LITERATURE REVIEW

INTRODUCTION

In view of rapid changes in land utilization for various developmental activities, a completely up-dated data of the biodiversity, especially plant diversity and its decline, obligatory pre-requisites for better scientific forest conservation and planning for management. To meet such assessment for collecting data for conservation of plant diversity, one may adopt either the conventional method of ground surveys or use advanced sophisticated techniques of remote sensing and GIS.

A brief review of literature is presented here, which will cover global, national and regional scenario, including the Indian situation, inclusive of biodiversity studies in the Western Ghats. Aspects pertaining to definition, assessment and conservation of biodiversity especially plant diversity are reviewed along with the application of remote sensing and GIS on forestry aspects. The details regarding plant diversity assessment and monitoring especially of tropical vegetation are also considered. Some of the relevant studies are presented in the tabular column.

BIODIVERSITY

Biological diversity or biodiversity is the basic characterization of all living beings. It manifests itself at all levels of biological organization from cell to ecosystem. It is considered essential for the proper functioning of all living systems to cope with the destabilizing forces of the physical and biotic environments (Pande and Sharma, 1999).

DEFINITION

The term Biological diversity appeared for the first time in literature at a relatively late date probably with Norse and McManus (1980). It was shortened to "Biodiversity" and made popular beyond the realm of biology by Wilson (1988) in his book of the same title "Biodiversity". Wilson did not define the term biodiversity. The term biodiversity was used in its long version (biological diversity) by Lovejoy (1980) and is most commonly used to describe the number of species. "Bio" is derived from the Greek word, *bios* meaning life. Biological and biotic are terms that refer to life, living organisms, and assemblages of living organisms. The scope of the term biological can be further understood in the context of components and processes that are considered biological. There are numerous definitions of biological diversity (Huntley, 1988). Yet biodiversity does not have a universally agreed on definition and it is often redefined on each occasion to the context and purpose of the author (Swingland, 2001), most of them treating it as a qualitative state at genetic, species or ecosystem levels (Wilson, 1988). Within sciences of population biology and ecology, diversity is a multidimensional concept (MacArthur, 1985). Wilcox (1984) defines biodiversity as the variety of life forms, the ecological roles they perform, and the genetic diversity they contain. A definition by the US office of Technology Assessment (OTA) states that biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can also be defined as the number of different items that range from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes, and their relative abundance (OTA, 1987).

The important 1992 convention on biological diversity in Rio de Janeiro interprets biological diversity precisely as "*The variability among the living organisms from all sources, including interalia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part: this includes diversity within species, between species and ecosystem*" (UN, 1992). Younes and di Castri (1996) have defined biodiversity as "*the ensemble and hierarchical interaction of genetic taxonomic and ecological scales of organization and different levels of integration*".

BIODIVERSITY IN GENERAL

About 1.7 million species are known till date, but it is estimated that there are nearly 20 million species on this earth. The estimations, based on differing projections, span a spectrum of 5 million (Stork, 1993) and more than 360 million (Andre *et al.*, 1994) species. In all probability, we have knowledge of 8.5 % of all species for the richest and most diverse group, the insects.

In contrast, knowledge of the diversity of vascular plants is relatively comprehensive. As producers, and thus fundamental to the entire ecological system, they determine the biodiversity of terrestrial ecosystems.

Pioneering taxonomists like Willdenow (1797 - 1807) had listed only 17,457 species of Phanerogams in his edition of *Species Plantarum* (Barthlott *et al.,* 1999) and it was further improved by Humboldt (1850) who recorded a total of 2,13,000 vascular plant species while also mentioning the poor knowledge of insects and their relation to plant species. He thereby readjusted his earlier estimation of 80,000 species (Humboldt, 1806), which is quite remarkable as plants unlike birds, account for only one to two species each year in the tropics. According to Raven's (1976) tabulation, approximately *ca*. 1,50,000 species are found in tropics. Bramwell (2002) argues that recent research and new inventories suggest that we may have been underselling plants and hence he proposed that the number of plant species may be 40% higher and he estimated the world flora to 421,968 species.

BIODIVERSITY IN THE TROPICS (GLOBAL)

Tropical forest ecosystems are of global importance and interest for several reasons. Tropical forests, with their incomparable variety of plant and animal species, offer an irreplaceable source of biological diversity (Myers, 1980). Tropical forests cover only 14% of the land surface (Lanley, 1982) yet hold at least half of the world's species and most of them have neither been identified nor studied. The tropical habitats have been described as the most species rich formation on earth and Mittermier and Weiner (1990), while identifying mega diversity regions of the world observed that more than 80% of the diversity is stored in the tropics. Tropical humid forests are amongst the most diverse, most productive and most threatened biological communities (Daniels *et al.*, 1995). Indeed 14 to 18 biodiversity hotspots have been identified by Myers (1988, 1990).

BIODIVERSITY IN THE TROPICS (NATIONAL)

India covers only 2% of total landmass on this earth yet it is recognized as one of the mega diversity regions with 75.06 million ha. (22.88%) of pristine and secondary forests (Shyamsundar and Parameswarappa, 1987).

The country is divided into ten botanical zones with distinct bioclimatic conditions. These include:

1. Coromandel
2. Malabar
3. Indus plain (Indian desert)
4. Gangetic Plain
5. Assam
6. Eastern Himalaya
7. Central Himalaya
8. Western Himalaya
9. Andaman and Nicobar islands
10. Lakshawdeep and Minicoy group of Islands.

India boasts of 17,000 species of vascular plants under *ca.* 320 families and floral diversity including 64 species of Gymnosperms, 1200 species of pteridophytes, 2850 species of bryophytes, 372 species of mammals, 1228 species of birds, 428 species of reptiles, 204 species of amphibians, 2546 species of fishes, 5000 species of molluscas and 57000 species of insects and totally aggregate to about 48,000 floral and 80,000 faunal species (Hajra and Mudgal, 1997).

India also has the largest assemblages of woody species (5000) in the world, of which at least half (2500 sp) are trees (Puri, 1995).

Peninsular India has the Western Ghats and much segmented stretch of the Eastern Ghats.

Western Ghats

The Mountains of the Western Ghats, known locally as the Sahyadri hills extend from near the southern tip of India northward to Southern Gujarat, a stretch of 1600 km that is interrupted only by the 30 km Palghat gap between the cities of Coimbatore and Palghat.

The most detailed study of the Western Ghats rain forest is that of Pascal (1988), who identified six major associations at low altitudes (less than 850 m), four at medium elevations (850 - 1500 m), and one at elevation about 1500 m. Approximately 4000 plant species occur in the Western Ghats of which about 1400 (35%) species are endemic. There are also 58 endemic plant genera, of which 42 are monotypic, while others are highly speciose (e.g. *Nilgrianthus* spp. with 20 species). Among the region of the western ghats, Agasthyamalai hills in the extreme south of the western ghats are believed to harbour the highest levels of plant diversity and endemism at species level .(Mittermeier *et al.*, 1999).

Eastern Ghats

The Eastern Ghats are "*Tors*" of geological antiquity with isolated mountains lying between the Mahanadi and Vaigai rivers covering Orissa, Andhra Pradesh and Tamil Nadu States and running parallel to the length of Coromandel Coast and Western Ghats on the eastern and western side respectively. The Eastern Ghats along the peninsular India are divisible into three zones, the Northern, the Middle and the Southern Eastern Ghats, extending over 1750 km covering the area under 11° 30 ' - 21° 0' N Latitudes and 77° 22' to 85° 20' E longitudes (Rawat, 1997). These broken chains are surrounded by civilization on its fringes and which as ever are contributing to the decline of its vegetation.

They are well known for their rich biodiversity encompassing varied vegetation types which range from evergreen, semi evergreen, Dry mixed deciduous and Savanna Scrub. Several investigators have stressed the need for better conservation of the Eastern Ghats (Ellis, 1982; Nayer *et al.*, 1984: Rawat and Babu, 1995). The flora and fauna of the region have been well-documented (Fyson, 1932; Rao, 1958; Kapoor, 1964; Sebastine, 1968; Subba Rao, 1979; Rao and Sudhakar, 1982; Suryanarayana and Murthy 1984; Matthew, 1983). Gamble (1915-1936) accounted for the floristic details of the Eastern Ghats in Andhra Pradesh and TamilNadu in his '*Flora of Madras Presidency*'. Legris and Viart (1959) and Legris and Meher-homji (1972-1982) have analyzed the bioclimatic regions of India including the Eastern Ghats. Ramesh (1989) has studied the vegetation pattern, structure and succession in Biligirirangan hills. Studies of the endemic and endangered plant and animal species of the Eastern Ghats and the Western Ghats were taken up by Kumaravelu and Chaudhuri (1999). Other studies include mapping hydrogeomorphology in the northern part of Salem district, which forms part of the Eastern Ghats (Anbazhagan and Sarananthan (1991). A study on the phenology of exotics and distribution of the aggressive weed *Lantana camara* L. throw light on the level of degradation in the hill slope vegetation in the Pacchaimalai hills (John Britto *et al.*, 2001).

ENDEMISM

Among the world's eighteen hotspots, two are located in India (Daniels *et al.*, 1995) *i.e.* the Western Ghats and the Eastern Himalayan region. Indian floral diversity includes 7650 endemic species and 140 endemic genera. According to Dhar and Kachroo (1983 a, b) the Himalayas have 4196 endemic species, whereas Nayer (1987) downsized it to 2532 species. Peninsular India is estimated to have about 2200 endemic species and most of them (*ca.* 1500) are found in the Western Ghats (Mill, 1995).

RARE AND THREATENED PLANTS

Not all the countries in this region have a complete Red Data Book of threatened plants, but India has produced Indian Red Data Books in three volumes (Nayer and Sastry, 1987,1988,1990), accounting for 1500 threatened species. Many papers have been published on threatened plants of individual states of India. The most comprehensive compendia are that of Jain and Rao (1983) and Jain and Sastry (1983).

TAMIL NADU (REGIONAL)

One of the hotspots, the Western Ghats are located partially in Tamil Nadu. These Ghats run parallel to and are close to the west coast of India. The process of loss of forest cover in the Western Ghats is being contained yet the pressures leading to the loss of forest biomass and local extinction of species still continue (Pascal, 1988; Gadgil and Subash Chandran, 1989; Nadkarni *et al.,* 1989).

EASTERN GHATS OF TAMIL NADU

The Eastern Ghats of Tamil Nadu have been investigated earlier chiefly on the floristics and biodiversity studies are confined to small prioritized pockets only These hills serve as catchment areas of many small rivers, which crisscross the plains The forest cover of the Eastern Ghats is no exception to this devastation, owing to anthropogenic exploitation (Khosoo, 1986)

The Eastern Ghats of Tamil Nadu begin from the border of Andhra Pradesh and end near the Vaigai River The Ghats also cover part of Dharmapuri and Periyar districts, parts of Mysore and Kolar districts of Karnataka state Abutting the southern flanks of the Eastern Ghats lie the Tamil Nadu uplands which cover parts of the Periyar, Dharmapuri and North Arcot districts and almost all of Coimbatore, Madurai and Salem Districts The major hill ranges of this region are Javadi, Shervarayan, Kalrayan, Chitteri, Pacchaimalai, Bodamalai, Kollimalai and Kanjamalai These hill ranges form a chain of low, flat hills and they are dissected by the Ponnaiyar, Cauvery and Vellar rivers (Agarwal and Narain, 1997)

IMPORTANCE OF BIODIVERSITY

Biodiversity provides to the human kind enormous direct economic benefits in the form of timber, food, fiber, medicines, industrial enzymes, food flavours, fragrances, cosmetics, emulsifiers, dyes, plant growth regulators and pesticides (Mannion, 1995) The indirect ecological benefits from biodiversity include regulation of the gaseous composition of the atmosphere, soil formation, processing and acquisition of nutrients, trophic dynamics regulation of populations etc Biodiversity supplies the buffering capacity and stability of life on the planet by maintaining the interactive dynamics of ecosystems. Costanza *et al.*, (1997) have estimated the current economic value of the 17 ecological services from 16 biomes and extrapolated this for the entire biosphere in the range of US $ 16.54 trillion (10^{12}) per year (Singh and Khurana, 2002).

BIODIVERSITY CRISIS

There is widespread agreement that global biodiversity is declining at an accelerated rate (Myers, 1980; Wilson, 1988). According to estimation of Eckhom (1978), the extinction rate is about one wildlife species per year and when plants and invertebrate animals are included, it could be as high as one species per day. The vast majority of these extinctions are occurring in tropical forests (Myers, 1986). The loss of biodiversity is a significant ecological problem and an important component contributing to global environment changes (Ehrenfeld, 1972; Lovejoy, 1986; Soule 1986, 1991; Wilson, 1988). The major cause of biodiversity loss is human action, primary land use that alters habitat (Freedman 1989; Pimm and Gilpin, 1989; Gangwar, 1990; Parrotta and Knowles, 2001). Habitat destruction is considered the most widespread anthropogenic cause of biodiversity loss (Brown, 1985; Myers 1986; Wilson 1988). Habitat destruction like mining operation has adverse impact on the vegetation, which results in landscape fragmentation (Pant *et al.*, 1999) and affect the forest communities (Parrotta and Knowles, 2001). Habitat fragmentation may differentially increase the vulnerability of species to extinction (Lovejoy, 1986; Vermij, 1986). Biologically species loss may lead to synergistic effects upon the species, such as altered energy flows and nutrient cycling (Freedman, 1989), reduced ecosystem services such as oxygen production and climate modification (Mueller-Dombois *et al.*, 1983; Norton, 1986). Decline in species richness has been associated with specific land use changes such as power line construction (Nickerson *et al.*, 1989), Colonization in areas adjacent to protected areas (Newmann and Machlis, 1989), Urbanization (Leidy and Fielder, 1985) and forest fragmentation (Hanson *et al.*,1990)

About ten top countries (Table 1) having intact tropical forest (14,076,490 km^2) *i.e.,* equivalent to 58% of North America, is now being lost at a faster rate and estimated to about 69,584 km^2 annually (Hartshorn, 2001).

Inventory, Monitoring and Assessment of biodiversity

A wide variety of biological, ecological and cultural information is required to make biodiversity assessment (Davis *et al.,* 1990). There is also significant disagreement regarding the measurement of biological diversity (Norton, 1986). Current measures select different components of ecosystems for emphasis. Potential indicators include number of species richness (Scott *et al.*, 1987; Magurran, 1988), abundance and distribution of populations (Krebs, 1972; Westman, 1990), number of endangered species, centers of species richness with high endemism (Myers, 1988), taxic diversity (Vane-Wright *et al.,* 1990), other ecosystem functions (Ray, 1988), natural communities (The Nature Conservency, 1975; Western *et al.*, 1989), targeting ecosystem features (Turner *et al.,* 1999) as key measures of diversity.

A biodiversity inventory is a formal cataloguing of the occurrences at a point in time of defined elements of biodiversity that are contained in a defined geographic unit. To be conducted formally, this cataloguing must be done in response to a clearly stated purpose according to well established field procedures, within statically valid sampling design, and using rigorous quality

Table 1: Status of the forest cover loss in the countries of the tropical belt

S.No.	Country	Forest km²	Cover %	Annual loss km²	% of loss
1.	Brazil	4,427,200	52.4	25,544	0.5
2.	Democratic Republic of Congo	1,352,650	60.0	7,402	0.7
3.	Indonesia	9,11,I340	50.3	10,844	1.0
4.	Peru	7,82,960	61.2	2,168	0.3
5.	Bolivia	6,86,380	63.3	5,814	1.2
6.	Venezuela	6,02,330	68.3	5,034	1.1
7.	India	5,40,140	18.2	2,708	0.5
8.	Colombia	5,35,540	51.6	2.622	0.5
9.	Mexico	4,57,650	24.0	5,080	0.9
10.	Angola	3,75,640	30.1	2,368	1.0
Subtotal of top 10 countries		10,671,830	46.5	69,584	0.65
Total of 85 countries		14,076,490	10.8	1,54,000	0.8

control and data administration practices. This cataloguing might involve data on the biodiversity element itself or might also include data on biological or non-biological factors found in association with the biodiversity elements being catalogued. Because of lack of funds, time and trained personnel, this cataloguing almost invariably will represent a sampling, rather than a complete listing of the biodiversity of an area (di Castri *et al.*, 1992). An inventory can have three general levels of intensity: Qualitative, quantitative and relational (Dennis and Ruggiero.1996).

Monitoring biodiversity requires quantitative methods for measuring and comparing diversity. Eventhough the concept of community diversity and its measurement have received considerable attention in community ecology studies for more than four decades, much work is still needed to develop measures useful in assessing the success or failure of management activities (Grove *et al.,* 1996). The selection, evaluation and implementation of indicators and/or measures are critical in establishing a monitoring program for biodiversity. These can be individual measurements or variables or a combination of measurements or variables, such as indices. Three basic interrelated types of indicators and indices are known: 1) Species measures, 2) measures that integrate composition, structure and functions of biodiversity and 3) ecological indicators as applied at landscape scales (Jones and Riddle, 1996).

Systematics and biodiversity research in India

India has a reasonably good institutional set-up for biodiversity research. A host of institutions like Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) administered under the Ministry of Environment and Forests (MoEF), Department of Science and Technology (DST), Department of biotechnology (DBT), Department of Space (DOS), Indian council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR). Universities under the network of the University Grants Commission (UGC) and Environment departments in various states, non-governmental organizations like Bombay Natural History Society (BNHS), M.S. Swaminathan Research Foundation (MSSRF), Tata Energy Research Institute (TERI), Foundation for Revitalization and Local Health Traditions (FRHLT) and World Wildlife Fund for Nature (WWF-India) are currently involved in diverse fields of research and development of India's biodiversity (Pushpangadan and Nair, 2001).

Remote sensing and Geographic information system for Assessment of Biodiversity

Myers (1989) recommended the use of remote sensing data to improve global assessments and he commented that remote sensing data are not available on a biome-wide basis to establish the present status of all tropical forests. In the early 1990s, a few initiatives based on Remote sensing data were launched by several organizations, including the Food and Agriculture organization of the Unites Nations (FAO), the World Conservation Union (IUCN), the European Commission Joint Research center (JRS), the National Aeronautics and Space Administration (NASA) and Woods Hole Research Center (WHRC) in order to establish a reliable baseline tropical forest resource inventory (Mayaux *et al.*, 1998).

Mooney (1991) has observed that different scientific constituencies have so far represented the research themes of biodiversity and global change.

Despite widespread scientific and public interest in biodiversity, the remote sensing community has had some involvement to date in supporting biodiversity research, largely concentrating instead in the global domain. Most of the discussion concerning potential roles for remote sensing in biodiversity assessment has come from conservation biologists and ecologists (Soule and Kohm, 1989; Noss, 1990; Lubchenco *et al.*, 1991).

REMOTE SENSING

Remote sensing is defined as the collection of information about an object without being in physical contact with it. Remote sensing with its capability of synoptic coverage of extensive areas at short intervals and in multi spectral sensing is a potential mean in updating information on different aspects of forest resources. The time taken for assessing the forest resources can be greatly reduced using remote sensing technology as compared to conventional field inventory methods; in addition the cost and manpower involved would also be considerably reduced (Patel and Singh, 1999). Estimates of regional variation in biodiversity can be useful in analyzing diversity patterns, monitoring changes, and aiding in conservation efforts (Mooney and Chapin 1994; Rey-Benayas and Pope, 1995; O'Neill *et al.*, 1997; Stohlgren *et al.*, 1997).

A typical strategy for evaluating biodiversity in arid landscapes has been to develop cover type maps that characterize vegetation pattern and then attribute the various vegetation cover classes with relevant biodiversity values. The biodiversity status is then assessed indirectly through a map analysis of total coverage, patch size, fragmentation or other spatial measures, or directly with ground-based surveys. These maps, except in their most generalized form, require extensive field surveys and intensive image analysis, whether one is using satellite imagery of some other media such as high-resolution aerial photography or airborne sensors (Muldavin *et al.*, 2001).

Forest Cover Assessment in India

In India, the initial attempt to assess forest cover at national level has been on 1:1 million or 1:2,50,000 scales by visual interpretation of the False Colour images. National Remote sensing Agency studied images in 1:1 million scale for the periods 1972-75 and 1980-82 and forests were broadly classified into three categories: Closed (>40%), Open / Degraded (10 - 30%) and Mangroves (NRSA, 1983). Subsequently Forest Survey of India (FSI) used similar technique in 1981-83 for forest mapping at 1:250,000 scale and continued it to regular intervals (**Table 2**). This experiment has been applied to monitor national vegetation regularly by FSI. So far FSI has monitored the status of forest cover in India six times (Ranganath *et al.,* 2000).

Studies pertaining to remote sensing application in forestry is discussed in **Table 3** and **4.**

GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Geographical Information Systems (GIS) are a versatile tool for planning and management in a wide variety of application areas. Their ability to store data on various associated attributes under study, such as multitemporal spatial and non-spatial data, allows easy operations to address a host of problems and their solutions. GIS has developed into a very powerful tool for collecting, storing, retrieving, transforming, integrating and displaying spatial and non-spatial data either in isolation or in conjunction (Rao *et al.*, 1994). It is no longer an emerging

Table 2: Status of forest cover in India

(Areas in million hectares within brackets)

Years / Number of assessment							
Forest Category	1972 - 75 NRSA	1981 - 83 First	1985 - 87 Second	1987 - 89 Third	1989 -91 fourth	1991 -93 Fifth	1993 -95 Sixth
Dense	14.2% (46.55)	10.99 % (36.14)	11.51% (37.84)	11.71% (38.50)	11.72% (38.55)	11.73% (38.57)	11.178% (36.72)
Open	7.38% (24.28)	8.41% (27.65)	7.83% (25.74)	7.6% (24.99)	7.61% (25.04)	7.59% (24.93)	7.95% (26.13)
Mangrove	0.10% (0.30)	0.12% (0.40)	0.13% (0.42)	0.13% (0.42)	0.13% (0.42)	0.14% (0.45)	0.15% (0.48)
Total	21.60% (71.03)	19.52% (64.20)	19.47% (64.01)	19.47% (63.92)	19.47% (64.01)	19.46% (63.96)	19.27% (63.34)

Table 3: Remote sensing application in Forestry and other fields (Global)

Categories	Satellite data used	Location	Authors
Assessment of Tropical forest	NOAA- AVHRR	Global	Jaakola *et al.*,1992
Vegetation type	TM	Columbia	Niemann, 1993
Vegetation type	Landsat TM, CASI	Newfoundland, Canada	Franklin *et al.,* 1994
Forest mapping	Landsat TM	SW Germany	Dees *et al.*, 1998
Forestry overview	--	South Africa	Thompson and Whitehead, 1992
Landscape ecology and diversity patterns	Landsat TM	Northeastern Guatemala	Rey and Pope, 1995
Mapping forest cover disturbances	AVHRR	Papua New Guinea	Esterguil and Lambin, 1996
Mapping land scape and biological diversity	NOAA-AVHRR	Ferio region of Senegal	Jorgensen and Nohr, 1996
Forest recreation planning	Landsat TM	Malaysia	Jusoff and Hassan, 1997
Mapping deforestation	Synthetic Aperture Rada (SAR)	Rhondonia, Brazil	Saatch *et al.*,1997
Mapping biological diversity	Landsat TM and AVHRR	West African Sahel zone	Nohr and Jorgensen, 1997
Forest Inventory	Landsat TM	Eastern Finland	Tokola and Hekkila, 1997
Vegetation change	Kosmos MK-colour space photography	Astrakhansiy biosphere reserve (Lower Volga Delta Russia)	Baldina *et al.*, 1999
Tropical forest cover mapping	--	Humid tropics	Achard *et al.*, 2002
Land Cover mapping	NOAA- AVHRR	Asia	Tateishi, 2002

Table 4: Remote sensing application in Forestry and other fields (National)

Categories	Satellite data used	Location	Authors
Vegetation cover	Landsat MSS	Karnataka	Madhulika-Sinha, 1988
Forest cover	IRS-1A LISS II	Sikkim	Sudhakar *et al.*, 1994
Land use change detection	IRS 1A / 1B	Mamlay Watershed of Sikkim Himalaya	Krishna *et al.*, 1994
Change detection study	IRS-1A LISS-I Landsat-4 / MSS and Landsat-2/MSS	West Bengal	Vinod Kumar *et al.*, 1994
Hydrogeomorpho-logical mapping	Landsat TM	Keonjhardistrict, Orissa	Das *et al.*, 1997
Temporal studies of land use and land cover	Landsat TM and IRS IA	Varaha Basin, Andhra Pradesh	Murthy and Venkateswara Rao, 1997
Mapping land cover	Aerial photographs and Landsat TM	Chimmony wildlife sancturary, Kerala	Suraj *et al.*, 1997
Hydrogeomorphology	IRS1 – LISS II	Sangrur district	Thomas *et al.*, 1999
Landforms and Geomorphology	IRS-1A	Baitarani River Basin	Shibani, 1999
Land Degradation	IRS-1B LISS II	Purulya district, West Bengal	Saini *et al.*, 1999
Soil Information	IRS-1B LISS II	Mahoba district UP	Dwivedi *et al.*, 2000
Soil resources	IRS LISS II	Western Rajasthan	Khan and Singh, 2000
Vegetation type	IRS 1C/1D WiFS	Himalaya, Himachal Pradesh	Joshi *et al.*, 2001
Biome level Characterization	IRS 1C WIFS	Rajasthan	Joshi *et al.*, 2002

technology and it provides universal tools for handling spatial data (Burrough and Frank, 1995).

GIS methods have been effectively used to derive information for many resources based upon the relationships of mapped environmental variables (Dangermond, 1989). Davis *et al.*, (1990) proposed an approach to integrate existing data on species distributions and habitat characteristics in biodiversity assessments using GIS. Goodchild *et al.*, (1993) included several chapters on the use of GIS in ecological modeling and Haines-young *et al.* (1993) discussed applications of GIS in landscape ecology. Geographic information systems (GIS), with separate data layers of environmental information, provide means of integrating spatially explicit collection databases with species-specific information. Linking data layers in Geographic systems and floras provide a mechanism for efficient transferal of complex information about biological diversity (Shultz, 1998). **Table 5** described GIS application in forestry and other relevant fields.

Remote sensing and GIS with an integrated basis on theoretical and methodological aspects have helped to develop conceptual framework for geographical data and vegetation mapping (Goodchild, 1994). Stephan and Davis (1994) highlighted remote sensing and GIS application and analysis to plant communities. Remote sensing coupled with GIS can provide information about landscape history, soil, rainfall, temperature and other climatic conditions about present day habitat and soil coverage on which the distribution of species depend (Noss, 1996). **Table 6** and **7** described Remote sensing and GIS application in forestry and other fields in Global and National respectively.

Table 5: GIS application in Forestry and other relevant fields

Categories	Location	Authors
Forest land Management	Indonesia	Weir *et al.*,1988
Tree population parameters	Rocky Mountain National Park – Colorado	Baker and Weisberg, 1997
Modelling floristic richness	Switzerland	Thomas Wohlgemuth, 1997
Zoning timber extraction zone	Brazilian Amazon	Verissimo *et al.* 1998
Under Represented ecosystems	USA	Loomis and Ecohawk, 1999
Spatial-temporal characterization of land use	USA	Scott and Udouj, 1999
Landscape assessment	Alaska	Duffy *et al.*, 1999
Species distribution	Northern new South Wales	Ponder *et al.*, 2001
Road less areas in biodiversity conservation	United states	Strittholt and Della Sala, 2001
Tectonic activity and biological diversity	Global	Kathuria and Ganeshaiah; 2002
Derivation of terrain parameters	Global	Jayaprasad *et al.*, 2002

Table 6: Remote sensing and GIS application in Forestry and other fields (Global)

Categories	Satellite data used for the study	Location	Authors
Vegetation types at tree line topography and biophysical disturbance variables	Aerial photographs, Landsat TM	East – Central portion of Glacier National park, U.S./ Canada border	Daniel, 1994
Fire on landscape heterogeneity	Landsat TM	Wyoming, USA	Monica *et al.,* 1994
Deforestation	Landsat TM	Costa Rica	Sáuchez-Azofeifa *et al.*,1999
Vegetation type	Landsat TM	Wyoming , USA	Driese *et al.*, 1997
Ecological survey of dedicuous woodlands	CASI	Hampshire, UK	Blackburn and Milton,1996
Land cover mapping for tropical forest rehabilitation	Landsat TM	Mindoro, Philippines	Apan, 1997
Landscape pattern and species richness	Landsat TM	Great Bntain	Griffiths *et al* , 2000
Human modeled landscape	Landsat TM	South Africa	Maddock and Benn, 2000

Table 7: Remote sensing and GIS application in Forestry and other fields (National)

Categories	Satellite data used for the study	Location	Authors
Visualization of biodiversity	Landsat TM	Arunachal Pradesh, India	Narendra Prasad *et al.*, 1996
Landuse/Land cover change	IRS 1B	Central Himalaya, India	Ghosh *et al.*, 1996
Ecological analysis of Forested landscape	Landsat TM	Madhav National park, Madhya Pradesh, India	Ravan and Roy, 1997
Impact of Coal mining	Landsat MSS and TM	Singrauli coal field, MP, India	Singh *et al.,* 1997
Mapping and Modelling degraded lands	Landsat TM	Jaunpur District, UP, India	Sujatha *et al.*, 2000
Land use Planning	IRS-1B LISS II	Yacharam Watershed, AP, India	Gourangakar, 2001
Biodiversity assessment at landscape level	IRS 1C/1D	Arunachal Pradesh	Roy and Behera, 2002
Mapping and monitoring biodiversity	IRS 1C .	Elagiri hills,Tamil Nadu	John Britto,2002

CONSERVATION

Many problems regarding conservation are centered mostly in the tropics, where biodiversity is rich, but species and whole ecosystems are being lost most rapidly (Raven, 1987). Tropical deforestation is associated with a pervasive cycle of initial timber extraction followed by shifting cultivation, land acquisition and subsequent conversion to pasture (Partridge, 1984), all of which leads to loss of forest resources, reduction of biodiversity and impoverishment of rural people (Gomez-Pompa and Kanus, 1990). The roots of the problem of resource use in tropical countries are social, compounded by the lack of adequate institutional infrastructure to deal with resource management and the scarcity of trained human resources. Their solution requires greater attention to socio economic factors (Lugo and Brown, 1996). In developing countries, the issues are most intense, because they involve hundreds of millions of people and their ongoing struggle for survival (Repetto, 1988).

There is a heightened consciousness to globally prioritize conservation efforts (Turner and Gardner, 1990; Kareiva, 1993; Mooney and Chapin, 1994; O' Neill *et al.*, 1997). Conservation of biodiversity has been a theme recurrent the use of discussion over the last decade in the light of irreversible and accelerating losses of global biodiversity (Myers, 1988, 1990; Pressey *et al.*, 1993; Balmford and Long, 1995; Williams *et al.*, 1996; Mittermier *et al.*, 1998; Reid, 1998). Assessing the distribution of the diversity of life forms on the earth and the efficacy of measures for their conservation is one of the major scientific challenges of the day (Nagendra and Gadgil, 1999).

Conservation planners have sought objective, quantitative criteria for setting priorities among elements of biodiversity to be protected (Usher, 1986). Various quantitative methods that allow relatively expeditious identification of conservation-priority areas have been proposed in recent years. These approaches include identification of hotspots of biodiversity (Myers, 1988 and 1990; Dobson *et al.,* 1997), rapid biodiversity assessment (Oliver and Beattie, 1993 and 1996), identification of indicator and surrogate species (Curnutt *et al.*, 1994), development of rarity and complementary sets (Williams *et al.*, 1996), gap analysis (Scott and Csuti, 1996; Ramesh *et al.*, 1997), identification of key ecoregions (Olson and Dinerstein, 1998) and cost minimizing of land value analysis (Ando *et al.*, 1998). Davis *et al.*, (1990) described information systems approach to the preservation of biodiversity. Lakshmi *et al.*, (1998) stressed tools like remote sensing and GIS for decision-making and to derive meaningful outputs for plant resources and conservation management.

One of the significant conservation investigations for India was undertaken by WWF India in the biodiversity conservation project BCPP (Singh *et al.*, 2000). This was arguably the largest and most comprehensive exercise ever undertaken in India to priorities site, species and strategies for biodiversity conservation. Glimpses of Remote sensing and GIS application in conservation are described in **Table 8**.

Table 8 Remote sensing and GIS application for conservation

Categories	Satellite data used	Location	Authors
Gap analysis	Landsat TM	California	Davis *et al.*, 1995
Landscape ecology approach to biodiversity conservation	--	Western Ghats India	Menon and Bawa, 1997
Vegetation based approach to biodiversity gap analysis	--	Western Ghats	Ramesh *et al.*, 1997
Biodiversity conservation	--	Latin America	Jones *et al.,* 1997
Biodiversity priority setting	--	Madagascar	Hannah *et al.,* 1998
Vegetation resource study for conservation and management	IRS 1A LISS-II	Ropar wet land ecosystem, Punjab, India	Verma *et al.*, 1998
Systematic reserve selection	--	Columbia Plateau ecoregion of the north Western United States	Davis *et al.*, 1999
Conservation application	Astronaut Photograph	Australia, Japan, Botswana	Robinson *et al.*, 2001
Conservation priority areas	Landsat TM, MSS, IRS LISS II	Arunachal Pradesh, India	Menon *et al.*, 2001
Determining conservation priorities and making land allocation decision	--	Yellow stone ecosystem,North America	Noss *et al.*, 2002
Conservation of Wet-lands	--	India	Prasad *et al.* 2002