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Forest Dynamics in the Eastern Ghats of Tamil Nadu, India

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Abstract The primary deciduous forests in the Eastern Ghats (EG) of Tamil Nadu (TN) India have undergone many changes owing to various need-based forest managements, such as timber extraction for industry, railway sleepers, charcoal, and forest clearance for hydroelectric projects and agriculture, during preindependence and postindependence periods (i.e., from 1800 to 1980). The enactment of a forest conservation act during the 1980s changed the perception of forest managers from utilization to conservation. This study was taken up to assess the forests dynamics in the EG of TN spatially between 1990 and 2003 and nonspatially between 1900 and the 1980s. Landsat Thematic Mapper (TM) and Indian Remote Sensing satellite (IRS) 1D Linear Imaging and Self Scanning (LISS III) data were used to assess forests during 1990 and 2003, respectively. Field floristic survey and secondary data (such as published literature, floras, books, and forest working plans) were used to assess the forest dynamics in terms of forest type and species composition among the preindependence period, the postindependence period, and the present (i.e., before and after 1980). The satellite data analysis revealed a considerable amount of changes in all forest types during the 13 years. The comparison of species composition and forest types between the past and present revealed that need-based forest management along with anthropogenic activity have altered the primary deciduous forest in to secondary and postextraction secondary forests such as southern thorn and southern thorn scrub forests in the middle [400–900 m above mean sea level (MSL)] and lower slopes (<400 m MSL). However, the evergreen forests present at the upper slope (>900 m MSL) and plateau seemed not to be much affected by the forest management. The changes estimated by the satellite data processing in the major forest types such as evergreen, deciduous, southern thorn, and southern thorn scrub are really alarming because these changes have occurred after the implementation of a forest conservation act. The dependence of local people on forests for various purposes in this region is also considerably high, which might be a key factor for the changes in the forests. The results of this study not only provide an outlook on the present status of the forests and the change trends but also provide the basis for further studies on forests in the EG of TN.

Keywords Forest dynamics · Eastern Ghats · Change detection · Forest management · Remote sensing · Species distribution · Tropical forest

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Introduction

Natural forests, one of the most magnificent terrestrial ecosystems and living treasures of the world, have come to be regarded as greatly important, as they not only satisfy the immediate needs of innumerable living creatures but also play a very significant role in maintaining or reestablishing environmental harmony (Behera and others 2000; Jha and others 2000; Nagendra and Gadgil 1999). However, the structure, composition, and functioning of forest undergo changes as a result of natural process such as forest succession or because of disturbance and previous forest management (Bhat and others 2000; Champion and Seth 1968). Forests in the world are getting depleted at an alarming rate owing to various reasons such as deforestation, fire, shifting cultivation, grazing, and so forth (Boyd and Danson 2005).

Most of the forests in India are secondary and primarily postextraction secondary forests (Bhat and others 2001). The forests in India have passed three distinct phases: (1) the precolonial period (1000 bc–ad 1800), (2) the colonial period (1800–1947), (3) postindependence period (1947–1980) (Bhat and others 2001; Milward 1949).

During the precolonial period (until the intervention of external/market forces), the forests in southern India, especially in the Madras Presidency, did not undergo many changes, as it was maintained by tribal/nontribal communities or kings in a sustainable manner (Bhat and others 2001; Kurien 1992). Tribal people, who settled in hill areas, used the forest resources mainly for livelihood and not for commercial purposes. As the density of population was very low and sparsely distributed, their minimum requirements and lack of specialization posed not much threat to the forests even though shifting cultivation was practiced (Kurien 1992) and moreover the community managed the forests as a common property resource (Saravanan 2003, 2004). The nontribals in the plain areas fulfilled their needs (fuelwood, fodder for cattle) from the commonly available resources such as uncultivable lands. Thus, the forest resources were not used for the commercial purposes either by the tribals or by the nontribals until the close of the 18th century.

However, during the colonial period, the forests were exploited for revenue, fuelwood and charcoal, railway sleepers, ship building, sandal wood, iron-making industries, and establishment of tea and coffee plantations. During the latter part of the 18th century, the Britishers were forced to find timber resources from India for the construction of the fleet in England (Stebbing 1922). In the early 19th century, timber extraction was mainly to meet the demand of the King's Navy (Pathak 2002; Stebbing 1922). From the forests of the Madras Presidency, timber (worth of US$ 574,629) was also exported to Bombay, Scinde, Bengal, and Burma (Maclean 1885). A large quantity of sandalwood was extracted (e.g., sandalwood worth US$ 3688 between 1863 and 1875) and coffee and tea plantations were also established in the high lands of various districts of the Madras Presidency during the 1830s and 1850s in southern India (Saravanan 1998). The establishment of Madras Railways in the Madras Presidency during the latter part of the 19th century also demanded more timber from forest resources (Saravanan 1998). According to Brandis (1883), the fuelwood requirement for Madras Railways in 1878 was around 90,000 tons. Moreover, the forests were diverted to "working circles" (i.e., the area allocated to timber extraction under a "working plan" and that has a 30-year extraction cycle) (Bhat and others 2001; Milward 1949). The extraction and disturbance of forest resources during the colonial period led to the formation of secondary and postextraction secondary forests (Bhat and others 2001; Milward 1949; Ramachandran and others 2007).

In the postindependence period (1947–1980), the foremost priority of the Indian government was to fulfill the needs of poor people by alleviating poverty. Sufficient supplies of timber for farm-building construction, fuelwood for both urban and rural domestic purposes and timber for industry, and land for agriculture and hydroelectric projects, were the primary targets of the government (i.e., need-based forest management), whereby vast areas of forest were cleared and selectively cut, which further deteriorated the remaining primary and secondary forests (Bhat and others 2001; Prasad 2000; Ramachandran and others 2007). Diversion of forests to working circles for shorter periods was very common. During the present period (1980 onward), various plantation programs were implemented to increase the forest areas but resulted in failure because of site condition and poor choice of species (Pandey 1992), resulting in further disturbance and deterioration of the condition of the forests.

The Joint Forest Management (JFM) was introduced in the forest regions of Tamil Nadu by the Tamil Nadu Forest Department and completed the first phase between 1997 and 2005 under Tamil Nadu afforestation project (TAP) for conservation and benefit sharing. The primary objective of JFM is to ensure sustainable use of forests to meet local needs equitably while ensuring environmental sustainability (Jayakumar and others 2007). However, JFM activities are not successful because of various issues (Kashwan 2003).

The enactment of a revised forest policy during 1988 (MoEF 1988) gave priority to the conservation of forests and biodiversity rather than benefits from forests, which affects the people who depend on forests for various needs to a great extent. This led to the overexploitation of forests (Prasad 2000). The rural poor people who depend on forest for fuelwood and fodder and people who were evacuated for development projects and were resettled in the forests exerted additional pressure on the forests (Bhat and others 2001). Moreover, forest fire, in many cases caused by humans either deliberately or accidentally, also causes serious damages to forests and the forest areas prone to fire and ranged from 30% to 90% in various states of India (Kumar 2002). The major reasons for man-made forest fire in India are pasture development, creation of forest land to agriculture, collection of nonwood forest produce, and conflicts over land rights claims (Kumar 2002; Schmerbeck and Seeland 2007).

Conservation of forests calls for a clear understanding of the details, such as forest type, cover density, species composition, and areal extent and their changes (Jayakumar and others 2002b). With the advent of the remote sensing technique, Forest Survey of India (FSI) prepared a countrywide forest cover map by visual interpretation on a 1:1 million scale using a Landsat Multi Spectral Scanner (MSS) during 1987 (FSI 1987). Mapping the areal extent, type, and cover density of forests through remote sensing data has advantages over conventional ground survey methods (Tiwari and others 1996). Mapping of vegetation through satellite images can be performed using visual interpretation of images (Beaubren 1986) or through computer-aided digital classification methods such as supervised classification, unsupervised classification (Jensen 2000), hybrid classification (Behera and others 2000; Hoffer 1986), on-screen visual interpretation (Jayakumar and others 2002a; Kushwaha and others 2000), or expert classification (Ramachandran and others 2007). Satellite remote sensing techniques with reasonably high spatial and temporal resolution could be used as potential tools for monitoring changes in different surface and subsurface features on spatial and temporal scales (Jayakumar and others 2000; Lillesand and Kiefer 1978). In fact, remotely sensed data have been applied by many investigators in order to illustrate forest changes over time (Hall and others 1988, 1991; Iverson and others 1989; Green and Sussman 1990; Sader and Joyce 1988).

Remote sensing data have been very well used to classify forest types and cover density and to estimate areal extent and changes. Using Shuttle Radar Topography Mission (SRTM) and National Elevation Dataset (NED) along with Landsat Thematic Mapper (TM) data, Heo and others (2006) have attempted to estimate age in a loblolly pine plantation. Although Van-Aardt and Wynne (2001) have demonstrated the discrimination of tree species through remote sensing in temperate forest, it is still at the developmental stage (Foody and Cutler 2003) because it will be very difficult in the tropics, where heterogeneous forest covers with variety of species occur (Boyd and Danson 2005). Hence, the details, such as the species composition and stand density of forests, could be obtained only through field floristic sampling studies. There have been many floristic studies carried out in India (e.g., Behera and Kushwaha 2007; Devi and Yadava 2006; Kadavul and Parthasarathy 1999a, b; Padalia and others 2004; Parthasarathy 2001; Pascal and Pelissier 1996, Sagar and Singh 2005; Saxena and Singh 1982) and other parts of world (e.g., Campbell and others 1992; Heaney and Proctor 1990; Kalacska and others 2004; Lieberman and Lieberman 1987; Marin and others 2005; Paijmans 1970; Penfound and Hall 1939) using plot sampling methods to identify the structure and species composition of forests.

In India, forests are mainly situated in Himalayas, Western Ghats, and Eastern Ghats. Unlike Himalayas and Western Ghats, Eastern Ghats is a broken chain of hills extent from Orissa to Tamil Nadu and is surrounded by many settlements. Eastern Ghats of Tamil Nadu cover totally ~6000 km^2 and harbor different forest types, but the majority of the area is covered with secondary and postextraction secondary forests in the middle and lower slopes [400–900 m and <400 m above mean sea level (MSL), respectively], as it was subjected to various need-based forest management and anthropogenic pressure (Harikrishnan 1977; Ramachandran and others 2007). The reliable spatial records on the extent of forests cover and their changes prior to Indian independence (1947) and after are limited until the first countrywide forest cover assessment done by FSI during 1987. However, Mayuranathan (1929), Gamble (1933), and Matthew (1983) have documented the species composition of different forest types of Eastern Ghats of Tamil Nadu in the form of floras, Champion and Seth (1968) have recorded the forest types and its species composition of the entire of India in the form of book and the working plans of the Tamil Nadu Forest Department (Harikrishnan 1977) could be considered as an authentic source of information for species occurrence in the Eastern Ghats of Tamil Nadu during the preindependence and postindependence periods. In the present study, we intend to know two things: (1) whether the need-based forest management implemented during the preindependence and postindependence periods has altered the species composition of forests (the unavailability of reliable spatial database on forests until the 1980s restrict this study only up to a species-level comparison) and (2) how is the forest condition after the implementation of Forest Conservation Act compared to the 1980s (i.e., whether the forests have been protected from external factors).

Therefore, the present study was taken up with two objectives: (1) to estimate, using geospatial techniques, the changes in the areal extent of forest between 1990 and 2003 and (2) to identify the changes in species composition as a result of need-based forest management during the preindependence and postindependence periods between the existing literature and the present status.

Materials and Methods

Study Area

The Eastern Ghats (EG) of Tamil Nadu, India is a rugged and dissected hilly terrain, which starts from Jawadi Hill and extends to Alagar Hill (Fig. 1). Jawadi, Elagiri, Shevaroy, Chitteri, Kalrayan, Bodamalai, Kolli, Pachaimalai, Semmalai, Aiyalur, Karandamalai, Sirumalai, and Alagar are the major hills, covering an area of $\sim$6024 km^2. Geographically, the EG is situated between 10°00′00″ to 13°00′00″ N and 77°50′00″ to 79°10′00″ E. The area of the hills of the EG range from 70 to 1,860 km^2. The altitude of this region ranges from 200 m MSL to 1700 m MSL at the foothills and the Sholaikaradu peak of Shevaroy Hill, respectively. The mean temperature ranges from 17°C to 33°C, and the mean rainfall ranges from 800 and 1600 mm (Anon 2005). Many tributaries of major rivers such as the Ponnaiyar, Palar, Sweta, and Cauvery originate in these hills.

Datasets

As the present study was aimed to carry out on a 1:50,000 scale Landsat Thematic Mapper (TM), the digital data of 23 April 1990 for path 143 and rows 51, 52, and 53 and using Indian Remote Sensing Satellite (IRS) 1D Linear imaging and self-scanning (LISS) III, the digital data of 26 April 2003 for path 101 and rows 64, 65, and 66 were used. Apart from satellite data from Survey of India (SOI) topographical maps of 1:50,000 scale, prepared during the 1960s and 1970s, a LEICA GS 20 PDM global positioning system (GPS), a IBM WORKSTATION; HP PLOTTER (42″); compass, floristic field-measurement materials, ERDAS IMAGINE 9.0 for satellite data processing and analysis, and ARCGIS 9.1 for map generation were also used.

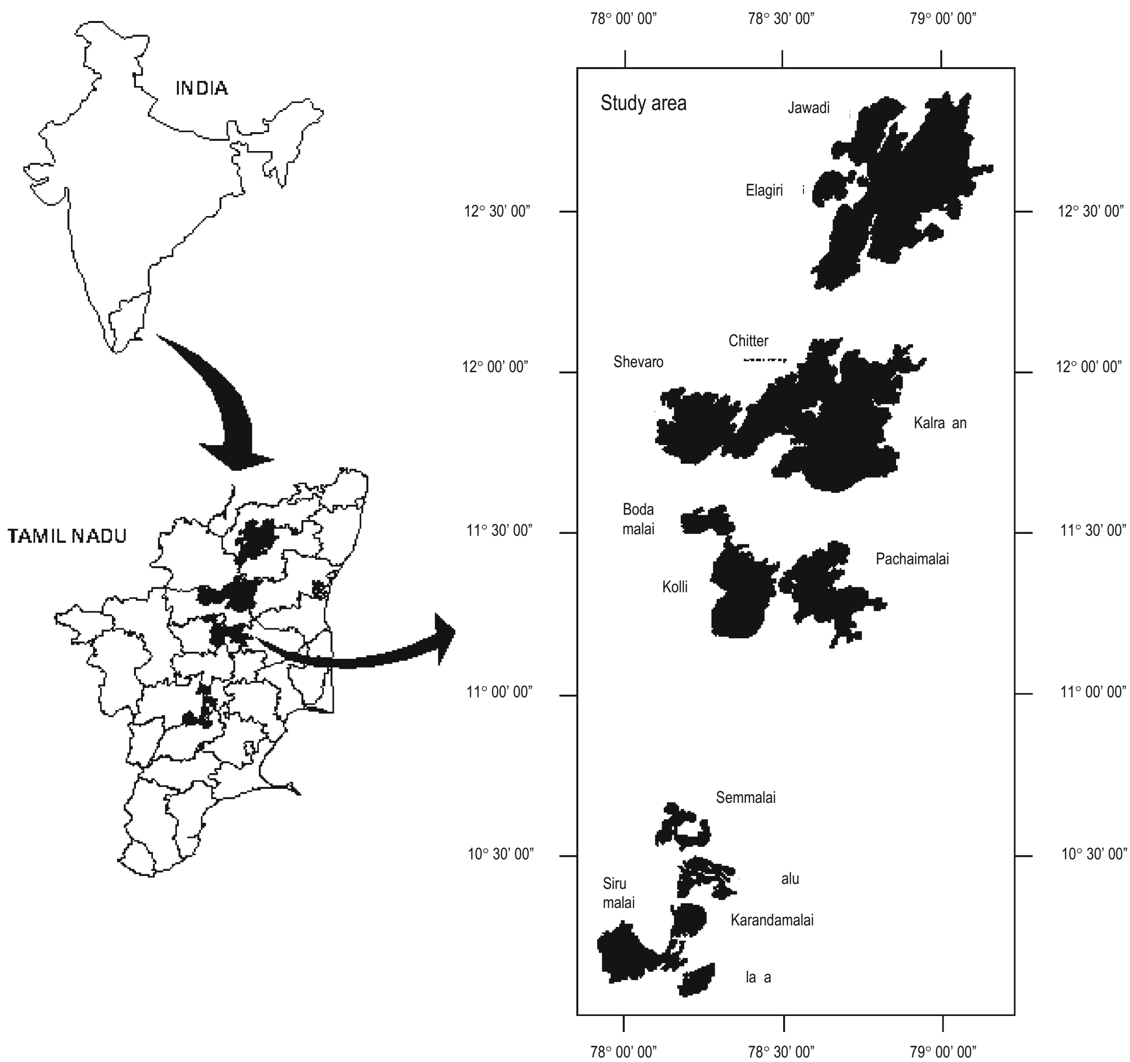


Fig. 1 Map of the study area

Ancillary data pertaining to the study area such as the forest working plan for Thiruppattur, Vellore, Thiruvannamalai, Harur, Salem, Attur, Tiruchy, Dindigul, and Madurai divisions, flowering plants of the Madras Presidency and its neighborhood (Mayuranathan 1929), flora of the Presidency of Madras (Gamble 1933), flora of the Tamil Nadu Carnatic (Matthew 1983), and revised forest classification of India (Champion and Seth 1968) were used in the present study to identify the forest type and species composition.

For our first objective, a comparison of spatial data of forests in the EG for two different periods has to be done, and for the second objective, a comparison of species composition of forests in the EG between the past and present has to be done. Objective 1 was carried out by forest classification and change detection using satellite data processing between two different periods (1990 and 2003). Objective 2 was carried out by documenting the present species composition of different forests through field floristic study and subsequently comparing with existing records such as flowering plants of the Madras Presidency and its neighborhood (Mayuranathan 1929), Flora of Presidency of Madras (Gamble 1933) Flora of Tamil Nadu Carnatic (Matthew 1983), Revised forest classification of India (Champion and Seth 1968), and forest working plans.

As in the present study, it was decided to carry out the floristic diversity study by the stratified random plot (quadrate) technique (Magurren 1988; Padalia and others 2004); it required a homogenous vegetation group and its area to proportionately distribute the sample. It was also decided to sample at least 1 ha in each forest type or 0.001% of the total area (NRSA 1998). Thus, satellite data processing, classification, and change detection of the forest was done first and the floristic diversity study, documentation of species composition, and comparison with existing records were conducted subsequently. The detailed methodology is given below.

Forest-Cover Mapping and Change Detection

The TM digital data (three scenes), of 30-m ground resolution, were corrected geometrically, taking sufficient ground control points (GCPs) from the SOI maps. All of the satellite data were geometrically corrected using, with ERDAS IMAGINE software, a first-order polynomial geometric model with a root mean square error (RMSE) of less than 0.5 pixels.

The reserved forest (RF) areas of each hill were subset from the digital data of 1990 and 2003, and the RF subset alone was processed in order to avoid misclassification. False color composites (FCCs) were generated from the TM data using bands 4, 3, and 2 in red, green, and blue (RGB) color guns and from the IRS LISS III data using bands 3, 2, and 1 in RGB, and they were printed on a 1:50,000 scale. The forest type and cover density map was prepared from TM and LISS III satellite data using the expert classification technique adopted from Ramachandran and others (2007) (Figs. 2 and 3). The density of the forest was divided into three categories according to crown closure: dense (>40% crown closure), open (10–40%), and degraded (<10%). The classified forest type and cover density maps of the various hills were printed on a 1:50,000 scale. Intensive field verification was carried out with SOI maps, an FCC hard copy, classified maps, a compass, and a GPS. For 1990, a field check was performed only in the unchanged area. Corrections were made in the interpreted maps wherever necessary, spatial information such as RF boundaries, roads, and villages were overlaid, and the final forest type and density maps for 1990 and 2003 were finalized. After finalization, the maps were printed on a 1: 50,000 scale and an accuracy check was carried out in 125 points for each class using a GPS to estimate the accuracy of classification (Congalton and others 1983). For 1990, an accuracy check was carried out only in the unchanged areas. Once all of the points were checked, the producer and user accuracy of the individual class as well as the overall accuracy of the classification were calculated.

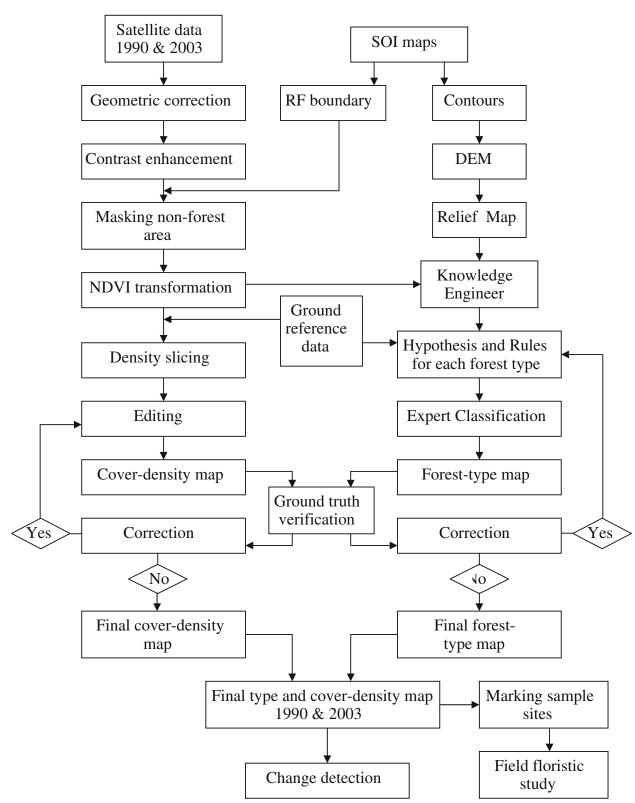


Fig. 2 Paradigm for forest-cover and type map preparation and field floristic sampling

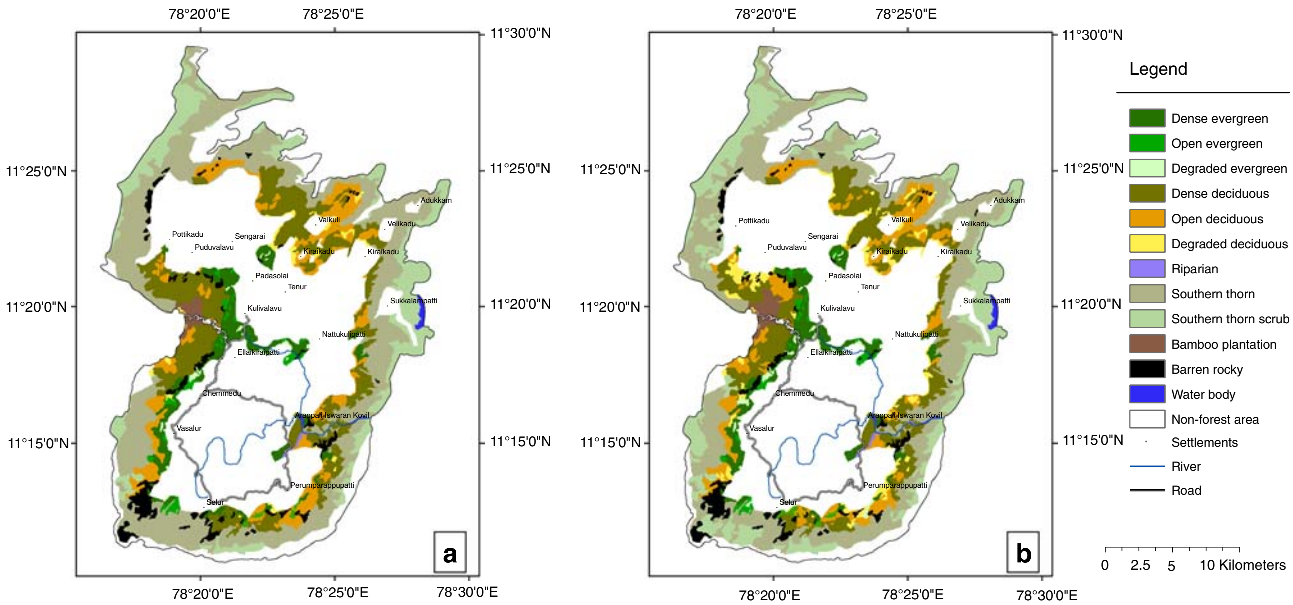


Fig. 3 Classification of forest types in the Eastern Ghats of Tamil Nadu: (**a**) forest type in Kolli hill during 1990 and (**b**) forest type in Kolli hill during 2003

Changes in the forests were analyzed using the ERDAS IMAGINE software. Change detection maps for the various hills were prepared (Fig. 4), and the area for each class was estimated. The name of forest types were based on the Champion and Seth (1968) revised forest classification of India. The terrain was divided into three classes: lower slope (<400 m), middle slope (400–900 m), and upper slope (>900 m) according to (Harikrishnan 1977). A Digital Elevation Model (DEM) was prepared for each hill from the contours, traced from the SOI map, and it was classified into three slope categories using the RECODE option in the ERDAS IMAGINE software. The categorization of terrain into three categories was due to the fact that the need-based forest management activities and

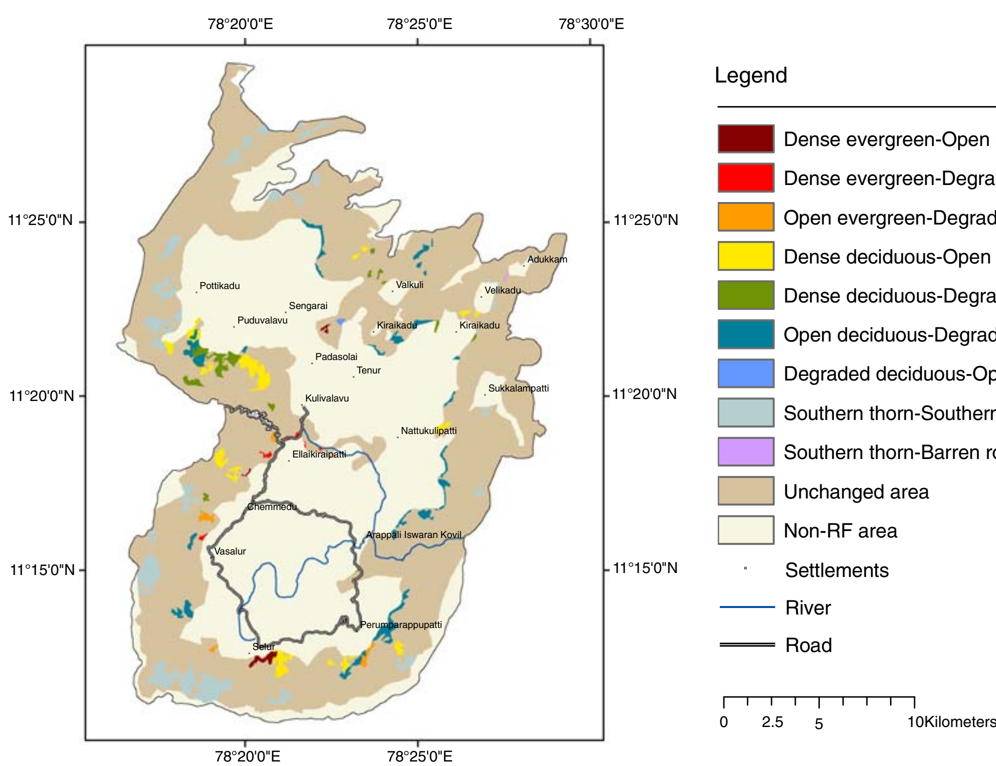


Fig. 4 Change detection map of one of the hills (Kolli) in the Eastern Ghats of Tamil Nadu, India between 1990 and 2003

subsequent plantation activities were carried out only in the middle and lower slopes (Harikrishnan 1977).

Field Floristic Survey

In order to identify the present species status and distribution for each forest type, an intensive field quadrate sampling study was conducted. The quadrate size for each forest type was determined based on the species area curve method (Barbour and others 1980). The quadrate dimensions were determined to be 20 × 20 m for the evergreen and deciduous forest types and 10 × 10 m for all of the other forest types (viz. riparian, savannah, southern thorn, and southern thorn scrub). For the evergreen and deciduous forests, 50 quadrates (2 ha) each were sampled, and for all of the other types, 100 quadrates (1 ha) each were sampled. All in all, 8 ha of the various forest areas were studied. The entire field work was carried out between May 2005 and September 2006.

The sample points for the floristic diversity study were randomly marked on the map for the different forest types using the "create random points" option in the ERDAS IMAGINE software, and the geographical coordinates of each point were noted. In the field, the sample locations were identified with the help of the GPS. As the mapping scale was 1:50,000 and the level of GPS accuracy was within 5 m throughout the area, there was no problem in identifying the sample location. After locating the sample site, the quadrate was laid for the dimensions of 20 × 20 m or 10 × 10 m, according to the forest type, and measurements were made. Inside the quadrate, all of the living trees ≥ 10. cm diameter at breast height (dbh) were identified and measured at a point 1.3 m from the ground. For buttressed trees, measurements were taken above the buttressing (Jayakumar and others 2002a, 2002b, 2002c; Parthasarathy 2001). Leaf and flower samples from each species were also collected and preserved in triplicate for herbarium specimens and later were compared with specimens available at the Rapinat Herbarium, Tiruchirappalli, and the Botanical Survey of India (BSI), Coimbatore, India.

Anthropogenic Disturbance

The local people depend on forests for their various needs (Table 1). Their dependence and the disturbance to forests were ranked into five categories. The qualitative ranking was done based on the sighting of people (Mani and Parthasarathy 2006; Venkateswaran and Parthasarathy 2003) in the forest during our field floristic survey as follows: very low (rank value 1), sighting twice a month; low (rank value 2), sighting once in a week; medium (rank value 3), sighting twice a week; high (rank value 4), sighting thrice a week; very high (rank value 5), sighting every day. The sum of all of the scores that showed high ranks reveal a high level of anthropogenic disturbance and low rank express low disturbance.

Comparison of Species Composition Between Preindependence and Postindependence Periods and the Present Study

The composition of species in different forest types in the lower, middle and upper slopes of the study area during the pre and post independence periods were collected from the literature (Champion and Seth 1968; Gamble 1933; Matthew 1983; Mayuranathan 1929; and forest working

Table 1 Ranking of disturbance to forest by local people based on their visit

Disturbance	Major hills													Total
	JW	EL	SH	CT	KR	BM	KL	PM	SM	AR	KM	SR	AL	
Fuelwood	4	4	5	4	4	4	4	4	5	5	4	4	5	56
Fodder	2	2	3	3	3	4	3	3	4	4	3	4	4	42
Grazing	3	2	3	4	4	5	4	3	4	5	4	4	5	50
Agriculture implements	1	2	2	2	2	2	2	2	2	3	2	2	2	26
Household materials	1	1	2	1	1	2	2	2	1	1	1	2	1	18
Transport	4	1	3	4	4	1	4	3	3	1	4	3	1	36
Recreation	1	3	4	2	2	1	3	1	1	1	1	3	5	28
Sacred groves	1	1	2	3	3	1	2	2	1	1	1	2	1	21
Medicinal plants	2	1	2	3	2	2	4	1	1	1	2	3	3	27
Edibles	2	1	2	3	2	2	2	1	1	1	1	3	1	22
Total	21	18	28	29	27	24	30	22	23	23	23	30	28	

Note: Data based on field observation. Very high: 5 (every day), high: 4 (thrice a week), medium: 3 (twice a week), low: 2 (once in a week), very low: 1 (twice a month) in the 13 hills of Eastern Ghats of Tamil Nadu (JW = Jawadi, EL = Elagiri, SH = Shevaroy, CT = Chittery, KR = Kalrayan, BM = Bodamalai, KL = Kolli, PM = Pachaimalai, SM = Semmalai, AR = Ayyalur range, KM = Karandamalai, SR = Sirumalai, AL = Alagar plan reports) and tabulated. The present status of forest types and species composition in the three slope categories was prepared using satellite data and field floristic survey, respectively. Finally, the datasets were compared to identify the changes.

Results

General Forest Status in the Eastern Ghats in Different Slope Categories

The forest area in the EG of Tamil Nadu, India was classified into nine major classes: tropical dry evergreen (7/C1), southern dry mixed deciduous (5A/C3), tropical riparian (5/1S1), southern thorn (6A/C1), southern thorn scrub (6A/DS1), dry savannah (5/DS2) and dry grassland (5/DS4), bamboo plantation, and barren/rocky. In the study area, evergreen forest occupied the upper slope (>900 m MSL), deciduous forest occupied the middle slope (400–900 m MSL), and southern thorn and southern thorn scrub forests occupied the lower slope (<400 m MSL) (Fig. 5). All of the other classes were distributed in patches between those forest types.

According to accuracy assessment, the overall accuracy of classification of 1990 and 2003 were 75% and 81%, respectively (Tables 2 and 3). The minimum and maximum value of user and producer accuracies of forest cover classes of 1990 ranged between 62% and 100% and between 56% and 100%, respectively. In the case of 2003, the minimum and maximum value of user and producer accuracies ranged between 58% and 100% and between 55% and 100%, respectively.

Overall Forest-Cover Status and Changes in the EG Between 1990 and 2003

The total RF area in the EG of Tamil Nadu was estimated to be 4198.1 km^2. The deciduous forest occupied a maximum of 34% of the total forest area, followed by the southern thorn and southern thorn scrub forests, at 31% each. The evergreen forest occupied only 2%, and all of the other classes together occupied 2% of the area between 1990 and 2003 (Fig. 6a and b, Table 4). According to forest-cover density, dense evergreen and deciduous forest covers occupied 634.6 km^2, accounting for 15% of the forested area, open forest cover occupied 495.2 km^2, accounting for 12% of the forested area, and degraded forest cover occupied 2994.5 km^2, accounting for 71% of the forested area, whereas riparian, savannah, bamboo plantation, grassland, and barren rocky occupied only 2% of the forest area during 2003 (Table 4, Fig. 6c). During 1990, the total area under dense forest cover was 733.64 km^2, accounting for 17% of the total forested area, the open forest cover occupied 516.83 km^2, accounting for 12% of the forested area, and the degraded forest cover occupied 2884.55 km^2, accounting for 69% of the forested area. There was a 2% decrease in the dense forest cover and a 2% increase in the degraded forest cover between 1990 and 2003 (Table 4, Fig. 6c, d).

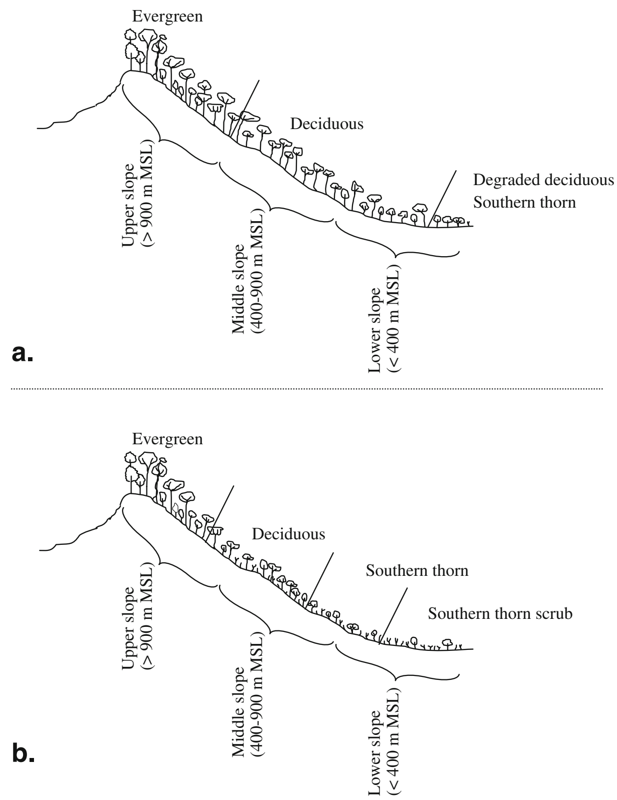


Fig. 5 Structure of different forests types in the Eastern Ghats on different slopes (not to the scale): (**a**) structure of forests before 1900s and (**b**) structure of forests after 1900

Forest-Cover Status and Changes in Aerial Extent of Each Forest Type Between 1990 and 2003

Evergreen Forest

Evergreen forest was present in the Jawadi, Shevaroy, Chittery, Kalrayan, Kolli, Pachaimalai and Sirumalai hills within the study area. It occupied 95 km^2 overall (Table 4). Within the overall evergreen forest area, dense evergreen forest occupied 52.3%, followed by open evergreen (25.5%) and degraded evergreen (22.2%), during 2003. Compared with 1990, decreases of about 0.48 and 5.63 km^2 were noted in the dense and open evergreen forests during 2003, 0.9% and 18.8%, respectively. An increase in area (6.11 km^2) during 2003 was noted for the degraded evergreen forest (Tables 4 and 5, Fig. 7a).

Table 2 Accuracy assessment of different forest types of 1990 in the Eastern Ghats of Tamil Nadu, India

	Den eg	Op eg	Deg eg	Den dec	Ope dec	Deg dec	Sava	Gr land	St	Sts	Rip	Bam	Barr	Total	User acc
Den eg	110	11	4	0	0	0	0	0	0	0	0	0	0	125	88
Ope eg	8	85	14	12	6	0	0	0	0	0	0	0	0	125	68
Deg eg	0	17	100	6	2	0	0	0	0	0	0	0	0	125	80
Den dec	0	9	2	106	8	0	0	0	0	0	0	0	0	125	85
Ope dec	0	3	5	14	81	18	0	0	4	0	0	0	0	125	65
Deg dec	0	0	0	0	32	78	0	0	11	4	0	0	0	125	62
Sava	0	0	0	0	0	19	91	0	9	6	0	0	0	125	73
Gr land	0	0	0	0	0	5	18	93	6	3	0	0	0	125	74
St	0	0	0	0	0	8	0	15	78	24	0	0	0	125	62
Sts	0	0	0	0	0	0	0	13	21	91	0	0	0	125	73
Rip	0	0	0	0	12	10	0	0	5	5	93	0	0	125	74
Bam	0	0	0	0	10	1	8	3	5	4	0	94	0	125	75
Barr	0	0	0	0	0	0	0	0	0	0	0	0	125	125	100
Total	118	125	125	138	151	139	117	124	139	137	93	94	125	1625	
Pr acc	93	68	80	77	54	56	78	75	56	66	100	100	100		
Overall accuracy: 1225/1625 = 75%															

Den eg = dense evergreen, Op eg = open evergreen, Deg eg = degraded evergreen, Den dec = dense deciduous, Ope dec = open deciduous, Deg dec = degraded deciduous, Sava = savannah, Gr land = grass land, St = southern thorn, Sts = southern thorn scrub, Rip = riparian, Bam = bamboo, Barr = barren/ rocky, User acc = user accuracy, Pr acc = producer accuracy

Table 3 Accuracy assessment of different forest types during 2003 in the Eastern ghats of Tamil Nadu, India

	Den eg	Op eg	Deg eg	Den dec	Ope dec	Deg dec	Sava	Gr land	St	Sts	Rip	Bam	Barr	Total	User acc
Den eg	115	8	2	0	0	0	0	0	0	0	0	0	0	125	92
Ope eg	8	90	20	7	0	0	0	0	0	0	0	0	0	125	72
Deg eg	7	15	100	0	3	0	0	0	0	0	0	0	0	125	80
Den dec	2	7	0	94	18	4	0	0	0	0	0	0	0	125	75
Ope dec	0	5	3	12	94	11	0	0	0	0	0	0	0	125	75
Deg dec	0	0	0	0	35	73	0	0	17	0	0	0	0	125	58
Sava	0	0	0	0	0	0	109	16	0	0	0	0	0	125	87
Gr land	0	0	0	0	0	0	17	108	0	0	0	0	0	125	86
St	0	0	0	0	0	8	2	0	98	17	0	0	0	125	78
Sts	0	0	0	0	0	9	5	0	15	96	0	0	0	125	77
Rip	0	0	0	0	15	2	0	0	1	2	105	0	0	125	84
Bam	0	0	0	0	5	6	0	3	3	2	0	106	0	125	85
Barr	0	0	0	0	0	0	0	0	0	0	0	0	125	125	100
Total	132	125	125	113	170	113	133	127	134	117	105	106	125	1625	
Pr acc	87	72	80	83	55	65	82	85	73	82	100	100	100		
Overall accuracy: 1313/1625 = 81%															

Den eg = dense evergreen, Op eg = open evergreen, Deg eg = degraded evergreen, Den dec = dense deciduous, Ope dec = open deciduous, Deg dec = degraded deciduous, Sava = savannah, Gr land = grass land, St = southern thorn, Sts = southern thorn scrub, Rip = riparian, Bam = bamboo, Barr = barren/ rocky, User acc = user accuracy, Pr acc = producer accuracy

Deciduous Forest

Deciduous forest was present in all of the hills of the EG except Ayyalur, Bodamalai, and Semmalai. The total area under deciduous forest was 1448.8 km^2 during 2003 and 1459.6 km^2 during 1990 (Table 4). Dense deciduous forest occupied 584.87 km^2, followed by open deciduous at 471 km^2 and degraded deciduous at 392.9 km^2, accounting for 40.3%, 32.5%, and 27.1% of the total deciduous forest area during 2003. Compared with 1990, there was an ~10% decrease (98.6 km^2) in the dense deciduous forest area and a 35.9% increase (103.8 km^2) in the

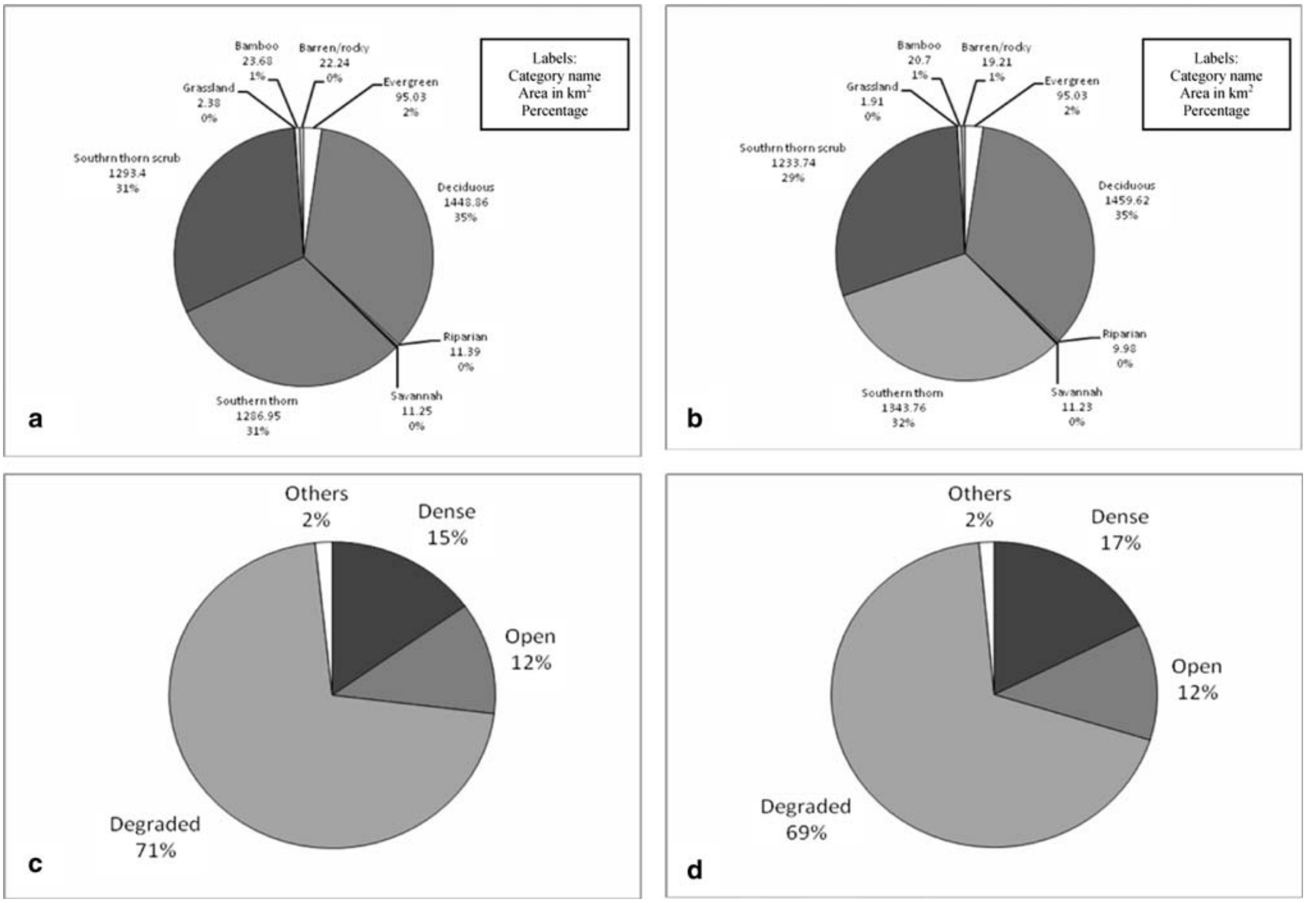


Fig. 6 Distribution of area: (**a**) in different forest types during 2003, (**b**) in different forest types during 1990, (**c**) in different density classes during 2003, and (**d**) in different density classes during 1990 in the Eastern Ghats of Tamil Nadu

Table 4 Forest-cover and areal extent changes between 1990 and 2003, and stand density for the various forest types in the Eastern Ghats of Tamil Nadu

Sl. No.	Forest-cover type	Area in km^2		Changes in area (km^2)	Percentage of changes (%)	Stand density per hectare
		1990	2003			
Upper slope (>900 m MSL)						
1	Dense evergreen	50.19	49.71	−0.48	−0.9	537
2	Open evergreen	29.81	24.18	−5.63	−18.8	302
3	Degraded evergreen	15.03	21.14	6.11	+40.6	128
Middle slope (400–900 m MSL)						
4	Dense deciduous	683.49	584.87	−98.62	−10.0	348
5	Open deciduous	487.02	471.02	−16.00	−3.2	273
6	Degraded deciduous	289.11	392.97	103.86	+35.9	178
7	Savannah	11.23	11.25	0.02	0.0	62
8	Grassland	1.91	2.38	0.47	+24.3	–
Lower slope (<400 m MSL)						
9	Southern thorn	1343.76	1286.95	−56.81	−4.2	171
10	Southern thorn scrub	1233.74	1293.40	59.66	+4.5	92
11	Riparian	9.98	11.39	1.41	+14.1	401
12	Bamboo (plantation)	20.70	23.68	2.98	+13.4	–
13	Barren rocky	19.21	22.24	3.03	+15.7	–

Table 5 Matrix analysis of change detection of forests between 1990 and 2003 in the Eastern Ghats of Tamil Nadu, India

		2003													Total
		Den eg	Op eg	Deg eg	Den dec	Ope dec	Deg dec	Sava	Gr land	St	Sts	Rip	Bam	Barr	
1990	Den eg	49.71	0.48	0	0	0	0	0	0	0	0	0	0	0	50.19
	Ope eg	0	23.7	6.11	0	0	0	0	0	0	0	0	0	0	29.81
	Deg eg	0	0	15.03	0	0	0	0	0	0	0	0	0	0	15.03
	Den dec	0	0	0	584.87	56.78	41.84	0	0	0	0	0	0	0	683.49
	Ope dec	0	0	0	0	414.24	70.16	0	0	2.62	0	0	0	0	487.02
	Deg dec	0	0	0	0	0	280.97	0	0	7.14	0	1.0	0	0	289.11
	Sava	0	0	0	0	0	0	11.23	0	0	0	0	0	0	11.23
	Gr land	0	0	0	0	0	0	0	1.91	0	0	0	0	0	1.91
	St	0	0	0	0	0	0	0	0	1277.19	65.23	0.41	0	0.93	1343.76
	Sts	0	0	0	0	0	0	0.02	0.47	0	1228.17	0	2.98	2.1	1233.74
	Rip	0	0	0	0	0	0	0	0	0	0	9.98	0	0	9.98
	Bam	0	0	0	0	0	0	0	0	0	0	0	20.7	0	20.7
	Barr	0	0	0	0	0	0	0	0	0	0	0	0	19.21	19.21
	Total	49.71	24.18	21.14	584.87	471.02	392.97	11.25	2.38	1286.95	1293.4	11.39	23.68	22.24	4195.18

Note: Den eg = dense evergreen, Op eg = open evergreen, Deg eg = degraded evergreen, Den dec = dense deciduous, Ope dec = open deciduous, Deg dec = degraded deciduous, Sava = savannah, Gr land = grass land, St = southern thorn, Sts = southern thorn scrub, Rip = riparian, Bam = bamboo, Barr = barren/ rocky, User acc = user accuracy, Pr acc = producer accuracy

degraded deciduous forest area. In contrast, there was only a 3.2% decrease (16.0 km^2) in the open deciduous forest area (Table 4, Fig. 7b). The decrease of area in the dense deciduous forest was changed into open (56.78 km^2) and degraded (41.84 km^2) deciduous forest (Table 5). From the open deciduous forest, 70.16 km^2 was changed into degraded deciduous forest and 2.62 km^2 into southern thorn forest. Despite the addition of area to degraded deciduous, change could also be noted in this forest (7.14 km^2), which was converted into southern thorn forest (Table 5).

Riparian Forest

Riparian forest was present in the Jawadi, Shevaroy, and Kolli hills. This forest was situated on both sides of the perennial rivers in these hills and guarded by moderate deep valleys on both sides. It occupied 11.4 km^2 during 2003 and 10.0 km^2 during 1990. Progressive change was noted in this forest type. The increase of 1.41 km^2 was partly from degraded deciduous and southern thorn forests.

Tree Savannah Forest

This forest type was present only in the Pachaimalai and Sirumalai hills, occupying 11.2 km^2 both in 1990 and 2003. Surprisingly, no changes could be noted for this forest type (Fig. 7c). It was located at the western side of the two hills on the middle slope, surrounded by deciduous forest.

Southern Thorn Forest

This forest type was present in all of the hills and was located on the lower-middle and lower slopes. It occupied a maximum of 1343.8 km^2 and 1286.9 km^2 during 1990 and 2003, respectively (Table 4). A change of about 56.8 km^2 was noted during 2003 (Fig. 7d), a 4.2% drop from 1990. However, 65.23 km^2 was changed into southern thorn forest, 0.41 km^2 was changed into riparian, and 0.93 km^3 became barren/rocky class (Table 5).

Southern Thorn Scrub Forest

This forest type was also present in all the hills on the lower slope and was the most degraded. The total area for this forest type was 1236.6 km^2 during 1990 and 1293.4 km^2 during 2003 (Table 4). Although an increase of about 56.7 km^2 was recorded, this was only retrogressive in nature (Fig. 7d). Moreover, change could also be noted in this forest type from the matrix analysis (Table 5). Savannah, grassland, bamboo, and barren/rocky classes gained area from this forest.

Grassland and Bamboo (Plantation)

Grassland was present only on Pachaimalai Hill, and bamboo was present in the Shevaroy, Chittery, and Kolli hills. The grassland occupied only 1.9 km^2 during 1990 and 2.4 km^2 during 2003, for an increase of about 0.47 km^2 (Table 4; Fig. 7c). The bamboo occupied 20.7 km^2 during

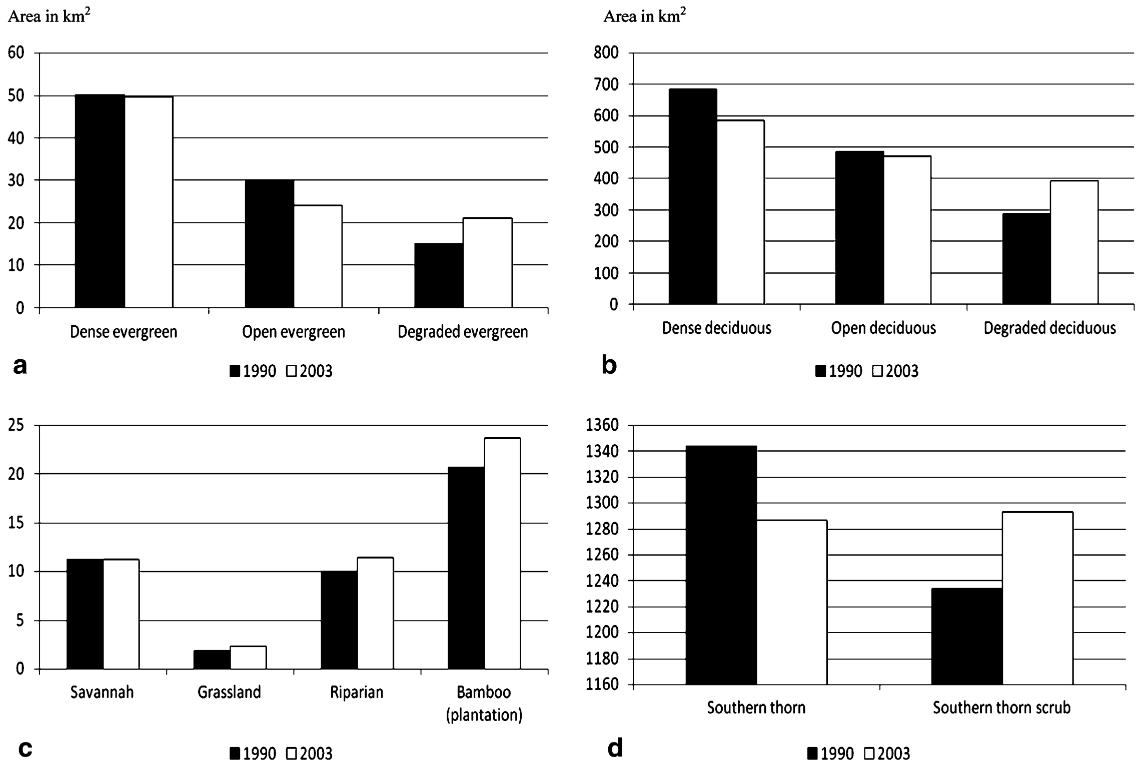


Fig. 7 Changes in the forest cover between 1990 and 2003: (**a**) evergreen with three density classes, (**b**) deciduous with three density classes, (**c**) savannah, grassland, riparian and bamboo plantation, and (**d**) southern thorn and southern thorn scrub forest

1990 and about 23.7 km^2 during 2003, for an increase of about 3.0 km^2, which was 13.4% higher than the total bamboo area during 1990 (Table 4, Fig. 7c). Neither of these two categories was included in the quadrate study.

Species Composition and Stand Density in Different Forest Types

Evergreen Forests

The dominant tree species recorded during plot sampling were *Alangium salviifolium, Artocarpus heterophyllus, Canarium strictum, Elaeocarpus serratus, Mallotus stenanthus, Memecylon edule, Neolitsea scrobiculata, Persea macrantha, Prunus ceylanica, Memecylon umbellatum, Nothopegia beddomei, Syzygium cumini, Syzygium jambos, Terminalia bellirica*, and *Terminalia chebula*. The total stand density recorded in the dense evergreen forest was 537 stems/ha, and in the open and degraded evergreen forests, it was 302 and 128 stems/ha, respectively (Table 4). However, the mean stand density of the entire evergreen forest was only 335.6 stems/ha. The distribution of tree stands in different girth classes is illustrated in Fig. 8. In the dense evergreen forest, more than 160 tree stands were recorded in the 130–180-cm class range, but in the open and degraded evergreen forests, the number was only 95 and 16, respectively (Fig. 8a–c). Many mature stems were recorded in the dense evergreen forest, whereas in the open and degraded evergreen forests, only a few stems were recorded in the higher girth ranges.

Deciduous Forest

The dominant tree species recorded in this forest were *Azardirachta indica, Bridelia retusa, Chloroxylon swietenia, Cochlospermum religiosum, Commiphora berryi, Commiphora caudata, Dalbergia paniculata, Feronia elephantum, Givotia rottleriformis, Gyrocarpus americanus, Gyrocarpus jacquinii, Kydia calycina, Lannea coromandelica, Moringa concanensis, Sapindus emarginatus, Sterculia urens, Sterculia gattata, Strychos nux-vomica, Tectona grandis*, and *Wrightia tinctoria*. The stand density in the dense deciduous forest was 348 stems/ha, and in the open and degraded deciduous forests, it was 273 and 178 stems/ha, respectively (Table 4). About 71.5% of the total stands recorded in the dense deciduous forest were within the girth range of 30–130 cm. Likewise, in the open and degraded deciduous forests, the recorded tree stands within the girth range of 30–130 cm amounted to 77.3% and 76.4%, respectively (Fig. 8d–f).

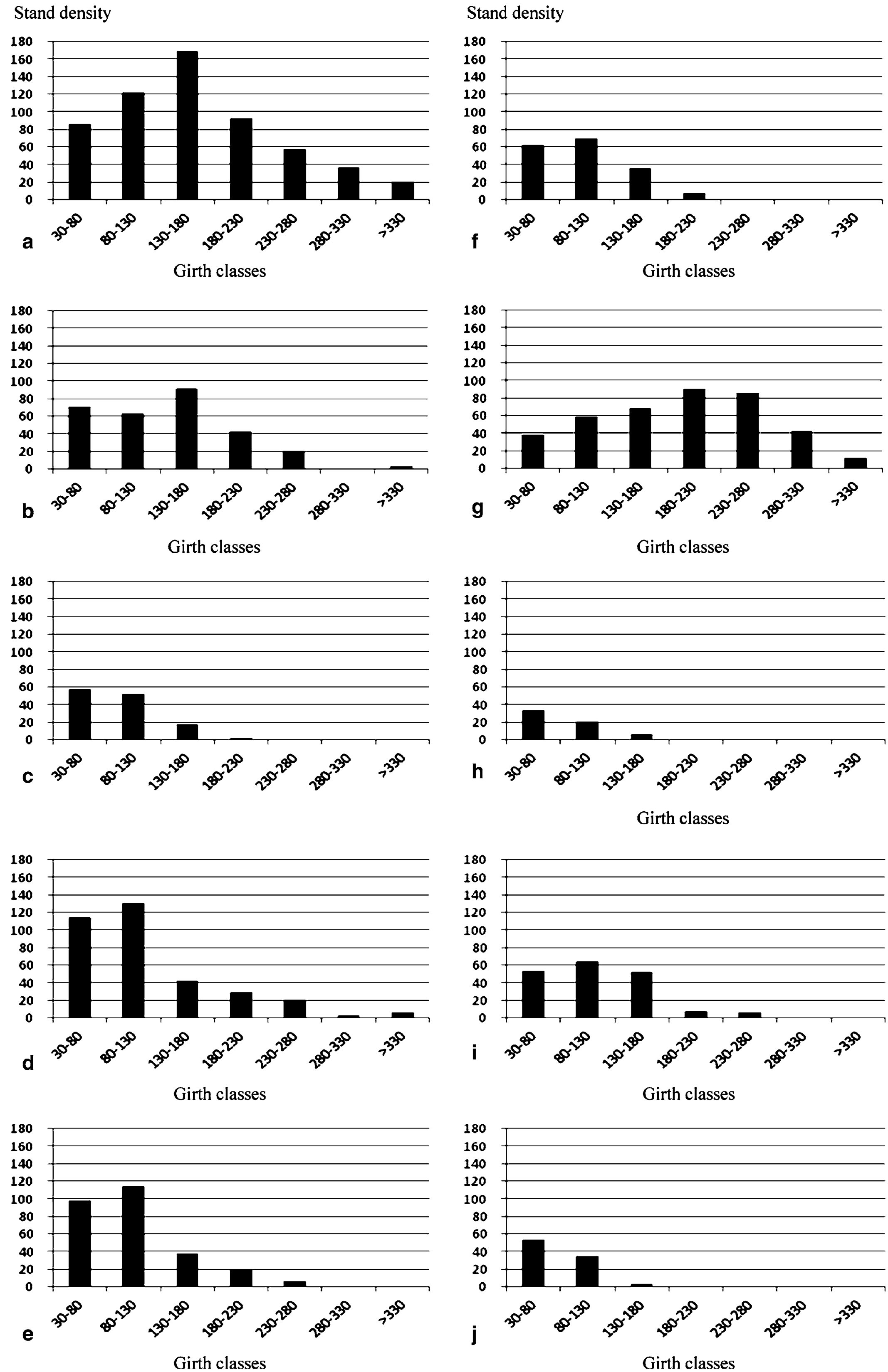
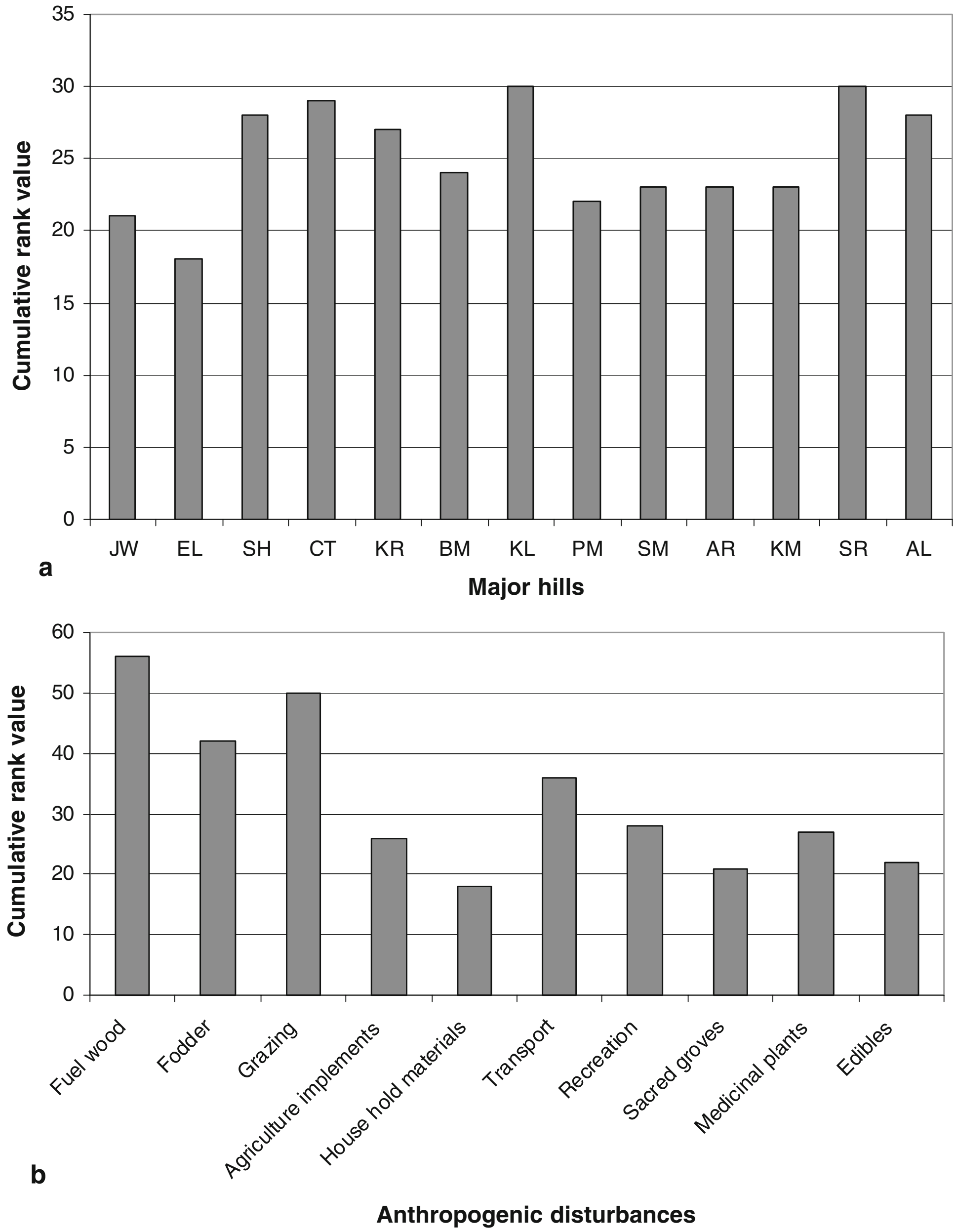


Fig. 8 Distribution of stand density in each forest class for different girth classes: (**a**) dense evergreen, (**b**) open evergreen, (**c**) degraded evergreen, (**d**) dense deciduous, (**e**) open deciduous, (**f**) degraded deciduous, (**g**) riparian, (**h**) savannah, (**i**) southern thorn, (**j**) southern thorn scrub

Fig. 9 Anthropogenic disturbance in the Eastern Ghats of Tamil Nadu, India: (**a**) amount of anthropogenic pressure in each hill and (**b**) level of people's dependence on forests for their various needs



Riparian Forest

The dominant species were *Alangium salvifolium, Biscofia jawana, Mangifera indica, Mitragyna parvifolia, Pungamia pinnata*, and *Terminalia arjuna* for this forest type. The calculated stand density was 401 stems/ha (Table 4). The tree stands followed a normal distribution (Fig. 8g).

Tree Savannah Forest

The dominant tree species recorded was *Pterocarpus marsupium.* The stand density was only 62 stems/ha (Table 4). All of the trees were young, falling mainly within the 30–80 and 80–130 girth classes (Fig. 8h) and usually stunted in growth.

Southern Thorn Forest

The dominant tree species recorded were *Albizia amara, Commiphora caudata, Gyrocarpus asiaticus, Moringa oleifera*, and *Psydrax umbellate.* The stand density was 171 stems/ha and the majority of the tree stands were in the range of 80–130 cm gbh (Fig. 8i).

Southern Thorn Scrub Forest

The dominant tree species were *Albizia amara, Euphorbia tortilis*, and *Morinda pubescens*. The total stand density was 92 stems/ha, recorded in the girth range of 30–130 cm (Fig. 8j).

Table 6 Species composition in the Eastern Ghats of Tamil Nadu during preindependence, postindependence, and present

	Preindependence (before 1947)	Postindependence (after 1947)	Present (2005–2006)
Middle slope (400–900 m)	*Anogeissus latifolia, Chukrasia tabularis, Chloroxylon sweitenia, Dalbergia latifolia, Hardwickia binata, Premna tomentosa, Pterocarpus marsupium, Pterospermum personatum, Santalum album, Sterculia guttata, Strychnos potatorum, Terminalia sps.,*	*Azardirachta indica, Dalbergia paniculata, Dodonia viscosa, Euphorbia antiquorrum, Feronia elephantum, Lanea coromandalica, Pongamia pinnata, Povetta indica, Kydia calycina, Randia dumetorum, Sapindus emarginatus, Sterculia urens, Toddalia asiatica, Trema orientalis*	*Azardirachta indica, Bridelia retusa, Chloroxylon swietenia, Cochlospermum religiosum, Commiphora berryi, Commiphora caudata, Dalbergia paniculata, Feronia elephantum, Givotia rottleriformis, Gyrocarpus americanus, Gyrocarpus jacquinii, Kydia calycina, Lannea coromandelica, Moringa concanensis, Sapindus emarginatus, Sterculia urens, Sterculia gattata, Strychos nux-vomica, Tectona grandis, Wrightia tinctoria*
Lower slope (<400 m)	*Adaina cordifolia, Albizia labbek, Albizia odoratissima, Anogeissus latifolia, Boswellia serrata, Buchanania lanzan, Butea monosperma, Canthium dicoccum, Cleistanthus collinus, Cassia fistula, Dendrocalamus strictus, Feronia elephantum, Garuga pinnata, Gmelina arborea, Mallotus phillippensis, Pterocarpus marsupium, Pterolobium indicum, Santaum album, Sedrella tuna, Strychnos nux-vomica, Streblus asper, Ziziphus oenopilia*	*Accacia chundra, Acacia lateronum, Commiphora caudata, Erithroxylum monogynum, Euphorbia antiquorum, Gyrocarpus jacquinii, Moringa oleifera, Pterolobium hexapetalum, Toddalia asiatica, Zizipus oenoplia*	*Albizia amara, Commiphora caudata, Gyrocarpus asiaticus, Moringa oleifera Psydrax umbellata, Euphorbia tortilis, Morinda pubescens*

Anthropogenic Pressure

According to the qualitative analysis, the level of materials demand and the corresponding pressure to each hill are clearly understood. Although all 13 hills are under pressure, Kolli, Sirumalai, Chittery, Shevaroy, and Alagar gain more pressure than other hills (Fig. 9a). The local people mostly depend on forest for fuelwood, livestock grazing, and fodder (Fig. 9b). In spite of stringent rules, the local people are constantly using the forests for various purposes.

Changes Identified in Forest Type and Species Composition as a Result of Need-Based Management Between 1800 and the 1980s

The present study clearly identified the changes in species composition, forest type, and areal extent of the various forests in the EG of Tamil Nadu. Those changes were the results mainly of need-based forest management implemented during both the preindependence and postindependence periods. The changes observed in the present study revealed that the middle (400–900 m MSL) and lower (<400 m MSL) slopes were highly disturbed compared with the upper slopes.

It is evident to note that the forest type and its species composition recorded by Mayuranathan (1929), Gamble (1933), Champion and Seth (1968), Harikrishnan (1977), Matthew (1983) and Puri and others (1989) show that the middle and lower slopes in the EG were predominantly occupied only by species of deciduous forest but that by the 1980s, species of southern thorn forest and southern thorn scrub forest were also present in those regions. As a result of the management activities, the original nature of the vegetation pattern of the deciduous forest was completely changed.

The species composition during the preindependence, postindependence, and the present periods are given in Table 6. It is apparent from the present floristic diversity study that the species composition of past and present in the middle and lower slopes are completely different.

Discussion

In India, the forests are being disturbed from pre-independence period to until today for various reasons (Bhat and others 2001; Milward 1949; Prasad 2000; Saravanan 1998, 1999, 2003; Stebbing 1922). During the precolonial period, the sustainability of forest was unaffected neither by the tribal people nor by the other forest users, as the resources were not exploited for the commercial purposes and, moreover, the population density was much less (Kurien 1992; Saravanan 1998). The destruction and denudation of pristine forests for various needs started during the colonial period with commercial motive (Saravanan 1998) and continued until independence led to the loss of the original biodiversity of primary forest and the formation of secondary and postextraction secondary forests (Bhat and others 2001; Kurien 1992; Ramachandran and others 2007; Saravanan, 1998; Stebbing 1922). After Indian independence, various management strategies in the name of various working circles and developmental action plans such as tandem replanting of degraded areas with a strategy of clear-cutting and uprootal of the existing jungle growth (Pandey 1992; Prasad 2000; Rao and others 1961) led to further deterioration and the virtual loss of the secondary forest.

These disturbances could well be observed from the present study. The forest type and species composition have totally been altered in the middle and lower slopes. However, it is interesting to note that the evergreen forest present in the upper slope is less disturbed. It could be confirmed from the stand density status of this forest. The total stand densities of the dense evergreen forest (537 stems/ha) and the riparian forest (401 stems/ha) were comparable to those of the undisturbed forest recorded at Mylodai, the Courtallum reserved forest 482 (Parthasarathy and Karthikeyan 1997), and other tropical forests of the world such as Costa Rica 448–617 (Heaney and Proctor 1990) and Brazil 420–777 (Campbell and others 1992). The stand densities recorded for the other forest classes were appreciably smaller than those of the other tropical forests. The results of disturbance and various management strategies were very apparent in the deciduous forest situated on the middle slope. About 348 stems were recorded in the dense deciduous forest cover among which more than 71% were in the 30–130-cm girth class. The changes in the species composition, forest types, and stand density clearly indicate that the vegetation parameters were not unique to the original composition of the deciduous forest. The unavailability of literature on forest dynamics for this region allowed only species-level comparison with available literature such as published books, floras, and working plans.

Disturbances to forest structure, either anthropogenic or as a result of forest management, affect light and soil conditions and their characteristics significantly (Clark and others 1993; Connell 1978; Huston 1979; Iriarte and Chazdon 2005; Peet and others 1983). Under unique combinations of these environmental conditions, trees and stands of trees are able to grow. Different types of trees or stands require, according to their particular adaptations, different combinations of those conditions (Iriarte and Chazdon 2005; Welden and others 1991). When one or more conditions are deficient, the growth and development of the trees or stands are affected (Beckage and Clark 2003). The combined conditions of soil fertility, moisture, and texture determine whether a species will thrive on any given site (Ricard and others 2003). Each condition plays a role in the life cycle of the tree and must be present for survival and successful growth (Coomes and Grubb 2000; Grubb and others 1996; Ricard and others 2003). Interactions between heterogeneity in the forest overstory (gap or closed canopy) and understory microenvironments can affect seedling performance, subsequent community composition, and the potential for species coexistence (Beckage and others 2000; Heinemann and others 2000).

The key factors, such as nutrients, moisture, light, and space, required in appropriate quantities for optimum growth and development of species (Clark and others 1993; Clark and others 1993; Iriarte and Chazdon 2005; King 1991; Montgomery and Chazdon 2002; Poorteer and Werger 1999; Sterck and others 1999; Welden and others 1991) might have been altered by the activities of the preindependence and postindependence periods on the middle and lower slopes. Thus, the land might have been unsuitable for some of the key stone deciduous species and suitable for secondary and tertiary forests of southern thorn and southern thorn scrub forest species.

The remote sensing analysis of the changes in forest-cover density and areal extent revealed that the forests on the upper slope were less disturbed than the forests on the middle and lower slopes. With regard to the evergreen forest, a greater reduction of area was noted for the open-cover class (5.63 km^2) than for the dense-cover class (0.48 km^2). However, in the deciduous forest, there was a greater reduction of area for the dense-cover class (98.62 km^2) than for the open-cover class (16.0 km^2). Because the evergreen forest was surrounded by many settlements, anthropogenic pressure in the form of illegal felling might have been a cause of the area reduction in the open evergreen forest. The fewer disturbances in the dense evergreen forest likewise might have been due to its position, because it was surrounded by open evergreen forest. In the case of the dense deciduous forest, the changes recorded were mostly near the plateau. However, in both the evergreen and deciduous forests, there were corresponding increases in the degraded-cover classes. In the evergreen forest, the increase in the degraded class was mainly due to the degradation of open evergreen forest, and in the deciduous forest, it was mainly towed to the dense deciduous forest. The reduction in the southern thorn forest (−56.81 km^2) was almost identical to the increase in the southern thorn scrub forest (59.66 km^2). This also was mainly due to degradation. However, change of area could also be noted in the southern thorn scrub forest. Increase of area (2.94 km^2) was also recorded in the barren/rocky class, which was from the southern thorn and southern thorn scrub forests. The reasons for such increase in the area should be investigated further. Considering the scale of mapping and accuracy of the present classification, the increases and decreases in the other forest-cover classes were not sufficiently significant to be considered.

In this study, majority of the classes were classified with more than 70% accuracy, except the open and degraded deciduous forests. The lesser accuracy obtained in these two classes was mainly due to the spectral similarity and, moreover, these two forests were situated contiguously in the midslope. The thorny bushes growth in the degraded forest resembles the open deciduous in many regions.

As per the remote sensing data analysis for 1990 and 2003, it was clear that there were changes in the forest-cover and areal extent, invariably for all of the major forest covers such as evergreen, deciduous, southern thorn, and southern thorn scrub. It is interesting to note that these changes occurred over a period of 13 years, even after the conclusion of need-based forest management. From the results of this analysis, it could be understood that there were damage-causing factors still operating on the forests of the EG. Although many factors such as fire, flood, wind, earthquake, mortality caused by insect, or disease outbreaks might cause damage to forests, there was no literature on these damage-causing factors in these region except human disturbance. One of those factors might be anthropogenic disturbances in the form of fuelwood collection, livestock grazing, illegal felling, and extraction of timber for agriculture and household purposes, particularly because the EG is a broken chain of hills surrounded by a number of human settlements of various population sizes. The tribal settlements in the plateau regions on each hill, which are closer to the vicinity of the forests, might also cause considerable damage to the forests (Jayakumar and others 2002b). The forest disturbance studies in the EG (Chittibabu and Parthasarathy 2000; Kadavul and Parthasarathy 1999a, b) also revealed the anthropogenic pressure on these forests. The forest fire, which occurs every year in this region, might also contribute to the changes in forest cover. However, in India, the data on forest fire and its damage are very sketchy and fragmented (Kumar 2002). Intentional and controlled forest fire helps forest management (Schmerbeck and Seeland 2007), but unintentional fires might cause damage.

Conclusion

In the EG of Tamil Nadu, the forest management practices undertaken during preindependence and postindependence periods until 1980 have totally altered the forest dynamics. That activity has also favored the secondary growth of other forests, such as southern thorn and southern thorn scrub, on the middle and lower slopes. However, the unavailability of spatial database on forest dynamics during preindependence and postindependence periods allowed only qualitative analysis of forest dynamics. The satellite-based study of forest dynamics during 1990 and 2003 clearly portrays the changes in different forest types quantitatively. From this, it is evident that the forests in the EG is still under constant pressure even after the conclusion of need-based forest management and after the enactment of a conservation policy. Although the satellite-based forest-cover assessment facilitated the estimation of the changes in different forest types, the present approach has classified the open and degraded deciduous forests less accurately. Therefore, alternative methods should be tried to improve the accuracy of classification.

The qualitative analysis of anthropogenic pressure in the EG is also ascertained by the dependence of local people on forests. It is also interesting to note that the forests are under anthropogenic pressure, in spite of JFM, which is in practice in these regions. Nonetheless, it is very difficult to assume that this anthropogenic pressure is the only reason for the changes in the forests. Other disturbance factors might also contribute to some extent to the changes in the forests. However, it is very difficult to quantify the effect of other factors because of lack of data and literature. The forest dynamics studies in the Western Ghats (Bhat and others 2000; Sukumar and others 1992) and the floristic study in the EG (Chittibabu and Parthasarathy 2000; Kadavul and Parthasarathy 1999a, 1999b) have clearly portrayed the human disturbance. Thus, such studies should be initiated in this region to quantitatively monitor the status and dynamics of forests and also to fill the gap in the data availability. Effective conservation strategies should be implemented in view of the demand and pressure of local people and other factors in order to protect the existing forest resource from further deterioration. Change in the JFM policies is needed for effective implementation. Plantation programs should be implanted taking into account the site condition with suitable species.

It is also worthwhile to consider the following in future studies: (1) why there were major reductions in the area of open evergreen, dense deciduous, and southern thorn forests between 1990 and 2003, (2) why the tree stands in the evergreen forest remained in the immature, actively growing stage although undisturbed by need-based management activities, (3) how other factors, especially forest fire, contribute to the forest dynamics in these region, (4) what is the trend in forest succession between forests, and (5) in order to identify the forest dynamics in the Eastern Ghats, it is necessary to set up and monitor few permanent quadrates of 1 ha each or more in different forests in each hill for longer periods.

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