Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India

D. M. Bhat*, M. B. Naik, S. G. Patagar, G. T. Hegde, Y. G. Kanade, G. N. Hegde, C. M. Shastri, D. M. Shetti and R. M. Furtado

Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India

Species richness, tree and stem density, basal area and recruitment details were monitored for ten years (1984 to 1994) in eight one-hectare forest sites in evergreen and moist deciduous forest zones of the tropical rain forests in Uttara Kannada district of the Western Ghats in southern India. Changes in species richness and basal area were observed in majority of the forest sites. Loss of more number of stems and trees as well as species was observed in minor forests of the evergreen forest zone. Higher species richness and basal area were observed in reserve forests, perhaps as a result of restricted access. Occurrence of more number of species over ten years in minor forests of moist deciduous zone indicates opening of canopy, favouring growth of other species. Regeneration of existing species in the study plot is suggestive of the site potentiality to retain its physiognomic status. Appearance of species with different physiognomic characters and reduction in basal area suggest greater extraction pressure, implying the deteriorating vegetation status. Increase in the basal area could be due to recruitment, compensatory growth of the existing trees/stems and due to the fast growth of the coppicing trees/stems.

TROPICAL forests have received much attention in recent years because of their species richness[1], high standing biomass[2] and greater productivity[3]. These forests also act as the major carbon sink[4]. However, the structure, composition and functioning of forests undergo changes as a natural process or on account of human and livestock intervention. As a result, there is a lot of spatial and temporal variation in the reported values of species richness, composition and productivity. Understanding of the dynamics of the forest can help to increase the productivity, to maintain species composition, to limit the financial inputs and to develop prescription for silvicultural operations[5]. Continuous monitoring of forest stand on a long-term basis is useful to document the vegetation dynamics satisfactorily[6–10].

Though the tropical rain forests of the Western Ghats region in south India harbour a large variety of species, and are experiencing human and livestock-induced disturbances, data concerning stand structure, composition and dynamics on the long-term basis are scanty. Except forest working plans (prepared by the state forest department) for the extraction of timber for commercial use and urban supply, and a few studies pertaining to basal area, volume increment, stand structure, floristic composition, biomass, productivity and regeneration in gaps[11–20], there are few systematic studies[10,21] concerned with the changes in vegetation and other related parameters of the forest stands in the Western Ghats forest region. In this region local people are dependent on forests for grazing, fuel wood, small timber, leaf-manure and non-timber forest products. To assess the response of the forest to human and livestock-induced disturbances, long-term investigation forest plots were established and monitored for 10 years in different forest land use categories in Uttara Kannada district. The present study reports the findings of a long-term study of two vegetation types of Uttara Kannada district of Western Ghats in peninsular India.

Materials and methods

Study area

The study was conducted in Uttara Kannada district (13°55′ to 15°31′N lat., 74°9′ to 75°10′E long.) of the Western Ghats part of peninsular India (Figure 1). Comprising an area of 10,200 km^2, the district is hilly terrain with gentle slopes and broad valleys, with an altitude ranging from the sea coast to a little over 1000 m. It is one of the most forested tracts of southern India. Topographically the district can be divided into three zones: the flat and narrow coast, abruptly rising ridge and the flat and elevated eastern zone that joins the Deccan Plateau. The district experiences south-west monsoon and the rainfall is received mostly between June and September. Annual rainfall in the district ranges from 350 cm near the coast to more than 500 cm along the ridge of the hills. The eastern side of the district receives about 120 cm of rainfall annually.

Natural vegetation of the district is evergreen/semi-evergreen type along slopes and moist deciduous type towards east of the ridge[22–25]. Puri[26] has classified the forest facing the western slope as tropical wet evergreen type and included the eastern part in the tropical moist

*For correspondence.

deciduous forest type. Champion and Seth[27] have classified the forest on the western slope as tropical evergreen type and included the forest of the eastern zone in the category of south Indian moist deciduous type. Considering the abundance of species, Pascal[18] classified the vegetation of the lower elevation of the district as *Persea macarantha–Diospyros* spp.*–Holigarna* spp. series type. According to him, the summits of the plateau are covered with *Memecylon umbellatum–Syzygium cuminii–Actinodaphne angustifolia* series type of forests. In evergreen/semi-evergreen forests (henceforth called evergreen forests) *Hopea wightiana*, *Bischofia javanica*, *Holigarna arnottiana*, *Flacourtia montana* and *Ixora brachiata* species dominate the canopy; the undergrowth consists of *Strobilanthus* sps, *Calamus* sps and *Uvaria* sps. In moist deciduous forests *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Terminalia tomentosa*, *T. paniculata* and *T. bellerica* are the emergent tree species and the undergrowth includes species such as *Psychotria dalzelli*, *Eupatorium odoratum*, *Wagatea spicata* and *Ziziphus* sps. Based on rainfall and vegetation types, the district can be broadly divided into evergreen/semi-evergreen forest zone and drier secondary/moist deciduous zone (Figure 1). The forests of the district have been classified administratively as reserve forests (RFs), minor forests (MFs) and leaf-manure forests (LMFs). The RFs account for more than 60%, MFs form about 15% and the LMFs, locally known as 'Soppina bettas', constitute about 5% of the total geographical area of the district. The management system is different for these three forest categories: (i) in RFs, wood and timber extraction is highly regulated by the state and the accessibility to the people is banned; (ii) in MFs, extraction of forest products is not regulated and it is an open access system, meant for meeting biomass demands of local people, and (iii) in LMFs, leaf and dry wood extraction is permitted only to the assigned farmers under certain privileges. A brief description of the study sites is given in Table 1.

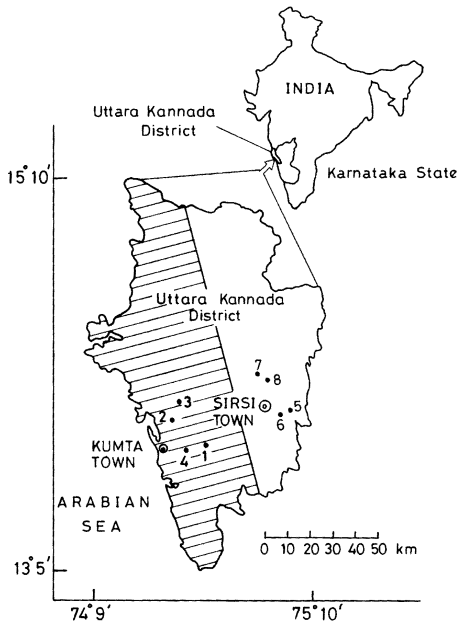

Figure 1. Map of Uttara Kannada district showing broad vegetation types and location of sites. ▨ Evergreen/semi-evergreen zone; ▭ Secondary/moist deciduous zone. 1. Santgal; 2. Mirzan; 3. Nagur; 4. Chandavar; 5. Sugavi; 6. Bidralli; 7. Sonda; 8. Bhairumbe.

Methods

Representative areas from two forest categories, viz. RFs and MFs were selected in evergreen and moist deciduous vegetation zones which fall in Sirsi and Kumta blocks of the district. In each forest category, plots measuring 100×100 m (one ha) were demarcated. There were a total of eight one-ha forest plots representing four RFs, two of which were from the above-ghat area (i.e. in the moist deciduous forest zone) and the other two were from the coastal area (i.e. in the evergreen forest zone); four MFs, two of which were from a higher elevation and the other two from the coastal area. All woody plants (which include tree-saplings, shrubs, lianas, climbers, etc.) with a circumference of ≥ 10 cm at breast height (i.e. at 132 cm) were enumerated as trees. For convenience during the enumeration, each plot was split into five strips (20×100 m) and each tree was numbered with embossed metal tag. At the time of enumeration, branches of a tree with a circumference of ≥ 10 cm at the breast height were noted as stems and they were marked as A, B, C, etc. and their girth at breast height (GBH) was measured. A black strip was painted on each tree and stem at the breast height. Plants were identified to the species level, but in case of uncertainty they were identified up to genera or family level and in the case of doubtful entities they were called as unknown I, II, III and so on. After the completion of the benchmark enumeration of all the eight plots, which began in 1983 and continued in the early part of 1984, the annual growth measurement was continued in the subsequent years up to 1994. Periodic measurements were made for trees and stems by putting the tape exactly on the black strip, i.e. the mark of the benchmark year.

During the 10th year the plots were visited again and trees that had attained GBH ≥ 10 cm were enumerated (not those which were encountered previously) and considered as recruits.

Results

Changes in the number of stems, trees and recruitment (population dynamics)

Loss of trees and stems was observed in all the study sites (Table 2). The loss of trees between two enumerating years ranged from 8.15 to 33.66% in moist deciduous forest and 15.35 to 49.14% in evergreen forest zone. The

Table 1. Some important characteristics of the study plots located in two vegetation zones of Uttara Kannada district

Name of the study site	Bhairumbe	Sugavi	Bidralli	Sonda	Mirzan	Chandavar	Nagur	Santgal
Land use category	MF	MF	RF	RF	MF	MF	RF	RF
Elevation in m (above sea level)	475	550	500	475	25	25	105	350
Level of biotic disturbance	High	High	High	High	Very high	High	Moderate	Minimum
No. of families (as in 1984)	23	18	19	24	21	28	29	27
No. of species (as in 1984)	40	44	31	51	33	32	51	63
Dominant trees	*Terminalia paniculata* *T. tomentosa* *T. bellerica* *X. xylocarpa* *Phyllanthus emblica* *Ziziphus xylopyrus* *Randia spinosa*	*Terminalia bellerica* *T. paniculata* *T.tomentosa* *Lagerstroemia microcarpa* *Adina cordifolia* *R. spinosa* *P. emblica*	*Xylia xylocarpa* *L. microcarpa* *A. cordifolia* *Schleichera oleosa* *T. paniculata* *R. spinosa*	*Terminala paniculata* *T. tometosa* *X. xylocarpa* *Xantolis tomentosa* *Flacourtia montana* *Ervatamia heyneana* *A. lindleyana*	*Spondias accuminata* *Alseodaphe semicarpifolia* *Wrightia tomentosa* *E. heyneana* *Ixora brachiata* *Z. xylopyrus* *R. spinosa*	*Hopea wightiana* *L. microcarpa* *A.semicarpifolia* *Aporosa lindeyona* *Flacourtia. montana* *Ixora brachiata*	*Hopea wightiana* *Holigarna arnottina* *Pterospermum* sp. *A. lindleyana* *Myrstica attenuata*	*Bishcofia javanica* *Dysoxylum binectariferum* *Nephelium longana* *Nothopodytes foetida* *Nothopegia colebrookiana*
Undergrowths	*Acacia caesia* *Alangium lamarkii* *Eupatorum odoratum* *Ziziphus oenoplia* *Z. rugosa*	*A. caesia* *Allophyllus cobbe* *Clerodendrum infortunatum* *Murraya koengii* *Pavetta* sp. *Wagatea spicata*	*Allophylus cobbe* *M. koengii* *Breynia* sp. *C.infortunatum* *Eupatorium odoratum*	*Psychotria* sp. *Carrissa carandas* *R. spinosa* *A. cobbe* *Grewia microcos*	*Carissa* *Carandas* *Hippocratea* sp. *Holarrhena antidysenterica* *Z. oenoplia* *Z. rugosa*	*Grewia microcos* *Psychotria flavida* *Strobilanthus* sp. *Uvaria* sp.	*Draecena ternifolia* *Glycosmis pentaphylla* *P. flavida* *Uvaria* sp. *Neolitsea* sp.	*Eugenia macrocephala* *Leea* sp. *Calamus* sp. *Ancestrocladus henyanus* *G. pentaphylla* *Gymnosporia rothiana* *Tarenna zeylanicum*
Percentage composition:								
Evergreen species	26	18	24	47	37	50	66	76
Deciduous species	74	82	76	53	63	50	34	24

MF, minor forest; RF, reserve forest.

Table 2. Changes in number of stems and trees from 1984 to 1994 in different study sites of two vegetation zones in Uttara Kannada district. (Values in parenthesis indicate %, MF = Minor forest, RF = Reserve forest.)

Forest zone	Forest site and land use category	No. of stems (no/ha) 1984	No. of stems (no/ha) 1994	Difference in no. of stems (1984–1994) (%)	Number of trees/ha 1984	Number of trees/ha 1994	Difference in no of trees (%)	No. of trees added as recruitment	Total no. of trees by 1994 (no./ha)	Net change in number of trees (%)
Moist deciduous zone	Bhairumbe-MF	597	404	– 193 (– 32.3)	415	301	– 114 (– 27.47)	486	787	+ 372 (+ 89.6)
	Sugavi-MF	458	402	– 56 (– 12.3)	405	372	– 33 (– 8.2)	845	1217	+ 812 (+ 200.5)
	Bidralli-RF	322	212	– 110 (– 34.16)	306	203	– 103 (– 33.66)	245	448	+ 142 (+ 46.40)
	Sonda-RF	775	573	– 202 (– 26.06)	692	520	– 172 (– 24.86)	438	958	+ 266 (+ 38.44)
Evergreen forest zone	Mirzan-MF	392	209	– 183 (– 46.68)	312	183	– 129 (– 41.34)	14	197	– 115 (– 36.9)
	Chandavar-MF	654	316	– 338 (51.68)	580	295	– 285 (– 49.1)	141	436	– 144 (– 24.83)
	Nagur-RF	1800	1200	– 600 (– 33.3)	1619	1121	– 498 (– 30.76)	435	1556	– 63 (– 3.89)
	Santgal-RF	1116	843	– 273 (– 24.46)	964	816	– 148 (– 15.4)	112	928	– 36 (– 3.7)

loss of stems ranged from 12.3 (56 stems in Sugavi-MF) to 34.16% (110 stems in Bidralli-RF) in moist deciduous forest zone; it was more in evergreen forest zone ranging from 24.46 (273 stems in Santgal-RF) to 51.68% (338 stems in Chandavar-MF).

After 10 years it was observed that trees added as recruits in all the study localities varied from 245 to 845 trees/ha in moist deciduous forest zone and 14 to 435 trees/ha in evergreen forest zone. In two sites (Bhairumbe-MF and Sugavi-MF) of the moist deciduous forest zone the recruits out-numbered the already existing trees, but in evergreen forest zone recruits were less in MFs. In spite of addition of trees as recruits after 10 years, there was a decline in total number of trees in forest sites of the evergreen forest zone ranging from 3.73 to 36.86% and an increase (38.44 to 200.49%) in moist deciduous forest zone.

Changes in species richness (species dynamics)

The species richness (i.e. number of species/ha) varied from 31 (in Bidralli-RF) to 51 species (in Sonda-RF) in moist deciduous forest zone and it was 37 (in Mirzan-MF) to 63 species/ha (in Santgal-RF) in evergreen forest zone (Appendix I). After 10 years, the total number of species, regeneration and occurrence of other species varied from plot to plot. No more species were added in Chandavar-MF and Nagur-RF of evergreen forest zone and in Bidralli-RF of moist deciduous forest zone. But in the remaining study plots, occurrence of other species varied from 1 in Sonda-RF to 23 in Sugavi-MF. Table 3 gives the details of total number of species and their dynamics in different forest plots of the two forest zones of the district.

It is interesting to note that in evergreen forest zone in Mirzan-MF, many deciduous species have been recruited and in the moist deciduous forest zone in Sonda-RF, evergreen species have been recruited in large numbers (Appendix II).

Changes in basal area (growth dynamics)

Table 4 gives the basal area of the study plots during 1984 and 1994 and the contribution by the recruitment and the net changes in the basal area. Even with remarkable variation in species richness and tree densities, the basal area was higher in RFs than in MFs in both the forest zones of the district. It ranged from 21.59 to 32.62 m^2/ha in moist deciduous forest zone and 7.69 to 32.13 m^2/ha in evergreen forest zone. After 10 years, reduction in basal area was observed in one MF (Bhairumbe) and one RF (Bidralli) in moist deciduous zone and two MFs (Mirzan and Chandavar) and one RF (Santgal) of evergreen forest zone. Exceptionally high growth of basal area (76.23%) was observed in Nagur-RF of evergreen forest zone.

Contribution to basal area from recruits was high in MFs of moist deciduous forest zone and it ranged from 0.79 to 1.22 m^2/ha; it was minimum in MFs of evergreen forest zone ranging from 0.02 to 0.29 m^2/ha. Except Santgal-RF in which the contribution to basal area by recruits was minimum (0.15 m^2/ha), in the remaining RFs it was around 0.5 m^2/ha. Considering the change in basal area over 10 years and contribution by recruits, net gain in basal area was observed in Sugavi-MF and Sonda-RF of the moist deciduous forest zone and in Nagur-RF of the evergreen forest zone. In the remaining study localities there was a reduction in basal area ranging from 0.74

Table 3. Number of species (no./ha) and their changes from 1984 to 1994 in different study sites in two vegetation zones of Uttara Kannada district. (Values in parentheses indicate %, E = Evergreen species, D = Deciduous species, MF = Minor forest, RF = Reserve forest.)

Forest zone	Forest site and land use category	No. of species in 1984	No. of species that disappeared by 1994			No. of new species			Total no. of species in 1994	Net change (and per ent change) by 1994	No. of existing species contributing recruitment		
			E	D	Total	E	D	Total			E	D	Total
Moist deciduous forest zone	Bhairumbe-MF	46	0	2	2	3	5	8	52	+ 6 (+ 13)	9 (27)	24 (73)	33 (72)
	Sugavi-MF	36	–	–	–	11	12	23	59	+ 23 (+ 63.88)	4 (15)	22 (85)	26 (72)
	Bidralli-RF	31	–	–	–	–	–	–	31	–	1 (5)	19 (95)	20 (65)
	Sonda-RF	51	–	–	–	1	–	1	52	+ 1 (+ 1.96)	25 (63)	15 (38)	40 (78)
Evergreen forest zone	Mirzan-MF	37	4	5	9	–	2	2	30	– 7 (– 18.92)	2 (40)	3 (60)	5 (14)
	Chandavar-MF	47	2	2	4	–	–	–	43	– 4 (– 8.51)	13 (65)	7 (35)	20 (43)
	Nagur-RF	58	4	1	5	–	–	–	53	– 5 (– 8.62)	18 (95)	1 (5)	19 (33)
	Santgal-RF	63	2	3	5	1	2	3	61	– 2 (– 3.17)	15 (94)	1 (6)	16 (25)

(– 0.16 m^2/ha in Bhairumbe-MF) to 17.04% (– 1.3 m^2/ha in Mirzan-MF).

Discussion

Tree mortality and growth are continuous processes in the community dynamics. Annual mortality rates of trees in tropical rain forests have been reported in the range from 1 to 2% (ref. 6). But in the present study, considerable number of stems (12.3 to 51.68%) and trees (8.15 to 49.14%) were lost. Loss of stems results in loss of canopy and creates light gaps, changes basal area and biomass, decreases population density and alters the micro-environment. Loss of stems in particular may not reduce the number of species or density of trees in the forest, though it reduces biomass. However, such an instance would enhance light gap and enhance the chance for other species to colonize. In spite of addition of trees as recruits, net loss of trees after 10 years was in the range from 3.73 to 3.89% in RFs and 24.83 to 38.44% in MFs. Decrease in the tree densities has been reported as a consequence of tree-cutting for domestic use[28]. Poor recruitment as observed in Mirzan-MF and Chandavar-MF of the evergreen forest zone could be due to excessive utilization of these forest sites by the local community. On the contrary, increase in the tree density in MFs (89.6 to 200.49%) and in RFs (38.44 to 46.4%) of moist deciduous forest zone indicates recovery of forests in spite of local use. Restoration of forest site by providing protection from extraction and disturbance has been reported[29] and recovery of goat-damaged vegetation by enclosures and covers has proved the capacity of vegetation to recuperate[30]. Pelissier *et al.*[21] have reported in case of a dense evergreen forest in the Western Ghats that, after a single selective felling, the composition of the forest was not significantly altered but the growing stock had gradually recovered and it may take about 20 years to resemble the non-logged forest. According to them, repetition of selective felling is not suitable for the recovery of forest. Therefore, if protection is provided, moist deciduous zone may return to the pre-disturbance condition faster than their counterparts in evergreen forest zone.

Tropical forests have been shown to be rich in species density[31–33] and many studies have considered the factors for the diversity[34–37]. According to Proctor *et al.*[9] and Whitmore[1], in tropical rain forests tree species number per ha is in the range of 20 to a maximum of 223. Studies from the Western Ghats have reported 84 species/0.4 ha (ref. 38), 30 species/ha (ref. 20), 91 species/3.12 ha (ref. 19). In the present study, the number of species ranged from 31 to 63/ha in the benchmark year and after 10 years a decrease in the number of species was observed in evergreen forest zone. In moist deciduous forest zone, except Bidralli-RF, there was an increase in the number of species. Species diversity is often correlated to rainfall, nutrients[39,40] and disturbance levels[41]. Human-induced disturbances (such as mining, timber extraction, etc.) and livestock grazing also impart changes[41] in species number, tree density and basal area. The degradation and loss of forest has been attributed to commercial exploitation of timber, conversion to agriculture, fuel wood gathering and cattle ranching[42]. Unrestricted open accessibility and permanent human settlement closer to the forest have been reported to exert enhanced utilization pressure, finally ending in a species-poor state[43,44]. In Uttara Kannada district, the minor forests are subjected to over-exploitation because of open access. This could be the reason for the poor species status in MFs of both the forest zones in Uttara Kannada district. But presence of more species in RFs (excluding Bidralli-RF) could be attributed to restricted accessibility. Lower species richness (31) in Bidralli-RF

Table 4. Basal area (m^2/ha) of study sites during 1984 and 1994 and contribution by recruits in two vegetation zones of Uttara Kannada district. (MF = Minor forest, RF = Reserve forest, values in parentheses indicate %)

Forest zone	Forest site and land use category	Basal area during 1984	Basal area during 1994	Difference and (% change)	Basal area contribution by recruits	Total basal area in 1994 including contribution by recruits	Net change and (% change)
Moist deciduous forest zone	Bhairumbe-MF	21.59	20.64	– 0.95 (– 4.4)	0.79	21.43	– 0.16 (– 0.74)
	Sugavi-MF	22.52	23.89	+ 1.37 (+ 6.08)	1.22	25.11	+ 2.59 (+ 11.50)
	Bidralli-RF	26.42	24.66	– 1.76 (– 0.07)	0.45	25.11	– 1.31 (– 4.96)
	Sonda-RF	32.62	33.41	+ 0.79 (+ 2.42)	0.64	34.05	+ 1.43 (+ 4.38)
Evergreen forest zone	Mirzan-MF	7.69	6.36	– 1.33 (– 17.30)	0.02	6.38	– 1.31 (– 17.04)
	Chandavar-MF	21.75	18.52	– 3.23 (– 14.85)	0.29	18.81	– 2.94 (– 13.52)
	Nagur-RF	20.95	36.92	+ 15.97 (+ 76.23)	0.51	37.43	+ 16.48 (+ 78.66)
	Santgal-RF	32.13	28.94	– 3.19 (– 9.93)	0.15	29.09	– 3.04 (– 9.46)

could be due to the selective logging in the past by the state forest department.

The role of gaps as the site of silvigenetics is well recognized and the tree regeneration in the gaps has been shown to be dependent upon the history of forest community, seed availability and biology of the species[45]. According to Whitmore[1], existing species develop in small gaps and in large gaps species belonging to different ecological synusiae appear. In the present study even with disturbances, except Bidralli-RF, in other RFs more evergreen species have appeared as recruits, implying the site potentiality to retain evergreen physiognomic status of vegetation. But appearance of more number of deciduous species in MFs is an indication of changing site quality. In Bidralli-RF, 95% of the species that have regenerated over 10 years were deciduous, suggesting replacement of evergreen species and transformation of the habitat conducive to such invading species.

It is interesting to note that in spite of disturbances, increase in basal area was observed in some of the forest sites, which could be attributed to compensatory growth of the existing trees. Such growth behaviour has been reported from deciduous forest in southern India[46]. Stimulation of diameter increment (of 50%) in case of emergent and upper canopy tree species has been reported[21] from a logged dense wet forest in Western Ghats. Fast growth of the trees after the wind damage has also been reported[47]. Opening of canopy enhances light penetration facilitating growth of trees[6], and decline in tree density and reduction in competition favouring fast growth of existing trees has been reported[48]. In addition, recruits have also contributed to the basal area of the stands. Many broad-leaved tropical tree species are good coppicers and coppiced shoots have faster growth[49]. This could be the reason for the observed high growth of basal area in Nagur-RF.

Reduction in basal area could be due to extraction of timber, debarking, rotting of boles, etc. Even the physiological processes such as hydration and dehydration in trees have been shown to affect the basal area[50]. Site quality and species composition are correlated to productivity[11] and decrease in basal area has been suggested as an indicator of deterioration of site quality[14]. According to Smiet[28], basal area values seem to be correlated to the rate of disturbance. So, in heavily disturbed forest localities, the basal area is expected to be low. Therefore, the observed low basal area values in Mirzan and Chandavar-MFs and decrease in basal area over 10 years, imply the excessive extraction pressure on these forest localities leading to a degraded state.

Conclusion

Monitoring forests for their response to human and livestock-induced disturbances for a period of 10 years in the Western Ghats region showed changes in tree-density, species richness, basal area and recruitment pattern. Increasing and decreasing trends were observed with respect to species richness and basal area among different forest types. No uniform degradation of forest plots was observed. Accessibility and the distance from the human settlements seem to play a key role in extraction of forest products, altering structure, composition and regeneration as observed in MFs and even in RFs. Openness and indiscriminate extraction of trees, and removal exceeding the addition has led to degradation. However, the re-building of the forest stands continued through compensatory growth of the existing trees, appearance and replacements of species and through recruits. But for an accurate and precise assessment of succession and degradation processes, monitoring of the forest vegetation for longer duration is required.

Appendix I. List of species and number of trees in different forest sites in two vegetation zones of Uttara Kannada district. (MF = Minor forest, RF = Reserve forest)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest sites Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Species								
Acacia torta	10	5	0	0	0	0	0	0
Actinodaphne hookeri	0	0	0	2	0	0	4	4
Adina cordifolia	1	5	12	0	0	13	0	0
Aglaia odoratissima	0	0	0	0	4	17	4	0
Ailanthus malabarica	0	0	0	0	0	1	0	0
Alangium lamarkii	19	0	0	0	0	0	0	0
Albizzia odratissima	0	3	0	0	0	0	0	0
Allophylus cobbe	2	0	6	25	1	2	0	0
Alseodaphne semicarpifolia	0	5	0	2	20	4	4	1
Alstonia scholaris	3	2	2	1	0	1	0	0
Ancistrocladus heyneanus	0	0	0	0	0	0	1	3
Aporosa lindleyana	1	0	0	67	4	80	62	3
Ardisia solanacea	0	0	0	0	0	0	12	0
Arenga wightii	0	0	0	0	0	0	0	1

(*Contd*. . .)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest sites Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Argeria sp.	1	0	0	0	0	0	0	0
Artabotrys zeylanicus	0	0	0	0	0	0	5	4
Artocarpus hirsutus	1	0	0	0	0	0	0	0
Artocarpus lakoocha	1	0	0	1	0	0	0	1
Bassia latifolia	2	7	0	3	0	0	0	0
Bischofia javanica	0	0	0	0	0	0	0	29
Bocagea dalzelli	0	0	0	0	1	0	0	0
Bombax malabaricum	1	1	0	0	0	0	0	0
Bridelia sp.	0	0	1	1	0	0	1	0
Bryenia rhamnoides	0	0	0	0	1	0	0	1
Buchanania lanzan	5	8	1	1	13	0	3	0
Callicarpa tomentosa	0	0	0	3	0	0	0	0
Calycopteris floribunda	15	4	2	14	4	13	10	2
Capparis sp.	0	0	0	0	0	0	12	0
Carallia integirrima	0	0	0	0	0	1	2	0
Careya arborea	11	20	2	6	19	14	1	0
Carissa carandas	2	1	0	1	1	2	1	0
Caryota urens	0	0	0	0	0	0	8	2
Cassia fistula	0	2	12	0	0	1	1	0
Chukrassia tabularis	0	3	0	0	0	0	0	0
Cinnamomum zeylanicum	0	0	0	2	0	0	9	19
Cissus discolor	1	0	0	0	0	0	0	0
Colebrookia oppositifolia	0	0	0	0	0	0	0	4
Diospyros microphylla	0	0	0	0	0	0	3	0
Dalbergia latifolia	0	6	3	0	0	0	0	0
D. paniculata	1	0	0	0	0	0	0	0
D. sympathetica	4	0	0	0	3	3	0	0
Derris scandens	0	0	0	0	0	0	1	0
Dillenia pentagyna	0	0	1	28	0	2	25	0
Diospyros candoleana	0	0	0	0	0	0	17	99
Diospyros montana	15	6	6	1	1	0	0	0
Diospyros pruriens	0	0	0	0	0	0	0	1
Diospyros sp.	0	0	0	0	0	0	15	0
Dysoxylum malabaricum	0	0	0	0	0	0	0	10
Dysoxylum sp.	0	0	0	0	0	0	9	73
Elaeocarpus serratus	0	0	0	0	0	7	1	0
Elaeocarpus sp.	0	0	0	0	0	0	0	2
Embellia sp.	0	0	0	0	7	0	0	0
Erhetia sp. II	0	0	0	26	0	0	0	0
Ervatamia heyneana	0	11	0	53	2	57	8	8
Eugenia jambolana	4	2	0	3	0	0	3	0
Eugenia sp.	0	0	0	0	0	1	0	9
E. umbellata	0	0	0	0	0	13	7	0
Ficus arnottiana	0	0	0	0	3	4	0	0
Ficus asperrima	0	0	0	0	0	0	0	2
Ficus sp.I	0	0	11	1	0	0	0	0
F. callosa	0	0	0	0	0	0	0	1
F. hispida	0	0	0	1	0	0	0	0
Ficus sp.	1	0	0	0	0	0	0	0
Ficus sp.	0	0	0	0	0	0	1	0
Ficus sp. II	0	0	0	0	0	0	0	1
Ficus sp. III	0	0	0	0	0	0	0	2
Ficus sp. (var)	0	0	0	0	0	0	0	1
Flacourtia montana	0	0	0	67	0	31	7	3
Flacourtia sp.	6	0	0	0	0	0	0	0
Garcinia indica	0	0	0	1	1	2	2	2
Glochidion sp.	0	0	9	0	0	0	0	0
Gmelina arborea	0	1	0	0	0	0	0	0
Gnetum sp.	0	0	0	1	0	3	2	1
Grewia microcos	0	0	0	1	2	5	0	0
Grewia tiliaefolia	0	0	11	0	0	0	0	0
Heterophragma sp.	0	0	0	0	4	0	0	0
Holigarna arnottiana	1	0	0	7	0	40	116	0
Hopea wightiana	0	0	0	0	0	26	898	13
Unknown II	0	0	0	0	0	0	0	25
– ” – III	0	0	0	0	0	0	0	2

(*Contd. . .*)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest sites Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Unknown IV	0	0	0	0	0	0	0	1
Unknown IX	0	0	0	0	0	0	0	3
Ixora brachiata	0	0	0	0	30	109	50	0
Jasminum malabaricum	5	0	0	0	0	0	0	0
Kydia calycina	0	0	1	0	0	0	0	0
Lagerstroemia laceolata	2	12	13	0	0	1	5	4
Lauraceae member	0	0	0	0	0	0	0	15
Leea indica	1	0	0	7	0	11	0	9
Linociera malabarica	7	0	0	0	0	0	0	12
Luvunga eleutherandra	0	0	0	1	0	0	0	0
Macaranga peltata	0	0	1	5	0	0	2	13
Machilus macarantha	0	0	0	0	0	0	4	0
Madhuca nerifolia	0	0	0	0	0	1	0	0
Mallotus philippinensis	0	0	0	0	0	0	0	17
Mangifera indica	0	0	0	1	0	8	4	2
Meliaceae II	0	0	0	0	0	0	0	42
Memecylon sp.	0	0	0	0	12	10	0	0
Mimusops elangi	0	0	0	0	3	7	2	0
Mitragyna parviflora	2	1	0	0	0	0	0	0
Murraya koenigii	0	0	3	3	2	0	0	0
Murraya sp.	0	0	0	0	0	0	0	12
Myristica attenuata	0	0	0	0	0	0	52	0
Myrtaceae member	0	0	0	0	0	0	0	22
Neolistea sp.	0	0	0	0	0	0	27	5
Nothopegia colebrookiana	0	0	0	1	0	0	6	198
Nothopodytes foetida	0	0	0	0	0	0	0	23
Ochrocarpus longifolia	0	0	0	0	11	0	1	0
Odina woodier	1	2	1	2	26	1	5	0
Olea dioica	1	0	0	21	2	27	117	32
Paramignya monophylla	0	0	0	0	0	8	0	0
Phyllanthus emblica	6	19	1	3	2	0	0	0
Plectronia didyma	0	0	0	0	0	0	4	0
Polyalthia fragrans	0	0	0	0	0	0	0	14
Psychotria dalzellii	0	0	0	36	0	0	0	0
Pterocarpus marsupium	4	2	0	0	0	0	0	0
Pterospermum spp I	0	0	0	0	0	0	4	71
Pterospermum spp II	0	0	0	0	0	0	0	22
Randia spinosa	93	1	1	50	17	4	4	0
R. uliginosa	22	4	19	9	0	0	0	0
R. rugosa	0	0	0	0	0	0	1	1
Sapindus laurifolius	0	0	0	0	0	1	0	0
Sapium insigne	0	0	0	0	8	3	1	0
Schleichera triguga	0	0	1	0	3	3	5	0
Shorea talura	3	0	0	0	0	0	0	0
Simplocos sp.	0	0	0	0	0	0	0	13
Sterculia guttata	0	0	1	9	0	0	1	0
Sterculia sp.	0	0	1	0	0	0	0	0
Stereospermum personatum	1	1	3	7	0	1	0	0
Strombosia ceylanica	0	0	0	0	0	0	0	57
Strychnos sp.	0	0	0	0	0	1	0	0
Strychnos nux-vomica	55	0	2	2	10	5	1	0
Tarenna sp.	0	0	0	0	0	0	0	3
Terminalia bellerica	4	25	1	13	2	2	7	3
T. chebula	0	3	0	0	0	0	5	0
T. paniculata	21	128	66	38	29	7	34	0
T. tomentosa	18	67	1	35	23	0	0	0
Unknown I	0	0	0	7	0	0	0	0
– ” – III	0	0	0	5	0	0	0	0
– ” – IV	0	0	0	1	0	0	5	0
– ” – II	1	0	0	0	0	0	0	0
– ” – II	0	0	0	0	0	1	0	0
– ” – II	0	0	0	0	7	0	0	0
– ” – III	0	0	0	0	2	0	0	0
– ” – IV	0	0	0	0	0	0	0	0
– ” – I	0	0	0	0	0	0	0	7
– ” – V	0	0	0	0	0	0	0	4

(*Contd*. . .)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest sites Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Unknown VI	0	0	0	0	0	0	0	9
– ” – VII	0	0	0	0	0	0	0	2
– ” – VIII	0	0	0	0	0	0	0	11
Vitex altisima	0	0	0	0	3	23	20	2
Vitis sp.	0	0	0	0	0	0	0	2
Wagatea spicata	0	3	0	0	2	3	0	4
Wrightia sp.	0	0	0	0	25	0	0	0
Xantolis tomentosa	0	1	0	11	0	0	2	0
Xylia xylocarpa	9	41	108	82	0	0	0	0
Zantoxylum rhetsa	2	0	0	21	0	0	0	0
Zizipus oenoplia	37	0	0	0	0	0	0	0
Zizyphus rugosa	2	3	3	3	0	0	0	0
Z. xylopyrus	10	0	0	0	2	0	0	0
Total	415	405	306	692	312	580	1619	964

Nomenclature follows Cooke[51].
Unidentified species given by family or generic names or as Unknown I, II, III, etc. refer to a particular forest site.

Appendix II. List showing recruitment details (i.e. number of species and individuals) in different forest sites of two vegetation zones of Uttara Kannada district

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest site Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Species								
Acacia torta	0	14	0	0	0	0	0	0
Actinodaphne hookerii	0	0	0	1	0	0	0	11
Adina cordifolia	0	4	3	0	0	0	0	0
Aglaia sp.	0	0	0	0	0	2	0	0
Alangium lamarkii	9	1	0	0	0	0	0	0
Albizzia procera	1	1	0	0	0	0	0	0
A. lebbek	4	17	0	0	0	0	0	0
Allophylus cobbe	0	10	9	27	0	1	0	0
Alseodaphne semicarpifolia	0	15	1	16	1	0	0	0
Alstonia scholaris	4	6	0	0	0	0	0	0
Ancistrocladus heyneanus	0	0	0	0	0	0	0	10
Aporosa lindleyana	4	2	0	66	0	0	7	0
Argeria sp.	0	0	0	0	0	0	0	5
Artabotrys zeylanicus	0	0	0	0	0	0	0	4
Artocarpus lakoocha	1	4	0	0	0	0	0	0
Bauhinia racemosa	0	1	0	0	0	0	0	0
Bassia latifolia	14	0	0	1	0	0	0	0
Breynia sp.	0	0	0	0	0	1	0	0
Bridellia sp.	1	1	0	3	0	0	0	1
Buchanania lanzen	1	6	0	0	0	0	0	0
Callicarpa sp.	0	0	0	2	0	0	0	0
Carissa carandas	0	0	0	1	0	2	0	0
Caryota urens	1	0	0	0	0	0	0	1
Casearia sp.	0	0	0	4	0	0	0	1
Cinnamomum zeylanicum	0	0	0	3	0	0	1	3
Calycopteris floribunda	26	35	3	8	0	0	3	5
Caralia integerrima	2	0	0	0	0	0	0	0
Careya arborea	19	8	4	2	0	1	0	0
Cassia fistula	1	12	7	0	0	0	0	0
Chukrasia tabularis	0	15	0	0	0	0	0	0
Colebrookia sp.	0	0	0	0	0	0	0	1
Connaris sp.	0	0	0	0	0	0	0	1
Dalbergia latifolia	1	10	0	0	0	0	0	0
D. sissoo	5	0	0	0	0	0	0	0
Diospyros candoleana	0	0	0	0	0	0	3	7
Dillenia pentagyna	0	3	1	0	0	0	0	0
Diospyros melanoxylon	0	8	0	0	0	0	0	0
Diospyros microphylla	0	0	0	0	0	0	1	0

(*Contd*. . .)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest site Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
D. montana	37	1	0	1	0	1	0	0
Dysoxylum malabaricum	1	0	0	0	0	0	1	0
Eugenia umbellata	0	0	0	0	0	1	0	0
Erhetia sp.	1	4	0	5	0	0	0	0
Elaeocarpus serratus	0	0	0	0	0	2	0	0
Ervatamia heyneyana	7	132	0	8	0	7	1	0
Eugenia jambolana	3	1	0	5	0	1	0	0
E. macrocephala	0	0	0	0	0	0	0	5
Ficus infectoria	1	2	0	0	0	0	1	0
F. aspirrima	0	0	60	0	0	0	0	0
Ficus sp.	0	0	10	2	0	0	0	0
Flacourtia montana	0	0	0	56	0	13	6	0
Flacourtia sp.	4	1	0	0	0	0	0	0
Garcinia indica	0	0	0	3	0	5	0	0
Glochidion sp.	0	1	1	0	0	0	0	0
Glycosmis pentaphylla	0	0	0	0	0	0	0	1
Gmelina arborea	4	0	0	0	0	0	0	0
Gnetum sp.	2	0	0	2	0	0	9	2
Grewia microcos	0	0	13	0	0	0	0	0
Grewia tiliaefolia	0	4	10	0	0	0	0	0
Gymnosporia rothiana	0	0	0	0	0	0	0	1
Elaegnus conferta	0	1	0	0	0	0	0	0
Helictoris isora	0	1	0	0	0	0	0	0
Holigarna arnotiana	0	1	0	4	1	60	39	0
Hopea wightiana	0	0	0	0	0	7	248	0
Ixora braceata	0	0	0	0	0	23	26	0
Jasminum malabaricum	8	1	0	0	0	0	0	0
Myristica attenuata	0	0	0	0	0	0	43	0
Lagerstroemia lanceolata	0	25	6	0	0	0	0	0
Leea indica	0	0	0	7	0	1	2	1
Litsea sp.	0	2	0	0	0	0	0	0
Linociera malabaricum	0	0	0	5	0	0	0	0
Memycelon sp.	0	0	0	2	0	0	0	0
Mimisops elangi	0	0	0	1	0	0	1	0
Meliaceae member	0	0	0	0	0	0	0	11
Myristica malabarica	0	0	0	1	0	0	3	0
Mangifera indica	0	0	0	1	0	1	0	0
Machilus macarantha	0	0	12	15	0	0	1	1
Murraya exotica	0	0	0	0	3	0	0	0
Murraya koengii	0	6	20	7	0	0	0	0
Neolitsea sp.	0	0	0	0	0	0	13	1
Nothopodytes foiteda	0	0	0	0	0	0	0	1
Nothopegia sp.	0	0	0	0	0	0	4	2
Olea dioica	2	15	0	12	0	1	8	0
Paramignya monophylla	0	2	0	7	0	7	0	0
Phyllanthus emblica	1	28	2	0	1	0	0	0
Plectronia didyma	0	0	0	1	0	0	0	0
Polyalthia fragnans	0	0	0	0	0	0	0	1
Psychotria dalzellii	0	0	0	77	0	0	2	0
Pterocapus marsupium	13	0	0	0	0	0	0	0
Sarcostigma kleinii	0	0	0	0	0	0	0	0
Streculia guttata	0	0	2	2	0	0	0	0
Strombosia zeylanica	0	0	0	0	0	0	0	12
Stereospermum personatum	3	5	0	0	0	0	0	1
Strychnos nux-vomica	34	0	1	2	3	0	0	0
Terminalia chebula	0	6	0	0	0	0	0	0
T. paniculata	86	136	54	4	0	0	1	0
T. tomentosa	20	23	0	0	0	0	0	0
T. bellerica	3	1	0	0	0	0	0	0
Torrena zeylanica	0	0	0	0	0	0	0	2
Unknown I	0	0	0	0	0	0	0	8
Uvaria sp.	0	0	0	3	0	0	6	0
Vitex altissima	0	1	0	2	0	0	0	0
Vitis sp.	0	0	0	0	0	0	0	7
Wagatia spicata	0	42	0	0	0	1	0	1
Zantoxylum rhetsa	0	0	0	8	0	0	0	0
Randia uliginosa	20	8	8	6	0	0	0	0

(*Contd*. . .)

Forest zone	Moist deciduous forest zone				Evergreen forest zone			
Forest site Land use category	Bhairumbe MF	Sugavi MF	Bidralli RF	Sonda RF	Mirzan MF	Chandavar MF	Nagur RF	Santgal RF
Xantolis tomentosa	20	8	0	29	0	2	0	0
Randia spinosa	83	22	17	25	4	1	5	0
Xylia xylocarpa	11	180	0	0	0	0	0	0
Z. rugosa	8	10	1	1	0	0	0	0
Z. xylophyra	8	0	0	0	0	0	0	0
Ziziphus oenoplea	12	2	0	0	1	0	0	0
Total	486	845	245	438	14	141	435	112

Nomenclature follows Cooke[51].
Unidentified species given family or generic names or as Unknown I, II, III, etc. refer to a particular forest site.

1. Whitmore, T. C., *Tropical Rain Forests of the Far East*, Claredon Press, London, 1984, 2nd edn.
2. Brunig, C. F., in *Tropical Rain Forest Ecosystems: Structure and Function* (ed. Golley, F. B.), Elselvier Scientific Publishing Company, Amsterdam, The Netherlands, 1983, pp. 49–75.
3. Jordan, C. F., in *Tropical Rain Forest Ecosystems: Structure and Function* (ed. Golley, F. B.), Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, 1983, pp. 117–136.
4. Lugo, A. E. and Brown, S., *For. Ecol. Manag*., 1992, **54**, 239–255.
5. Oliver, C. D. and Larson, B. C., *Forest Stand Dynamics*, McGraw-Hill, 1990, p. 3.
6. Swaine, M. D., Lieberman, D. and Putz, F. E., *J. Trop. Ecol.*, 1987, **3**, 359–366.
7. Herwitz, S. R. and Young, S. S., *Biotropica*, 1994, **26**, 350–361.
8. Leigh, E. G. Jr., Rand, A. S. and Windsor, D. M., *The Ecology of Tropical Forest, Seasonal Rhythms and Long-term Changes*, Smithsonian Institution Press, Washington DC, 1982, p. 468.
9. Proctor, J., Anderson, J. M., Chai, P. and Vallack, H. W., *J. Ecol.*, 1983, **71**, 237–260.
10. Sukumar, R., Dattaraj, H. S., Suresh, H. S., Radhakrishnan, J., Vasudeva, R., Nirmala, S. and Joshi, N. V., *Curr. Sci*., 1992, **62**, 608–618.
11. Gadgil, M. and Vartak, V. D., *J. Univ. Poona, Sci. Technol*., 1977, **50**, 1–7.
12. Rai, S. N. and Proctor, J., *J. Ecol.*, 1986a, **74**, 439–454.
13. Rai, S. N. and Proctor, J., *J. Ecol.*, 1986b, **74**, 455–463.
14. Rai, S. N., *Indian For*., 1983, **109** 198–211.
15. Rai, S. N., *Indian For*., 1984, **110** 754–764.
16. Sha, A. A., *Indian For*., 1990, 356–368.
17. Bhat, D. M., *Proc. Indian Acad. Sci.* (*Plant Sci*.), 1990, **100**, 139–152.
18. Pascal, J. P., *Wet Evergreen Forests of the Western Ghats of India*, Institute Francais de Pondicherry, India, 1988.
19. Pascal, J. P. and Pelissier, R., *J. Trop. Ecol.*, 1996, **12**, 191–214.
20. Chandrashekara, U. M. and Ramakrishnan, P. S., *J. Trop. Ecol*., 1994, **10**, 337–354.
21. Pelissier, R., Pascal, J. P., Houllier, F. and Laborde, H., *For. Ecol. Manag*., 1998, **105**, 107–119.
22. Daniels, R. J. R., Ph D thesis, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India, 1989.
23. Pascal, J. P., *Vegetation Maps of South India*, Karnataka Forest Department and French Institute, Pondicherry, India, 1982.
24. Pascal, J. P., *Vegetation Maps of South India*, Karnataka Forest Department and French Institute, Pondicherry, India, 1984.
25. Pascal, J. P., *Explanatory Booklet on the Forest Maps of South India*, French Institute, Pondicherry, India, 1986.
26. Puri, G. S., *Indian Forest Ecology*, Oxford Book Co, New Delhi, India, 1960, 2 volumes.
27. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*, Government of India Press, Nasik, India, 1968.
28. Smiet, A. C., *J. Trop. Ecol*., 1992, **8**, 129–152.
29. Reddy, Y. A. N., Venugopal, S., Swaminathan, M. H. and Vadiraj, B. A., *My For.*, 1989, **25**, 33–42.
30. Scowcroft, P. G. and Hobdy, R., *Biotropica*, 1987, **19**, 208–215.
31. Richards, P. W., *The Tropical Rain Forest*, Cambridge University Press, 1952.
32. Paijmans, J., *J. Ecol*., 1970, **58**, 77–101.
33. Parson, S. R. F. and Cameron, D. S., *Biotropica*, 1974, **6**, 202–203.
34. Janzen, D. H., *Am. Nat*., 1970, **104**, 501–528.
35. Connell, J. H., *Science*, 1978, **199**, 1302–1310.
36. Hubbell, S. P., *Science*, 1979, **203**, 1299–1309.
37. Leigh, E. G. Jr., in *The Ecology of Tropical Forest, Seasonal Rhythms and Long-term Changes* (eds Leigh, E. G. Jr., Rand, A. S. and Windsor, D. M.), Oxford University Press, 1983, pp. 63–67.
38. Singh, J. S., Singh, S. P., Saxena, A. K. and Rawat, Y. S., *Environ. Conserv*., 1981, **11**, 223–233.
39. Huston, M., *J. Biogeogr*., 1980, **7**, 147–157.
40. Faber-Langendoen, D. and Gentry, A. H., *Biotropica*, 1991, **23**, 2–11.
41. Rao, P., Barik, S. K., Pandey, H. N. and Tripathi, R. S., *Vegetatio*, 1990, **88**, 151–162.
42. Myers, N., in *Tropical Rain Forest Ecosystems: Structure and Function* (ed. Golley, F. B.), Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, 1983, pp. 289–300.
43. Vetaas, O. R., *Biotropica*, 1993, **25**, 164–175.
44. Murali, K. S., Uma Shankar, Ganeshaiah, K. N., Uma Shaanker, R. and Bawa, K. S., *Econ. Bot*., 1996, **50**, 252–269.
45. Hubbell, S. P. and Foster, R. B., in *Plant Ecology* (ed. Crawley, M. J.), Blackwell Scientific Publications, Oxford, 1986, pp. 77–96.
46. Sukumar, R., Suresh, H. S., Dattaraj, H. S. and Joshi, N. V., in *Forest Bio-Diversity, Research Monitoring and Modelling – Conceptual Background and Old World Case Studies* (eds Dallmeir, F. and Comiskey, J. A.), Man and Biosphere Series vol. 20, 1998, Chap. 28, pp. 318–327.
47. Brokaw, N. V. L. and Walker, L. R., *Biotropica*, 1991, **23**, 442–447.
48. Manokaran, N. and Kochummon, K. M., *J. Trop. Ecol*., 1987, **3**, 315–330.
49. Evans, J., *Plantation Forestry in Tropics*, Oxford University Press, 1992, 2nd edn.
50. UNESCO/UNEP/FAO, *Tropical Forest Ecosystems* (Indian edition 1990), International Book Distributors, Dehra Dun, India, 1978, pp. 202–204.
51. Cooke, T., *The Flora of Presidency of Bombay*, Botanical Survey of India, Calcutta, 1967 (second reprinted edition).

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