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Anthropogenic Pressure on Structure and Composition of a Shola Forest in Kerala, India

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Abstract: The montane closed evergreen forests found at altitudes above 1,800 m in the Western Ghats of India possess a distinct vegetation type and are called shola forests. Despite the fact that these forests are located in relatively inaccessible areas, they are still under anthropogenic pressure leading to continued habitat degradation and loss of biomass and biodiversity. A case study was conducted in Mananvan shola, the largest shola forest in Kerala of Western Ghats, to recognize the impact of disturbance on vegetation structure, composition and regeneration pattern, to identify the socio-economic reasons for disturbance and to evolve strategies for its management. In the disturbed part of the forest, dominance of light demanding species in tree, shrub and herb communities has been recorded. Here even the dominance of exotic species in tree seedling, shrub and herb communities is prominent. Skewed girth class distribution of tree community with poor representation by the individuals of girth class 30.1 to 90.0 cm, is also an indication of the collection of small wood and poles from the forest. The RISQ (Ramakrishnan Index of Stand Quality) in the disturbed area of the forest is above 2.0 as against near to 1.0 in relatively undisturbed forest stands suggesting that the disturbance is intensive and thus natural recovery process would be slow. Socio-economic analysis in villages located near the shola forest revealed the fact that the people depended heavily on this forest for their livelihood. Thus, the crux and the success of future management and conservation strategy depend on how one can reduce the dependency of people on the shola vegetation. Enrichment planting in disturbed parts of shola, enhancement of firewood by raising energy plantations, as well as development of lemongrass and firewood based agroforestry systems and reduction of grazing pressure by developing silvopastoral systems are the major strategies for the conservation of these shola forests.

Key words: Anthropogenic disturbance; montane forest; shola forest; species composition; western ghats of India

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Introduction

Tropical region is endowed with a vast tract of diverse vegetation (Gentry 1992). Among different types of forests, the montane forests, due to their unique features including rich biodiversity and

prominent ecological services, have always attracted biologists, bio-geographers, ecologists and forest managers (Doumenge *et al.* 1995). In India, montane forests covering 7.9 % of total forest area occur in the Himalayan, northeastern and southern parts of the country (Lal 1989). In southern India, the montane forests, generally found at the altitude above 1,800 m in the Western Ghats, are commonly known as shola forests (Ranganathan 1938). These forests designated as tropical upper montane rain forests (Burtt-Davy 1938), temperate rain forests in the montane region (Schimper 1903), montane temperate forests (Champion 1936) and southern montane wet temperate forests (Champion and Seth 1968) are characterized by having stunted evergreen trees with dense, round or umbrella shaped crown consisting of entire and coriaceous leaves. Moreover, trees are clothed and festooned with rich epiphytes (Champion 1936). From the point of view of biodiversity, shola forests are regarded as unique due to rich flora and fauna, particularly rare and endemic elements (Blasco 1970, Jose *et al.* 1994). Even though these forests are located in relatively inaccessible hilly areas, many of them have been cleared and converted into plantations and agricultural lands. Thus for instance in Kerala State of southern India, only about 70 km^2 forest area (0.74 % of the total forest area of the State) is now remained under shola forests (Nair 1991). However, conversion of these forests was discontinued in the recent past, once their ecological functions were realized to some extent. Even then these forests are still under anthropogenic pressure leading to continued habitat degradation and loss of biomass and biodiversity (Rangarajan 1997). However, systematic studies to analyse socio-economic factors responsible for disturbance and to analyse the impact of such disturbance on the vegetation structure, composition and regeneration pattern are lacking. Such studies are also useful to develop strategies for management and restoration of impacted ecosystems. The present study conducted in Mannavan shola forest, the largest in the Kerala State with an area about 5.18 km^2, aimed to a) investigate socio-economic issues responsible for the forest degradation, b) analyse the impact of disturbance on vegetation structure, composition, regeneration and ecosystem recovery processes in the forest, and c) evolve location-specific strategies for conservation and management.

1 Study Area and Climate

The Mannavan shola forest (77° 18′ 14″ N and 10° 15′ 26″ E) comes under Marayoor Forest Range of Munnar Division (Figure 1) and is located at an average elevation of 1,950 m. The weather data collected from the nearby weather station indicate that the mean annual temperature is about 20 ℃ and mean annual precipitation between 2,000 and 3,000 mm. In this forest, the soil is red, sandy loam, oxysol, acidic (pH = 4.2) in reaction with 4.6 % ~ 14 % organic carbon content.

2 Material and Methods

2.1 Socio-economic analysis

The study relied on both primary and secondary data. For generating primary data, four villages, namely, Kanthallur, Perumala, Puthur and Kolachavayal (Figure 1), which are proximal to the forest, were selected. From each village, 25 households were randomly selected for studying the problems of the Mannavan shola forest. The primary data were collected using a structured questionnaire. Participatory Rural Appraisals were also conducted among the people to know the major problems of the shola area. In addition to the primary data, the secondary data were collected from the Government Offices, such as the Forest Department, Panchayath Offices, for this study. Besides, 10 elder respondents from the above mentioned villages were selected for collecting historical data regarding migration, socio-cultural tradition of the people, destruction of shola, *etc*.

2.2 Vegetation analysis

In Mannavan shola forest, both disturbed and undisturbed areas can be clearly identified. Qualitative indicators of anthropogenic disturbance considered to determine whether a given area in the forest patch is disturbed or undisturbed include the presence of a) stumps of cut trees, b) debris including branches and leaves

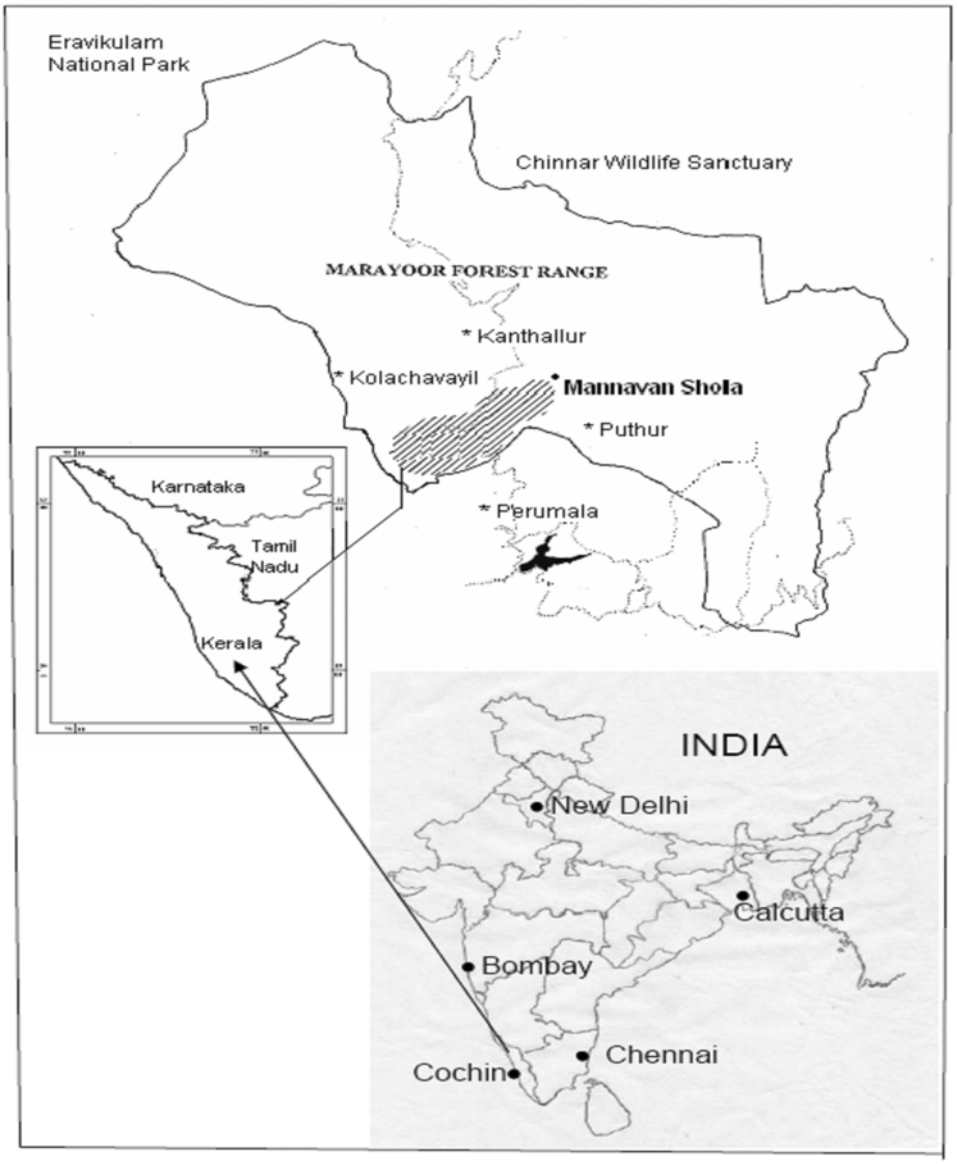

Figure 1 Location map of Mannavan shola in Kerala State, India

of cut trees, c) remnants of lopping, d) occurrence of paths, e) cattle or their excreta, hoof mark, trampled soil or compacted soil, f) large and abnormal canopy gaps, g) understorey plants which are not characteristic to relatively undisturbed forest patch, and h) exposed soil. Interviews and discussions with local people also provided the information on whether a given area in the forest is disturbed or not. In both disturbed and undisturbed areas of these forests, vegetation analysis has been conducted.

Three plots were demarcated in the undisturbed and disturbed areas of the forest, respectively. The size of each plot was 1 ha and the minimum distance between any two plots in a given type of forest was 500 m. Vegetation analysis was carried out in the these plots by establishing randomly laid 25 quadrats, each of 10 m × 10 m in size. These quadrats were used for studying mature trees (individuals with girth at breast height (gbh, measure at 1.37 m above ground) more than 30.1 cm) and saplings (individuals with 10.1 ~ 30 cm gbh). In each quadrats, while the subquadrats each of 1 m × 1 m in size were established for studying tree seedlings (individual with girth 1.0 ~ 10 cm), and subquadrats of 5 m × 5 m in size were

established for studying shrubs and herbs. Number and occurrence of all species in each quadrat were measured. Girth at breast height (gbh at 1.37 m above ground) of all trees and saplings was also recorded. For trees with large buttresses the girth was measured from above the buttressed part. For seedlings, shrubs and herbs girth at ground level was taken.

The vegetation data were analyzed for relative density, relative frequency and relative dominance (Phillips 1959) and the sum of values for these parameters represented by Importance Value Index (IVI) for various species (Curtis 1959).

Sorensons's Similarity index (Mishra 1989) was calculated for comparing the vegetation of disturbed area and undisturbed area of a given shola forest.

$$\text{Similarity index} = 2C / A+B$$

Where, C is total number of common species of disturbed and undisturbed areas of the forest, A is total number of species in disturbed area, and B is total number of species in undisturbed area.

The quadrats established in disturbed areas of the above mentioned shola forests were also used to record number and girth of recently cut or removed trees and saplings of different species.

2.3 Determination of forest stand quality

Considering the life history pattern, tree species of shola forest can be categorised into primary species (shade-tolerant species), late secondary species and early secondary species (shade intolerant species). Based on the available literature (Chandrasekharan 1960, Chandrashekara *et al.* 1994, Chandrashekara *et al.* 1998, Gamble 1928, Pascal 1988, Rai 1979), species encountered in the study area were categorized into three groups. Each group was given an index number, its pioneer index 1 for the group requiring a small gap for regeneration and 3 for the group of strong light demanders with a strong canopy disturbance requirement. The procedure to determine the stand quality (Chandrashekara 1998) followed is given as below

$$\text{RISQ} = \Sigma\{(n_i / N) \times \text{species pioneer index}\}$$

Where, RISQ is Ramakrishnan Index of Stand Quality, n_i and N are the same as in the Shannon index of general diversity. Pioneer index 1 is for the species whose seedlings establish in closed canopy area but need small canopy gaps to grow up. Pioneer index 2 is for the species whose seedlings establish in small gaps but need small to medium size gaps to grow up. Pioneer index 3 is for the species whose seedlings need larger canopy gaps for both establishment and growth. The RISQ of a given site can vary from 1.0 (all stems, group 1 species; forest stand is undisturbed) to 3.0 (all stems, group 3 species; forest stand is highly disturbed).

The undisturbed and disturbed areas of the forest were compared statistically for the values obtained for a given parameter using Student's *t*-test.

3 Result and observation

3.1 Socio-economic analysis

According to the informants who participated in the senior citizen interview, about 5 decades ago there were hardly 10 households located near Mannavan shola and dependent on the forest for their livelihood. They mainly depended on shola forest and its neighboring areas in three ways, such as shifting cultivation, collection of NWFPs and firewood. However, the origin of the present resource use in the shola areas dates back to early 1970's when migration of the people from the nearby Tamil Nadu State and southern Kerala began to occur (Kunhikrishnan 2001). The migrated farmers did not follow the shifting cultivation in their new place partly because there was no adequate land and partly due to their lack of awareness of various practices of the shifting cultivation. On the other hand, they introduced a cropping pattern, which they knew. The new cropping pattern introduced by the migrant farmers predominantly consisted of vegetables, such as carrot, beans, cabbage, garlic and ginger. However, in due course of time, with a view to enhance their income, the farmers diversified their agricultural activities in two ways: grazing and lemongrass cultivation. It was estimated that there were about 295 livestock, including 77 % cattle, in

the selected 100 households from the four villages near Mannavan shola forest. It was also estimated that cattle rearing provided on an average about 12 % of the total income of the households. However, about 85 % of the cattle in the villages were sent for grazing in shola forest.

Around Mannavan shola, lemongrass was cultivated in about 188 ha and it was the major source of income, accounting for 45 % of the total household income. But most important demerit of lemongrass cultivation was that for distilling lemongrass oil, and a huge quantity of firewood was required. For example, according to the cultivators, on an average, distillation of lemongrass collected in one-year period from one hectare required about 9,839 kg of firewood. Thus, it is estimated that about 1,867 tones of firewood was required per year for the distillation of lemongrass cultivated in 188 ha in the villages near Mannavan shola forest.

It was found that firewood constituted the major source of energy for 90 % of the selected households in the villages near Mannavan shola forest. About 10 % of the households in Mannavan shola area used other energy sources like cow dung and LPG gas, in addition to firewood. Firewood was invariably collected from the shola areas and plantations of wattle (*Acacia mearnsii*) nearby. The most preferred and widely collected species of firewood were *Viburnum* spp., *Strobilanthes homotropa* and *Syzygium* spp. It was estimated that about 2,761 tones of firewood was collected annually from Mannavan shola and the nearby wattle plantation. While about 63 % of the total firewood collected came from shola, 35 % was from wattle plantation and the rest from homesteads. Of the total firewood collected, 33 % was used for domestic purpose and the rest for lemongrass oil distillation. Firewood collection was mainly for self-consumption although some sold a part of their collection. However, about 10% of the total respondents used firewood exclusively for sale. The PRA survey also indicated that cutting of tree fern *Cyathea nilgiriensis* and *Cyathea crinita* for the purpose of decoration during the festivals and marriages was also a regular activity.

3.2 Phytosociology of tree species

Phytosociological studies revealed that *Hydnocarpus alpina, Isonandra stocksii* and *Gomphandra coriacea* were dominant at the mature tree phase in undisturbed areas. Whereas in disturbed areas, *Symplocos cochinchinensis* and *Daphniphyllum neilgherrense* were dominant and contributed about 50 % to the total IVI of the mature trees (Table 1). At the sapling phase of undisturbed forest area, *Mastixia arborea, Hydnocarpus alpina* and *Chionanthus ramiflorus* were dominant species, while *Symplocos cochinchinensis*, *Maesa indica* and *Daphniphyllum neilgherrense* were dominant in the disturbed forest area. The seedling population of undisturbed plots was co-dominated by *Beilschmiedia wightii* and *Chionanthus ramiflorus* followed by *Hydnocarpus alpine*. On the other hand, at the seedling phase of disturbed forest plots *Symplocos cochinchinensis*, *Daphniphyllum neilgherrense*, and an exotic species *Acacia mearnsii*, were dominant. In the undisturbed forest plots, herb and shrub communities were dominated by *Lasianthus accuminatus*, *Strobilanthes homotropa* and *Ardisia rhombifolia*, while in the disturbed plots apart from the above mentioned species, *Oplismenus* sp., *Vigna trilobata* and *Ageratina adenophora* were dominant (Table 2). Only two species (*Persea macrantha* and *Syzygium densiflorum*) were present at all three phases in both plots. Only 14 % of the total number of species recorded was present at the seedling phase in both plots. Similarly, only 7.6 % of the total number of species recorded was present at the sapling and mature phases in both plots. The study also revealed that about 76 % of species in the disturbed plots were not typical of the undisturbed forest plots.

Comparison of disturbed and undisturbed forest areas for the density and basal area of tree saplings and shrubs and herb community indicated that values were significantly less ($P<0.05$) in disturbed areas (Table 3). The similarity index values of mature trees, saplings, seedlings and shrub and herb communities were 0.250, 0.225, 0.3109 and 0.381, respectively. These values revealed that there was a significant difference between disturbed and undisturbed areas, with regard to vegetation composition.

Table 1 Mean Importance Value Index (IVI) of different tree species in relatively undisturbed forest (UF) and disturbed forest (DF) plots in Mannavan shola, Kerala, India. Mature trees (≥30.1cm gbh), saplings (gbh 10.1 cm to 30.0 cm), seedlings (girth 1.0 to 10.0cm, height ≤1 m).

Species	Mature trees		Saplings		Seedlings	
	UF	DF	UF	DF	UF	DF
Abarema subcoriacea	0	2.88	0	0	0	0.84
Acacia mearnsii	0	2.83	0	0	0	24.82
Acronychia pedunculata	5.7	0	1.76	3.82	3.95	0
Actinodaphne bourdillonii	9.72	0	25.4	0	18.85	0
Aglaia apiocarpa	0	0	0	0	5.37	0.84
Aglaia elaeagnoidea	1.25	0	1.18	0	0	0
Alseodaphne semecarpifolia	5.31	8.3	0	7.93	8.6	2.91
Beilschmiedia wightii	26.26	0	3.91	0	48.87	0
Bhesa indica	3.93	0	0	0	4.64	0
Canthium dicoccum	1.26	0	0	3.72	0	0.84
Catunaregam spinosa	1.37	0	0	0	0	0
Celtis philippensis	0.91	0	0	0	0	0
Celtis tetrandra	0	0	0	0	0	5.81
Chionanthus linocieroides	0	0	0	0	0	2.91
Chionanthus ramiflorus	25.01	0	27.94	0	48.4	0
Cinnamomum perrottetii	0.65	0	1.88	0	0	0
Cinnamomum sulphuratum	6.83	0	8.64	0	0	0
Cinnamomum travancoricum	0.44	0	0	0	4.65	0
Cinnamomum wightii	0.47	3.04	0	3.93	0	0.84
Clerodendrum viscosum	0.43	0	0	0	6.38	0.84
Cryptocarya bourdillonii	0.74	0	2.4	0	0	0
Cryptocarya lawsonii	8.8	0	9.48	0	0	0
Cyathea crinita	0	0	5.59	0	0	0
Cyathea nilgiriensis	2.53	0	0	58.51	0	0
Daphniphyllum neilgherrense	0	47.55	0	4.59	0	46.16
Debregeasia longifolia	0	0	0	3.72	0	0
Elaeocarpus recurvatus	0	0	1.18	0	1.18	0
Elaeocarpus serratus	1.53	0	0	0	0	2.91
Erythrina indica	0	2.66	0	0	0	0
Eugenia calcadensis	0.46	0	1.19)	0	0	0
Eurya nitida	1.02	0	2.48	0	1.18	0
Glochidion neilgherrense	2.34	21.51	3.05	4.59	6.12	9.63
Gomphandra coriacea	26.29	0	3.97	0	2.33	5.35
Gomphandra sp.	0	0	5.43	0	0	0
Hydnocarpus alpina	56.9	0	28.7	0	28.87	0.84
Ilex denticulata	0	0	4.15	0	0	0
Ilex wightiana	0	0	0	0	1.02	0
Isonandra stocksii	39.99	0	4.5	0	6.76	0
Ligustrum perrottetii	0	0	0	0	0	2.45
Litsea beddomei	0	0	3.51	0	0	0

-Continued-

Species	Mature trees		Saplings		Seedlings	
	UF	DF	UF	DF	UF	DF
Litsea floribunda	0.44	0	2.39	0	0	0
Litsea insignis	0	0	1.06	0	0	0
Litsea ligustrina	0	0	0	0	1.18	0
Litsea wightiana	0	5.86	0	15.31	1.18	11.48
Mallotus ferrugineus	0.67	0	0	0	0	0.84
Mastixia arborea	22.84	0	78.19	0	19.38	0.84
Maesa indica	0	0	0	59.06	0	22.49
Meliosma pinnata	0	3.64	0	4.05	0	0
Meliosma simplicifolia	0	18.1	0	4.74	0	1.68
Microtropis ramiflora	0	0	7.23	0	0	0
Murraya paniculata	0	0	0	0	2.04	0
Neolitsea cassia	0	0	2.57	0	12.1	12.01
Neolitsea scrobiculata	0.97	0	0	0	3.95	0
Pavetta indica	0	0	4.86	0	1.02	0
Persea macrantha	10.18	25.03	1.24	11.27	15.45	3.36
Phoebe lanceolata	0.91	0	13.81	0	6.98	0
Photinia integrifolia	0.93	0	0	0	0	0.84
Photinia serratifolia	0	0	3.53	0	0	0
Polygala arillata	0	0	1.7	0	0	0
Prunus ceylanica	0.54	0	1.22	0	0	0
Psychotria sp.	0	0	1.56	0	0	0
Rapanea wightiana	0	0	0	4.89	1.09	2.52
Rhododendron arboreum	0	5.45	0	5.06	0	0
Rauwolfia densiflora	0	0	1.25	0	0	0
Saprosma foetens	6.92	0	18.79	0	8.17	0.84
Schefflera racemosa	0.45	2.71	2.05	4.3	0	2.06
Symplocos cochinchinensis	0	104.21	0	63.67	1.28	96.19
Symplocos macrophylla	0	0	0	0	11.52	0
Symplocos pendula	0	0	1.18	0	0	0
Syzygium caryophyllatum	0	0	0	14.12	0	5.04
Syzygium cumini	2.84	15.05	0	3.45	0	0
Syzygium densiflorum	11.24	3.91	1.64	4.3	7.93	16.52
Syzygium gardneri	2.08	0	0	0	0	1.68
Syzygium rubicundam	0	0	0	0	8.38	0
Syzygium tamilnadensis	0	0	4.25	0	0	1.22
Ternstroemia japonica	5.95	0	0	0	0	0
Turpinia cochinchinensis	0	0	0	0	0	3.75
Turpinia nepalensis	2.9	4.34	3.06	0	1.18	0
Vaccinium leschenaultii	0	2.83	2.09	9.4	0	0.84
Viburnum coriaceum	0	8.57	0	5.58	0	7.8
Viburnum punctatum	0	11.7	0	0	0	0

Table 2 Mean Importance Value Index (IVI) of herbs and shrubs in relatively undisturbed Forest (UF) and disturbed forest (DF) plots in Mannavan shola, Kerala, India.

Species	UF	DF
Ageratina adenophora	0.9	68.53
Anoectochilus elatus	2.24	0
Ardisia rhomboidea	31.23	0
Arisaema leschenaultii	1.46	4.12
Barleria involucrata	0	1.63
Bulbostylis densa	3.84	0
Calanthe masuca	5.92	0
Carex sp.	8.82	11.22
Cocculus laurifolius	0	1.36
Coffea sp.	0	1.14
Coleus malabaricus	6.03	1.2
Diplocyclos palmatus	5.14	0
Elatostema lineolatum	7.17	0
Erigeron karvinskianus	0	3.46
Hydrocotyle javanica	2.21	14.9
Jasminum roxburghianum	0	1.67
Laportea bulbifera	2.41	0
Lasianthus accuminatus	94.09	20.7
Leptochilus decurrens	23.41	0
Nephrolepis auriculata	1.75	0
Oplismenus sp.	13.4	45.77
Pavetta breviflora	0	3.65
Piper sp.	12.39	0.71
Polygonum chinense	0	1.43
Pteridium aquilinum	0	2.87
Pteris quadriaurita	10.41	5.51
Rubus ellipticus	0.9	13.41
Sarcococca coriacea	0	2.94
Shutteria vestita	8.54	0
Sida rhombifolia	0	1.5
Solanum anguivi	0	1.91
Solena amplexicaulis	0	6.66
Strobilanthes asperrimus	7.21	20.22
Strobilanthes homotropa	43.73	6.28
Strobilanthes kunthianus	0	6.09
Toddalia asiatica	3.96	12.24
Urena lobata	0	1.81
Vernonia bourneana	0	6.48
Vigna trilobata	0	29.88
Wattakaka volubilis	0	0.71
Zehneria maysorensis	2.84	0

Table 3 Basic statistics of tree, shrub and herb communities in undisturbed and disturbed forest plots of Mannavan shola, Kerala, India. Mature trees (>30.1 cm gbh), saplings (gbh 10.1 cm to 30.0 cm), seedlings (girth 1.0 to 10.0 cm, height <1 m). Values in parentheses are S.E.

	Mature trees	Saplings	Seedlings	Shrubs and herbs
Density (individuals ha^{-1})				
Undisturbed plots	571 (12)	509 (34)	12,858 (291)	231,490 (4,649)
Disturbed plots	450 (17)	228 (8)	97508 (3,534)	122,729 (4,386)
t-value	41.9	18.72	45.2	176.2
Level of significance (P)	0.00063	0.00144	0.00022	0.00031
Basal area ($m^2 \cdot ha^{-1}$)				
Undisturbed plots	55.67 (1.53)	1.43 (0.11)	2.97 (0.24)	27.90 (0.80)
Disturbed plots	23.10 (1.08)	0.73 (0.04)	21.03 (0.72)	8.10 (0.38)
t-value	74.4	16.2	65.3	81.7
Level of significance (P)	0.00018	0.00377	0.00024	0.00015
RISQ				
Undisturbed plots	1.242 (0.045)	1.273 (0.039)	1.249 (0.058)	--
Disturbed plots	2.413 (0.055)	2.647 (0.067)	2.532 (0.082)	--
t-value	26.82	23.5107	27.3427	--
Level of significance (P)	0.00161	0.00183	0.00134	--

Table 4 Mean density (individuals ha-1) of trees at different girth classes in the undisturbed and disturbed forest plots in Mannavan shola, Kerala, India. Values in parentheses are S.E.

	Girth class*							
	A	B	C	D	E	F	G	H
Undisturbed plots	98,159 (1238)	688 (37)	468 (13)	260 (13)	122 (9)	75 (3)	34 (2)	37 (2)
Disturbed plots	97,095 (850)	260 (15)	282 (34)	146 (14)	36 (6)	16 (2)	0 (0)	9 (1)
t-value	4.75	14.26	15.34	56.35	49.65	57.98	29.44	48.50
Level of significance (P)	0.042	0.0049	0.0042	0.0003	0.0004	0.0003	0.001	0.0004

*Note: A: Seedlings (girth <10.0 cm, height <1 m), B: Saplings (gbh 10.1 to30.0 cm), and C~H: Mature trees, gbh 30.1~60.0, 60.1~90.0, 90.1~120.0, 120.1~150.0, 150.1~180.0 and >180.1 cm, respectively.

Table 5 Density (individuals ha^{-1}) and frequency of distribution of cut trees in disturbed plot of Mannavan shola

Species	Frequency (%) of distribution of cut trees	Density (individuals ha^{-1}) of cut trees	
		10~30 cm gbh	30.1~60 cm gbh
Symplocos cochinchinensis	80	225	95
Daphniphyllum neilgherrense	45	85	15
Maesa indica	30	50	0
Syzygium cumini	30	40	0
Litsea wightiana	25	35	5
Alstonia venulata	20	10	0
Glochidion neilgherrense	20	20	0
Acacia mearnsii	15	15	0
Photinia integrifolia	15	10	10
Strobilanthes homotropa	15	30	0
Acronychia pedunculata	10	10	0
Alseodaphne semecarpifolia	10	20	10
Eurya nitida	10	10	0
Mastixia arborea	10	20	0
Persea macrantha	10	15	10
Syzygium caryophyllatum	10	10	0
Turpinia cochinchinensis	10	15	0
Viburnum coriaceum	10	10	0
Beilschmiedia wightii	5	10	0
Celtis tetrandra	5	5	0
Chionanthus linocieroides	5	5	0
Cyathea nilgiriensis	5	0	5
Neolitsea cassia	5	5	0
Rapanea wightiana	5	5	0
Saprosma foetens	5	5	0
Sarcococca coriacea	5	5	0
Syzygium densiflorum	5	5	0
Vaccinium leschenaultii	5	5	0
Total		680	150

In general, density of trees in sapling and different girth classes at the mature phase was less in the disturbed plot ($P<0.05$) than that in the undisturbed plot (Table 4, see above). Furthermore, in the disturbed plot trees in the girth class between 150.1 cm and 180 cm gbh were completely absent. Unlike undisturbed plot, disturbed plot showed the presence of stumps, small branches and foliages of tree cut by the people. Thus, quantification was made for the density and frequency of distribution of recently cut trees in the disturbed plot. Totally, 830 individuals of 28 species per ha were cut during a period of 2 years. All these individuals belong to the girth class between 10.1 cm and 60 cm gbh (Table 5, see above). The removal of individuals of higher girth classes was not recorded. More individuals of *Symplocos cochinchinensis*, *Daphniphyllum neilgherrense* and *Maesa indica* were cut from the plots.

To determine the level and intensity of forest disturbance, Ramakrishnan Index of Stand Quality (RISQ) was estimated. The RISQ values obtained for mature trees, saplings and seedlings were much higher ($P<0.05$) in the disturbed patch than those in the benchmark undisturbed area (Table 3).

4 Discussion and Conclusion

The study revealed that main driving forces behind these disturbances and degradation of forests stemmed from human activities. Change in cropping pattern in the villages around Mannavan shola forest led to over-exploitation of resources from forests. For instance, the farmers undertook the lemongrass cultivation as a source of supplementary income, and it then became a major source of income accounting for 45 % of the total household income. It is generally thought that the lemongrass cultivation is a profitable business. The average per hectare net returns of the lemongrass cultivation for 5 years was estimated as Rs. 37,500 (excluding the value of land) (Thomas 2000). Another study in the neighboring area of the Mannavan shola indicated that net annual monetary benefit by lemongrass cultivation was Rs. $23,713 \pm 5,997$ ha^{-1}, with monetary output / input ratio of 1.81 ± 0.14 when the costs of firewood and land were not accounted (Chandrashekara 2000). The farmers in the study areas also indicated the profitability of the cultivation. Three reasons attributed for the profitability are: a) the price of lemongrass oil is high and less fluctuating (between Rs. 400~450 per kilogram of lemongrass oil during last 5 years), b) firewood required for its distillation is taken freely from the forest areas, which reduces the cost, and c) wage rate is less in shola area (Rs.40 per female labour) when compared to other places (Rs. 100). However, lemongrass cultivation could be considered as the major cause for forest degradation as large quantity of dead and fallen wood and also live trees are collected to distill lemongrass oil. It may also be pointed out that even the collection of a large quantity of fallen and dead wood is not advisable in the context of ecological resilience of the forests. If dead wood is left to decompose in the forests with the help of microorganisms, it adds to the stock of existing humus, strengthens soil structure, enriches soil composition, and retards soil loss and erosion (Roba 2000). As sholas are confined to uplands and play an important role in watershed protection, this aspect may also be taken in to account while formulating the strategy for its conservation.

Both field observation and discussion with the respondents indicated clearly that some parts of the shola forest are experiencing overgrazing and also that the grazing pressure is increasing day by day. Such a raise in grazing pressure frequently has the effect of lowering the resilience of the ecosystem (Perrings and Walker 1997). Moreover, increasing grazing pressure implies reduction in the proportion of palatable plants and increase in both unpalatable grasses and wood plants, which are susceptible to fire (Knoop and Walker 1985). Furthermore, overgrazing leads to undesirable alterations in the biomass (Perrings 1989), change in species composition including the dominance of unpalatable shrubs such as *Laportea bulbifera* and *Achyranthes bidentata*, and even invasion of exotic weedy species like *Ageratina adenophora* in Mannavan shola.

Disturbance in the shola forest has also some other impacts on vegetation structure, composition and recovery processes. For instance, some dominant species of undisturbed plots, that is, *Beilschmiedia wightii* and *Isonandra stocksii* are completely absent in the disturbed plots. In the

disturbed area, *Hydnocarpus alpina* another dominant tree species in the relatively undisturbed forest plots can only be found at seedling stage. Invasion of exotic species is another impact of disturbance seen in the shola forest. Acacias, such as *Acacia mearnsii* and *Acacia melanoxylon*, have already invaded and established in Mannavan shola. These species have not been recorded at the sapling and mature phases not because they are not recruiting to these phases but because they are prone to be cut by the local people. Disturbance in Mannavan shola also led to the reduction in density and basal area of trees, particularly at the sapling phase (Table 3). Even the understorey shrubs and herb community showed a drastic reduction in stem density and basal area. Such low values for density and basal area in disturbed plots can be attributed to the collection of poles and stems of shrubs like *Strobilanthes homotropa* by the local people from these plots. However, both density and basal area of tree seedlings in disturbed area are more than those in undisturbed regions. This is due to the fact that early secondary native species and exotic species have a tendency to recruit well when canopy gaps are created. For example, it was noted that in the disturbed plot light demanding species like *Symplocos cochinchinensis, Daphniphyllum neilgherrense* and *Acacia mearnsii* contributed 64 % of the total basal area of seedlings. Canopy openings formed by human disturbances are known to offer favourable microenvironment for establishment and growth of such early secondary species (Denslow 1980). Thus, due to disturbance, species composition changed as recorded low similarity index values obtained for mature trees, saplings, seedlings and shrub and herb communities in the relatively undisturbed plots and disturbed plots.

The RISQ values obtained for mature trees, saplings and seedlings in the disturbed patch were significantly more than those obtained for the benchmark undisturbed area (Table 2). This indicates the fact that the intensity of disturbance is high and it in turn could lead to changes both in species composition and stand structure of the forest. This analysis also reveals that since the RISQ value obtained for the disturbed site is much higher than the expected value for an undisturbed site, the rate of recovery by the forest could be slow.

From the forgoing discussion, it is clear that firewood collection and grazing are the major threats to the effective conservation of the Mannavan shola forest. These factors should be taken into account, while formulating strategies for conservation and management of this shola forest. Some of the strategies to be adopted include enrichment planting of suitable species in disturbed plots and enhancement of firewood base for the villages. Species that may be considered for enrichment planting in Mannavan shola are listed in Table 6. The firewood base can be enhanced, by converting monocropping of lemongrass into an agroforestry system with the incorporation of tree components particularly, firewood species, and by increasing the growing stock and better management of the existing wattle plantations with a view to provide firewood at a concession rate to the local people. Many of the above mentioned strategies may be implemented through eco-development programmes aiming at overall

Table 6 Species suitable for enrichment planting in disturbed parts of Mannavan shola, Kerala, India

Acronychia pedunculata	*Elaeocarpus munronii*	*Neolitsea scrobiculata*
Actinodaphne bourdillonii	*Elaeocarpus recurvatus*	*Persea macrantha*
Alseodaphne semecarpifolia	*Glochidion neilgherrense*	*Rhododendron arboreum*
Beilschmiedia wightii	*Gomphandra coriacea*	*Schefflera racemosa*
Canthium dicoccum	*Hydnocarpus alpina*	*Symplocos cochinchinensis*
Chionanthus ramiflorus	*Litsea floribunda*	*Syzygium cumini*
Cinnamomum sulphuratum	*Litsea wightiana*	*Syzygium densiflorum*
Cryptocarya bourdillonii	*Mastixia arborea*	*Syzygium gardneri*
Cyathea nilgiriensis	*Meliosma pinnata*	*Turpinia nepalensis*
Daphniphyllum neilgherrense	*Microtropis ramiflora*	*Vaccinium leschenaultii*
Elaeocarpus serratus	*Neolitsea cassia*	*Viburnum coriaceum*

development of the shola, as well as people living nearby. These programmes may undertake plantation of firewood species, supply of inputs, increase facilities for marketing their produces, increase availability of fodder plants and additional employment generation activities. As part of these programmes, campaigns for creating awareness for conservation and sustainable management of shola and nearby ecosystems may be undertaken. Inhabitants, especially tribes, may be employed in forestry related work so that pressure on shola may be reduced.

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