeology

• Socio economics

Size – vary from few sq.m to thousands of Sq.km.

• Main watershed Main watershed , Sub-watershed watershed , Milli watershed, Micro watershed, Mini-watershed etc.

Watershed Approach

Watershed approach - appropriate to solve several resources problems - for planning, implementation & management

Managing Land and Water Land and Water - watershed scale , appropriate- environmentally, financially & socially.

Environmental scale Environmental scale - watershed defined by natural watershed hydrology - Resources becomes a focal point in order to understand factors that contributes the problem.

Financial and social benefits of watershed approach Core of watershed approach - better understanding of environmental factors.

Tasks such as modeling, monitoring and reporting under watershed framework - saves time and money .

People’s participation pillar of watershed approach - gives sense of ownership; greater public involvement and ensures sustainability of interventions planned.

Integrated Approach

This approach suggest the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic needs of the people and animals in a sustainable manner. This approach aims to improve the standard of living of common people by increasing his earning capacity by offering all facilities required for optimum production. In order to achieve its objective, the integrated watershed management suggests to adopt land and water conservation practices, water harvesting in ponds and recharging of groundwater for increasing water resources potential and stress on crop diversi1cation, use of improved variety of seeds, integrated nutrient management and integrated pest management practices, etc.

Consortium Approach

Consortium approach emphasizes on the collective action and community participation including of primary stakeholders, government and non-government organizations and other institutions. Watershed management requires multidisciplinary skills and competencies. Easy access and timely advice to farmers are important drivers for the observed impressive impacts in the watershed.

These lead to enhance the awareness of the farmers and their ability to consult with the right people when problems arise. It requires multidisciplinary proficiency in field of engineering, agronomy, forestry, entomology, horticulture, animal husbandry, social science, economics and marketing. It is not always possible to get all the required support and skills-set in one organization.

Thus, consortium approach brings together the expertise of different areas to expand effectiveness of the various watershed initiatives and interventions

Necessity g of Watershed Management

a. For better water & land management.

b. For stability of land use in lower areas.

c. For arresting soil erosion, improving soil moisture reducing floods and droughts moisture, reducing floods and droughts.

d. For developing water, land and biomass resources with a focus on social and environmental aspects.

e. For judicious use of natural resources - active participation of stake holders, in harmony with the ecosystem.