The study highlights the significance of digital image processing and GIS analysis of the satellite sensor data in accurately assessing the physical environmental conditions and changes thereof in inaccessible terrains, such as in the case of the Kolleru lake, so that appropriate preventive and/or remedial measures can be taken up to protect such fragile but important coastal wetland ecosystems.

1. Sadakata, N. and Nageswara Rao, K., Radiocarbon ages of the subsurface sediments in the Krishna delta and their geomorphological implications. *Quart. J. Geog.*, 1997, **49**, 163–170.
2. Hema Malini, B., Murali Krishna, G. and Nageswara Rao, K., Degradation of wetlands and microclimatic change – A study on Kolleru lake environment. *Indian J. Landsc. Syst. Ecol. Stud.*, 1999, **22**, 127–132.
3. Venkata Raju, D. Ch., Rajesh, R. S. and Mishra, D. C., Bouguer anomaly of the Godavari basin, India and magnetic characteristics of rocks along its coastal margin and continental shelf. *J. Asian Earth Sci.*, 2003, **21**, 535–541.
4. Manmohan, M., Rao, M. R. R., Kamaraju, A. V. V. S. and Yalamarty, S. S., Origin and occurrence of lower cretaceous high gamma – high resistivity (Raghavapuram) shale – a key stratigraphic sequence for hydrocarbon exploration in Krishna–Godavari basin, A.P., *J. Geol. Soc. India*, 2003, **62**, 271–289.
5. Nageswara Rao, K., Evolution of landforms in the area between the Krishna and Godavari deltas. *Indian Geogr. J.*, 1985, **60**, 30–36.
6. Kolleru lake – Andhra Pradesh, World Wildlife India: 2002–2003. http://www.wwfindia.org/programs/fresh-wet/koleru.jsp?prm=100.
7. Kolleru is going. *Down To Earth*, 1993; available at http://www.rainwaterharvesting.org/Crisis/Kolleru_etc.htm#degr.
8. Lillisand, T. M. and Kiefer, R. W., *Remote Sensing and Image Interpretation*, John Wiley, New York, 2000.
9. McFeeters, S. K., The use of normalized difference water index (NDWI) in the delineation of open water features. *Int. J. Remote Sensing*, 1996, **17**, 1425–1432.
10. Chatterjee, C., Kumar, R. and Mani, P., Delineation of surface waterlogged areas in parts of Bihar using IRS-1C LISS III data. *J. Indian Soc. Remote Sensing*, 2003, **31**, 57–65.
11. ERDAS IMAGINE on-line help, Copyright ©1991–2000 by ERDAS, Inc.

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Identification of conservation priority sites using remote sensing and GIS – A case study from Chitteri hills, Eastern Ghats, Tamil Nadu

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Conservation of the forest resources is being rightly considered as an urgent task to be pursued throughout the world. This communication deals with the delineation of conservation priority sites for effective management in the Chitteri hills, forming a part of the Eastern Ghats, Tamil Nadu using IRS 1C-LISS III satellite data and GIS overlay analysis. The various thematic layers such as vegetation type, species richness, endemic and red-listed plant species, biotic pressure zone and socio-economic value zone are overlaid using GIS in order to identify conservation-priority zones. This study reveals that about 8.2% (5367.85 ha) of the total hill area could be delineated as conservation-priority zone.

THERE is widespread agreement that global biodiversity is declining at an accelerated rate[1,2]. The main threat to tropical forest biodiversity is habitat loss, particularly loss of forest cover[3]. Even in protected areas, encroachment is widespread[4]. Protected areas in India have historically been established on an ad hoc basis, with little attention to the conservation value of an area[5]. For effective management of biodiversity, there is a need to prioritize areas, especially those which are considered most essential for conservation, i.e. biodiversity-priority areas[6]. Prioritization of strategies is again important to ensure that efforts at conservation yield best possible results avoiding the undesirable side effects, especially the alienation and impoverishment of local communities[7].

There is a need to prioritize such areas and in this case, the Eastern Ghats, a rugged hilly terrain running almost parallel to the eastern coast of India and covering three states, viz. Orissa, Andhra Pradesh and Tamil Nadu. The southeast portion of the eastern ghats in Tamil Nadu consists of several broken hill ranges, viz. Javadi, Elagiri, Melagiri, Shervarayan, Chitteri, Kalrayans, Kolli hills, Pacchaimalai hills and Bodamalai. They are dissected by rivers such as the Ponnaiyar, Cauvery and Vellar.

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Prioritization of sites for conservation also needs to be done with reference to the well-defined values, which include vegetation types[8], species richness[9], endemism[10], red-lists[11], economic value of bio-resources[12] and also the biota[13].

The optimal and efficient management of forest resources calls for reliable technologies with a provision to store, update, retrieve and analyse data. Towards this, tools like GIS and remote sensing have been used for decision-making and to derive meaningful output for plant resources conservation and their management[14]. Take, for example, the Agastyamalai hills in the Western Ghats, wherein the conservation zones are delineated using vegetation uniqueness, species richness, endemic flora and endemic fauna[5] based on the forest patch characteristics. Likewise, in some cases, the phytosociological data, topographic, bioclimatic and disturbance levels are considered for the same in the other wet evergreen forests of the Western Ghats, Tamil Nadu[15].

The above-described conservation-priority criteria are adapted for the present study area, i.e. Chitteri hills, wherein the criteria are developed and overlaid in GIS domain to identify conservation-priority sites.

Chitteri hills, one of the segments of the Eastern Ghats, Tamil Nadu, is situated towards northeast of Salem town within the geographical limit of 78°15′00″–78°45′00″E long. and 11°44′00″–12°08′00″N lat. and occupies an area of about 654.52 km^2 (Figure 1). The hills form a compact block consisting of several hill ranges, and contain tangled ridges and ravines running in the northeast and southwest directions, enclosing many narrow valleys (rivers), viz. Kallar, Varattar, Kambalai and Anaimaduvu. The mean maximum and minimum temperatures are 39.5°C and 19°C, while in winter they are 31°C (maxi-

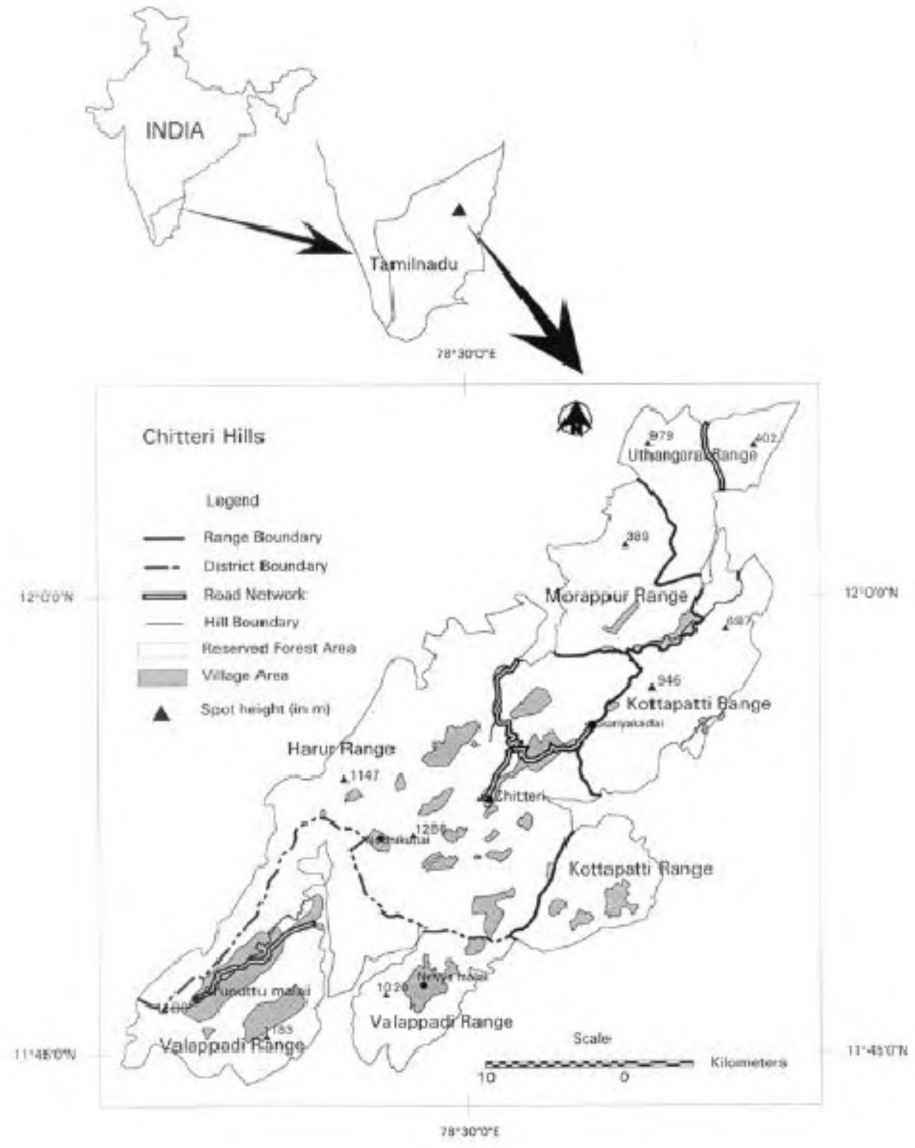

Figure 1. Location map of Chitteri hills.

mum) and 18°C (minimum) respectively. The annual average rainfall ranges from 620 to 1400 mm, both from the northeast and southwest monsoons. Topographically, the area is undulating with an altitude varying from 240 to 1266 m. The rocks on Chitteri hills are chiefly gneisses/granitic in composition. Soil is generally shallow and reddish-loam, varying in fertility and often mixed with gravel and boulders. Black soils are seldom found in the forests.

IRS 1C LISS III (path 101 and row 65) digital data of 26 February 1999 are used to identify the vegetation types of the Chitteri hills. GCP (Ground Control Points) collected from SOI (Survey of India) toposheets as well as from GPS (Global Positioning System) were used as bases to register on the images and were geometrically corrected. The satellite image was transformed with a standard defaulted 23.5 m resolution (default for IRS LISS III images) and projected to polyconic coordinate system using nearest neighbourhood resampling method and radiometrically corrected using histogram equalization tool in ERDAS Imagine 8.3.1 software. From the entire scene, the whole study area was extracted using *subset option* in ERDAS Imagine 8.3.1 software and FCC (False Colour Composite) displayed with the band combination of 4, 3, 2 on the computer screen (Figure 2). The Reserved Forest (RF) boundaries were traced from the SOI toposheets and digitized. The image was then visually interpreted onscreen and classified based on the interpretation key prepared during reconnaissance field visits and attributed to the corresponding vegetation types[16]. The accuracy of map was assessed, i.e. comparing the map with ground observations for a set of sample point[17], which resulted in a reliable overall classification accuracy of 86.5%.

For each vegetation type, the field data (tree and lianas) were collected in 20 m × 20 m quadrats and the frequency and number of vascular plant species were utilized to estimate Margalef richness index (Dmg)[18].

$$\mathrm{Dmg} = \frac{S-1}{\log N},$$

where S is the number of species recorded, N is the total number of individuals of all the species and log is $\log_e$. Each polygon of the respective vegetation type was replaced by Margalef diversity index and species richness values of all polygons are grouped under three classes, i.e. low, medium and high.

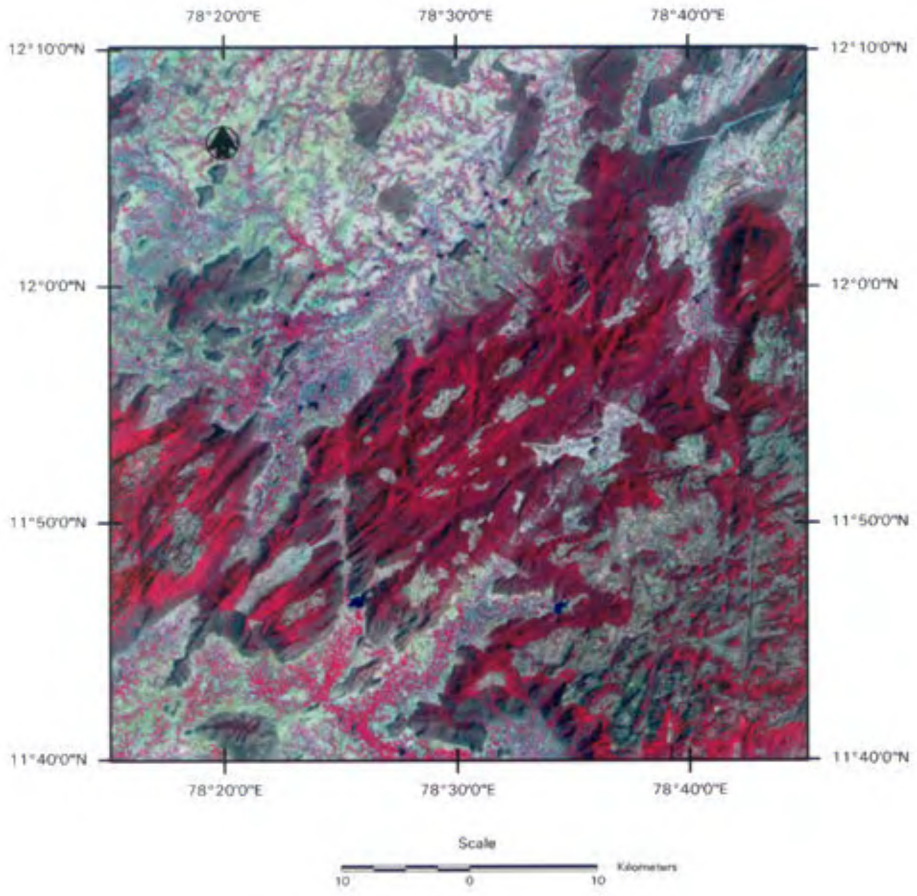

Figure 2. FCC of Chitteri hills.

Mapping of the red-listed and endemic species (Table 1) is normally done based on the data collected from the above-described quadrats and cross-checked with the appropriate literature. Weightages were attributed based on the summation of species under endemism and red-listed category[19] and again regrouped into three categories.

For preparation of economic-value map, the economic values (i.e. medicinal (5), edible (2) and others (fuel, 2, fodder, 2 and timber, 2) of each species that is encountered in each quadrat were summed and the summed values were attributed to the respective representing polygons as described above, to reclassify similar-valued polygons to form the final economic-value map.

The anthropogenic pressure increases near the hamlets and road network (metalled, unmetalled and footpath) and might create secondary and tertiary routes to and within the forest area, thereby increasing accessibility and vulnerability of the forest stand in the proximity. The buffers, if prepared, will (in a way) include almost all of the hill area and are unfeasible for studies on this scale,

Table 1. List of endemic and red-listed plant species in Chitteri hills

Red-listed plant species	Endemic species
Actiniopteridaceae *Actiniopteris radiata* – Vulnerable	Cycadaceae **Cycas circinalis* – Endemic
Ranunculaceae *Naravelia zeylanica* – Vulnerable	Elaeagnaceae ***Elaeagnus indica* – Endemic
Rutaceae *Aegle marmelos* – Vulnerable	Asclepiadaceae **Decalepis hamiltonii* – Endemic
Ochnaceae *Ochna obtusata* var. *gamblei* – Rare	***Hemidesmus indicus* – Endemic
Vitaceae *Cissus heyneana* – Rare	Euphorbiaceae †*Euphorbia fusiformis* var. *fusiformis* – Endemic
Sapindaceae *Sapindus emarginatus* – Lower risk	Orchidaceae **Nervilia aragona* – Endemic
Anacardiaceae *Buchanania lanzan* – Lower risk	**N. plicata* – Endemic
Nothopegia colebrookiana – Indeterminate	Zingiberaceae ***Curcuma neilgherrensis* – Endemic
Papilionoideae *Canavalia virosa* – Rare	
Crotalaria longipes – Endangered	
C. medicaginea var. *hernarioides* – Rare	
C. speciosa – Rare	
Pseudarthria viscida – Near-threatened	
Combretaceae *Terminalia arjuna* – Lower risk	
Myrsinaceae *Embelia tserium-cottam* – Vulnerable	
Asclepiadaceae *Marsdenia brunoniana* – Rare	
Sarcostemma intermedium – Rare	
Acanthaceae *Andrographis paniculata* – Lower risk	
Santalaceae *Santalum album* – Threatened	
Orcidaceae *Habenaria multicaudata* – Endangered	
Polystachya concreta – Rare	
Hypoxidaceae *Curculigo orchioides* – Vulnerable	
Liliaceae *Gloriosa superba* – Lower risk	
Smilax zeylanica – Vulnerable	
Gramineae *Digitaria radicosa* – Rare	
Zenkeria elegans – Endangered	

*Endemic to India; **Endemic to peninsular India; †Endemic to Eastern Ghats.

i.e. 1 : 50,000. So the buffer zone is restricted to a single one-km buffer for the road network and hamlet to form the biotic pressure map. In this study, threat posing as risk from human activities too was included as one of the thematic layers for identifying conservation-priority zones. The endemic, red-listed and biotic pressure-zone maps were stored as temporary raster layers and used during GIS overlay analysis.

Procedures for deciding on conservation-priority zones need a systematic and explicit approach. Considering conservational importance and plant species status for each unit, the scores were designated to identify priority areas. Vegetation types and their corresponding vegetation classes and dominant species composition are given in Table 2. The components of various units from the themes of vegetation type, floristic richness, endemism and red lists with respective weightages (Table 3), i.e. weight class are essential to develop various conservation-priority zones.

Overlay or superimposition creates a composite output GIS file by combining a number of input GIS files based on the minimum or maximum values of the input files[20]. For preparation of conservation-priority map, the respective thematic maps are overlaid on one another, wherein the vegetation type (Figure 3) forms the lowermost tier and other layers are superimposed/overlaid in sequence, i.e. species richness (Figure 4), red-list, endemism, economic value, vegetation type and finally the biotic pressure (road and Hamlet buffer) map. These thematic maps are rasterized and the resulting polygons codified using the *criteria* function in ERDAS. The resulting maps were subjected to modelling using *model maker* where the polygons, i.e. intersects/extracts with different features were assigned a new class value followed by union/integration of common polygons to generate the conservation-priority map (Figure 5).

Six major types of vegetation, i.e. evergreen forests (143.14 ha), semi-evergreen (110360 ha), dry mixed deciduous forests (36769.9 ha), riparian (304.18 ha), dry deciduous scrub (7407.66 ha) and southern thorn scrub (3650.15 ha) were classified. The rest of the hill constitutes build-up lands, barren and forest plantations, etc. The study area includes 412 vascular plants species, pteridophytes (6 sp.), gymnosperms (1 sp.) and angiosperms (395 sp.), wherein the overall diversity of species is 131 trees, 81 shrubs/sub-shrubs, 46 lianas, 33 climbers/vines/twiners and 121 herbs. About 212 species are considered economically important. About 60 species are of multi-utility (i.e. edible, medicinal and other categories), and 24 species are used both as medicinal and edible, 63 species are exclusively medicinal, 15 species are edible, 16 species are used as fuel, fodder and timber. Red-listed and endemic species of the Chitteri hills are described in Table 3. This study has identified five conservation-priority sites (Figure 5) and the characteristics of the sites (5367.85 ha) are discussed in detail along with justifications for the conservation strategy. For the highest scoring priority sites (in GIS overlay), they are numbered accordingly and discussed separately as each site differs in content or characteristics. Each site has its own priority and characteristics.

Table 2. Vegetation types and their dominant species of Chitteri hills and the corresponding vegetation types of Champion and Seth[16]

Vegetation type	Champion and Seth classification	Dominant tree species
Dry evergreen forest	Tropical dry evergreen forest (7/C1)	*Vitex altissima*, *Psydrax dicoccos*, *Syzygium cumini*, *Filicium decipiens*, *Nothopegia colebrookiana* and *Schleichera oleosa*
Semi-evergreen forest	Tropical semi-ever green forest (2A)	*Memecylon edule*, *P. dicoccos*, *N. colebrookiana*, *Ligustrum perrottetii* and deciduous species like *Anogeissus latifolia*, *Diospyros ferrea*, *Diospyros peregrina* and *S. oleosa*
Dry mixed deciduous type	Southern dry mixed deciduous forest (5A/C3)	*Psydrax dicoccos*, *A. latifolia*, *Albizia amara*, *Ixora pavetta*, *Chloroxylon swietenia*, *D. ferrea*, *Drypetes sepiaria*, *Hardwickia binata*, *Gardenia resinifera*, *Commiphora caudata*, *Gyrocarpus asiaticus* and *Premna tomentosa*
Riparian forest	Dry tropical riverain forest (5/1S1)	*Pongamia pinnata*, *Tamarindus indica* followed by *Alangium salviifolium*, *Terminalia arjuna*, *Wrightia tinctoria*, *Mangifera indica*, *Cleistanthus collinus* and *Strychnos nux-vomica*
Dry deciduous scrub	Dry deciduous scrub (5/DS1)	*Euphorbia antiquorum* and *Albizia amara*
Southern thorn scrub	Southern thorn scrub (6A C2/DS1)	*A. amara* and *Chloroxylon swietenia* with throny shrubs

Table 3. Criteria used for selection of conservation priority sites in Chitteri hills

Theme	Criterion used	Weight class*
Vegetation type	Evergreen	1
	Semi-evergreen	2
	Riparian	3
	Dry mixed deciduous	4
	Dry deciduous scrub	5
Species richness map	Low (1–4)	3
	Medium (4.1–8)	2
	High (> 8)	1
Endemic/red-listed category	Low	3
	Medium	2
	High	1
Biotic-pressure zone map	Road buffer	1
	Hamlet buffer	1
Economic value	Medicinal and other categories	1
	Edible	2

*Weight classes[20] are designed such that the scores represent priority in the ascending order, i.e. score one has the highest priority and so on.

Site one occupies a stretch of about 7.66% (411.54 ha) of the total conservation-priority area. Due to the intense anthropogenic pressure, the forest resources are being depleted drastically. This region is endowed with dense vegetation and the dominant tree species are *Psydrax dicoccos*, *Chionanthus mala-elengi*, *Chukrasia tabularis*, *Garuga pinnata*, *Phyllanthus emblica* and *Semecarpus anacardium*. There are also endemic and endangered species, namely *Smilax zeylanica*, *Pseudarthria viscida*, *Curculigo orchioides*, *Elaeagnus indica*, *Andrographis paniculata* and *Hemidesmus indicus*. Species such as *Albizia odoratissima*, *Alangium salviifolium*, *Atalantia monophylla*, *Cassia fistula*, *Diospyros montana*, *Erythroxylum monogynum*, *Gmelina arborea*, *Mallotus philippensis*, *Pterocarpus marsupium*, *Schleichera oleosa*, *Streblus asper*, *Terminalia bellirica* and *Vitex altissima* are used as medicine. They are edible and also are utilized as timber and fuel. Numerous natural bamboo (*Dendrocalamus strictus*) clumps are seen inside the site.

Site two, with about 5% (268.39 ha), is recommended for immediate conservation. It falls under both road and hamlet buffers and thus the anthropogenic pressure of this site will be higher when compared to other sites. Rivers and streams traversing the site add to the varied microclimatic conditions and as a result species composition also varies. The area abounds in resources for most of the valuable forest products like timber, medicine and other non-timber forest products. The major timber-producing tree species are *T. bellirica*, *P. marsupium*, *Tectona grandis*, *P. emblica* and *Madhuca indica*. The vegetation cover is dominated by *Anogeissus latifolia*, *Chloroxylon swietenia*, *Buchanania axillaris*, *E. monogynum*, *G. arborea*, *V. altissima* and *Terminalia paniculata*. These sites include numerous endangered species such as *P. viscida*, *Ochna obtusata*, *Digtitaria radicosa*, *A. paniculata*, *C. orchioides*, *Nothopegia colebrookiana*, *Embelia tseriam-cottam*, *Smilax zeylanica* and *Miliusa eriocarpa*. The study highlights several multiuse species, i.e. *Aglaia*

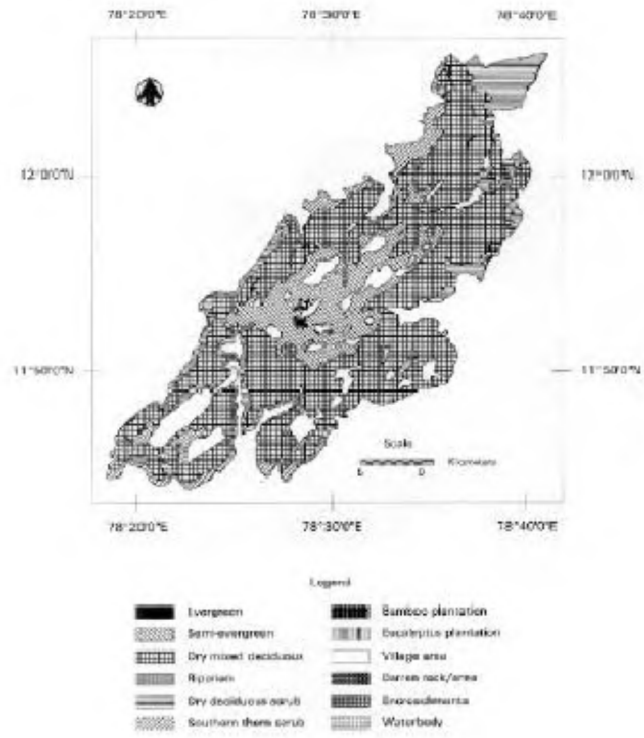

Figure 3. Vegetation type map of Chitteri hills.

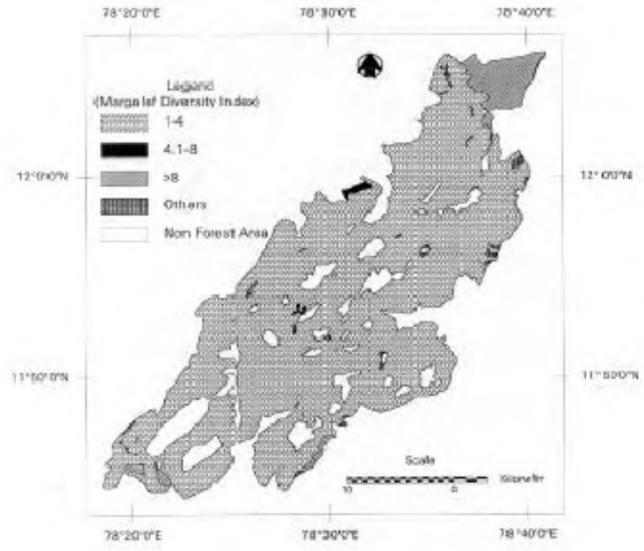

Figure 4. Species richness map of Chitteri hills.

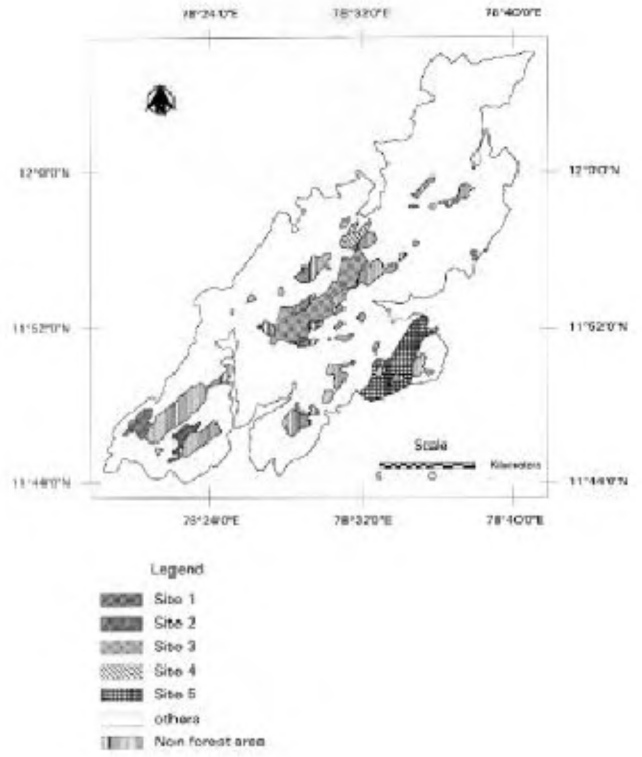

Figure 5. Conservation priority sites of Chitteri hills.

roxburghiana, *Albizia amara*, *Cassia fistula*, *Chloroxylon swietenia*, *D. montana*, *Dodonaea viscosa*, *G. arborea*, *M. philippensis*, *Mimusops elengi*, *S. oleosa* and *S. anacardium*.

Site three represents 39% (2111.360 ha) of the total selected conservation sites. The vegetation is unique and is dominated by *P. dicoccos*, *Memecylon edule*, *A. latifolia*, *Dalbergia latifolia* and *V. altissima*. The dense vegetation in this reserved forest consists of several economically useful plants and also houses some of the rare and endangered plants like *Buchanania lanzan*, *Curculigo orchioides*, *E. indica*, *E. tseriam-cottam*, *Hemidesmus indicus*, *N. colebrookiana*, *Pseudarthria viscida*, *Sapindus emarginatus* and *S. zeylanica*. Some of the conspicuous and multipurpose use species are *A. odoratissima*, *A. monophylla*, *Butea monosperma*, *B. axillaris*, *C. swietenia*, *Dalbergia lanceolaria*, *Diospyros ebenum*, *Dodonaea viscosa*, *Ficus arnottiana*, *Holoptelea integrifolia*, *Ixora pavetta*, *M. philippensis*, *M. elengi*, *Phyllanthus emblica*, *P. marsupium*, *S. anacardium*, *Syzygium cumini*, *T. bellirica* and *Zizyphus oenoplia*. This site is characterized by fodder grasses such as *Oplismenus compositus* and *Isachne miliacea*, which are grazed by cattle and the extent of deforestation intensity has intensified due to indiscriminate lopping for fodder and green manure.

Site four comprises ca. 393.644 ha (0.6%) with the dry mixed deciduous and riparian forests. The topography is characterized by plateau and moderate slopes. The river Varattar and numerous streams criss-cross the area causing inundation of the forest during the summer. Generally the forests are known for richness, together with rare and endangered species and species of economic value. So they are exploited for their timber and firewood. Some of the dominant species are *A. latifolia*, *Diospyros melanoxylon*, *Diospyros peregrina*, *Cleistanthus collinus* and *Hardwickia binata* in dry mixed deciduous forests and *Tamaridus indica*, *Terminalia arjuna*, *Pongamia pinnata* in the riparian forests. Typical timber tree species are *Holoptelea integrifolia*, *D. latifolia*, *T. bellirica* and *A. salviifolium*. The endemic and endangered species are *A. paniculata*, *H. indicus*, *Naravelia zeylanica*, *N. colebrookiana*, *S. emarginatus*, *S. zeylanica* and *Santalum album*. This site has the maximum number of valuable plant species and they are *Albizia amara*, *Albizia lebbeck*, *A. salviifolium*, *A. monophylla*, *B. axillaris*, *Carissa carandas*, *Commiphora caudata*, *D. montana*, *Diospyros melanoxylon*, *E. monogynum*, *Garuga pinnata*, *Gymnema sylvestre*, *I. pavetta*, *M. indica*, *Toddalia asiatica*, *Ventilago maderaspatana*, *Wrightia tinctoria* and *Z. oenoplia*.

Site five includes about 40% (2182.93 ha) of the total conservation area. Dry mixed deciduous forest is a major contributor and is dominated by *H. binata*, *Psydrax dicoccos*, *A. latifolia* and *T. bellirica*. Subject to constant exploitation and ecological pressures, some of the species have become rare, endangered and threatened. However, repeated survey unearthed new distributional records of species. Hence a thorough and a detailed documentation is necessary to evolve an appropriate conservation strategy for rare and endangered species like *C. orchioides*, *D. radicosa*, *S. emarginatus*, *Sarcostemma intermedium* and *S. zeylanica*. It is worth noting that ecologically important species like *Abutilon indicum*, *A. monophylla*, *Bauhinia racemosa*, *C. carandas*, *C. fistula*, *D. montana*, *D. viscosa*, *E. monogynum*, *I. pavetta*, *Phoenix sylvestris*, *Randia dumetorum*, *Scutia myrtina*, *Spondias pinnata*, *T. asiatica*, *W. tinctoria* and *Z. oenoplia* have also been recorded in this study. This site has more fodder species than other sites, comprising *Apluda mutica*, *Aristida hystrix*, *Chloris barbata*, *Digitaria bicomis* and *Paspalum flavidum*.

Conservation efforts generally have addressed the problems posed by pressing local issues, which are themselves an outcome of measures of economic development by exploitation of selected native species and habitats. The present investigation has highlighted the level of conservation required in the proposed protected sites. The reserved forests are quite sensitive to degradation brought by intense logging and grazing, in spite of protection. This might be due to unscrupulous agents who exploit them for commercial enterprise by laying secondary pathways which themselves are detrimental to the existence of natural forests. The proposed sites for conservation need to be intensely safeguarded by the Forest Department, so that the genuine needs of local population and conservation interests are not sacrificed. This study has not considered other areas that need to be prioritized for protection. The principal aim of this study has been to evaluate, justify and recommend the quality and quantity of the above mentioned sites for intensified preservation by an intensive study of its richness, endemicity and the risk factors. The criteria included were disturbance sites/areas (buffer zones), which are likely to face more destruction, if the present trend were to continue.

1. Myers, N., *Conversion of Tropical Moist Forests*, National Academy of Science, Washington, DC, USA, 1980.
2. Wilson, E. O. (ed.), *Biodiversity*, National Academy Press, Washington, DC., 1988.
3. Whitmore, T. C. and Sayer, J. A. (eds), *Tropical Deforestation and Species Extinction*, World Conservation Union, Gland, Switzerland and Chapman and Hall, London, 1992.
4. Howard, P. C., *Nature Conservation in Uganda's Tropical Forest Reserves*, Publication 3, Forest Conservation Programme, World Conservation Union, Gland, Switzerland, 1991.
5. Ramesh, B. R., Menon, S. and Bawa, K. S., A vegetation-based approach to biodiversity gap analysis in the Agasthyamalai region, Western Ghats, India. *Ambio*, 1997, **26**, 529–539.
6. Margules, C. R., Pressey, P. L. and Williams, P. H., Representing biodiversity, Data and procedures for identifying priority areas for conservation. *J. Biosci.*, 2002, **27**, 309–326.
7. Singh, S. and Taneja, B., Prioritisation for biodiversity conservation values and criteria. *Setting Biodiversity Priorities for India*, (eds Singh, S. *et al.*), World Wide Fund for Nature – India, New Delhi, 2000, vol. 1, pp. 28–41.
8. Williams, P. H., Margules, C. R. and Hilbert, D. W., Data require-

ments and data sources for biodiversity priority area selection. *J. Biosci.*, 2002, **27**, 327–338.
9. Scott, J. M., Csuti, B., Jacobi, J. D. and Estes, J. E., Species richness: A geographic approach to protection of future biological diversity. *Bioscience*, 1987, **37**, 782–788.
10. Kier, G. and Barthlott, W., Measuring and mapping endemism and species richness: a new methodological approach and its application on the flora of Africa. *Biodivers. Conserv.*, 2001, **10**, 1513–1529.
11. Kumar, A., Walker, S. and Molur, S., Prioritisation of endangered species. *Setting Biodiversity Priorities for India*, (eds Singh, S. *et al.*), World Wide Fund for Nature – India, New Delhi, 2000, vol. 1, pp. 341–386.
12. Tisdell, C. A., Issues in biodiversity conservation including the role of local communities. *Environ. Conserv.*, 1995, **22**, 216–223.
13. Stoms, D. M., GAP management status and regional indicators of threats to biodiversity. *Landsc. Ecol.*, 2000, **15**, 21–33.
14. Udaya Lakshmi, V., Murthy, M. S. R. and Dutt, C. B. S., Efficient forest resources management through GIS and remote sensing. *Curr. Sci.*, 1998, **75**, 272–282.
15. Amarnath, G., Murthy, M. S. R., Britto, S. and Dutt, C. B. S., Diagnostic analysis of conservation zones using remote sensing and GIS techniques in wet evergreen forests of the Western Ghats – An ecological hotspot, Tamil Nadu, India. *Biodiver. Conserv.*, 2003, **12**, 2331–2359.
16. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*. Manager Publications, Government of India, New Delhi, 1968.
17. Congalton, R. G., A review of assessing the accuracy of classification of remotely sensed data. *Remote Sensing Environ.*, 1991, **37**, 35–46.
18. Margalef, C. R., Information theory in ecology. *Gen. Syst.*, 1958, **3**, 36–71.
19. Roy, P. S., Sarnam Singh and Hegde, V. S., Biodiversity characterization at landscape level using satellite Remote Sensing and Geographical Information System. In Proceedings of ISRS National Symposium on *Remote Sensing Applications for Natural Resources, Retrospective and Perspective*, ISRS and NNRMS Publications, Bangalore, 1999, pp. 206–218.
20. Murthy, K. S. R., Groundwater potential in a semi-arid region of Andhra Pradesh – a geographical information system approach. *Int. J. Remote Sensing*, 2000, **21**, 1867–1884.

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Ash layer at ~ 8 Ma in ODP Site 758 from the Bay of Bengal: evidence from Sr, Nd isotopic compositions and rare earth elements

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Strontium and neodymium isotopic compositions are widely used to delineate the provenance of sedimentary formations. These isotopes have characteristic signatures for crust and mantle material and therefore can distinguish between volcanic and other rock types. We report here $^{87}Sr/^{86}Sr$, ε_{Nd} (0) and rare earth elements (REE) of clastic sediments from ODP Site 758 in the Bay of Bengal. The age model for this site is based on biostratigraphy, which shows good agreement with the Sr-isotope derived ages. Most of the samples have $^{87}Sr/^{86}Sr$ of ~ 0.712 and ε_{Nd} (0) of ~ – 12, except one sample (at ~ 8.2 Ma) that exhibits distinctly low radiogenic Sr and high radiogenic Nd ($^{87}Sr/^{86}Sr$ = 0.708 and ε_{Nd} (0) = – 1.1). REE pattern of this sample looks similar to that reported for volcanic ash from Toba, Sumatra. We suggest this sample to be a tephra layer, which originated from the Indonesian Volcanic Arc and got inter-stratified with the sediments. Our results clearly show that Sr and Nd isotopes can identify thin ash layers that otherwise may not easily be recognized.

As a result of weathering and denudation on land, large amount of sediments are brought to the Bay of Bengal via major rivers from different regions, namely Himalaya-Tibet, the Indian subcontinent and western Burma. Interstratified with these sediments, several tephra layers are reported from North Indian Ocean[1–5]. Geochemical, including isotopic studies of ocean sediments through time are expected to reveal the provenance and erosional history of the source region(s). Sr and Nd isotopic compositions of clastic sediments are useful tracers to delineate provenance of ocean sediments. These isotopic fingerprints also contain effects of tectonic and climatic processes that prevailed in the source region.

Several attempts have been made to study the sediments from the Bay of Bengal for provenance, uplift in Himalaya-Tibet, erosional history and tephrochronology[1,5–8]. Based on Sr, Nd isotopic and clay mineralogical studies on terrigenous sediments at ODP Leg 116 in the distal Bengal Fan, the provenance is suggested to be High Himalayan Crystalline[6]. Ninkovitch[1] has described several tephra layers in deep-sea sediments of northeastern Indian Ocean, ranging in age from late Miocene to Recent. Geochemical studies of fragments of altered ash layer and

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