CHAPTER II
REMOTE SENSING & GIS

2.1 REMOTE SENSING:

Almost all the turmoil of the world around us is beyond the reach of the sensors one is born with. Human eyes respond to light in the minute portion of the spectrum between 4000 and 7000^0A and ears to sound between 16 and 20,000 cycles/sec and the skin to relatively large changes in temperature and the rest goes unheeded (Parker & Wolff, 1973). Over the years, men have extended his limited capabilities for perceiving at a distance by building a variety of specialized instruments. Thus, the use of cameras, infrared detectors, and radio-frequency receivers to detect electromagnetic radiation, seismometers to detect acoustical energy and scintillation counters to detect radioactivity has become evident. We measure force fields with magnetometers and gravity meters and we acquire still more information about unknown objects with "active" systems like radar and sonar. All these devices allow doing what is today labeled as "Remote Sensing", which was coined for the first time in the early 1960s, by the staff of the Office of Naval Research (ONR), Geography Branch (Pruitt, 1979; Fussell *et al.,* 1986).

Remote sensing can be defined as, "the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study" (Colwell, 1983). Another definition of remote sensing reads as, "the non contact recording of information from the ultraviolet, visible, infrared and microwave regions of the electromagnetic spectrum by means of instruments such as cameras, scanners, lasers, linear arrays and/or area arrays located on platform such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing" (Jensen, 2004).

2.1.1 Principle:

The basic characteristic of Electro Magnetic Radiations (EMR) is its wavelength (Figure 4). Sun's light is the form of EMR that is most familiar to human beings (Mather, 2004). Solar radiation consists of wide range of wavelengths stretching from less than 10^{-6} μm to more than 10^{7} μm. This continuum is divided into several divisions called bands, which are useful for remote sensing.

A very small portion of this spectrum called the visible region is detectable to human eye (Figure 4). However the remote sensing sensors are equipped to sense variety of radiations that are otherwise beyond the scope of human eye.

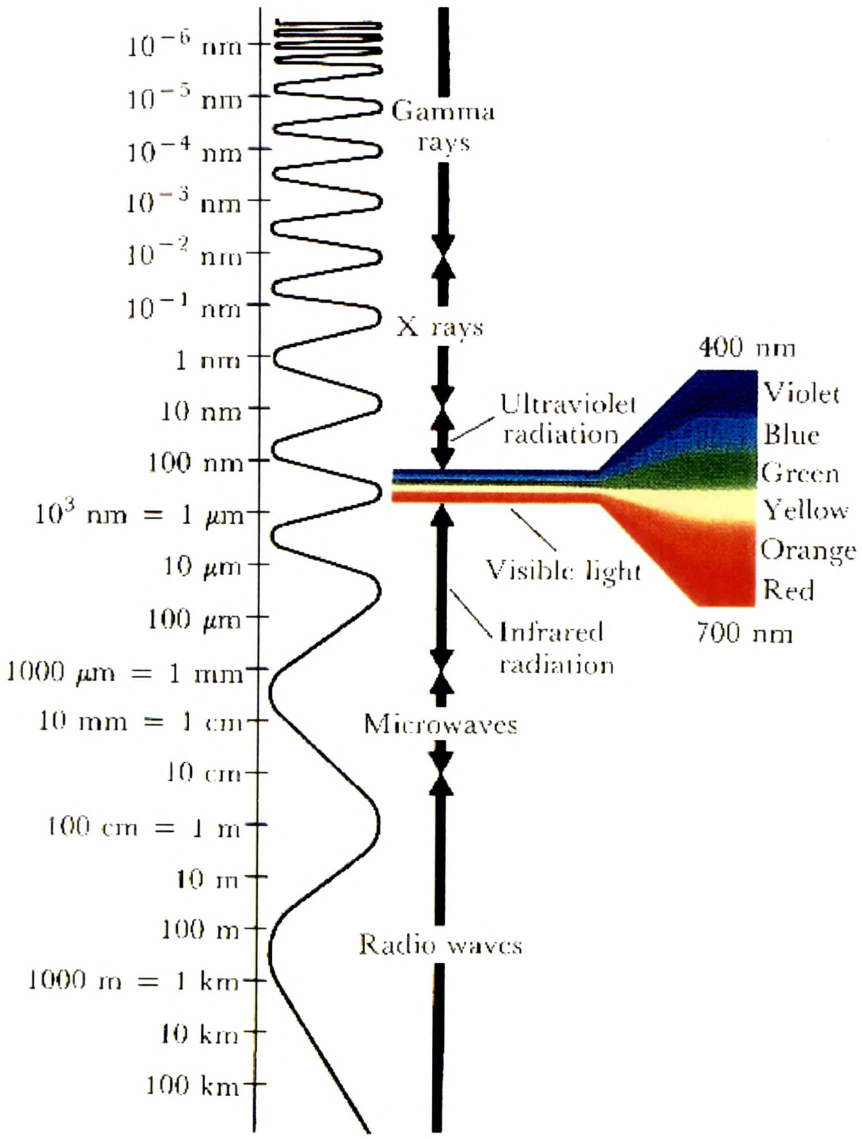

Figure 4. Electro Magnetic Spectrum

2.1.2 Atmospheric Windows:

Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These set of reflectance or radiance value is dependent on irradiance (incoming solar flux), viewing geometry of the sensor and the environmental factors (Nag & Kudrat, 1998). Strong absorption of EMR in specific wavelength region by constituents of atmosphere restricts the availability of the entire electromagnetic spectrum to passive remote sensing. However, electromagnetic spectra at specific wavelength spectra at specific wavelength regions are transparent to atmosphere and are termed as atmosphere windows, and these regions are being used in remote sensing (Figure 5).

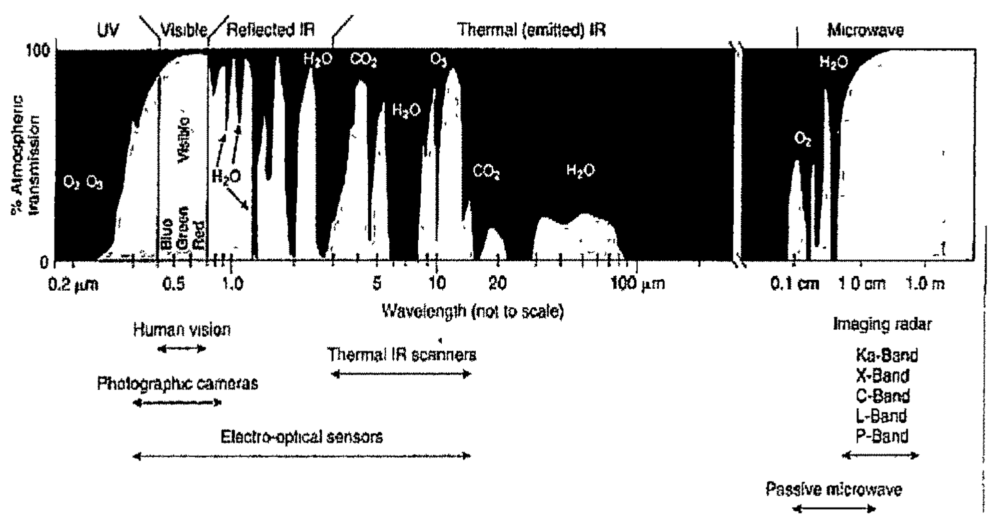

Figure 5. Atmospheric Windows

2.1.3 Spectral Signature:

Depending on the composition and nature of the material different objects show different spectral characteristics which is better called as "spectral signature", a set of measurement values for reflectance or radiance of the earth objects, each value corresponding to specific well defined wavelength interval (Slater, 1980). Changes in the amount and properties of the EMR become, upon detection by the sensor, a valuable source of data for interpreting important information on shape, size and other physical and chemical properties. Figure 6 depicts typical spectral reflectance curves of different materials. Comparing the spectral reflectance curves of vegetation and soil shows that healthy green vegetation almost always manifests the "peak-and-valley" configuration while soil curve shows considerably less peak-and-valley variation in reflectance. That is, the factors that influence soil reflectance act over less specific spectral bands (Lillesand & Kiefer, 2002).

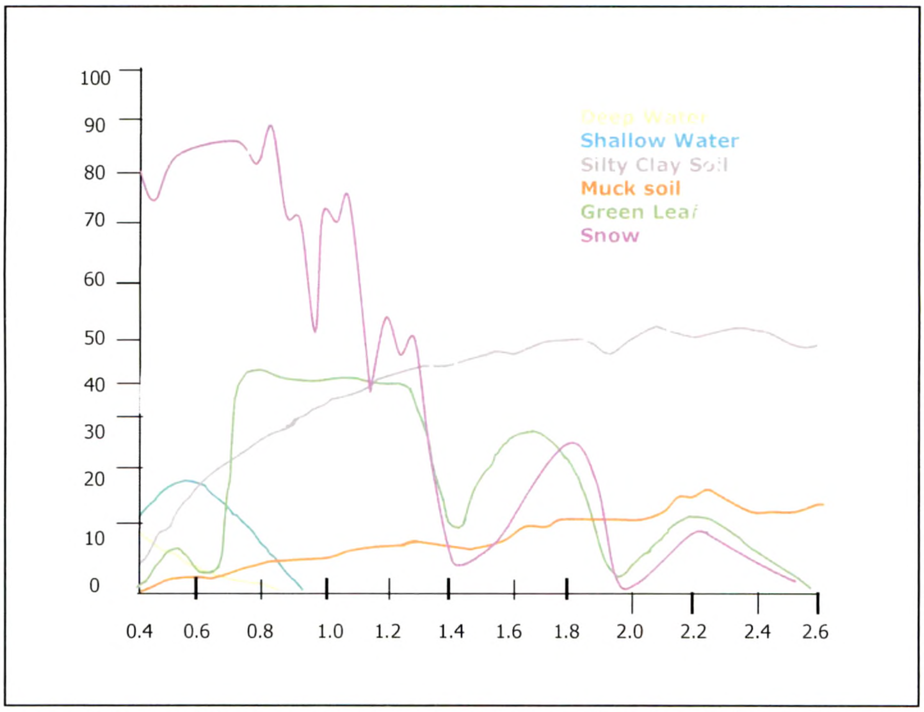

Figure 6. Spectral Reflectance Pattern of Different Materials

The spectral reflectance curves of soils are generally characterized by a rise in reflectivity as wavelength increases- the opposite, in fact, of the shape of the spectral reflectance curve for water. The characteristic spectral reflectance curve for water shows a general reduction in reflectance with increasing wavelength, so that in the near infrared the reflectance of deep, clear water is virtually zero. However, the spectral reflectance of water is affected by the presence and concentration of dissolved and suspended organic and inorganic material and by the depth of the water body (Mather, 2004).

2.1.3.1 Spectral Characteristics of Vegetation:

The spectral signature or reflectance of green vegetation is very distinctive and quite variable with wavelength. Dominant factors controlling leaf reflectance in the region from 0.35- 2.6 µm are depicted in Figure 7 & 8. In visible region

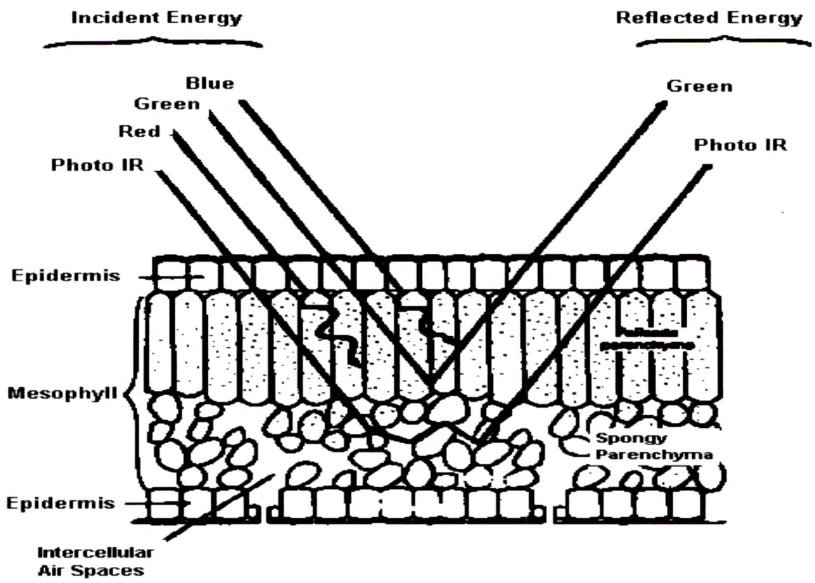

Figure 7. Absorption of Different Wavelengths by Cellular Layers of Leaf

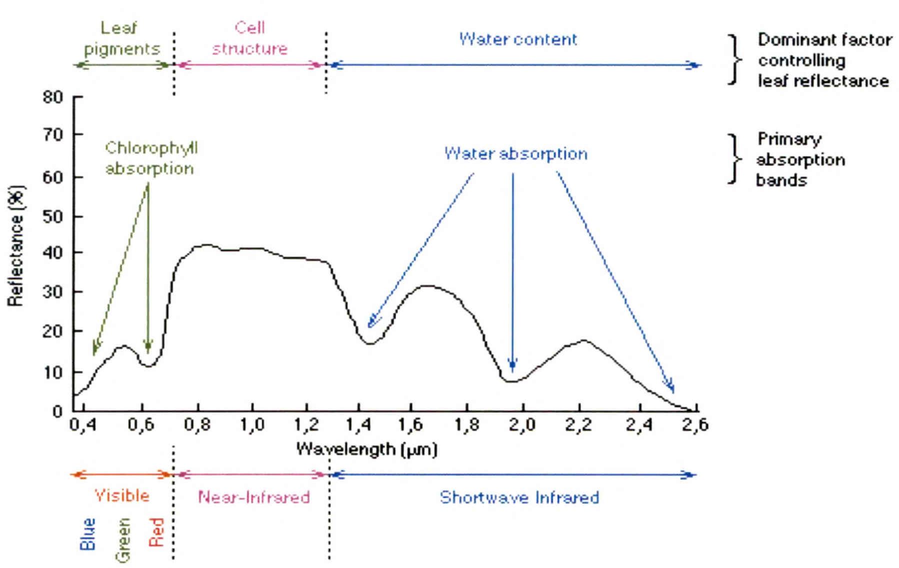

Figure 8. Spectral Reflectance of Vegetation

strong absorption are prominent at about 0.45 μm and 0.66 μm. The strong depressions or absorption in the blue and red regions of the visible spectrum corresponds to the chlorophyll absorption (Chl-a and Chl-b) bands, because the chlorophyll in the leaf absorbs most of the incident energy in these wavelengths for photosynthesis and higher reflection in green wavelength, cause normal healthy foliage to appear green (Mather, 2004).

There is a very marked increase in reflectance in passing from visible to near infrared region at ~0.7 μm. In this region healthy green vegetation is characterized by high reflectance, very high transmittance and low absorption as compared to the visible wavelength region. For majority of vegetation, it is observed approximately 45-50% reflectance and 45-50% transmittance and less than 5% absorption in the near infrared region (Hoffer *et al.*, 1978).

The internal structure of plant leaves, which is mainly mesophilic /spongy tissues, is very complex, and it is this internal structure that largely controls the reflectance of near infrared region (Gates *et al.*, 1965). The internal structures of different species are different and this leads to various amount of reflectance in NIR. However, in the middle infrared portion of the spectrum, the degree to which incident solar radiation is absorbed by vegetation is a function of the total water content of the leaves (Nag & Kudrat, 1998). As different species differ with respect to the concentration of photosynthetic pigments, moisture content, and internal organization of leaves, the difference in species composition, would be expressed in the multispectral data (i.e. data recorded from different regions/parts of the electromagnetic spectrum) and so different vegetation types can be separated through remote sensing.

In addition to the species discrimination, stressed and non-stressed plants can also be identified. As vegetation become stressed or senescent, chlorophyll absorption decreased, red reflectance increases and NIR reflectance decreases due to closing of inter-cellular air spaces. Ratio of the reflectance in the near infrared to red or any of the derived indices is sensitive indicators of vegetation growth/vigor (Dubey, 2002).

2.1.4 Data Acquisition:

The EMR emitted from sun consists of wide range of wavelength regions from cosmic rays to radio wave that plays an important role in obtaining remote sensing data. The EMR acts as medium of transmitting information from earth surface object to sensor board. Various objects on earth reflect, transmit/radiate and absorb EMR at different wavelengths and net reflected energy is captured by the sensor with different spatial and spectral resolutions, resulting in the generation of data in pictorial or digital form. The data captured by sensors in digital form is termed as image. An image consists of small equal areas of picture elements (pixel) in regular, rows and columns. Each pixel has numerical value called Digital Number (DN) that records the intensity of electromagnetic energy measured for the ground resolution cell represented by that pixel.

2.1.5 Sensors and Satellites:

Sensors are the devices used for making observations and consist of lenses with filter coatings to focus the area under observation and satellite act as a platform for the sensor. A sensor is an instrument that is sensitive to a particular physical radiation and has the ability to capture a quantity of radiation into a value that data can be stored and processed.

Sensors show certain characteristics viz. spatial resolution- the capability to discriminate the smallest object on ground, spectral resolution- the spectral bandwidth with which the imagery is taken, radiometric resolution- the capability to differentiate the spectral reflectance/emission between various targets, number of bands- the optimum number of bands required to extract at specific region of the EMR. A further important property of the remote sensing system is the temporal resolution of the system, that is, the time that elapses between successive dates of imagery acquisition for a given point on ground (Mather, 2004). The sensor characteristics are different for different sensors, which are used for various applications.

Sensors based on the radiation sensing properties are of two types viz. passive and active. Sensors which sense natural radiations either emitted or reflected from the earth surface are passive sensors while the one, which produce their own electromagnetic radiation are active sensors. Sensors whether active or passive depending on their data recording nature are again of two types, imaging (camera) and non-imaging (radiometer). Within imaging, the data recording may be instantaneous i.e. the area under the field of view of sensor is imaged instantaneously and image is then recorded electronically or on a photographic film or line scan i.e. the sensor records one picture element at a time to generate 2D image eg. Linear Imaging Self Scanning sensors (LISS III).

For remote sensing platforms-satellite, its orbital characteristics namely, revisit interval, swath width, illumination and observation angle, mission life time, altitude and resolution of remote sensing system are very important. Some of the major orbital characteristics of some of the important satellites round the globe are presented in table 5.

Table 5. Features of Different Remote Sensing Satellites

	SPOT	IRS series	LANDSAT	NOAA	IKONOS
Orbit	Near polar sun synchro-nous	Near polar sun-synchronous	Sun synchronous	Near polar sun-synchronous	Sun Synchro-nous
Altitude	832 km	904 km	233 km	833-870 km	681 km
Inclination	98.7 degrees	99.03 degrees	99 degrees	98.7 degrees	98.1 degrees
Equatorial crossing time	10.30 hrs	10.00 hrs	11.00 hrs	07.30 19.30hrs	10.30hrs
Period	101.5 min	103 min	103 min	102 min	98 min

2.1.5.1 Indian Imaging Systems:

Aerial photography was first used in India in the year 1920, in a survey experiment (Bhavsar, 1980). The Earth Observation Satellite of India (Bhaskara-I) was launched in 1979. This was followed by Bhaskara-II in 1981. The spatial resolution of the image from the Bhaskara satellite was about 1 km and the data was used for specific applications in geology, forestry, land use etc. However in 1970, Prof. Pisharoty and his colleagues initiated the use of multi-spectral information for early detection of coconut plantation disease, in India. (Dakshinamurty *et al.*, 1971).

India's first indigenously built sun-synchronous polar orbiting satellite, IRS-1A, was launched in March 1988, with the help of Soviet Launcher VOSTAK (Navalgund & Kasturirangan, 1983). The data was received at NRSA (National Remote Sensing Agency) ground station in Hyderabad. After the launch of first operational remote sensing satellite IRS-1A, IRS-1B which was identical to IRS-1A was launched in August 1991. IRS-P2 was the first satellite to be launched successfully by indigenously developed launching vehicle (PSLV) in October 1994. One of the best second generation satellites IRS-1C was launched in December 1995 while IRS-1D was launched September 1997 using PSLV-D4 (Joseph, 1996).

OCEANSAT was launched in June 1998 to study the various oceanic features like winds, temperature, humidity, waves and currents. The payload of OCEANSAT, Multi-frequency Scanning Microwave Radiometer (MSMR) can even penetrate through clouds. IRS P6 better known as ResourceSat was launched into polar orbit in October 2003. ResourceSat enhances the service capabilities in the areas of agriculture, disaster management, land and water resources with better resolution imagery. CARTOSAT-1 launched in May 2005, carries two state-of-the-art Panchromatic (PAN) cameras that take black and white stereoscopic pictures of the earth in the visible region. The cameras are mounted on the satellite in such a way that near simultaneous imaging of the same area from two different angles is possible. This makes CARTOSAT-1 unique and facilitates generation of three- dimensional maps. An overview of different earth observation satellites is given in Table 6.

Table 6. Indian Imaging Systems (CARG, 2002)

SATELLITE	SENSORS	BANDS (µm)	SPATIAL RESOLU -TION (m)	SWATH (km)	REPET-IVITY (Days)
IRS 1A, 1B	LISS-I	0.45-0.52	72.5	148	22
		0.52-0.59			
		0.62-0.68			
		0.77-0.86			
	LISS- II	0.45-0.52	36.25	74	2
		0.52-0.59			
		0.62-0.68			
		0.77-0.86			
IRS-1C, 1D	LISS-III	0.52-0.59	23.5 (70.5 for band 4)	141 (148 for band4) 70	24
		0.62-0.68			
		0.77-0.86			
		1.55-1.70			
	PAN	0.55-0.75	5.8	810	5
	WIFS	0.62-0.68	188		5
		0.77-0.86			
IRS-P4 (OCEAN SAT-1)	OCM	402-422	360	1420	2
		433-453			
		480-500			
		500-520			
		545-565			
		660-680			
		745-785			
		845-885			
	MSMR	6.6, 10.6, 18, & 21 GHz	120,80,40, 40	1360	2
IRS-P5 CARTO SAT-1	PAN	0.4 - 0.7	2.5	27.5 55	5
IRS-P6 RESOURCE SAT	AWiFS	4vnir & swir	59	700	5
	LISS-III	4vnir & swir	23.5	141	24
	LISS-IV	4vnir	5.8	23.5	24

2.1.6 Application Trends of Various Sensors for the Study of Natural Resources:

2.1.6.1 Geology:

Earlier Landsat TM data was considered reasonably good for regional geological mapping at 1: 250 000 scale or smaller (Bhattacharya, 1988). However, the availability of IRS-LISS III data of 5.8 m resolution has enlarged the scope of mapping at larger scales as well. Ravindran (1987) used IRS-LISS II data for lithological mapping of Dehra Dun area. For this mapping work, he used enhanced techniques such as principle component analysis, correspondence analysis, brightness index and edge enhancement for generating color composites.

Bhan *et al* (1989) applied Laplacian filtered bands and HIS transformed color composites of IRS-LISS I data for geological and structural interpretation of the hilly terrains of Shimla-Solan-Sarahan ranges and Nahan-Ponta area of Himachal Pradesh. Digitally enhanced images using edge enhancement and directional filtering had brought out several lineaments which are not discernible in the raw images in the Himalayan region (Ravindran & Bhan, 1991).

2.1.6. 2. Hydrology:

Satellite imagery can be used in delineating and identifying linear features such as fractures or faults and paleochannels which are usually the zones of localization of ground water in hard rock and alluvial areas respectively (Nag & Kudrat, 1998).

2.1.6.3. Soil:

Imhoff *et al* (1982) and subsequently Lee *et al* (1988) claimed that if PCA images can be use in addition to normal remote sensing data, land form delineation becomes more comfortable. For soil mapping, Fukuhara *et al* (1978) used ratio images in vegetated area.

Wetness index was attempted in assessing soil moisture (Crist & Cicone, 1984). Vande Griend *et al* (1985) used thermal data from geostationary satellites to demonstrate the feasibility of measuring soil moisture. Microwave remote sensing for measuring soil moisture and it spatial variation include both passive and active microwave approaches with several advantages. The depth of penetration of the microwave in soil is a function of moisture content. Soil moisture experiment with Shuttle Imaging Radar (SIR)-B was used to demonstrate the high resolution capacity of SAR from space platform (Wang *et al.*, 1986). C-band of SAR data collected from ERS-I has been use to derive soil moisture information.

Thermal band data of NOAA AVHRR channel 4 (10.5-11.5 um) and 5 (11.5-12.5 um) have been used for estimation of LST (Land Surface Temperature). LST is a useful input for modeling energy balance components and ultimately evopotranspiration (ET) i.e. for modeling of land surface processes (Bhattacharya & Dadhwal, 2005).

2.1.6. 4. Agriculture:

Most of the agricultural studies using remote sensing are done using FCC imagery of IRS-TM. Since every crop has its own unique leaf arrangement, growing period and unique internal leaf structure, spectral signature or characteristics will enable the user to discriminate various crop cover through remote sensing techniques. Several times it has been observed that two crops shows similar spectral signature on a given data. This can be circumvented by using multi-date data of *rabi* and *kharif* seasons. Pre-harvest crop production forecast for *kharif* season is poor due to the lesser probability to get cloud-free optical remote sensing data. Inorder to overcome this drawback, microwave data having the capability to penetrate cloud is used in yield models for rice (Dutta *et al.*, 2001).

The use of Vegetation Index images (NDVI, VI, GVI etc.) has been beneficial in giving the biomass status of plants (Tucker, 1979). Based upon the NDVI values generated from OCM sensor or Wide Field Sensor or Advanced Wide Field Sensor, the status/condition can be assessed (Rao *et al.*, 2005).

Following the LACIE (Large Area Crop Inventory Experiment) the first worldwide experiment to demonstrate the operational capability of the satellite based remote sensing technology or crop production forecasting (Mac Donald, 1980), a project on Crop Acreage and Production Estimate (CAPE) is operational in India under the aegis of the Remote Sensing Application Mission (RSAM) (Anonymous, 1986, Navalgund *et al.*, 1991). However in CAPE only singlé date data is used in order to keep data load low. In recent years the concept of using, advanced wide field sensor with lower spatial resolution but improved temporal resolution for multi-date crop classification can be adopted for large scale crop inventory (Vyas *et al.*, 2005). Crop acreage is even estimated at village level by Singh *et al* (2005b) using LISS-III data using maximum likelihood classification approach.

METEOSAT 5 TIR images or any other geostationary satellite like INSAT or Kalpana-1 could be useful in assessing the within season spatial and temporal distribution of rainfall and hence help in yield forecasting (Rao *et al.*, 2005). RADARSAT data has unique attributes such as all-weather and day/night capability. It offers considerable advantages in monitoring the dynamics of crop growth. Compared with optical remote sensing, radar has more ambiguous relationship with crop canopy variables (Panigrahy, 2000).

2.1.6.5. Forest:

According to the Society of American Foresters, the satellite imagery and related technology is one of the top ten advances in forestry in past one hundred years (Kushwaha, 2003). Monitoring of forests is not only limited at national level but at global scale as well (Hudson, 1987; Horler & Ahren, 1986; Malingreau *et al*; 1989, Singh, 1990). The Forest Survey of India (FSI) monitors the forest cover of India biennially using IRS-1B, LISS-I data. Monitoring of forest not only estimate coverage but also forest types, density, species composition, stand height, crown density classes, health and disease damages, forest fire etc. Landsat MSS and TM and AVHRR data have been used for this purpose. Pahari & Murai, 1998 have developed a population-deforestation model to relate the population density with cumulative forest loss, for which NOOAA-AVHRR data had been used. Bortolot & Wynne, 2005 have used small footprint LiDAR data for locating individual trees their crown boundaries and heights and also forest biomass. Air borne laser scanning have also been used for discrimination of individual tree such as White Cypress Pine and Poplar Box tree (Moffiet *et al.*, 2004).

Roy *et al.,* (1991) have applied Normalized Vegetation Index (NVI) on IRS-1A LISS-II data. Further, NVI band was added to normal four bands of IRS-1A LISS-II data in order to create 5 band data. In another investigation, the radiometrically calibrated data of B3 and B4 of WiFS were used to calculate NDVI image. Ricotta *et al.,* 1999 had used annual time-series of broad-scale AVHRR NDVI for mapping and monitoring of net primary productivity. Madhavan Unni (1983) applied supervised classification using the data of leaf fall season, in part of Nallamalai Hill Range. Vogelmann and Roac (1986) using Landsat TM simulator data have used band ratios to discriminate low and high damage sites. It is interesting to note that spatial mix of different digital processes is also possible. For example for IRS-1C LISS-III scene covering Kaziranga NP, NDVI has been used for the areas inside the park while maximum likelihood classification for the rest of the area (Rao *et al.,* 1996). Roy *et al.,* 1996 have prepared Biotic Pressure Zone Map (BPZM) of Agra Reserve Forest using LISS-III data. For forest density mapping especially for density classes greater than 40%, Nandy *et al* (2003) advocated use of BM (Biophysical Modelling) which combines data from four indices viz. Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index (SI) and Thermal Index (TI). Similar study has also been adopted by Rikimaru and Miyatake (1997) for predicting forest density as well as health of the forest. Moderate Resolution Imaging Spectroradiometer (MODIS) data with its daily coverage over large regions with 250m resolution data in visible and near IR band was used for rapid ecological assessment studies by Chand *et al* (2005).

Studies related to merged data like LISS-III and PAN merged data that provides an advantage of colour and high resolution respectively. Such data has been used for forest growing stock assessment (Benchalli & Prajapati, 1998) as well as identification of suitable sites for Joint Forest Management in Katawari block of Barbatpur range of MP (Singh, 2003). Merged data is also quite useful in delineation of tree cover within and outside forest areas (Singh *et al.,* 2005a). Chhabra & Dadhwal (2004) has used SPOT-VEGETATION data to estimate monthly net primary productivity and net carbon fixation over India.

Night time data of Advance Along Track Scanning Radiometer (AATSR) on board ENVISAT-1 has the capability to detect forest fires that occupy less than a pixel area (Badrinath *et al.,* 2004a).

The remote sensing data provided opportunity to assess land cover status of dynamic ecosystems. Satellite derived images provide the best solutions to identify and map jhum-affected forest loss (Singh *et al.,* 2003a)

Similarly Katul and Albertson (1998) investigated high order closure models for forest canopy. Harding *et al.,* 2001, used laser altimetry to identify the canopy height profiles for validating the closed canopy of broad-leaved forest. The new coming very high spatial resolution satellite sensors, namely IKONOS-2 and QuickBird, combine the high spatial resolution of air-borne data and the more stable radiometric quality of space-borne data (Tanaka & Sugimura, 2001). Francois *et al* (2002) has used IKONOS data for forest stand mapping as well as species discrimination. This offers forest managers another valuable source of data suited for stand level forest inventory and mapping.

2.2 Synergy of RS and GIS:

In any approach applied to remote sensing, not only must the right mix of data acquisition and data interpretation techniques be chosen, but the right mix of remote sensing and "conventional" techniques should also be identified. RS data are currently being used extensively in computer based GISs (Lillesand & Kiefer, 2002). GIS is complementary to remote sensing technology and as well as tool for spatial representation of information obtained from remotely sensed data, which are essential as management input. The combination of image processing and GIS technologies are enormous and it is now becoming extremely difficult to differentiate both these technologies (Parker, 1991). Recent research on remote sensing-GIS integration supports a combination of data sources and techniques to provide a more comprehensive analysis of environmental changes. The GIS environment permits the synthesis, analysis and communication of virtually unlimited sources and types of biophysical and socio-economic data; as long as they can be thought of as the "eyes" of such systems providing repeated, synoptic (even global) vision of earth resources from aerial or space vantage point.

2.3 GEOGRAPHIC INFORMATION SYSTEM (GIS):

2.3.1 Roots of GIS:

GIS has its roots in the stimulus provided by the development of remote sensing, in the late 1960s and early 1970s, as a potentially cheap and effective source of earth observations. While many of the techniques for processing remote sensing data are highly specialized, GIS techniques become important in order to combine information derived from remote sensing with other collateral information (Star *et al.,* 1997).

It is however, important to note that the earlier investigators also realized the importance of such a computerized analysis of the spatial data. David Bickmore, the primary GIS innovator, has discovered that, GIS stems from the benefits of automating the map production process. Once information of any kind is in digital form, it is much easier to manipulate, copy, edit and transmit. Ray Boyle invented the "free pencil" digitizer and by 1964, Bickmore and Boyle set up the Oxford system for high quality digital cartography (Rhind, 1988).

2.3.2 GIS and Its Components:

GIS is a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth (Heywood *et al.,* 1998). Thus the four key activities performed by GIS are measurement, mapping, monitoring and modeling (Reddy, 2001).

The environment in which GIS operates is defined by hardware (the machinery including a host computer), a digitizer or scanner for converting the input data, a plotter for presentation of processed outputs and video display unit for commanding the systems by a user, the software (programs that tell the computer what to do) and the data (Pathan, 2002).

Thus, the four basic components of GIS are-

1. Geographic data base including both spatial and non-spatial databases
2. Hardware
3. Software
4. Users.

2.3.3 The Data Model:

The procedure used to convert the geographic variation into discrete objects in GIS environment is called a data model. There are two data models available to represent this variation in GISs. They are-

1. Raster data model

A raster model tells what occurs everywhere at each place in the area. Generally, raster data has high storage requirement. The basic entity in raster data is the grid cell hence it is not easily amenable to association of attribute data with spatial features such as points, line and polygons. Thus, it suffers to present precise details of measured quantities due to the discretization.

2. Vector data model

A vector model tells where everything occurs, gives a location to every object. Vector data is precise and has no approximate errors for measured quantities like area, length, perimeter etc. However, overlay and spatial analysis operations are computationally slower than raster data (Pathan, 2002).

2.3.4 Application of GIS-based Remote Sensing:

The integration of RS-GIS tremendously increases the scope of application rather than used in solitary. The most common application of this combination is the land cover mapping. Further such a combination is preferred, where the integration of spatial data with current information is required such as Land Information System (LIS) (Nag & Kudrat, 1998). Recently, GIS packages are also supported by Digital Terrain Models (DTMs) which has further enlarged the applicability. With better resolution and with always improving software, the topographical mapping requirements are being met by GIS remote sensing combination. It has become valuable source for cross checking or updating in digital surveying. Furthermore, the GIS software now accepts the GPS information in this program which is an additional advantage. For example the ARC/INFO GIS software now accepts GPS data through its GEOLINK module. A customized Unix-Arc Info based package "BIOCAP" is used for Landscape Analysis and Biodiversity characterization.

Rout *et al* (2005) demonstrated the use of orbital remote sensing along with GIS to analyze the impact of man made disasters on land and water over a period as in the case of breaching of the NALCOAsh pond which had caused a serious havoc in 26 villages of Angul district of Orissa.

RS and GIS was used in assessment of the status of the world's remaining closed forests (WRCF), population distributions, and protected areas in global biodiversity hotspots (Hua Shi & Singh, 2002). Robert *et al* (2000) developed an implemental habitat fragmentation model with the aid of mathematical graphs This integration can be of great help to the forest department in the enhancement, updating and diversifying the forestry knowledge of the state and national levels (Khan & Saxena, 1997) and also for change detection (Karia, *et al.,* 2001; Jayakumar & Arockiasamy, 2003)) monitoring and planning of forest, by mulitemporal interpretation of satellite data (Krishna, 2001). Nigam (2000) also investigated the application and evaluation aspects of remote sensing and GIS in the biomass estimation. While Singh (2004) and Karia & Garge (2006) used both these technologies for preparing forest management plans. Also fire danger maps for tropical deciduous forests using MODIS data has been generated (Badrinath, 2004b).