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Remote Sensing Applications

National Remote Sensing Centre

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Forest and Vegetation

3.1. Introduction

Forests are the natural resource, which provide mankind with numerous benefits both in goods and services. Managing this important resource base both spatially as well as temporally dynamic, can be a daunting task without the utilization of proper spatial tool. Space technology has immense influence in the decision-making processes especially in areas like forest resource management. Remote sensing as a tool has facilitated systematic and hierarchical approach of forest resources assessment and its monitoring using sensors of different spatial and spectral capabilities, the characterization, quantification and monitoring including specific efforts towards understanding the structure, composition and function of different natural habitats/ecosystems. These studies have provided key inputs for the regulation of the impact of developmental activities and to sustain the delivery of natural ecosystem goods and services. Forest resource assessment in India is being carried out in different levels e.g., bi-annual forest cover mapping using satellite remote sensed data.

With the availability of basic spatial coarse scale databases for important ecosystems, efforts have been made for understanding ecosystems structure and processes. The spatial information generated using remote sensing data is used in conjunction with ground based information in geospatial domain. Subsequently values have been added in terms of spatially explicit quantification for growing stock and biodiversity assessment. Process understanding related to landscape change and simulation, carbon sequestration, hydrology, generic ecosystem patterns, species niche models and regional climate models have also been addressed. The web-enabled information systems with significant impact factors are also useful to efficiently process, query and disseminate the data.

Optimal sampling designs for forest timber volume estimation; Automated forest cover retrieval and change assessment; Species exploration and niche modeling; Biodiversity monitoring and change modeling; Vegetation stress analysis; Forest ecosystem responses to climate change and anthropogenic impacts; Ecological Foot Printing analysis for sustainable development and Forest vulnerability and change assessment are the thrust areas identified for the retrieval of forest parameters using high resolution and hyperspectral data. But gaps in the information still exist in areas like forest fragmentation causes, invasion of exotics, rapid fire alarm system, shifting cultivation assessment and biodiversity assessment. This can be achieved through development of sensors with higher spatial and temporal resolution as well as enhanced spectral capabilities. Ground based information database is also lacking in Indian sub-continent region and this needs to be looked into urgently for spatial understanding of the ecosystem processes and their subsequent upscaling for regional level management.

3.2. Global and National Issues, Scenarios and Developments

3.2.1. Global Scenario

Retrieving information about forest resources is a process for obtaining information on the quality and quantity of forest resources and forms the foundation of forest planning and forest policy. While early concepts of sustainable forest management and forest inventory focused on timber production, modern forest inventory concepts support a holistic view of forest ecosystems addressing not only timber production but also the multiple functions of forest as well as the need to understand the functioning mechanisms of forest ecosystems.

Forest resources assessment facilitates a multifaceted analysis and study of forests is not only an important source of subsistence, employment, revenue, earnings, and raw materials to a number of industries but also critical for their vital role in ecological balance, environmental stability, biodiversity conservation, food security, and sustainable development of countries and the entire biosphere. Forests have to be managed judiciously not only for environmental protection and other services but also for various products and industrial raw material. In some parts of the world biological resources are being depleted faster than they can regenerate. Following the 1992 United Nations Conference on Environment and Development (UNCED) conference in Rio de Janeiro, considerable progress has been made in the area of sustainable forest management (Table 3.1). For example, the International Tropical Timber Organization (ITTO) and the Forest Stewardship Council (FSC) developed criteria and indicators for sustainable forest management and certification. The Kyoto Protocol of the United Nations Framework Convention of Climate Change (UNFCCC) describes measures to mitigate greenhouse gasses effects and addresses in Article 3.3 in particular the impact of deforestation and afforestation in global climate change. The Convention of Biological Diversity (CBD) that was ratified in 1994 deals with the protection and maintenance of biodiversity.

The information requirements from forest owners, policy planners, the scientific community, and society in general concerning forest resources have been growing steadily since the 1950s when the main focus was on information about timber supply. The multiple functions of forests biomass, global warming, biodiversity, and non-wood goods and services have since gained prominence.

The thematic scope of forest inventories can vary considerably. UNCED criteria and indicators for sustainable forest management have been formulated through several international, national, and nongovernmental processes. These include the Pan-European (or Helsinki) process (for European forests), the Montreal Process (for temperate and boreal forests), the Tarapoto Proposal of Criteria and Indicators for Sustainability of the Amazon Forest the United Nations Environment Program (UNEP) Food and Agriculture Organisation (FAO) Expert Meeting on Criteria and Indicators for Sustainable Forest Management in Dry-Zone Africa, or the Lepaterique Process of Central America. The ITTO, the Tarapoto Process (TARA), the Centre for International Forestry Research (CIFOR), the African Timber Organization (ATO) and the Central American Commission for Environment and Development (CCAD) developed systems of criteria and indicators for sustainable forest management which cover administrative, economic, legal, social, technical and scientific issues which affect natural forests and plantations. The criteria define the essential factors of forest management against which forest sustainability may be assessed. Each criterion relates to a key management factor which may be described by one or more qualitative, quantitative, or descriptive indicators. Through measurement and monitoring of selected indicators, the effects of forest management action, or inaction, can be assessed and evaluated and action adjusted to ensure that forest management objectives are more likely to be achieved. Table 3.2 summarizes the criteria and indicators identified by the processes and initiatives and should facilitate the definition of inventory objectives.

Table 3.1: Increase in information needs about forest lands in the USA (source: Franklin, 2001)

Timber	Multiple resources Timber	Biomass Multiple resources Timber	Global warming Biomass Multiple resources Timbers	Ecosystems biodiversity NWGS Global warming Biomass Multiple resources Timber	Non forest lands habitats, old growth and primary forests Ecosystems biodiversity NWGS Global warming Biomass Multiple resources Timber
1950s	1960s	1970s	1990s	1990s	2000+

3.2.2. National Scenario

The Indian sub-continent is known for its diverse bioclimatic regions supporting one of the richest floras and fauna in the world. The continent is a confluence point of three major terrestrial biogeographical realms (viz., the Indo-Malayan, the Eurasian and the Afro-tropical) and the Antarctic realm and is ranked as one of the mega-biodiversity countries in the world with 49,219 numbers of plant species and 89,451 animal species. According to an estimate about 30 percent plant species are endemic to India.

The natural terrestrial ecosystems like forests, grasslands, scrub lands, fresh water & ocean systems, microbial ecosystems, managed vegetation systems-agriculture and plantations provide immense potential in terms of Bioresources. India has a forest cover of 67.8 million ha (covering 20.64% of total geographic area). Forests are widely distributed across the country across different bioclimatic and topographic zones. Indian forests offer valuable ecosystem services as carbon sinks, soil erosion control, flood mitigation and various goods. Its rich floral diversity is represented by 47,000 plant species. Much of the demand for timber, fuel wood and fodder are met through these forests.

The need for understanding and assessment of this multiplicity of biodiversity in terms of ecosystem services and goods is important in order to design appropriate conservation strategies. Wood products removed from forests and other wooded land constitutes an important component of the productive function. The standing stock volumes

Table 3.2: Criteria and indicators for sustainable management
(source: Franklin, 2001)

Extent of forest resources and global carbon cycles:
Area of forest cover
Wood-growing stock
Successional stage
Age structure
Rate of conversion of forest to other use.
Forest ecosystem health and vitality external influences:
Deposition of air pollutants
Damage by wind erosion
Forest vitality indicators
Incidence of defoliators
Reproductive health
Forest influence indicators
Insect / disease damage
Fire and storm damage
Wild – animal damage
Anthropogenic influence indicators
Competition from introduction of nonnative plants
Nutrient balance and acidity
Trends in crop yields
Biological diversity in forest ecosystem :
Ecosystem indicators
Distribution of forest ecosystems
Extent of protected areas
Habitat suitability
Forest fragmentation
Area cleared annually of endemic species
Area and percentage of forest lands with fundamental ecological changes
Forest fire control and prevention measures
Species indicators
Number of forest- dependent species
Number of forest-dependent species at risk
Reliance on natural regeneration
Resources exploitation systems used
Measures for in situ conservation of species at risk
Genetic indicators
Number of forest-dependent species with reduced range
Productive functions of forests:
Percentage of forests/other wooded lands managed according to management plans
Growing stock
Wood production
Production of non-wood forest products
Annual balance between growth and removal of wood products
Level of diversification of sustainable forest production
Degree of utilization of environmentally friendly technologies

and the volume of wood removed indicate the condition of the forests and economic and social utility of forest resources to national economies and local communities. This information contributes to monitoring the use of forest resources by comparing actual removal with the sustainable potential.

Besides, there has been growing recognition of the role of Non Wood Forest Products as an integral part of sustainable forest management in developed and developing countries. A wide variety of products are collected from forests, woodlands and trees outside forests – a major portion of which are consumed by households or sold locally, while some find export markets. Understanding the potential contribution of NWFPs to sustainable rural development, especially in poverty alleviation and food security, requires good statistical data, which in most cases are gathered sporadically and are often unreliable.

Traditional rural population, particularly the tribes / aboriginal people depend heavily on very large spectrum of bio-resources associated with forest landscapes. Around 20,000 plant species are believed to be used for medicine in the developing world. In India the knowledge about medicinal value of plants has evolved in the form of traditional systems of medicinal sciences like, Unani, Ayurveda and Siddha. More than 8,000 species are used in some 10,000 drug formulations. It is estimated that about 0.5 million ton (dry weight) of plant material is collected each year from the forests. The global plant based drug trade is projected around US$ 62 billion with a 7% annual growth rate but India has only 2.5% share in it. The disproportionate demand and destructive methods of extraction have put unreasonable pressure on our wild phyto-resources. Due to this, pressing need is felt to have a reliable database on phyto resources such that a sustainable strategy can be formulated.

However, anthropogenic pressures are taking a heavy toll on the country's forests. About 2.5 Mha of the areas are under shifting cultivation. Forest fires cause a loss of nearly 10 million US$ every year. 95 % of these forest fires is man-made. Other types of biotic disturbances are grazing, mining activities, and construction of dams, agricultural conversions and urbanization. In view of the above, the precise estimates of Bioresources, their availability, location and extent, extraction and renewal systems are very important.

3.3. Conventional / Ground / Recent methods – Remote sensing

The forestry or vegetation science is one of the established and well flourished branches of science and we have at least one century old tradition of forestry management records. Similarly in the last decade several ecology and forest schools have contributed significantly in the development of basic concepts on structure and function of ecosystems. However, these so called conventional methods stand alone had several limitations. One of them was that they were not spatially explicit as well as there was lot of difficulty in revising those observations as well as there was no surrogate available to model them for different scenarios or for different niche conditions. Here came the advantages of remote sensing technology. With the mapping and stratification through remote sensing, the area coverage could be very large with even low intensity sampling by taking the advantage of stratification. The temporal revisit of the satellites have made it possible to assess and analyse changed scenario with better accuracy and precision. Additional applications include such as forest land appraisal, timber harvest planning, monitoring, logging and reforestation, planning and assessing plant vigor and health in forest nurseries, mapping "Forest fuels" to accesses fire potential, planning fire suppression activities, assessing potential slope features and soil erosion, planning forest roads, inventorying forest recreation resources, wildlife and assessing wildlife habitat, and monitoring vegetation regrowth in fire lanes and power line rights-of-way.

The terrestrial vegetation systems like forests, grasslands, scrub and agriculture provide unique reflectance properties of electromagnetic radiation received enabling to characterize using satellite remote sensing. In view of the very large extent and heterogeneity of the country, the modern tools like satellite remote sensing technology which can help in deriving synoptic and periodic information on Bioresources from forests, grasslands and scrub is considered as one of the potential complimentary tools for conventional ground assessment.

3.3.1. Satellite Remote Sensing Applications in Forestry

Remote sensing refers to the phenomenon of recording/observing/perceiving objects or events at remote places. In remote sensing, the sensors are not in direct physical contact with the objects or events being observed. The process of acquiring information about earth surface features, from orbiting satellites is known as Satellite remote sensing.

Technically, remote sensing usually refers to the technology of acquiring information about the earth surface and atmosphere using sensors onboard airborne (aircraft, balloons) or space borne (satellites, space shuttles) platforms. Most remote sensing is performed from orbital or sub orbital platforms using instruments, which measure electromagnetic radiation reflected or emitted from the terrain. Some sensors use other mediums such as magnetic fields, sound waves, *etc*. Remote sensing is a technique that can be used in a wide variety of disciplines, but is not a discipline or subject itself. Digital image processing helps scientist to manipulate and analyze the image data produced by these remote sensors in such a way as to reveal information that may not be immediately recognizable in the original form. The primary goal of remote sensing is not only the pursuit of knowledge, but also the application of any knowledge gained.

Optical sensors detect solar radiation in the visible and near infrared wavelength regions, reflected or scattered from the earth, forming images resembling photographs taken by a camera high up in space.

Different materials such as water, soil, trees, buildings and roads reflect visible and infrared light in different ways. Knowledge of spectral reflectance signatures of various materials on earth is thus required for interpretation of optical remote sensing images. Satellites acquire the digital data and transmit it to the ground stations, which can then be used to reconstitute an image of the earth's surface. Acquisition of images of earth from space has opened new frontiers in mapping. The multi-spectral satellite images provide definitions of vegetation patches, which are related to phenological types, gregarious formations and communities occurring in unique environmental setup. The temporal images help in monitoring all back processes a landscape has experienced (Delcourt and Delcourt, 1988). Satellites provide nearly global coverage of the Earth with spatial resolutions and repetition rates that vary from one platform to another. Improvements in spatial resolution have enabled availability of data in varying scales (Figure 3.1).

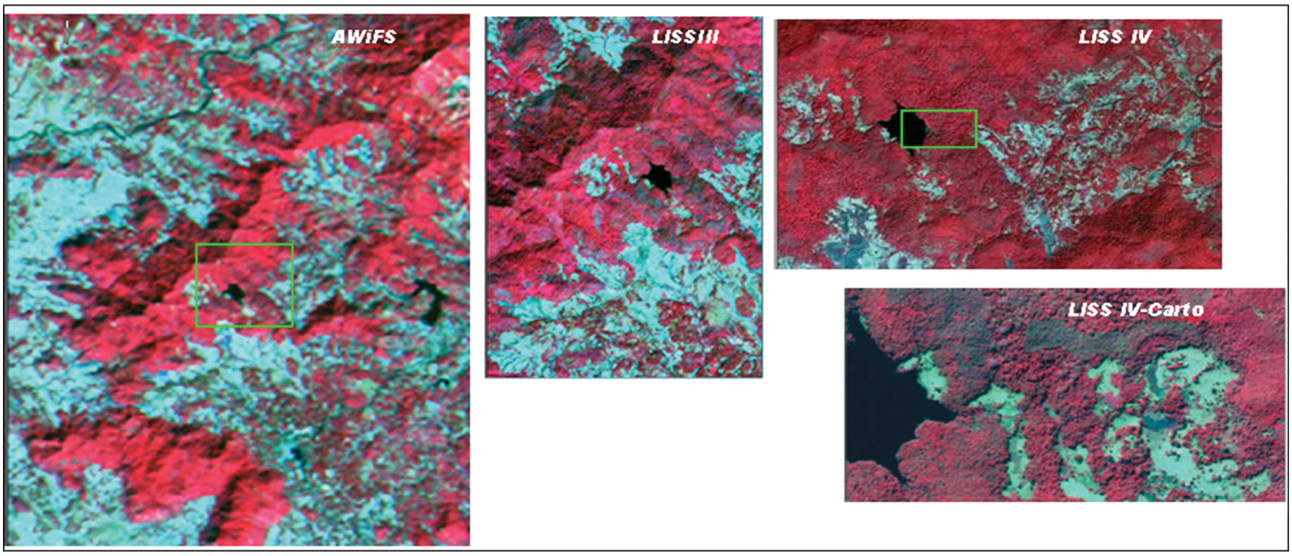

Figure 3.1: Scale diversity of remote sensing data

The images also provide digital mosaic of the spatial arrangement of landcover and vegetation types amenable to computer processing (Coulson *et al.*, 1990; Chuvieco, 1999). Biophysical spectral modeling techniques allow stratifying vegetation types based on the canopy closure (Roy *et al.*, 1996). Such an approach allows mapping and monitoring the forest condition and degradation processes.

Attempts have also been made to quantify forest biomass/volume and productivity using stratified sampling and spectral response modeling (Roy, 1994; Roy & Ravan, 1996). It is reported that the microwave remote sensing provides better estimation of biomass / volume due to better penetration. The surface and volume backscatter have strong relationship with the density and biomass (Hussin *et al.* 1991; Dobson *et al.* 1992; Luckeman, 1998). Recent studies indicate that the multi-wavelength, multi-polarization and varying look angle microwave sensors further improve mapping of structural parameters (Sardar, 1997; Pierce, 1998).

3.3.2. Multispectral basis of Remote Sensing and Vegetation

Spectral Signatures is the variability in the remote sensing data to identify the earth surface features spectrally. The proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending upon their material type and conditions. These differences permit us to distinguish different features on an image. The wavelength dependency means that, even within a given feature type, the proportion of reflected, absorbed, and transmitted energy will vary at different wavelengths. A graph of the spectral reflectance of an object as a function of wavelength is called a spectral reflectance curve. The configuration of spectral reflectance curves provides characteristics of an object and has a strong influence on wavelength regions in which remote sensing data are acquired for a particular application. Figure 3.2 shows the typical spectral reflectance curves for three basic types of earth features vegetation, soil, water and snow. The spectral reflectance of vegetation canopy varies with wavelength. Chlorophyll, contained in a leaf, has strong absorption at 0.45 µm and 0.67 µm, and the plant structure contributes to the high reflectance at near infrared (0.7-0.9 µm).

This results in a small peak at 0.5-0.6 (green color band), which makes vegetation green to the human observer. Near infrared is very useful for vegetation surveys and mapping because such a steep gradient at 0.7-0.9 µm is produced only by vegetation. Soil reflectance depends on the chemical and physical properties of the components such as moisture, organic matter, iron oxide, texture, surface roughness and sun angle. In visible spectrum, soils usually have higher reflectance than plants. However, it is opposite in case of near infrared band, where plants have higher reflectance than soil. The reflectance of EMR from water is affected by a number of variables such as suspended particles, floating materials and water depth. Water gives low reflectance in visible and almost nil reflectance in near infrared regions.

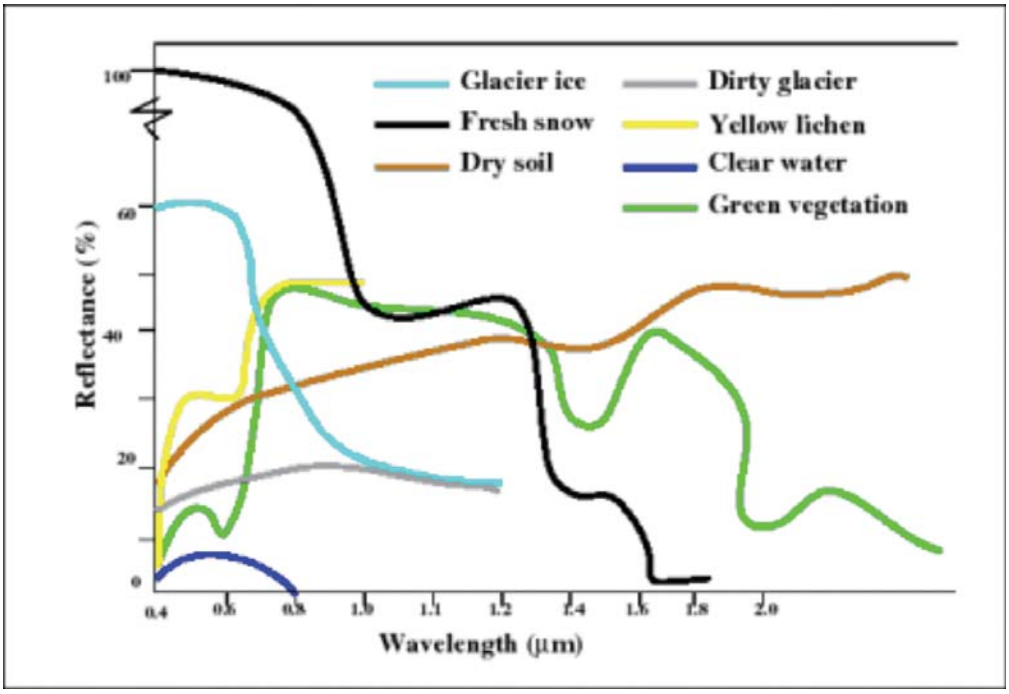

Figure 3.2: Spectral Reflectance curve

Microwave Remote Sensing: Optical remote sensing is not suitable for all atmospheric conditions. It cannot penetrate through clouds and haze. Microwave remote sensing is very useful as it provides continuous observation of the earth's surface regardless of the atmospheric conditions. The basic principle of Radar is to send out a signal and measure the time taken until it returns to the source, thus measuring the distance to that target. The microwaves are the electromagnetic waves with frequencies between 1300 MHz to 300 GHz. Advantage of Radar is its all weather, day and night capability to provide image data. Microwave portion ranges from the wavelength 1 mm to 1 m in the Electromagnetic spectrum.

By measuring the time delay between the transmission of a pulse and the reception of the backscattered "echo" from different targets, their distance from the radar and thus their location can be determined. As the sensor platform moves forward, recording and processing of the backscattered signals builds up a two-dimensional image of the surface. Depending on wavelength and polarization, radar can penetrate the canopy to different depths, and can sense plant parts of different sizes, shapes, and water content. This ability of radar to probe the canopy, and the expectation of retrieving biophysical forest descriptions, underlie much of the international impetus for forest radar research.

Backscatter is the outgoing radar signal that the target redirects back towards the antenna. Radar images are composed of many dots, or picture elements. In the image, darker areas represent low backscatter and brighter areas represent high backscatter. Backscattering from a diffused reflector is more than the backscattering from a specular reflector. Microwave interaction depends on the Angle of Incidence and Wavelength of the Radar. Radar remote sensing is also used to achieve Biomass Estimates and Carbon accounting. Radar data can also provide information about terrain surface and vegetation canopies. SAR provides important characteristics of soil and vegetation covers, for instance, inundation below closed canopies, fresh woody biomass of forested areas, freeze/thaw conditions of soil and vegetation, soil moisture and surface roughness in areas of low vegetation, and information on the orientation and structure of objects on the ground that reflect the incoming microwave radiation. Presently ERS-1, ERS-2 (European Space Agency), RADARSAT (Canadian Space Agency), and ENVISAT data are being used for analysis with specific reference to crop assessment, Soil moisture retrieval, Forest biomass etc. The role of multi-spectral, multi resolution sensors in quantifying the various forestry components as well as their sensitivity is described in Tables 3.3, 3.4 and 3.5.

Table 3.3: Role of Multi – Spectral RS derived parameters for various forestry components (H-high; M-medium; L-low)

S.No	Parameter	Pigmentation	Canopy structure and gaps	Composition	Temperature canopy water regimes
1	Phenology	H	M	H	M
2	Crown Closure	L	H	L	L
3	Vegetation Types	M	H	H	M
4	Species	M	H	H	H
5	LAI	H	H	M	
6	Biomass	H	H	H	M
7	Biochemistry	H	L	H	L
8	Transpiration	L	M	H	H

Table 3.4 : Sensitivity of RS wavelength bands in the quantification of forestry structural and functional parameters

Band	Wavelength	Description	Where it can be used	Index
Blue	**435-500**			
	415	Chlorophyll degradation, detects early stress	Drought, pathogen attack	NPQI
	420	Plant stress status	Drought, pathogen attack	PI1
	430	Carotinoid/chlorophyll-a content	Senescence, phenology	SRPI
	435	Chlorophyll degradation, detects early stress	Drought, pathogen attack	NPQI
	440	Vegetation health index, chlorophyll fluoresence ratios	Drought, pathogen attack	PI3, PI4
	500	Index of vegetation cover	Primary productivity	SGR
Green	**520-565**			
	531	Xanthophyll light response ~ photosynthetic efficiency, Sensitive to carotenoid/chlorophyll ratio	plant pathogen attack, senescence	PRI
Red	**565-740**			
	570	Xanthophyll light response ~ photosynthetic efficiency, Sensitive to carotenoid/chlorophyll ratio	plant pathogen attack, senescence	PRI
	599	Index of vegetation cover	Primary productivity	SGR
	600	Anthocyanins / Chlorophyll		RGR
	665	Index of green vegetation cover	Precision farming, soil organic content	SR, NDVI
	680	Carotinoid/chlorophyll-a content	plant pathogen attack, senesence	SRPI
	690	Vegetation health index, chlorophyll fluoresence ratios	Drought, pathogen attack	PI3

Band	Wavelength	Description	Where it can be used	Index
	695	Plant stress status		PI1, PI2
	699	Anthocyanins / Chlorophyll		RGR
	705	Leaf chlorophyll content	Detects trace quantities of vegetation cover in arid and semi-arid regions	mNDVI
	740	Vegetation health index, chlorophyll fluorescence ratios	Drought, pathogen attack	PI4
NIR	**750-1000**			
	750	Leaf chlorophyll content	Detects trace quantities of vegetation cover in arid and semi-arid regions	mNDVI
	760	Plant stress status	Drought, pathogen attack	PI2
	800	Carotinoid/chlorophyll-a concentration		SIPI
	840	Discriminates soil and dry matter	Precision farming, soil organic content	NDI, SACRI
	845	Index of green vegetation cover		SR, NDVI
	860	Leaf water content	Drought, precision farming	NDWI
	900	Leaf water content	Drought, precision farming	WBI
	970	Leaf water content	Drought, precision farming	WBI
SWIR	**1000-3000**			
	1240	Leaf water content	Drought, precision farming	NDWI
	1510	Foliar Nitrogen content	Impact of nitrogen loading	NDNI
	1650	Discriminates soil and dry matter	Precision farming, soil organic content	NDI, SACRI
	1680	Foliar Nitrogen content, Foliar lignin content	Impact of nitrogen loading	NDNI, NDLI
	1754	Foliar lignin content	Non-leaf based biomass	NDLI
	2020	Cellulose & lignin absorption features, discriminates plant litter from soils.	Precision farming, soil organic content	CAI
	2100	Cellulose & lignin absorption features, discriminates plant litter from soils.	Precision farming, soil organic content	CAI
	2220	Cellulose & lignin absorption features, discriminates plant litter from soils.	Precision farming, soil organic content	CAI

Table 3.5 : Role of sensors of different spatial resolutions in studying the major forestry components

S.No	Sensors	Greenness	Structure	Composition
1	Coarse (~1 km)	H	M	L
2	High (~20-250 m)	H	H	M
3	Very High (=10 m)	H	H	H

3.3.2.1. Red Edge

The region of the red-near infrared (NIR) transition has been shown to have high information content for vegetation spectra. This region is generally referred to as the “red edge”. It represents the region of abrupt change in leaf reflectance between 680 and 780 nm caused by the combined effects of strong chlorophyll absorption in the red wavelengths and high reflectance in the NIR wavelengths due to leaf internal scattering. Increases in the amount of chlorophyll, for example, results in a broadening of the major chlorophyll absorption feature centered around 680 nm, causing a shift in the red edge slope and wavelength of maximum slope towards longer wavelengths. The latter is termed the red edge position (REP). Shifts in the REP to longer or shorter wavelengths has been used as a means to estimate changes in foliar chlorophyll content and also as an indicator of vegetation stress.

Since the REP is defined as the inflection point of the red-NIR slope, an accurate determination of the REP requires a number of spectral measurements in narrow bands in this region. Fortunately, recent developments in imaging spectrometry have provided additional bands (contiguous spectra of less than 10 nm bandwidths) within the red edge region compared to broadband imagery such as Landsat Thematic Mapper. Subsequently, the REP is defined by the maximum first derivative of the reflectance spectrum. However, the limitation of this approach is that the maximum first derivatives of contiguous spectra have been well documented to occur within two principal spectral regions (around 700 and 725 nm) causing a bimodal distribution of REP data around 700 and 725 nm and a discontinuity in the REP/chlorophyll relationship. Several other studies have revealed the existence of this double-peak feature in the first derivative of contiguous spectra, identified two peaks in winter wheat at 703 and 735 nm, also found peaks in canopy spectra of grass near 702 and 725 nm. Using analytical Spectral Devices (ASD) FieldSpec FR spectroradiometer with a 1 nm spectral resolution, observed two peaks in canopy spectra of grass near 700 and 720 nm and also observed the double-peak feature at 690–710 nm and found out that it is a function of natural fluorescence emission at 690 and 730 nm.

3.3.3. Retrieval of forest parameters and integrated analysis

The figure 3.3 shown below explains the conjunctive use of ground data, Remote Sensing, GIS and GPS in forestry applications. The integrated use of these technologies helps in describing the four major components – the greenness, crown closure, mixed vegetation types and the species assemblages, both qualitatively and quantitatively.

The availability of large possibility of spatial, temporal and radiometric resolutions have made it possible to address the described components almost directly. However, ground measured parameters such as climatic, topographic and socio-economic need to be collected from ground and to be integrated with remotely sensed data into the GIS domain. With the help of various GIS analysis (described later in this chapter), various forestry products required for the forest managers, researchers and academia can be obtained as shown in Figure 3.3.

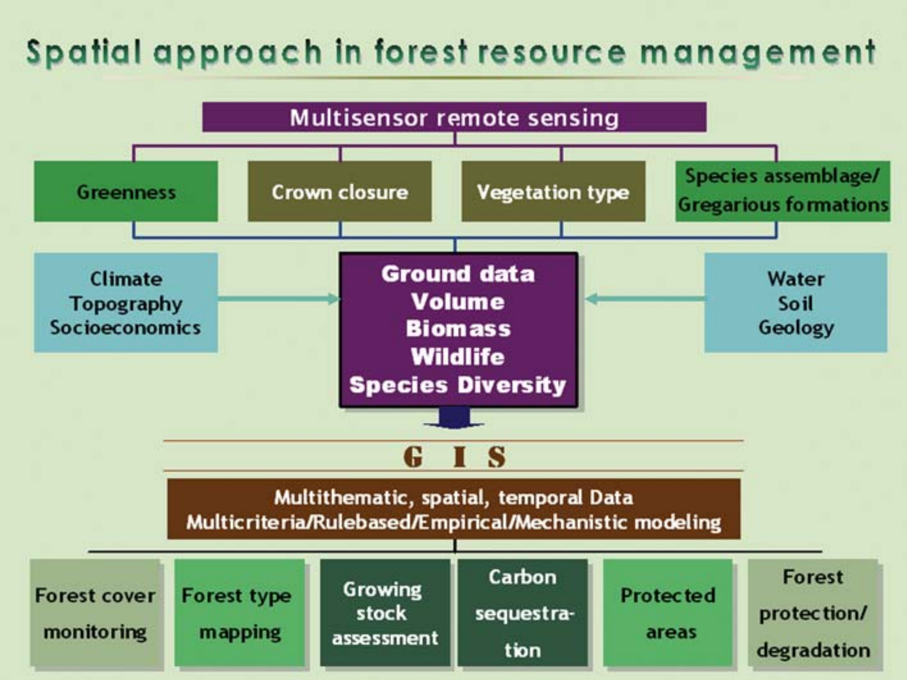

Figure 3.3: Spatial Resource in Forest resource Management

3.3.3.1. Greenness

The seasonality of vegetation also called phenology is one of the key elements of vegetation study. The understanding of greenness amount and its cycle along different season and its spatial distribution is crucial to any climate change study as it is directly linked to the role of vegetation in carbon and water cycle. The leafy biomass controls these two cycles and can be monitored comprehensively through the daily, weekly or seasonally orbiting remotely sensed data. The time series data of spectral vegetation index provide a powerful tool to learn from past events, monitor current conditions and prepare for future change. Comparison of current vegetation data records with historic long-term averages have been used to support ecosystem monitoring, and help evaluate the impact of rising global temperature and CO_2 levels and provide evidence of the impact of the 1989 and 1998 El Niño events around the world.

Global, regional and local natural resource survey and assessment strategies are increasingly incorporating remotely sensed imagery to monitor current and historical vegetation dynamics and often rely on the combined use of multi-sensor vegetation data. A rising number of national, regional and local users and applications are employing geospatial tools that incorporate time series of spectral vegetation index data and other reference data such as roads, rivers and soil information for spatially and temporally explicit natural resource and agricultural monitoring.

Although a variety of satellite sensor options are now available, practical considerations (i.e. data and processing costs, free distribution, the inherent trade-off between spatial and temporal resolution, and the influence of cloud cover) favor platforms that provide frequent images that are systematically processed into products useful for the assessment of vegetation. Two sensors among those that currently meet these criteria are the NOAA Advanced Very High Resolution Radiometer and NASA's Moderate Resolution Imaging Spectroradiometer. Since SPOT VEGETATION and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) NDVI data are not freely distributed, these data are not included in the analysis. Among other products, both AVHRR and MODIS reflectance data are transformed into the Normalized Difference Vegetation Index, the most widely used vegetation index.

3.3.3.2. Forest type Mapping

Digital method:

The general methodology flow of forest type and forest density classification is shown in the following flow chart (Figure 3.4) .

Multi-spectral images are primarily subjected to digital image classification using both supervised and unsupervised approaches depending upon the land-cover class response in spectral sensing. Supervised classification presumes occurrence of Digital Number (DN) value to a particular category. Image processing module is provided with sample areas of distinctive spectral zones over which computation is extrapolated over whole image. Unsupervised approach generates spectrally explicit classes without consideration for thematic distinction which is subjected to a posteriori grouping. Statistical comparison of each given pixel(s) with overall image statistics in iterative mode helps to cluster spectral associations in unsupervised technique.

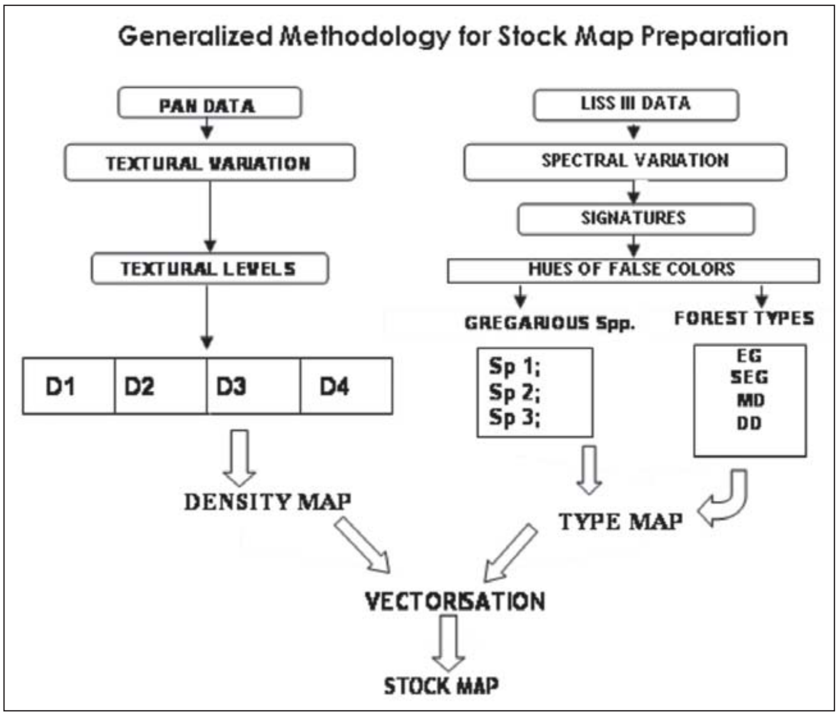

Figure 3.4: Generalised methodology for stock map preparation

Land-cover and vegetation classes of a typical area meant for forest management would usually be patterned with forested, agricultural and man-made features. Supervised classification is operated upon forested as well as agricultural tracts. Forests stand out uniquely due to the spectral distinction due to grades of foliage prevalence. Agricultural tracts consisting of cropped and fallow areas respond spectrally due to their separate class of near infrared / red reflectance relations. Bamboo dominated regions represents another spectral distinction. Other obviously distinguishable categories like water, barren areas, sand could also be recognized spectrally. Specimen spectral signatures are generated using Area Of Interest (AOI) facility in 'Signature editor' in Image processing S/W. The facility captures complete variation in a given irregular patch of pixels in terms of basic statistical parameters for each band viz., near infrared, red etc., which form the centre for segregation of classes. Spectral homogeneity, corresponding generally to a homogenous theme strata on ground, can be attained either using qualitative visual interpretation or region growing algorithms available. Region growing algorithms search all around the designated pixel for specified DN value range and envelop selected ones for signature collection.

Signature sets thus generated are purified iteratively, based on the contingency matrix depicting commission and omission, as well as using feature space based spectral ellipses of respective spectral classes. Supervised classification algorithm based on maximum likelihood algorithm is operated upon the image using these purified signature sets. The output classes are compared for theme-wise and subjected to class merging, if there is high similarity between classes.

Classified image was standardised for required number of land-cover classes and subjected to image smoothing using majority 3X3 filter to dampen spurious noise. These filters consider the modal value of nine pixels and resample the area for proper re-alignment. The area statistics are generated.

Visual method:

The image characteristics of shape, size, pattern, shadow, tone and texture are used by interpreters in tree species identification. For example, individual tree species have their own characteristic crown shape and size. Some species have rounded crowns, some have cone-shaped, and some have star-shaped crowns. Variations of these basic crown shapes also occur. In dense stands, the arrangement of tree crowns produces a pattern that is distinct for many species. When trees are isolated, shadows often provide a profile image of trees that is useful in species identification. In pure stands (plantation), the canopy is regular in pattern and tree height is even or changes gradually with the quality of site.

Phenological correlations are useful in tree species identification. Changes in the appearance of trees in different seasons of the year some times enable discrimination of species that are indistinguishable on a single date. The most obvious example is the separation of deciduous and evergreen trees that is easily made on images acquired when the deciduous foliage has fallen.

Visual image interpretation is used extensively for growing stock estimation, biomass and carbon stock estimation. The Primary objective of such operations is to determine the volume of timber that might be harvested from an individual or more stand of trees. To be successful in image-based timber cruising, biomass and carbon stock studies, one requires the skill of an integrated interpretation of both aerial or satellite and ground data. Image measurements on individual trees or stands are statically related to ground measurements of tree volume, biomass and carbon mass in selected plots. The results are then extrapolated to large areas. The parameters of interest in forestry derived from image analysis most often are (1) tree height or stand height, (2) tree-crown diameter, (3) density of stocking, and (4) stand area etc.

3.3.3.3. Preparation of Forest Crown Density Maps.

Forest crown density is used as one of the critical parameter in forest cover assessment, growing stock estimations and monitoring in India. Satellite remote sensing based crown density mapping started during 1984 and technology is made as operational activity at national level. Since then Forest Survey of India has carried out nine national biennial surveys using remote sensing. Since 1995 IRS LISS II and LISS III sensors satellite data with 36.25 and 23.5 m resolution respectively are used for the purpose. With the increasing spatial resolution of the sensors and the advancement in satellite data processing, the crown density mapping has progressed from two crown density classes viz., 10-40% and >40% to three crown density classes 10-40%, 40-70%, >70%. Based on the latest report of 2005, national forest cover is estimated as 67.7 M ha covering 20.6% of the total geographical area of the country. This database also stands as one of the important input for national forest growing stock assessments.

Detailed forest crown density mapping with crown density interval of 20% is also prepared using IRS PAN, IRS LISS IV sensors data at 1:25,000 scale for forest division and micro level planning. These databases are used for monitoring and evaluation of afforestation, reforestation activities and as stratification input for developing optimal sampling designs for growing stock assessments. Based on the forest crown density levels, rehabilitation and selection working circle are demarcated to facilitate conservation and harvest plans respectively. With the availability of CARTOSAT, IKONOS and QUICKBIRD series of satellite data, detailed forest crown based information viz. crown diameter, number of crowns, degree of overlap etc., are amenable for mapping. These data bases are prepared for microlevel monitoring and forest condition assessment.

Based on the interpretation key developed as shown in (Figure 3.5) , the respective satellite data is interpreted for forest crown density delineation on screen based standardisation and correlation from field experience along with ancillary information available.