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‘Science consists in the recognition of similarity and dissimilarity, so that the beginning and end of science is comparison’

Raunkiaer (1934)

Biodiversity and its conservation

Biodiversity or biological diversity is the variety of life: the different plants, animals and microorganisms, their genes and the ecosystems of which they are a part. Thomas Lovejoy coined the term biological diversity, while the word ‘biodiversity’ itself was coined by the entomologist Wilson in 1988. The United Nations Earth Summit held at Rio de Janeiro in 1992, defined biodiversity as “the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems”. It is widely accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity. The convention on biological diversity, is an agreement that came out of the Earth summit held in Rio de Janeiro in 1992. It has subsequently been ratified by over 180 states and was first truly global initiative attempting to conserve the world’s biodiversity. India is also a signatory to this agreement.
Habitat fragmentation is considered by many to be the most serious threat to biological diversity, and is the primary cause of the present extinction crisis (Wilcox and Murphy, 1985; Lovejoy et al., 1986; Wilcove et al., 1986). At least 44% of vascular plants and 35% of vertebrates are endemic to 25 biodiversity "hotspots" (Mittermeier et al., 2000). Recently, nine new biodiversity hotspots has been added to the existing list by the conservationalist to make total of 34 biodiversity hotspots, which account for 2.3% of the earth surface (Mittermeier et al., 2005, Fig. 1). Hotspots are not only the vital areas of species-level endemism, but are also highly significant reservoirs of unique and threatened evolutionary history (Sechrest et al., 2002).

Protected areas are necessary to safeguard the biological diversity in the face of the continuing onslaught of natural ecosystems. Currently, India has 94 National Parks covering 37,706.44 sq. km and 501 Wildlife Sanctuaries covering 118,222.39 sq. km representing 1.15% and 3.60%, respectively, of the country's geographical area. However, most of the protected areas in India are comparatively small in size (Anon., 2005 and Fig. 2).

The maintenance of biodiversity is essential for the long-term well-being of humans but who himself is major agent of change / destruction of natural ecosystems. Local species extinction appears to be very high in tropical forests due to large-scale deforestation (Stehli et al., 1969). Five identifiable patterns of deforestation are recognized - internal, indentation, cropping, fragmentation, and removal - and each of them has a distinct effect on habitat quality of forest patches in the eastern United States (Wayne, 1993).
Biodiversity Hotspots

Earth's biologically richest places, with high numbers of species found nowhere else. Hotspots face extreme threats and have already lost at least 70 percent of their original vegetation.


Fig.1: Biodiversity hotspots
Human alternation of the global environment has triggered the sixth major extinction event in the history of life and caused widespread changes in the global distribution of organisms. These changes in biodiversity alter ecosystem processes and change the resilience of ecosystems to environmental change. This has profound consequences for services that humans derive ecosystems (Chapin et al., 2000 and Fig. 3).

The Western Ghats region, like other parts of the tropics, is undergoing rapid transformation. The deforestation rate is high and forests are being transformed into agriculture and monoculture plantations. Only 7% of the original extent of the vegetation remains intact (Olson and Dinerstein, 1998).
2.2. Concept of diversity and its measurement

The biodiversity cannot be reduced to a single number, such as species richness. This is a real problem for biologists, because a single number is often what policy makers want. Perhaps it will be possible to go part way by using many indices of species diversity. The measures of diversity are frequently seen as indicators of the well being of the ecological systems (Maguran, 1988). It is a straight-forward concept, which can be quickly and painlessly measured. The diversity has two components, viz., variety and relative abundance of species. The number of
species present in a community is the oldest and simplest concept of diversity. McIntosh (1967) ascribed ‘species richness’ to this concept of diversity.

Simpson (1949) proposed the concept of diversity, which combined two separate ideas - species richness and evenness. He suggested that diversity is inversely related to the probability that two individuals picked at random belong to the same species. Simpson diversity ranged from 0 to almost 1. Simpson index measures the probability that two individuals selected at random from a sample will belong to the same species (Peet, 1974).

Shannon-Wiener index is the popular diversity measure, which is based on information theory. The information content in this diversity is the measure of uncertainty (Krebs, 1989). Higher the value, higher is the uncertainty of getting the same species in the area. Strictly speaking, this index should be used only on random samples drawn from a large community in which the total number of species is known (Pielou, 1966). Peet (1974) and (Pielou, 1966) recognized two categories of diversity indices - one, which is most sensitive to rare species in the community – Shannon-Wiener index, and, the other, sensitive to changes in the most abundant species in the community – Simpson index. Simpson index is with a small bias and low coefficient of variations even when 1000 individuals are sampled. This index is most suitable for detecting differences when it is necessary to rely on a relatively small sample size of less than 1000 individuals (Mouillot and Lepretre, 1999).
Diversity can be measured at two levels, viz., alpha and beta. Alpha diversity is the diversity of homogenous habitat (Whittaker, 1977). MacArthur (1965) identified this as within habitat diversity. Simpson and Shannon-Wiener indices are the common measurements of alpha diversity. Beta diversity is essentially a measure of how different (or similar) a range of habitats or samples are, in terms of variety (and some times the abundances) of species found in them. Beta diversity also looks at how species diversity changes along a gradient (Wilson and Mohler, 1983). Whittaker (1960) has given the simplest and straightforward beta diversity measure. Wilson and Shmida (1984) assessed all the available beta diversity indices and have come out with a comparative account of those indices.

Differences in the computation of Shannon-Wiener index could make comparisons difficult. Many people used ‘2’ as base for logarithm and a few used 10 and ‘n’ as the base. However, Magurran (1988) suggests the use of base 2 for all purposes.

While comparing the diversity of different community, one can encounter the problem of differences in sample size. This difference in sample size causes difficulty in direct comparison of diversity. However, when quadrant sampling is employed for community analysis, Quenouille (1956) proposed a nonparametric approach, the Jackknife, to estimate the species richness, which can be compared among communities. Sanders (1968) proposed a rarefaction method to overcome this problem. Rarefaction is a statistical method for estimating the number of species expected in a random number of samples. Heltshe and Bitz (1979) applied this measure in the diversity statistics.
All indices that quantify biological community are based on the number of species and their relative abundances. Ganeshaiah et al. (1997) developed an index called ‘Avlanche index’, which used effectively the taxonomic, morphological and biological differences. This index integrates the overall possible species combinations and their frequencies in the community.

2.1. Concept of vegetation


A plant community is a well-organized complex system association having a typical composition (floristic aspect) and structure (morphological aspect) that results from the interaction through time. It is not just a mere aggregation of plants (Cain and Castro, 1959) and he defined the community as, ‘a unit of any rank, occupying a territory and having a characteristic composition and structure’.

Earlier school of thought about the vegetation is related to the vegetation that consisted of community types into which it was classified. These community
types are assumed to be well-defined discreet natural units. These discreet units meet each other all along the narrow boundaries called ‘ecotones’. This theory was accepted in total at that time without assigning any particular name to this theory. It was Whittaker (1967) who coined the term ‘community unit theory’.

Gleason (1926) in his paper ‘Individualistic concept of the plant association’ put forward two important ideas about the vegetation viz., the principle of species individuality and the principle of community continuity. Following intense opposition to his ideas he modified or restated his ideas, as vegetation is a complex continuum rather than a mosaic of discontinuous units. Whittaker (1956) who tested this theory in Great Smoky Mountains at Tennesse and found that Gleason theory has practical applicability and that the species assemblages are changing continuously over the gradients and not as discreet units. McIntosh (1967) reviewed the development of world literature on continuum concept of the vegetation.

Whittaker’s studies led to the development of a new concept in ecology, which deals with the investigation of species assemblages with respect to the complex environmental variables, which he termed it as ‘gradient analysis’. During the same period, Curtis and his associates (Curtis and McIntosh, 1951; Brown and Curtis, 1952) carried out research on Wisconsin Mountains independently and came to the same conclusion as that of Whittaker.

Gradient analysis is a research approach to study the spatial patterns of vegetation. Whittaker (1967) used the gradient analysis as a technique for studying
vegetation. The distribution of vegetation and its species assemblages are primarily interdependent on the environmental factors. Schimper (1898), while studying the biogeography of the world vegetation clearly pointed out that within the tropics, vegetation is extremely varied and the principle types of vegetation are closely under the influence of the amount and seasonal distribution of precipitation. Thus, vegetation pattern is dependent on the interrelationships with the surrounding ecological, climatic and biotic factors.

Studies conducted in India (on ecology) point out a marked difference between the vegetation and the ecological concepts of temperate and tropical regions. Dudgeon (1920) for the first time provided an excellent account of the ecology of the upper Gangatic plains and employed the 'concept of succession'. At the same time, Kenoyer (1921) employed this concept to forests.

2.4. Vegetation studies based on physiognomy and phytoclimate

Physiognomy provides an easy basis for a rough differentiation of very broad categories. It was Humboldt (1805) who first proposed the classification of plants by their growth forms and used it to distinguishing the types, which imprint their distinctive characters on the vegetation in tropical America. He called growth forms as "vegetative forms" and described 15 types. Gresebach (1884) described 60 vegetative forms and his classification, like that of Humboldt, concerns the remarkable plant types, which decide the physiognomy and help in differentiating the important floristic regions of the world. After these classification systems,
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appeared the system of Drude (1897 and 1913), Kraus (1891), Pound and Clements (1898), and Warming (1909) and Raunkiaer (1934).

Raunkiaer system is based on the principles of protection of perrenating buds during unfavorable season. His system is widely accepted since this concept is clear, compact and consistent. He divided the phanerogamic flora of the world into four main types and they are- (1) phanerophytic climate in the tropics, (2) therophytic in the deserts, (3) hemicryptophytic in the cold temperate zone and (4) chameaophytic with a fair proportion of geophytes in cool climates.

Warming’s (1909) earlier study did not favor Raunkiaer’s concept of life forms as an indicator of climate. He did not accept that hemicryptophytes and cryptophytes are climatic types since he recorded many cryptophytes in various type of soils of other zones. Later in 1951, Badle also strongly opposed the Raunkiaer’s view and stated that climate alone cannot always be taken as an indicator of a vegetation of a place. Studies conducted by Lakshmanan (1962) in India also contradict Raunkiaer’s hypothesis.

Meher-Homji (1964, 1981) provided a detailed account of morphological criteria of biological spectrum in arid and humid regions in India. He proposed five criteria for judging the aridity and humidity of a region viz., the climatic criterion, epharmonic criterion, floristic criterion and vegetational criterion. His study showed the strong inter-relationship of the biological spectrum with the bioclimate.
Before Meher-Homiji, some scattered studies were available on life forms in India. Ferreira (1940) studied life form in Poona region and assigned the phytoclimatic type Nanophenero-chamaeophytic type. Kaul and Siran (1976) observed the decrease of phanerophytes and therophytes from lower strata to higher strata in mountains of Baderwah of Jammu and Kashmir. He assigned the phytoclimatic type Geo-chamaeophytic type.

Later, Sharma in 1990 studied the life forms in hilly terrain of Punjab and identified the phytoclimatic type of that region as therophytes-cryptophytic type. He attributed the dominance of therophytes and cryptophytes in that region to that of hot and dry climate. Rajendra Prasad et al. (1998) studied life forms and biological spectrum in sacred groves of Kerala and found that life form can be used as a potential tool for understanding the general structure and functioning of ecosystem, and also to analyze the impact of humans on vegetation.

2.5. Shape and size of leaves

Leaf size is also much studied in relation to environmental conditions and forest type. Richards (1952) compiled the whole available literature and concepts about the leaf size differentiation in tropics. He has given a basic account of the leaf size spectra and its applicability. Raunkaier (1934) developed the concept of leaf size based on the dimensions of leaves and categorized them into six different types. Studies conducted by Richards (1952) in tropical forests on leaf size showed that evergreen forests are dominated by mesophyll leaf size class (more than 80%). He explained that the influence of the rainfall is the major factor in determining the
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leaf size. Brown (1919) studied leaf size classification in mountains of the Philippines and observed equal representation of mesophyll and microphyll leaves. Studies conducted by Beard (1946) and Cain et al. (1955) also supported Richard’s view on leaf sizes. The prominence of small leaves in the drier and nutrient poor regions has been studied by many authors (Volkens, 1887; Schimper, 1898; Shields, 1950; Walter, 1978; Hall and Swaine, 1981).

It was Givinish (1978a, 1978b, 1979, 1984) who gave the detailed account of leaf size, its variation and inter-relationships with the climate. He observed that the average leaf width increased with increase in the amount of rainfall while it decreased with increase in altitude. He also noted that the percentage of compound leaves was more in the disturbed habitats as these habitats are indicated by more pioneer and colonizer species. The pioneers and colonizers generally have compound and larger leaves and find place in the forest gaps, where light is plenty, which could be harvested to the maximum. The compound and larger leaves have been shown to trap the light energy effectively as compared to the other types (Givinish, 1984).

The plant attributes such as leaf size, shape and arrangement have been useful in arriving at a physiognomic-structural classification of vegetation (Webb, 1968). Leaf size classification has also been found to be useful in elucidating the paleoclimate (Bonii, 2002)

Plant morphological attributes like the occurrence of gums and resins and the bark thickness have also been used effectively to understand the influence of local
climate on the plant community in terms of different stages of disturbance in the
evergreen forests (Chandran, 1997).

2.6. Floristic pattern of vegetation and its structural and functional aspects

The earliest floristic classification was given by Schouw (1823) who divided the world into 25 kingdoms and naming them based on the dominant and most characteristic plants. He placed the vegetation of Indian region in the kingdom of Scitaminae, while studying the world floristic classification.

Vestal/introduced the term ‘biotic province’ for a territory that is characterized by the biological ensemble, showing a correspondence between the distribution of particular animals and vegetation. He proposed two criteria for the identification of a biotic province - (1) similarity of range among animals of ecological habitat irrespective of their systematic relationship, and (2) closeness of correspondence of area between particular animals and vegetation provinces.

Clark (1898) divided India into 11 botanical provinces. Hooker (1906) modified it and grouped it into nine provinces. Chatterjee (1939) modified the Hooker’s classification and extended it into ten provinces. It was Razi (1955) who studied in detail and divided it into 21 botanical provinces.

Chatterjee (1939), while modifying the botanical province, reported 61.5% endemism of dicotyledonous plants in the erstwhile territory of British India.
excluding Ceylon. There are about 40% of the flowering plants of India of foreign origin that has undergone naturalization in different parts of the country.

Meher-Homji and Misra (1973) reviewed the phyto-geography of the Indian subcontinent and identified two aspects. The first aspect deals with the floristic phyto-geography while, the second with the vegetation plant geography.

In the year 1988 Rogers and Panwar made a detailed study on the protected areas in India and modified the bio-geographic provinces into ten main category and 13 subcategories.

Champion made a detailed study of forest ecology and proposed his scheme of Forest types of India and Burma in 1936. This classification was revised by himself and Seth in 1968 and provided detailed, comprehensive phenological vegetation types of the Indian subcontinent.

The quantification of habitat structure over large areas using metrics or spatial indices (Mace et al., 1999) or vegetation inventory databases (Rudis and Tansley, 1995) has emerged as an important aspect of management of natural resources. The pattern and dynamics of habitat structure are linked to the behavior or population dynamics of the species of interest (Debinski and Holt, 2000).

Potts (2002) showed that the abiotic factors are more influential in differentiating species associations in primary tropical rainforests than has recently been claimed, particularly in the Neotropics.
Ghate et al. (1998) studied the tree diversity pattern in the whole area of the Western Ghats and showed that more moist formations have higher endemics and evergreen species. And, he also observed that semi-evergreen formations harbor most diverse assemblages with wide spread species. Legris and Meher-Homji (1968) considered the evergreen and semi-evergreen series of the Malabar Coast (southwest India) as one of the two concentration zones of the Indo-Malayan floristic elements in India.

**Multivariate techniques in vegetation studies**

Ecologists and bio-geographers often are faced with the problem of defining significant differences in species compositions among locations ('biotic boundaries'). Practically speaking, the problem is in the analysis of matrix of species pattern and its location, and thus calls for a multivariate approach (Gauch, 1982). Numerous techniques are now available for multivariate analysis and many of which convert the matrix of species pattern and its location into secondary matrix of similarity coefficients and secondary matrix can be examined either by placing locations into theoretical continuous sequence (ordination) or by placing locations into distinct groupings (cluster analysis) (Gauch, 1982).

The need for quantitative procedure for examining vegetation as continuum prompted the development of ordination techniques. Goodall (1954) introduced the term ‘ordination’ for methods that arrange samples (or species) in relation to ‘multi dimensional series’
Among the ordination methods, correspondence analysis (CA) (Hill, 1974) is proved efficient for ordering sites and species, in particular, because it corresponds to the ecological model of species niche differentiation along environmental gradients, given the assumption of unimodal response curves (TerBraak, 1985).

CA along with its alterative, Detrended Correspondence Analysis (Hill and Gauch, 1980), and its extension, Canonical Correspondence Analysis (CCA) (Ter Braak, 1986) are extensively used to analyze species-environment relationships.

CA finds a common ordination of species and sites along the main environmental gradients, putting species at the weighted mean of site scores and conversely, sites at the weighted mean of species scores. By this reciprocal averaging, CA maximizes the correlation between species and sites. As a consequence, if a site contains only one species that conversely occurs only in that site, CA points out this strong association. For that reason, rare species are generally removed (Bolognini and Nims 1993, Heikkinen 1996).

CCA (Ter Braak, 1986, 1987) is a new technique for multivariate direct gradient analysis. CCA is derived from the multivariate indirect gradient analysis (ordination) technique known as CA (Hill, 1974). Both CA and CCA derive a set of ordination axis scores for species as well as sites. The significance of the relationship between species composition and environmental CCA axes is determined by a Monte Carlo permutation test (Ter Braak, 1987).
Gimaret-Carpentier et al. (1998) showed that the asymmetric approach of the Correspondence Analysis (Non-Symmetric Correspondence Analysis - NSCA) helps to overcome the problem of rare species, which otherwise gives additional importance in CA. They analyzed the distributional pattern of endemic species in the evergreen forests of the Western Ghats using NSCA and they provided separate ordinations of species and sites.

Studies of Ganesh et al. (1996) in Kalkad Mundanthurai Tiger Reserve (KMTR) showed the increase in species richness with increase in elevation. He attributed the elevational variation in species richness to changes in the vegetation types along the elevation gradients.

There exists a large variety of clustering algorithms (k means, fuzzy k means - Duda et al., 1998; neural k means - Kohonen, 1989; nearest neighbor, farthest neighbor, centroid, Ward, hypervolume, minimal spanning tree, Mojena’s upper tail, Wolfe’s test) designed to partition data into clumps (Everitt, 1993).

Recent contributions (He et al., 1997; Batista and McGuire, 1998; Condit et al., 2000; Plotkin et al., 2000) have quantified the average clumping characteristics of tree species by utilizing a family of measures derived from the Ripley K statistic (Ripley, 1976).
2.8. Assessment of Biodiversity - a geo-spatial perspective

The proper planning and meaningful management activities, which enhance the sustainability of the land use, depends on the availability of timely accurate and up-to-date information on land use/land cover map of an area of interest. These maps are produced from remotely sensed data (satellite images and aerial photography) at scales that are amenable to planning, environmental assessment, and development studies. The land use/land cover mapping involves the use of advanced tools and technologies like Global Positioning system (GPS), Remote Sensing (RS), Digital Image Processing (DIP) and Geographical Information System (GIS).

2.8.1. Global Positioning System (GPS)

GPS is a satellite-based navigation system, which provides 24-hour precise three-dimensional position, velocity and time information. It is available continuously on a worldwide basis and independent of meteorological conditions. It uses the characteristics of radio transmissions for location determination. It includes a constellation of 24 satellites rotating around the earth in 6 precisely known orbits at a height of 20,200 km. These satellites orbit in such a way that an observer can receive signals from any point of the earth with at least four GPS satellites. From the distance measurements, through the travel time of signal transmitted from each satellite, the receiver can calculate the position, altitude and velocity. GPS will provide accurate real-time positional locations, which enable updating of positional locations on the satellite image and facilitate the accurate mapping.
Precise location information about the species distribution pattern is very essential for species-specific conservation activities. Using GPS, recent phytosociological surveys have provided enormous information on species distribution with specific locations. These include the endemic atlas of the Western Ghats (Ramesh and Pascal, 1997), mapping of sandalwood (Ganeshaiah and Umashaanker, 2003), and studies on *Hopea canarensis* Hole, a narrow endemic species in the central Western Ghats of Karnataka (Sringeswara et al., 2002). Under the DBT-DOS project, studies conducted in the Northeast India and Western Himalayas, the Western Ghats and Andaman Nicobar Islands of India (Anon., 2003), are noteworthy.

### 2.8.2. Remote Sensing

Remote sensing by definition is the science of gathering information about any object without being in physical contact with it. The term ‘remote sensing’ was first used in 1961 (Pisharoty, 1991). Lillesend and Kiefer (2002) described it as ‘the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a devise that is not in contact with the object, area or phenomenon under investigation’. In simple remote sensing can be referred to as sensing from the distance. Remote sensing uses a devise to sense the object and is called ‘sensor’. Eye can be a good sensor. Devises on which the sensors are placed are called ‘platforms’. These platforms are ground-based, air-borne or space-borne in nature as in satellite remote sensing.
The spectral property of the object is the basis for remote sensing. The spectral property of an object could be explained as the reflectance pattern of the incident radiation in specific wavelengths of the electro magnetic spectrum (EMS) (Fig. 4). Resolution (the ability to differentiate) is another important factor of the remote sensing. There are four types of resolution (Jensen, 1996), viz., spectral – the segments of the EMR by which sensor sense the object, spatial – minimum area
on earth that sensor can sense as discreet unit, radiometric – intensity levels by which sensor detects the object and temporal – repetivity of the satellite that how often the satellite can look at the same part of the earth.

Indian remote sensing programme was started in late seventies with Indian built Bhaskara-I and Bhaskara-II satellites launched from Soviet Union in June 1978 and November 1981, respectively. With the launch of IRS series of satellites, India has become one of the frontier countries in remote sensing applications.

2.8.3. Geographical Information System (GIS)

GIS has many definitions as much as it is being used. Most accepted definition of GIS is that, it is ‘a system of hardware, software, data, people, organizations and institutional arrangements for collecting, sorting, analyzing and disseminating information about areas of the earth. In short, GIS is computer-based system that can deal with virtually any type of information, about features that can be referred by geographical locations (Lillesand and Kiefer, 2000). Goodchild and Quattrocchi (1997) defined it as computer based system that provide information of geographical nature with spatial database.

GIS with the integration of remote sensing can be potentially used as decision support system, which involves integration of spatial and non-spatial data. The database can contain any type of information that is spatially distributed, ranging
from socioeconomic (e.g. population density) to climatological, to fundamental biophysical variables.

2.8.4. Digital Image processing

Digital image processing is the manipulation and interpretation of data in digital format with the aid of computers. It enables better and accurate interpretation of the satellite data. It involves various processing techniques such as geometric correction, image enhancements, image classification and statistical analysis.

Before satellite imagery became so freely available in the 1970s, aerial photography was commonly used to map land cover. During aerial photograph interpretation (API) land cover is mapped manually. The interpreter combines their specific expertise such as knowledge of the relations that land cover features have with various biogeographical gradients, the landscape context in which different land covers are found, with their appearance in the aerial photograph. By using contextual information, much greater land cover detail is captured (Paine, 1981; Lillesand and Keifer, 1987). However, photographic data are relatively expensive and require much human effort to extract thematic information.

Now land cover is more usually mapped from remotely sensed imagery recorded by sensors mounted on satellites. Satellite imagery is cheap compared to alternative data sources such as aerial photography, covers large areas and has a high temporal frequency.
There are two important methods of classifying the satellite data, viz., supervised and unsupervised methods.

The classification algorithms used in the classification methods are – (1) Maximum distance to means classifier, (2) Parallelepiped classifier and (3) Gaussian maximum likelihood classifier.

Maximum likelihood, in essence, delineates ellipsoidal ‘equiprobablity contours’ and express the sensitivity of the likelihood classifier to covariance. Major drawback of this classifier is that it requires large number of computations to classify the pixel and it is one of the most commonly used algorithm (Lillesand and Kiefer, 2000).

The success of hybrid classification approach is very high than the straightforward supervised or unsupervised classification (Cihlar, 2000).

2.8.5. Application of remote sensing and GIS

Mapping of vegetation has its aim in recording and communicating a mass of information of the plant cover in concise graphic form (Meher-Homji 1973). Natural vegetation can be studied from floristic, physiognomic and successional aspects.

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Aerial photographic techniques have been applied for forest mapping as early as 1920 (Stamp, 1925). The extensive use of aerial photography for mapping coincides with the world wars. The high resolution and the stereotypic images of the aerial photographs proved to be valuable aids in many of the forestry activities. Aerial photographs can be assessed with ocularly or with the help of some measuring devise. The use of aerial photography was limited by its high cost and high dependence of the weather conditions. Furthermore, aerial photographs, when digitized at metric spatial resolution, have enabled numerical extraction of textural information in temperate forest (Sommerfeld et al., 2000) and semi-arid vegetation (Couteron and Lejeune, 2001; Couteron, 2002). Such techniques could thus also be applied to satellite images. Now land cover is more usually mapped from remotely sensed imagery recorded by sensors mounted on satellites. Satellite imagery is cheap compared to alternative data sources such as aerial photography, covers large areas and has a high temporal frequency.

The advent of satellite remote sensing with the launch of the Earth Resource Technology Satellite (ERTS), later named as Landsat, by National Aeronautics and Space Administration (NASA), USA in 1972, revolutionized the concept of
vegetation mapping. Since then, numerous studies used satellite remote sensing for mapping earth vegetation. It has played a pivotal role in generating information about forest cover, vegetation type and land use changes (Roy, 1993). Accurate measurements/estimation of the amount of land surface covered by different vegetation types are important to the developmental activities and it gives an understanding of the status and dynamics of any protected area (Gupta, 2005).

Remote sensing in India was first used during 1963-64 (Pisharoty, 1991). The use of remote sensing as a tool for analyzing environmental, cultural and natural resource management characteristics is well documented (Lillesand and Kiefer, 1987; Jenson, 1996).

It has been used to map vegetation even at the continental level using coarse resolution data such as Advanced Very High Resolution Radiometer (NOAA-AVHRR) (Tucker et al., 1985; Townshend et al., 1987 Hansen et al., 2000; Loveland et al., 2000), Vegetation (VGT) and Moderate Resolution Imaging Spectro-radiometer (MODIS). AVHRR has promising capabilities to evaluate the global change (Eidenshink and Fautdeen, 1998). System Probatoire d Observation de la Terre-Vegetation (SPOT-VGT) imagery is highly effective for discrimination of burnt forest, owing to the inclusion of a 1.65 μm Short Wave Infra Red (SWIR) channel that is sensitive to vegetation and water content. MODIS will be of much helpfidl in forestry applications with its daily viewing capability and 36 spectral bands with three-nested spatial resolution of 250 m, 500 m and 2 km. Moreover, MODIS has the significant use of producing an array of
biophysical product. These sensors have immense use for land cover mapping over a sufficiently large area (continental levels) and for quick mapping but for regional level, their resolution is too coarse and hence, it is not of much use for regional vegetation mapping. Most extensive application of satellite remote sensing technique has been reported using coarse and medium resolution data sets from sensors like NOAA-AVHRR, SPOT-VEGETATIO, ERS and IRS-WIFS (Roy, 2002). The IRS 1C WiFS data is well suited for quick and regional level vegetation mapping (Joshi et al., 2001a; 2001b; 2004; Roy and Joshi, 2003). These coarse resolution datasets have very temporal resolution, allowing reconstruction of phenological trend and could be used for discriminating major communities of the forest (Roy, 2002).

The national forest cover assessment, however, requires medium and high-resolution sensors depending on the areas of investigation. The sensors like Landsat MSS/TM, SPOT and IRS LISS will be of much use for small scale vegetation mapping and can be delineated for many community formations.

The increased spatial resolution gives forests a new set of mapping and monitoring options. The datasets such as SPOT Panchromatic (10 m), IRS P IV LISS III (5.8) and PAN (2 m), IKONOS (4 m multispectral and 1 m Panchromatic) and Quick bird (0.65 m) are as good as aerial photographs.

The medium resolution, multispectral data sets such as Landsat, SPOT, IRS are potential enough to provide the information in 1:250,000 scale. It is assessed to provide rapid forest cover mapping. NRSA (1983) used Landsat MSS data to map
the nationwide forest vegetation. The IRS LISS data has been successfully used to map biologically rich zones in India (Anon., 2002a; 2002b).


The application of Remote Sensing and GIS to forestry, varies from forest cover mapping (Anon., 1999; Joshi et al., 2004), vegetation type classification (Pascal, 1982; 1984; 1999 and 2000; Ranganath et al., 2002; 2003), forest stock mapping (Singh et al., 2003), above ground biomass estimation (Roy and Ravan, 1996, Kale et al., 2002), deforestation (Jha et al., 2000), wild life habitat analysis and loss (Roy et al., 1995, Kushwaha and Hazarika, 2004), forest fire (Ranganath et al., 1994, Ajai et al., 2003), pest and disease management and monitoring (Srivastava, 2001; Dhiman, 2000; Ranganath et al., 2004 and Mushinzimanja (2006), and assessment of species diversity (Nagendra and Gadgil, 1999).

Udayalaksmi et al. (1998) used remote sensing and GIS for decision-making and to derive meaningful output for plant resource conservation and their management. Nagendra (2001) used the remote sensed data for effective delineation of conservation priority area in the Western Ghats, India. Natarajan et
al. (2003) delineated conservation priority sites for the effective management of forest resources in Chitteri hills, Tamilnadu using remote sensing and GIS. They have used various layers such as species richness, endemic and red listed plant species, biotic pressure and social economic value. Joshi et al. (2004) analyzed the cover dynamics with respect to topography using geospatial tools, which also helps in delineating conservation areas. Ganeshaiah and Umashankar (2003) generated contours of distribution patterns of Bamboo, Ochlandra, Rattans, medicinal plants and major Non Timber Forest Products (NTFP), which are aimed at conservation of important species. Geostatistical techniques, viz. kriging or sequential Gaussian conditional simulation could be used to create an interpolated dataset map of individual species distribution from known sample information.

Satellite data have also been shown to be useful in monitoring forest vegetation vigor and species distributions (Walsh, 1980; Franklin et al., 2000). GIS provides the way to overlay different layers of data, the ecological conditions, the actual vegetation physiognomy and human pressure indices. The vegetation spectral response can also be used to infer various soil conditions.

Yang and Anderson (1996) used vegetation spectral responses to define management zones within fields. The management zones are an aid to soil sampling as they define logical boundaries for obtaining samples. Remotely sensed images are also being used in “directed soil sampling” where one can map “soil management zones” which would be sampled as separate units.
Sensitivity of the remote sensing data to atmospheric disturbances has led to use of vegetation indices (Jenson, 1996). Among the different indices, the Normalised Difference of Vegetation Index (NDVI) is the most important, simplest and widely used in various applications (Lillesand and Kiefer, 2000). NDVI can provide useful information about the health and amount of vegetative cover across the landscape (King and O'Hara, 2001). In view of the ability of the NDVI to better explain the variability in the vegetation, it has been used widely for vegetation classification, land use / land cover change detection (Bradley and Mustard, 2005), biomass estimation (Kale et al., 2002), and density classification (FSI, 2000). Ranganath et al. (2004) used NDVI to distinguish diseased rubber plantations in Karnataka.

2.8.6. Biodiversity prioritization through landscape analysis

Biosphere is a heterogeneous mixture of various patterns of land use / land cover that co-exists and influence one another. These heterogeneous mixtures are called landscape. Forman and Godron (1986) defined landscape as "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout". All landscapes have three basic qualities (Turner, 1989), viz., structure, function and change.

Vegetation, a dominant expression of the natural assemblage of various co-existing plant communities, plays a major role in characterizing a landscape with its biodiversity. Plant species found in a resource patch can differ from species in other patch(s) containing different levels of resources. Hence, patch characteristics
and the pattern of patches within the landscape matrix influence the flow of species, and structure and composition within and between landscapes. Increasing heterogeneity usually reduces the number of larger patches, thus decreasing the available habitat for interior species, which often need larger contiguous areas of relatively undisturbed habitat (Debinski et al., 2001; Peters and Goslee, 2001). Turner (1989) opined that the goal of landscape ecology is to determine where and when spatial and temporal heterogeneity matters, and how they influence processes.

Wayne (1993) identified different deforestation patterns and their effects on forest edge length and interior. His analysis showed that forest edge and interior dynamics were related not only to the amount of forest cover within a region but also to the type of deforestation patterns. These different deforestation patterns must be considered when modeling landscape dynamics to understand fully deforestation effects on landscape attributes and biodiversity.

Quantification of landscape heterogeneity is undertaken with the help of landscape metrics, such as patchiness, porosity, fragmentation, interspersion and juxtaposition. The heterogeneous distribution of communities is conditioned by soil, climate, and human activities. Hence, patch characterization will provide insight into the spatial organization of communities. Various GIS-based software packages, like Fragstats (McGarigal and Marks, 1995), Bio_CAP (Anon., 1999), and Patch Analyst, provide customized approaches to analysis of these parameters and to assessment of the impact on spatial biodiversity patterns.
Characterization of habitats, their configuration and degree of fragmentation, provides reliable information on the biodiversity distribution pattern. Fragmentation is the number of patches of forest and non-forest types in per unit area. The forest type map was reclassified into two classes, i.e. forest and non-forest, resulting in a new spatial data layer. A user grid cell of \( n \times n \) (e.g. \( n=500 \) m) is convolved with the spatial data layer with a criterion of deriving number of forest patches within the grid cell. The iteration is repeated by moving the grid cell through the entire spatial layer. An output layer with patch numbers is derived and associated to this a look-up table (LUT) is generated which keeps the normalized data of the patches per cell in the range of 0 to 10. Fragmentation studies have focused principally on the biotic effects of small, isolated forest patches within intensively managed landscapes (Robbins, 1979; Whitcomb et al., 1981; Wilcove et al., 1986).

Anthropogenic influence on the landscape is a discrete event through time that modifies landscapes, ecosystems, community, and population structure, changing the sub-strata, the physical environment and availability of resources (White and Picket, 1985). It is considered as the basic process responsible for many other processes, such as fragmentation, migration, local and regional extinction.

The basic variables of disturbance are magnitude, frequency, size and dispersion. At the landscape level, disturbance is related to patch structure and spatial arrangement that determines the fate of patches and their size and duration. The basic information is required to understand the disturbance caused by human intervention to the forest and surroundings. Baseline details on roads and
settlements are used to create a buffer (distance from the source of disturbance). A zone of 2-5 km based on the level of human induced factors and field knowledge, is considered for buffering. The disturbance index (DI) is computed by adopting a linear combination of the defined parameters on the basis of probable weightage (Anon., 1998).

Spatial heterogeneity of the environment increases with the variation in habitats, permitting a greater number of different resource-use strategies, preventing competition equilibrium and exclusion, and resulting in higher diversity. The natural heterogeneity coupled with spatially distinct disturbance regimes result in a complex habitat, which allows formation of different species assemblies. In order to understand the species diversity, distribution, importance and uniqueness in these complex habitats, the phyto-sociological analysis based on the sample point on the ground has been done. The aggregate value has been calculated for each vegetation type with respect to biodiversity value (BV), species richness (SR) and ecosystem uniqueness (EU).

The prioritization process for biodiversity conservation necessitates preserving species assemblies and the landscape structure needed by a target species, rather than simply preserving the species in isolation from the larger potentially changing environment. Management practices aimed directly at a particular species run the risk of losing previously unknown ecosystem functions, which might actually be crucial for the target species. Furthermore, maximum benefits for one species may be a threat to another. The ideal way is to preserve the overall ecosystem health and species diversity. Due to the presence of a large number of
species in the regions, it is impossible, or at least impractical, to manage each one of them. Instead, conservation biologists are now trying to identify ways to simplify the task using the approach of landscape level management. The biological richness at landscape level has been determined as a function of habitat, ecosystem uniqueness, species diversity, biodiversity value, terrain complexity and the disturbance index. The main parameters such as ecosystem uniqueness, species richness and biodiversity value come from sampling in the field. Various vegetation types available in the terrain are evaluated (Anon., 1998). In an important study of tropical deforestation in the Amazon rain forest, species in patches of various sizes have been compared to evaluate the importance of patch size for species number (Lovejoy et al., 1984). Large patches have proved to be generally the richest in species, because small patches provide only edge conditions (Laver and Haines-Young, 1993). Moreover, in small fragmented patches, population density is usually lower and the risk of extinction is increased (Farina, 1998). Amarnath et al. (2003) used conjunctive analysis of patch characteristics and species distribution in identifying the areas of prioritization in terms of eco-restoration and conservation in wet evergreen forests of India.

An extensive study was conducted in the Indian sub-continent, covering three major bioclimatic regions, viz., the North-East India, the Western Himalayas and the Western Ghats, with the use of concepts of landscape analysis to identify biologically rich zones (Anon., 2002). Customized software, Bio_CAP, was developed, which facilitates analysis of landscape parameters like, porosity, fragmentation, juxtaposition, interspersion and patchiness. These landscape
parameters are in turn integrated to develop a spatial disturbance index map. The disturbance index map is integrated with ground-based parameters like, species richness, ecosystem uniqueness, terrain complexity, and biodiversity value, to identify biologically rich zones as shown in figure 5.

Prasad et al. (1998) made a similar study in Kerala in prioritizing the biological rich areas through GIS approach. He used the animal and bird species database for his analysis with floristic parameters. However, he did not use the spatial databases in prioritizing the sites for conservation.

2.8.7. Vegetation transformations and its detection

Ecosystems are continuously changing, where change is defined as ‘an alteration in the surface components of the vegetation cover’ (Milne, 1988) or as ‘a spectral/spatial movement of a vegetation entity over time’. Forest is the major biological unit of the earth system and its contribution and influence reaching all other sub-system. Thus its management is very important. Rapid deforestation of the forested landscapes, especially in the tropics (Achard et al., 2002) has made the task of mapping the extent of vegetation and the transformation, which are critical for conservation planning.

Numerous remote sensing change detection methods have been developed, such as image differencing, vegetation index differencing, image ratioing, selective principal components analysis, Bi-temporal linear data transformation, Change vector analysis, Image regression, Multi-temporal spectral mixture analysis,
Fig. 5: Biodiversity characterisation at landscape level using remote sensing and GIS in Western Ghats, India
Multidimensional temporal feature space analysis and post-classification comparison (Gong, 1993; Lunetta and Elvidge, 1999).

Post-classification comparison is sometimes referred to as 'delta classification'. It involves independently produced spectral classification results from each end of the time interval of interest, followed by a pixel-by-pixel or segment-by-segment comparison to detect changes in cover type. By adequately coding the classification results, a complete matrix of change is obtained, and the analyst can define change classes. The principal advantages of delta classification lies in the fact that the two dates of imagery are separately classified, thereby minimizing the problem of radiometric calibration between dates. However, the accuracy of the post-classification comparison is totally dependent on the accuracy of the initial classifications.

A significant example of the use of the post-classification comparison approach is the work of Hall et al. (1991) in which Landsat images acquired in 1973 and 1983 were classified into five forest successional classes (clearings, regeneration, broadleaf, conifer and mixed). Liu and Zhou (2004) used post classification comparison for detecting change in urban fringe areas and proposed change rationality for accuracy assessment of the change detection.

Xu and Young (1990) preceded their post-classification comparison by a manual segmentation of the images according to ground features and characteristics of the scene. They then classified all segments separately for each date via a supervised maximum likelihood pattern recognition routine. They concluded that this
approach, sometimes referred to as 'pre-stratified delta classification', enabled them to avoid some obvious errors in classification (e.g. pixels classified as built-up areas on areas known to be moorlands in south-east Scotland).

Remote sensing images from Landsat and SPOT satellites have been used in land use and land cover change detection for years (Green et al., 1994; Kwarteng and Chavez, 1998; Li and Yeh, 1998; Masek et al., 2000; Weng, 2001; Zhang, 2001).

Beyond the two-time comparison method, multi-temporal comparison (i.e. use of more than two multi-temporal images) studies were also reported (Martin, 1989; Michener and Houhoulis, 1997; Petit et al., 2001).

Over the last few decades, numerous researchers have improved the estimation of land-cover change. Development of predictive models of land use/land cover change, under the auspices of the Land Use and Land Cover Change (LUCC) project of the International Geosphere Biosphere Programme (IGBP) and on Global Environmental Change (Lambin et al., 1999; 2003; Turner et al., 1995) has led to the understanding of the causes of land use change.

Land use change models follow a wide variety of modeling techniques and theoretical assumptions. Change detection can be carried out with two broad approaches. The first approach involves the comparative analysis of independently produced thematic classification from different dates. The second approach is simultaneous analysis of multi-temporal data. With in these two approaches, there are a number of methods and techniques. The post classification is the widely used technique for digital change detection. There is no universally 'optimal' change
detection method since change detection depends on the specific application and amount of details required (Virag and Colwell, 1987; Peter, 1995). Joyce et al. (1980) concluded that post classification comparison appear suitable for analyzing land cover change with landsat data where forested land has been transformed into an agriculture area.

Digital change detection finds use in studying the human dimensions (encroachment, deforestation and shifting cultivation) in the forest landscape. This has provided new dimensions into the understanding of ecosystem dynamics and biophysical parameters in the forested landscape.

Reviews, that characterizes and classifies land use models are provided by Lambin et al. (2003) and Kaimowitz and Angelsen (1998) for deforestation, while Bockstael and Irwin (2000) gave explanation of land use models based on economic theory.

The sensitivity of the remote sensing data to atmospheric disturbances has led to the use of vegetation indices (Jensen, 1996). Among the different vegetation indices used, the NDVI is the most important and widely used to map the existing vegetation (Sankaran, 2001; Krishnaswamy et al., 2004) and its transformation (Sader and Winne, 1992; Hayes and Sader, 2001; Sader et al., 2001). Ranganath et al. (2004) employed NDVI to detect the diseased in rubber plantation in Karnataka.
2.8.8. Forest fire assessment

In many ecosystems, fire is a part of the natural regeneration process stimulating the germination of certain species, clearing space for the invasion and growth of others and releasing a periodic flush of nutrients into the soil (Dawson et al., 2002). Though controlled fire is useful and legitimate tool in forestry practices for specific purposes, in many cases it is divesting and destroys the natural ecosystem.

The mechanism by which forest fires have modified the vegetation cover (with species attributes and selectivity of species) of the Western Ghats is outlined by Hegde et al. (1998). Kodandapani et al. (2004) used remote sensing for fire identification and its frequency and the effect on conservation of the protected area – Madumalai region, India.

In India, human population growth has led to extensive deforestation, which is greatly fragmenting the existing forests (Menon and Bawa, 1998; Jha et al., 2000). The forest fires are also contributing significantly to this deforestation. The forest fires in tropical forests are known to alter the species composition, demography and biomass of forests (Holdswoth and Uhl, 1997; Cochrane and Schulze, 1999; Haugaasen, 2000). The forest fires also modify the selectivity of the species and characters in its assemblages in a particular vegetation cover (Hegde et al., 1998).

In forest landscapes, disturbance by fire has been documented to affect vegetation patterns (Romme and Knight, 1981; Romme, 1982; Taylor and Skinner, 1998). Therefore, landscape scale vegetations patterns are dependent on the species-
imposed situation in response to environment and disturbance (Harman et al., 1983; Romme, 1982; Veblen et al., 1992).

On the basis of causative factors, the forest fires could be classified into three types—(1) Natural fires, (2) accidental fires and (3) deliberate or intentional fires.

The forest fires can also be classified on the basis of the place of their action into four types and they are -

1. Creeping fire (spreading slowly over the ground with low flame)
2. Ground fire (burns the ground cover only i.e. the carpet of herbaceous plants and low shrubs, which cover the soil)
3. Surface fire (burns not merely the ground cover but also undergrowth. e.g. the fires in the plains)
4. Crown fire (spreads through the crowns of trees and consumes all or part of the upper branches and foliage)

Forest Survey of India has conducted a series of inventories since 1965 and documented the extent of forest fire and its intensity in a number of states in India (Anon., 1987a; 1987b: 1995). About 9.2% of the inventoried area was affected by frequent fire and 44.5% by occasional fire. In Karnataka, the inventory showed that 6-11% of the total area is burnt due to frequent fires and 31-51% of the area with occasional fires (Rai and saxena, 1997). Roy (2000) compiled the literature on fire assessment in India and discussed the possible role of satellite remote sensing in identification and monitoring.