CHAPTER – 2

REMOTE SENSING AND GIS

2.1 Remote sensing

Remote sensing technology has tremendous potential for gathering enormous amount of ground information about the environment. It has been used for great variety of practical applications. Remote sensing technique by virtue of its synoptic and repetitive coverage has been a strong tool for surveying of natural resource at global to micro-level. Sensor related technological advancement have made it possible to acquire reliable information about the landscape (William and Nelson, 1986). Distribution patterns of vegetation, surface materials and cultural features can be accurately interpreted through satellite images. In order to achieve a better understanding of the process in which natural system operates, the application of remote sensing technology in conjunction with GIS is getting wide acceptability (Burrough, 1990; Karale, 1992; Legg, 1995; Palihawadana, 1995; Prasad, 1998; Dubey and Mathur, 2000; Behra *et al.,* 2001 Kushwaha and Roy, 2002; Chandrasekhar *et al.,* 2003; Kushwaha and Hazarika, 2004; Singh *et al.,* 2005).

Remote sensing finds its applicability in intensive ecological research, better landscape management by ways of providing template for up-to-date thematic map preparation. The spatial and temporal advantage provided by remotely sensed images helps in environmental monitoring, as it integrates spatially heterogeneous entities/elements into easily measurable format by quantifying spectral response at a specific scale over a time frame. It provides perspective horizontal view and helps in delineating different patches and their spatial characteristics (Godron, 1991). The state-of-art is being used by various disciplines. In the field of forestry, it is widely used to investigate vegetation, forest cover, land use/ land cover mapping, forest change dynamics, landscape and biodiversity characterisation, carbon estimation and host of other things (Lilisand and Kiefer, 1979; Anonymous, 1994; Tomar, 1998; Behra *et al.,* 2001; Kushwaha, *et al.,* 2002; Roy, 2002; Walter, 2004; Weiers *et al.,* 2004; Frosini de Barros Ferraz, 2005; Singh *et al.,* 2005; Kale *et al.,* 2005). For Biodiversity characterisation, the technology is being used to create sampling design, provide resources information for extrapolation of field observation, report and analyse results of inventories (Anonymous, 2003). This information provides basis for model building, store and documentation of data.

Satellite sensors extract maximum amount of vegetal information of an area in the form of an image. Though each can be measured on ground they may be interpreted more effectively from satellite image. The characteristic difference in structure, phenological state and biophysical properties of different vegetation types result in differential reflection properties i.e. spectral signature, unique to each vegetation type, which is captured by the satellite sensor and is translated into digital form. The added advantage of integrating both spatial and spectral information makes it more desirable for landscape study and planning. Data so obtained is utilised in different fields for studying different aspects in the concerned field.

Contemporary research on landscape studies has focussed on the ecosystem dynamics with large temporal scale. Such advantage allows tracing the environmental conditions of the past (Delcourt and Delcourt, 1988). The availability of data on various scales has opened new possibilities for integrating patterns and processes (Lubchenco *et al.*, 1991). Satellite images can be considered as a convenient tool to analyse landscape patterns since they provide a digital mosaic of the spatial arrangement of land covers (Coulson *et al.*, 1990; Chuvieco, 1999). Remotely sensed images can provide critical information on all these components, but this work focuses on the first one.

Advent of remote sensing as a technology for surveying and assessment of natural resources has helped to address the global scale to micro-level requirements. The remote sensing technique by virtue of its synoptic and repetitive coverage holds promise to meet the requirements. Acquisition of images of earth from space has opened new frontiers in mapping. The multi-spectral satellite images provide definition of vegetation patches which are related to phenological type, gregarious formations and communities occurring in unique environmental setup. The technique for the first time provided view of the Earth to the mankind and global perspective to study its environment.

2.2 Geographic Information System

Geographic information systems are computer-based systems that efficiently store, retrieve, manipulate, analyse and display spatial data according to user specification (Arnoff, 1991; Maguire, 1991). Burrough (1986) defines GIS as a "powerful set of tools for colleting storing, retrieving at will, transform and display spatial data from the real world". One of the most powerful aspects of GIS is the ability to examine spatially referenced objects over time. Storing, analysing ecological data by geographic co-ordinates and by using spatial data structures are powerful basis for establishing a GIS for multi-scale studies of ecosystems (Marble *et al.*, 1984; Iverson *et al.,* 1989). GIS structure has been found effective for both location analysis and for spatial modelling purposes. Spatial interaction that can be analysed by the GIS is the relationship between processes and landscapes. The recent emphasis for ecological studies of larger areas over longer time spans has coincided with the development of GIS that is superior and indispensable for different analyses over manual methods (Johnston and Naiman, 1990). Of particular importance to landscape ecology is the need for developing GIS that handle ecological data of a variety of scales in hierarchical fashion. GIS of varying complexity has emerged as a powerful tool in portraying landscape level phenomenon more efficiently. Many studies have employed user generated computer programs to perform the analysis rather than the commercially available GIS packages. GIS is associated with two different roles for a geographical perspective on biodiversity. It contains a powerful reference base (geographical location), i.e. maps of natural vegetation (endemic, multipurpose and endangered species), soil, land cover, topography, hydrology, bird migration, distribution of fauna, etc. locating these features associated with their attributes allows diverse database to produce new relationships between environmental features and associations between different biota. Secondly, it is a powerful and effective way of communicating a large variety of information (Salem, 2003) the spatial analyses and modelling capabilities of GIS render them useful in mapping and modelling habitats, analyzing gap in biodiversity, assessing degree of biodiversity, conservation planning and mapping of eco-regions at regional and landscape level. Recent development in GIS are in the analysis modelling applied to environmental data (Aspinall, 1995), notably predicting the distribution of species under present and changed environmental conditions, understanding the interaction of habitats and other aspects of ecological infrastructure within landscape, and interpreting and monitoring biodiversity for use in land use planning and management. GIS forms an integral part in any biodiversity information management system such systems are designed to harness the data that are available and extract the information that creates the kinds of knowledge needed to truly address conservation challenges and made the needs of the users (Salem, 2003).

GIS provides the way to overlay different 'layers' of data: the ecological conditions, the actual vegetation physiognomy and human pressure indices (settlement density, road network). It helps to assess disturbance levels; the spatial distribution of several species in order to determine biodiversity hotspots; past and present maps for monitoring land cover and land use changes. It provides possibilities to extrapolate observations e.g. to automatically define and map the potential area of a given species and to compare it with the locations where, it has been actually observed; or to combine different data sets for defining the potential list of species for a given forest types. GIS provides a database structure for efficiently storing and managing ecosystem related data over large regions. It enables aggregation and dis-aggregation of data between regional, landscape and plot scales. It also assists in location of study plots and/ or ecologically sensitive areas. GIS supports spatial statistical analysis of ecological distributions. It improves remote sensing information extraction capabilities, and provides input data/ parameters for ecosystem modelling.

2.3 Remote sensing and geographic information system for biodiversity characterisation

Biodiversity of an area is governed by several factors. Some of these factors include existing climatic conditions, different levels of disturbances, management, socio-economic conditions in adjacent areas etc. Of these, disturbance due to human induced activities has been most serious with adverse effects on biodiversity. Thus it is important to understand the issues for long term planning and management of natural resources. Each species requires minimum area for its survival and evolution. Conservation of single species is not feasible. Similarly, experience has shown *in situ* conservation in small areas may not be long lasting. Therefore, efforts have been made to conserve the vegetation over large areas. Landscape is an aggregation of land forms in any area. Conservation efforts in larger landscape are the need of the hour. Landscape characterisation deals with the application of landscape principles to understand structure, function and change aspects in a landscape.

Fragmentations due to deforestation or land use change have caused loss of biodiversity and the corridors required for their easy movement and migration. Patch characterisation is important to find out the relationships between biodiversity and various other landscape parameters like porosity, patchiness etc. (Anonymous, 2003b).

The concept of biological diversity needs to be addressed in the context of disturbance, its biological value, its species richness, its uniqueness etc. This approach gives a holistic view of an area in terms of biodiversity richness and disturbance. The analysis of these parameters has been possible using Geographic Information System. Recent trends are considering more and more such parameters to characterise biodiversity for planning, management and bio-prospecting (Anonymous, 1999, 2003b).

2.4 Community analysis

The term 'Community' denotes association of plants and animals occurring in a particular locality and dominated by one or more prominent species or by physical characteristics (Slobodkin, 1961; Shimwell, 1971; Daubenmire, 1968). Community differs in their number of species, relative abundance of those species (species diversity). Mathematical expression to measure species diversity thus provides a means of objective comparison of a community structure (Ricklef and Miller, 2000).

The detailed inventory through sampling in community/ vegetation is a prerequisite for its characterisation. A representative sample size is the best way of investigating communities as it provides clearer picture of the community-structure and saves time (Mueller-Dombois, 1974; Maguran, 1988). Therefore, working out the design of a sample that best suites becomes a fundamental task before carrying out such study. Such methods provide base line information on biological resources. The United Nation Convention on Environment and Development has emphasised on developing methodologies for evaluation of biological diversity (resources) for characterizing the status of ecosystems (Heywood and Watson, 1995).

The species inventory data are essential for building predictive classification and that permits estimation of character diversity for comparison of biota (Williams *et al.,* 1995).

They in turn can be used for bio-prospecting and prioritization for conservational and managerial strategies.

Biodiversity may be expressed in many ways as species richness and through various indices, which take account of individual of each species and their abundance. Various mathematical formulation related to diversity are applied to describe and compare communities of different habitat. Diversity is seen as an attribute of plant communities and is studied by ways of diversity indices based on species cover and abundance. Variations in species composition can be used as indicators of ecological gradient and the environmental quality of ecosystem (Alard *et al.*, 2000). The calculation of several diversity measures and comparison of the results has been considered as a desirable method of studying biodiversity (Baers and Penev, 1985).

2.5 Vegetation classification and mapping

Much of the studies on vegetation are based on conventional methods through extensive ground surveys (Puri, 1960; Champion and Seth, 1968; Meher-Homji, 1989). However, later advances in this field gave more emphasis on physiognomy, structure and composition and are being practiced widely (Fosberg, 1967). In India, reliable data on forest landscape, its structure and function are discrete. Hence, there is a necessity to obtain reliable data on the natural vegetation landscape at various levels. The principal source of such information can be the vegetation maps at landscape level. High level stratification at global and regional scale provides maps on a broad outlook about the vegetation. However, micro and macro level mapping of vegetation, which are based on the association of species in a community and physiognomy-floristic approach provides greater information regarding the landscape.

Vegetation maps present an inventory by aggregation in individual plant communities, depicting their location, extent and geographical distribution in the landscape on the real time basis. This sets up a ready reference for quantifying forest cover, vegetation change dynamics, environmental quality and host of other things. These maps can then be used as a basis for future landscape planning especially in the field of forestry, range management and agriculture etc. (Tomar, 1998).

With the increase in human population, dependence on forest resources to meet their needs for fuel, fodder and timber has increased manifold. As a consequence forest covers are diminishing at an alarming rate ever than before. The problem is further aggravated due to increased activities like mining, industrialisation, extension of human habitations, acquiring arable land, construction of roads and dams (for irrigation and/or power generation). Such human activities are taking a heavy toll on our biological resources. Species are coming into direct conflict with the humans. Large numbers of them are getting threatened due to highly fragmented forest ecosystems those provided congenial habitat; perhaps some must have vanished without coming into human notice. The survival of a species depends on the complex interplay of various abiotic and biotic components of an ecosystem and frequent interaction among the species in a community. Thus, characterisation of forest vegetation, with detailed inventory from time to time becomes imperative, when seen in the light of conservational and managerial aspects.

Recent advances in the field of remote sensing, has brought to the forefront the state of art in the creation of vegetation maps of very high perfection, both at the regional and national levels. It has been applied effectively to map the forest/ vegetation cover at micro, macro and meso levels. However, if the technology is judiciously combined with the ground truth data the vegetation cover maps at various scales can be achieved (Tucker *et al.*, 1984; Botkin *et al.*, 1984). Remote sensing techniques and GIS are being increasingly used to assess and monitor forest cover by the governmental and non-governmental organisations and academicians in recent years.

2.6 Landscape study

Landscape is the aggregation of land forms in any area. It is a large area composed of mosaic of patches or ecotopes, in which we introduce physical, biological and cultural elements. Landscape ecology focuses on spatial relationships and the interactions between patterns and processes. The spatial configuration of these landscape elements can be attributed to combination of environmental correlates and human forces (Forman and Godron, 1986). Both these factors bring about a change in the landscape patterns and can influence a variety of ecological phenomena (Turner, 1989) such as animal movements, spread of disturbances both natural and anthropogenic etc. (Freemark and Merriam, 1986; Franklin and Forman, 1987; Turner, 1987; Turner *et al.*, 1989).

Landscape ecology is the study of spatial distribution of different elements in space at variety of scales and the causes and consequences of those spatial patterns. It has important ecological consequences as it focuses on the structure, function and changes in landscapes (Forman and Godron, 1986; Turner, 1987, 1989). The spatial pattern includes the arrangement of patches, their shapes, size, abundance and configuration of the various elements (*i.e.* their spatial heterogeneity), which is a functional unit of landscape. The landscape patterns influence a variety of ecological phenomena, like population and community structure (Hasson, 1979; Danielson, 1991; Soule *et al.,* 1992; Pulliam *et al.,* 1992). Ecosystem interacts at the landscape level and function through ecological processes (Risser, 1995). The need for broadening the spatial scales of ecosystem ecology for the study of the ordered complexity of natural and cultural landscapes has led to the realisation of the theoretical and methodological relevance of the landscape ecology.

Many ecological phenomena are best studied at landscape level. With the rapid technological advances, through sophisticated and comprehensive techniques for obtaining accurate results, it is possible to study larger areas. Along with floristic-sociological approach, the field has been gaining ground on spatial statistics and modelling through technological advances in Remote Sensing and Geographical Information System (Gurevitch *et al.,* 2002). Some resource management decisions require real-time information, such as fire management, various natural and human induced disturbances, spatial distribution of plant communities and so forth. Yet others depend on the implication of projecting ecosystem responses over time (Warring and Running, 1998). Such ecosystem analyses have important implication for taking effective decisions by policy makers.

Recent approach emphasizes conservation of habitats rather than a single species. Tremendous effort, time and resource required for conservation of species by species has propelled a new concept of landscape ecology. This field addresses the problem in its entirety, the dynamic and complex ecological processes, and their resilience to various natural and anthropogenic perturbations. Explaining such complex ecological process operating in the ecosystem at landscape level is gaining wide popularity. A lot of attention has been directed towards studying biodiversity at a landscape level (Tomar, 1998; Behra, 2000; Kushwaha *et al.,* 2002; Roy and Tomar, 2002; Singh *et al.,* 2002; Singh and Roy

2004 Singh *et al.,* 2005) Management of habitats through interactive network of species at landscape level has been the guiding principle in conservational biology (Whittaker, 1977; Orians, 1993; Edwards *et al.*, 1994). The spatial arrangement of patches, their quality, the juxtaposition and the proportion of different habitat types are elements that influence and modify the behaviour of species populations and community structures (Lidicker, 1995).

A species requires minimum/ optimum area for its evolution and survival. Various physical factors and the interaction among the different species in a community determine the fate of a species. Such problems can be addressed in terms of habitat or at community level. Greater the variety of habitat types, richer will be the species diversity. Diversity of a species is also dependent upon the dispersal behaviour, juxtaposed patches, its dispersal behaviour and various disturbance regimes within a landscape. Thus biologically rich areas are those habitats, where landscape ecological conditions are favourable for natural speciation and evolutionary processes.

The land cover information can be directly used for landscape characterisation. Landscape parameters like patch, porosity, interspersion, juxtaposition and fragmentation could be estimated from a vegetation/ land cover map. These parameters when analysed with ground based information can yield valuable information on biodiversity.

2.6.1 Patch

Heterogeneity in natural ecosystems is a characteristic feature. Some regional ecological analyses can be accomplished by evaluating each landscape parameter individually. Ecosystem analyses require information about the size, distance and characteristics of adjacent cells, necessitating a sophisticated landscape description (Warring and Running, 1998). These are based on homogenous unit called a *patch.* Each patch exists within a matrix of other patches together forming the tapestry of a landscape (Forman, 1995). Patches occur at all scales that reflect the microclimatic distribution with mosaic of soil types, topographic variation and successional stages resulting from disturbances (Lambeck and Saunders, 1995). Identification of patch combines both qualitative and quantitative approach. Such approach gives a better understanding at which the landscape functions. Once the dimensions and other quantification of a patch are established, estimates of areas, shape, and frequency over a specified landscape can be analysed. The spatial arrangement of a patch with other patches and degree of regularity of a pattern is measured by proximity, dispersion and contagion. Using the neighbourhood concept, it is possible to measure the relative size and isolation of patches.

2.6.2 Contagion (interspersion and juxtaposition)

Interspersion/juxtaposition is the measures of connectivity of areas of similar habitats. It is a function both of the physical arrangement of patches and the behaviour of biotic component in response of that pattern. These are important landscape parameters in conservation biology. Interspersion is a measure of spatial intermixing of the vegetation type. It represents landscape diversity and dispersal ability of the species. Juxtaposition is a measure of proximity of habitat types and relative importance of adjacency (Lyon, 1983; Anonymous, 2003; Jeganathan, 2003). It also indicates the connectivity of areas of similar types. Juxtaposition is a unique index that represents preference of one habitat with the other.

2.6.3 Landscape fragmentation and biodiversity loss

Threat to global, regional and local biodiversity includes a wide range of factors. While specific threat to biodiversity differs among biomes (Sala *et al.,* 2000), but among different factors, one of the greatest threats to natural habitat is the fragmentation of entire system (Bierregard *et al.,* 1992; Hobbs and Lleras, 1995; Kattan *et al.,* 1994; Saunder *et al.,* 1991) that severely depresses biodiversity. Fragmentation study at landscape level takes into account various factors such as connectivity, the presences of ecotones, corridors, meta-population structure *etc.* It occurs when human activities such as agricultural development, road links, or urbanisation remove large proportion of the natural ecosystem and replace them with a greatly modified matrix, only the small remnants of the native ecosystem remains. The reduction in habitat and alteration in landscape processes resulting from fragmentation have huge impact on biota. Such fragmentation results in geographical isolation of species. It increases the vulnerability of these patches to external disturbances supporting biodiversity (Nilson and Grelsson, 1995).

Habitat destruction is widely considered as the most pervasive anthropogenic cause of the loss of biodiversity (Brown, 1985; Wilson, 1985; Myers *et al.*, 2000). Human impact on habitats takes two main forms: conversion from one habitat type to another and modification of conditions within a habitat type (Myers and Turner, 1992). Forests are the houses of biological resources. They are being rapidly depleted in the developing tropics through excessive uncontrolled human influence. Deforestation affects biodiversity through destruction of habitat, isolation of fragments of formerly contiguous habitat, edge effects within a boundary zone between forest and deforested areas (Skole and Tucker, 1993) and a variety of other mechanisms.

The response of biota to ecosystem fragmentations is well studied, which has basically centred on species and community responses to changes in ecosystem size and isolation. However, functional aspect that explores relationship between fragments in a natural ecosystem and the surrounding is only gaining attention recently. The ecosystem fragmentation not only affects biota of fragment in question, the effect of matrix derived influences has many other impacts. The switch from continuous cover of native vegetation to small fragments in a predominantly altered matrix brings many important consequences for remnant vegetation (Hobbs and Lleras, 1995). The consequences are particularly important at fragmented edges, where significant change in microclimate and vegetation occurs with concomitant effect on the native flora and fauna (Kapos, 1989; Laurance *et al.*, 1993; Matlack, 1993; Scougall *et al.,* 1993; Laurance, 1994). This also brings about hydrological imbalances that threaten the native vegetation.

2.7 Disturbance vis-à-vis biodiversity

Natural disturbance is an important and persistent component of environment under which biodiversity evolved at the species and population levels and has been assembled at the community, ecosystem and landscape levels. Disturbance is a physical disruption of the structure of a system. This is a very common and wide spread phenomenon in nature. They are normal characteristics of all ecosystems and play a crucial role in community ecology over a range of scale (Gurvitch *et al.,* 2002). *Disturbance may be defined as a relatively discrete event in time that causes abrupt change in ecosystem, community, or population structure and change resource availability, substrate availability, or physical environment* (White and Picket, 1985). Various biotic and abiotic agents have a profound effect on the community dynamics and their role in the functioning and maintenance of ecosystem. The process is brought about by a combined effect of natural and human induced activities. The process has far reaching consequences in natural ecosystem functioning. Among the visible consequences of disturbances are fragmentation of habitat, immigration and extinction of species. Fragmentation has a strong influence on the dynamics and fate of the material and energy moving across a landscape. Disturbance of ecosystems has implications for the maintenance and restoration of biodiversity of all hierarchical levels (Mc Naughton, 1989; Walker, 1989). Ecologically, disturbance is important as it provides chance to attain equilibrium between the two extremes of species population. It alters resources and environmental signals and regulators thereby allocate themselves among mutually exclusive structures and function (Cody, 1966; Picket, 1995). Those are used to predict species distribution in time and space.

Disturbance regime and their impact on communities and landscapes can be well understood by analyzing spatial and temporal architecture of disturbance (Moloney and Levin, 1996). At landscape level, disturbance is related to patch structure and spatial arrangement and determines the fate of patches, their sizes and duration. Severe disturbance or even a prolonged absence of disturbances generally has depressing effect on biodiversity, but intermediate disturbance seems to enhance diversity in a system (Connell, 1978; White and Picket, 1985).

Biodiversity and disturbance are closely interrelated. Like biodiversity, disturbance too is a hierarchical concept, with different expression at different levels of organization from population, communities to ecosystem (Picket *et al.*, 1989). However, they are independent of each other, thus events that disturbs a community may not disturb a landscape. More recent approach in the study of disturbance *vis-à-vis* biodiversity encompasses identification of sources and types of disturbance and their impact on the ecological systems at different organizational level through explicit models (White, 1979). Various ecological disturbances brought about by stress (environmental) or perturbation is differentially sensitive at various levels of organization that needs to be addressed while studying the relationship between biodiversity and disturbance. The temporal patterns as indicated by frequency and the unusual juxtapositions at the prevailing time have direct bearing on the ecological process.

Disturbances are characterised by certain regular features that are discernible in a system by combining type, frequency and scale (White and Picket, 1985). It exhibits intensity of the process or severity. These intensities are generally characterised by the energy expenditure in the process and provide a new habitat template for other species. Disturbance also exhibits recurrence with some characteristic frequency, which can be specified in absolute terms or relative to temporal extent of the process or longevity of the system of interest. Stratification of frequency by intensity provides valuable additional information on the whole subject. The spatial scale and distribution help to explain and predict the impact of disturbance on system.

Disturbance is the driver of the landscape dynamics and acts at all spatio-temporal scales. Human induced disturbance differs from natural disturbances especially in extension, severity and frequency. The capacity of landscape to incorporate human disturbance is overwhelmed and the disturbance process is transformed into a stress process, which reduces biodiversity. Human activities have widespread impact on biodiversity, affecting ecological entities from species to whole communities and ecosystems, though heterogeneity in the landscape can be due to regular occurrences of moderate disturbances. The disturbance regimes can be measured by using different indices i.e. degree of fragmentation, fractal dimension, contagion, juxtaposition, evenness and patchiness (Li and Reynolds, 1994; Tomar, 1988; Roy *et al.*, 2000; Millington *et al.*, 2002).

Different types of environment, landforms, man-made and natural landscapes and regions can be characterized by the kind, recurrence and spatial pattern of disturbances within them. This implies the regularity in patterns of disturbance that can help in evolutionary selection (Huston *et al.*, 1988) or ecologically assort species (Noble and Slatyer, 1980) the same way that general patterns in climate may do. Natural disturbance regimes owe much of their regularity to climatic patterns. Such a link points out the potential sensitivity of disturbance regime to global climate change. Models that rely on the relative repeatability of disturbance regimes can successfully account for species distribution and behavior (Horn *et al.*, 1989; Warring and Schlesinger, 1985). This is an important intersection between biodiversity and disturbance.

2.8 Economic, Ecological and Taxonomic evaluation

Quantification of biological entities addresses only a part and not in totality the biological richness or biodiversity of a place. Environmental as well as socio-economic aspect needs to be taken into consideration to bring about the essence of biodiversity study. Economic evaluations of species and ecological significance have gained increasing attention by planners and conservationists. Each and every species inhabiting earth surface has some use or the other. Biodiversity may have direct or indirect use. Therefore, evaluation of these biological resources in terms of economics, ethical or cultural, has become an important aspect in conservation biology.

The value of biodiversity to society depends on many things besides its ecological significance. These tend to vary from society to society and from place to place. Societies have their own preference for assigning values on biological resources depending on the societal needs, technology, their income all influence perception of values (Perrings, 1995).

Evaluation of biodiversity not only highlights its worth to a society but it gives the idea as to how the biological resources are being used or misused. Though, economic evaluation are market price driven, which has lead to biodiversity loss, but such approach provides means to quantify the error and testing its sensitivity to assumptions made about the distribution of income and assets and the weight given to consumption by members of future generation. It also indicates means and ways to reform market by ways of government intervention to protect biological resource for future generations.

The value of biological resource is the reflection of their social importance, the opportunities forgone by society by committing such resource (Perrings, 1995). Conservation of all species is not possible. However, such evaluation of biodiversity gives an idea about prioritization of certain species, habitat or ecosystem. The value accorded by society to biodiversity may be driven by moral or ethical concerns and their willingness to commit resources to conserve biodiversity should it involve their loss. Indeed this precisely why evaluation of biological resources is an important part in conservation and management of ecosystems.

Biodiversity may have direct and indirect values. Direct value is evaluated from the direct consumption of resource. Indirect values from resource are responsible for the production of resource that provides other services. Biodiversity falls in the latter category and are much more likely to be external to the market. Among the thousands of species in an ecosystem, small numbers of biotic and abiotic variables are responsible for maintaining the balance of species (Holling, 1992). Some of these species have a key role in the functioning of an ecosystem, loss of these species triggers fundamental transformation. There is a growing evidence that the great complexity and diversity within many ecosystems. The ecosystem is balanced by a small number of critically structuring process mediated either by individual Key stone species (Paine, 1966) or by set of species (Holling *et al.,* 1995). The resilience of ecosystem depends on the range of species capable of supporting the critical structure of those systems under different environmental conditions. A change in the composition of species that affects any one of the key structuring process may have profound consequences for the ability of an ecosystem to provide economically valued ecological services (Perrings, 1995).

2.9 Biological richness

Biodiversity characterisation involves two closely inter-related processes, the characterisation of the main unit of variation (genes, species and ecosystems) and quantification of variation within and between them. However, they are part of the same process. Characterisation of biodiversity depends critically on the work of three scientific disciplines i.e. taxonomy, ecology and genetics (Bisby, 1995). Each of these branches analyse the pattern and defines the unit of variation at its own hierarchical level. Biodiversity at landscape can be characterized by measures of species richness, species diversity, taxic diversity and functional diversity. Surrogates are often used for such measures (Sarkar, 2003). Habitat surrogates including classification of vegetation, details in the physical environment, factors determining the biodiversity loss in spatial context help in solving practical problems of ground sampling and the intensity at which it is to be done. It however, has limitations for choosing between the precision of the measure and the availability of data and the cost of its compilation. Higher level surrogates have the advantage of implicitly integrating more of the functional processes those favour viability.

Recent progresses in the field of landscape ecology have introduced a phenomenal change in the study of biodiversity. With ever increasing need to save species from disappearing in oblivion, conservational efforts using state of art techniques; remote sensing and GIS are coming to the forefront for inventorying, habitat modelling and monitoring species richness (Stom and Estes, 1993). Models incorporating parameters such as disturbance regime, terrain complexity, species richness, ecosystem uniqueness and biodiversity value (Roy *et al.*, 2000; Behra, 2000; Roy, 2002) to depict the areas of biological richness are gaining rapid popularity. The methodology is being widely used to assess biodiversity and their mapping at various regional and national levels. Biological richness of an area is determined by the socio-economic, ecological parameters and taxonomic importance. Such integrated approach provides valuable information on biological richness and help in habitat prioritization in conservation planning.

2.10 Review of literature

Since the launch of the first civilian earth-observing satellite in early seventies, satellite remote sensing has provided increasingly sophisticated information on the structure and function of forested ecosystems. Forest classification and mapping, common uses of satellite data, have improved over the years as a result of more discriminating sensors, better classification algorithms, and the use of geographic information systems to incorporate additional spatially referenced data such as topography. Land-use change, including conversion of forests for urban or agricultural development, can now be detected and rates of change calculated by superimposing satellite images taken at different dates. Landscape ecological questions regarding landscape pattern and the variables controlling observed patterns can be addressed using satellite imagery as can forestry and ecological questions regarding spatial variations in physiological characteristics, productivity, successional patterns, forest structure, and forest decline (Iverson, *et al.*, 1989).

Recent developments in remote sensing technology have indicated that if judiciously combined with ground-based studies, it is possible to carry out detailed forest inventories and monitoring of natural vegetation cover at various scales (Tucker *et al.*, 1984; Botkin *et al.*, 1984). The analogue representation of remote sensing and sensor related technological advancements have made it possible to acquire precise vegetation classification and mapping (Walsh, 1980; Daniel and Shenan, 1987; Hall *et al.*, 1991; William and Nelson, 1986; Prasad *et al.*, 1994). Kuchler (1988) has cited satellite remote sensing as the most useful tool for extensive vegetation mapping. Satellite remote sensing techniques have been used for vegetation mapping in various tropical forests (Townshed *et al.*, 1991; Skole *et al.,* 1994; Gracia and Alvarez, 1994; Malingreau and Tucker, 1988; Sader *et al.,* 1990; Rasch, 1994; Malingreau *et al.,* 1995; Singh *et al.,* 2005).

Use of satellite remote sensing has been effectively used to map broad vegetation types and biodiversity mapping combined with field survey (Fuller *et al.,* 1998; Tomar, 1998, Behra, 2000; Roy and Behra, 2002). Nagendra and Gadgil (1999) have identified and mapped landscape element types for monitoring species diversity in the Western Ghats using remote sensing and field assessment data. The techniques have been used for vegetation characterisation of many protected areas (Roy *et al.,* 1995; Porwal *et al.,* 1996; Kushwaha *et al.,* 2001), effect of slope on the community structure in Shervarayan hills (Balaguru *et al.,* 2003). Pant and Roy (1990) highlighted the utility of remote sensing data in obtaining spatial information of vegetation and existing land use through visual interpretation at 1:50,000 scale Landsat TM false colour composite of Aglar watershed. In the North Eastern region satellite remote sensing data has been used to characterise vegetation (Tomar, 1998; Behra, 2000). Behra *et al.* (2000) have attempted to stratify montane vegetation of Talley Valley of Lower Subansiri district through digital image processing techniques and reported that partial shadow pattern and varying illumination condition impart great difficulty in such study.

Menon and Bawa (1997) have used remote sensing technologies for biodiversity conservation following landscape ecology and spatial analysis approach. The approach includes analysis of consequences of land cover and land use change in the form of climate change in distribution of biodiversity. They also carried out gap analysis of effectiveness of protected area network in conserving areas of importance for biodiversity conservation and planning. Ramesh *et al.* (1997) have attempted a vegetation based approach for biodiversity gap analysis. This landscape based approach takes into account the extent of deforestation, distribution of vegetation types, patchiness and species diversity for each forest and uniqueness of the habitats. Geospatial modelling techniques are increasingly being used for characterising the biodiversity (Roy and Tomar, 2000; Singh *et al.,* 2004). Menon *et al.* (2000) have proposed a method for identifying conservation priority areas in Arunachal Pradesh based on predictive landuse modelling approaches. Behra (2000) has used remote sensing and GIS technology to characterize biodiversity of Subansiri district of Arunachal Pradesh.

Hobbs (1997) reviewed the present and future status of landscape ecology and also explored the extent to which landscape ecology has developed conceptual constructs and techniques, which are useful in applied sense. Godron (1991) has documented that remote sensing gives a perspective horizontal view and helps in delineating different landscape elements and their spatial characteristics. Ecosystems interact at the landscape level and function through ecological processes (Risser, 1995). Several studies have suggested that the landscape have critical threshold at which ecological processes will show dramatic qualitative changes (Gardner *et al.,* 1989; O'Neill *et al.,* 1989; Turner, 1989). Theoretical and empirical evidences that spatial pattern influence such ecological processes have been well documented by various workers like Krummel *et al.* (1987), Turner (1989), Wiens (1989), Menge and Olson (1990), Holling (1992), Wiens *et al.* (1993). The spatial and temporal scales in ecological studies also have been considered as important in such works (Allen and Star, 1982; Addicott *et al.,* 1987; Morris, 1987). Griffith *et al.* (2000) have explored the potential of remotely sensed data for measuring landscape structure as an important determinant of species diversity. Analysis of landscape structure from satellite imagery might provide a complementary view to field methods in assessing landscape patterns (Chuvieco, 1999).

The effects of anthropogenic disturbances on landscape have been studied by Krummel *et al.* (1987) and Iverson (1988). Turner and Ruscher, (1988) studied human influences on the landscape using historical and current data. Tilman *et al.* (1994) have demonstrated the negative effects of every slight increase in habitat fragmentation. By their study they correlated the environmental stochastic decrease in genetic heterozygosity, edge effects and human disturbances. Zuidema *et al.* (1996) have studied the effects of forest fragmentation in the maintenance of biological diversity and pointed different factors in the loss of biodiversity. Forest fragmentation studies has been documented at landscape level using GIS to describe patch size, shape, abundance and forest matrix characteristics (Ripple *et al.,* 1991; Lehmkhul and Ruggiero, 1991; Skole and Tucker, 1993; Shirish and Roy, 1997). Forest degradation and deforestation have been associated with the degree of spatial fragmentation of forests (Ludeke *et al.,* 1990; Mertens and Lambin, 1997). Harison (1991) studied vegetation resulting from forest clearing in tropics in relation to the human population.