© 2012 Triveni Enterprises
Vikas Nagar, Lucknow, INDIA
editor@jeb.co.in
Full paper available on: www.jeb.co.in

J. Environ. Biol.
33, 791-797 (2012)
ISSN: 0254-8704
CODEN: JEBIDP

Floristic diversity of regenerated tree species in Dipterocarp forests in Western Ghats of Karnataka, India

Author Details

A.G. Devi Prasad *(Corresponding author)*
Department of Studies in Environmental Science, University of Mysore, Mysore - 570 006, India
e-mail : agdprasad@yahoo.com

Nageeb, A. Al-Sagheer
Department of Studies in Environmental Science, University of Mysore, Mysore- 570 006, India

Publication Data

Paper received:
18 January 2011

Revised received:
30 Jun 2011

Re-Revised received:
16 August 2011

Accepted:
16 september 2011

Abstract

The research was focused on exploring the structure, diversity and form of regeneration process of the Dipterocarp forests in Western Ghats in relation to environmental factors. Eight populations in the distribution range of Dipterocarp forests were selected. In each population 32 plots of 2m×2m were laid down randomly. A total of 1243 seedlings ≤ 10 cm dbh (diameter at breast height) belonging to 99 species and 48 families were recorded. The number of regenerated tree species was found to be high in the populations of Mudigere (40), Sakleshpura (40) and Makuta (39), which are characterized by favorable locality factors and lower disturbances. The highest similarity index in species composition was recorded between the populations of Sampaje in Kodagu district and Gundya in Dakshina Kannada (60%) whereas the lowest similarity index was observed between the population of Sringeri in Chikmagalore and Sampaje (53%) and Gundya and Makuta (35%) in Kodagu district. *Dipterocarpus indicus* was found to be dominant among the regenerated tree species in all the sites studied except Gundy and Sampaje. The frequencies of regeneration classes (seedlings, saplings, poles and adult trees) were shaped as inverse J curve indicating the normal regeneration pattern under the present disturbance. The average disturbance of litter collection, grazing, fire, weeds and canopy opening were significant among different populations ($p \leq 0.05$). Negative correlation was observed between disturbance and species richness, number of individuals and density.

Key words

Floristic diversity, Dipterocarp forest, Important value index, Similarity index, Species richness.

Introduction

The Western Ghats of India is one of the 34 global hotspots of biodiversity with the highest human density (Arunachalam, 2002; Mittermeier, 2005). There are millions of people living in and around forests subsist on collections of non timber forest products (NTFPs). Their livelihood is dependent on these forest resources. This made the establishment and management of the protected areas difficult task (Chapin 2004; Brockington, 2008). It is reported that 33% of Indian plant species are endemic (Ramesh, 2003). These species provide a multitude of service to vast population. Common anthropogenic activities including livestock grazing, fuelwood extraction and burning have tremendous impact on the regeneration of tree species. The Western Ghats is a region which has smaller extent of area under strict protection and a large number of restricted range species, and therefore in need of special attention (Cincotta *et al.*, 2000; Gunawardene *et al.*, 2007). Dipterocarp forests have been exploited at presented rates in many regions of Western Ghats. Most of these are at the brink of disappearance in the very near future due to over exploitation owing to its timber value. Dipterocarps are typically canopy trees or emergent and reach considerable dimensions throughout forests of the region. The existence of these species in the community largely depends on its regeneration under varied environmental condition.

Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution (Uniyal *et al*., 2010). Regeneration is a critical phase of forest management, because it maintains the desired species composition and stocking after disturbance. The regeneration status/potential of species in a community can be assessed from the population dynamics of seedlings and saplings in the forest community (Duchok *et al*., 2005). In the light of these, the present study was carried out to assess the diversity of the regenerated tree species influenced by environmental gradients.

Materials and Methods

Study areas: The study was undertaken in Dipterocarp forests of Devimane, Gundya, Kattalekan in North Canara district, Makuta, Sampaje in Kodgu districts, Sakleshpura in Hassan district, Mudigere and Sringeri in Chikmagalur district (Fig. 1). These forests of Western Ghats of Karnataka have distribution range from 12° 10' N (Makuta) to 14° 57' N (Devimane) latitude range and from 74° 70' E (Devimane) to 75° 77' E (Sampaje) longitude range. Gundya represented the lower elevation (153 m.a.s.l) while Mudigere has the highest elevation (846 m.a.s.l) among the study sites. The average day temperature was maximum in Sringeri site (34.10°C), while Makuta site recorded the minimum temperature (31.22°C) among the study sites. The average rainfall recorded over a period of ten years (1998 -2008) was highest for Sampaje site (2575.98 mm) and lowest at Kattalekan site (1976.52 mm). The study areas fall under tropical climate in Western Ghats region, April – May being the hottest and December – January being the coldest periods with maximum rainfall during July – August. The soils were lateritic, shallow to medium in depth and reddish brown to dark yellowish brown and also at some place black in colour, usually leachable, poor in base saturation, cation exchange capacity and water holding capacity.

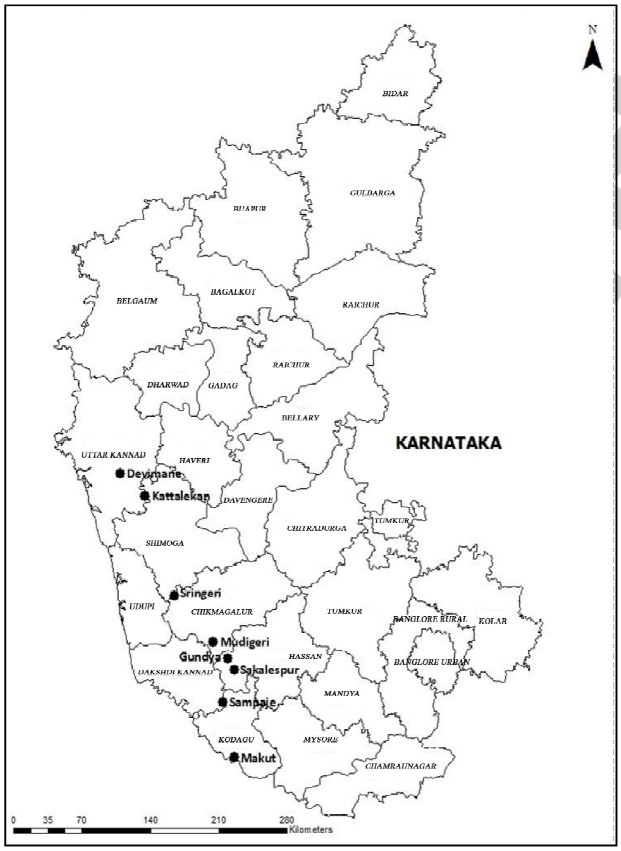

Fig.1: Sampling locations along Western Ghats of Karnataka, India.

Sampling procedures: The sampling procedures were carried out using single scale sampling method described by Synnott (1979) and Larpkern *et al.* (2009). In the distribution range of these forests, eight quadrats of 20 m×20 m were laid out randomly in each population. At the four corners of each quadrat 2 m×2 m plot was laid out and in this a total of 32 plots were laid out in each site. The species were identified as per Keshavamurthy and Yoganarasimhan, (1989), Pascal and Ramesh, (1997) and Saldanha, (1984, 1996). The species were collected and herbarium was prepared. In each plot, all the tree species $\leq$ 30 cm gbh were considered as regenerative seedlings and enumerated separately based on their height and girth into regeneration classes namely Class I(seedlings) < 40 cm height, Class II(saplings) between 40-100 cm height, Class III > 100 cm height and < 10 cm gbh, Class IV >100 cm height and >10 cm gbh. Menhinick's richness index (Menhinick, 1964), Shannon diversity index (Shannon and Weaver, 1949) and Evenness index (Pielou, 1969) were used to assess the species richness, diversity and distribution range patterns of individuals among the species, respectively. Jaccard's coefficients were used for similarities in family composition (Stohlgren *et al*., 1997). The importance value index (IVI) computed as the summation of relative productivity, relative density, and relative frequency (Curtis and McIntoch, 1951). Observation of the disturbance parameters such as grazing, lopping, cut stump, fire, litter collection, soil removal, weeds, footpath, domestic animal dung, wild animal dung and canopy cover in the plot were recorded and combined into field disturbance index. It comprises of the presence/absence of these parameters. The average score of each parameter was added to other average parameters to form the cumulative disturbance index (Kumar and Shahabuddin, 2005 and Mehta *et al.*, 2008). The above said indices were used to assess the regeneration structure, composition and status of Dipterocarp forests.

Results and Discussion

Species composition and diversity : A total of 1243 seedlings $\leq$10 cm gbh belonging to 99 species and 48 families were identified in all populations. The comparison among different populations in terms of species and families richness showed that, the highest species and families richness was observed in the populations of Mudigere (40 and 28) and Sakleshpura (40 and 27) followed by the population of Makuta (39 and 27) respectively as shown in Table 1. The species richness index (Menhinick) was found to be high in the populations of Sakleshpura (8.09), Makuta (7.62) and Mudigere (7.49). The highest Shannon diversity index was in the

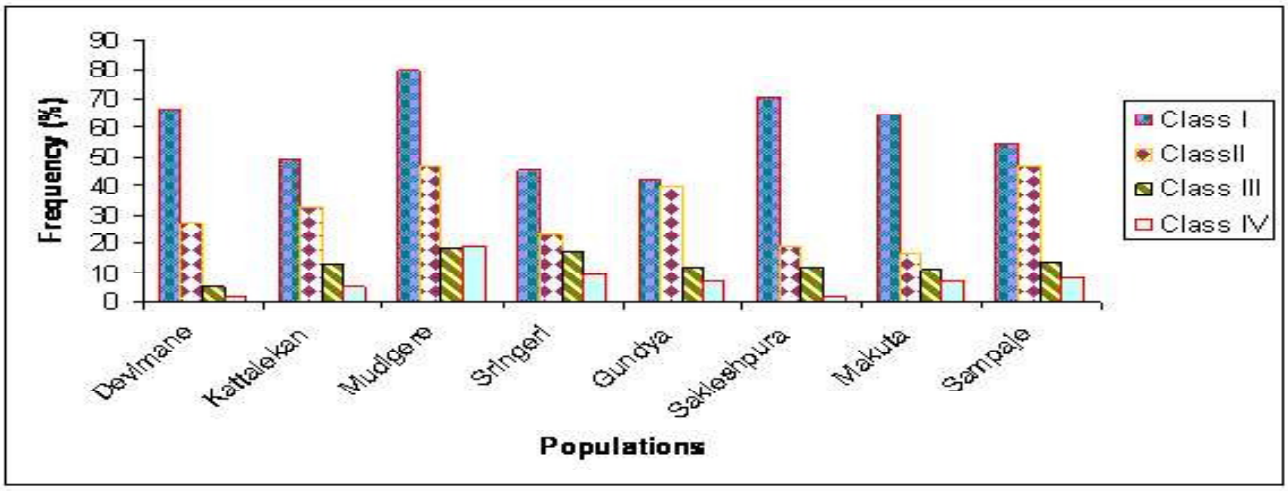

Fig. 2: Distribution of regeneration classes

population of Sakleshpura (3.33), Makuta (3.13) and Mudigere (3.05), whereas the lowest Shannon diversity index was in the population of Sringeri (2.77). The highest density and number of individuals was in the populations of Sampaje (15000 tree ha^{-1} and 197) and Mudigere (14218 tree ha^{-1} and 182), whereas the lowest density and number of individuals was in the populations of Sringeri (8828 tree ha^{-1} and 113) and Sakleshpura (9687 tree ha^{-1} and 124) respectively (Table 1). The highest similarity in species composition (Jaccard index) was recorded between the populations of Sampaje and Gundya (60 %) whereas the lowest similarity was observed in the population of Sringeri with the populations of Sampaje and Gundya (53 %) (Table 2). The highest similarity in families composition was obtained in the populations of Sampaje and Sakleshpura (62 %) followed by population of Sringeri and Devimane (61%). The species composition in Sringeri population showed less similarity as compared with the populations of Makuta (55 %) and Gundya (56 %) (Table 3). The highest richness in the populations of Sakleshpura, Mudigere and Makuta was attributed to the variations in locality factors and human disturbance as shown in Table 6. The existence of these populations in the high-altitude of

Table 1: Regeneration richness and diversity among different populations of Dipterocarp forests

	Regenerated tree species					Regenerated tree families			
Populations	**No. of individuals**	**Species richness**	**Menhinick's richness index**	**Shannon's diversity index**	**Density (ha^{-1})**	**Family richness**	**Menhinick's richness index**	**Shanonn's diversity index**	**Density (ha^{-1})**
Devimane	160	32	2.53	3.16	12500	20	1.58	2.57	12500
Gundya	165	27	2.10	2.93	12890	18	1.40	2.46	12890
Kattalekan	156	24	1.92	2.79	12187	18	1.44	2.43	12187
Makuta	146	39	3.23	3.13	11406	27	2.23	2.69	11406
Mudigere	182	40	2.96	3.05	14218	28	2.08	2.76	14218
Sakleshpura	124	40	3.59	3.33	9687	27	2.42	2.93	9687
Sampaje	197	28	1.99	2.92	15000	20	1.44	2.63	15000
Sringeri	113	24	2.26	2.77	8828	15	1.41	2.19	8828
Total	1243	99			p<0.000	48			p<0.05

Table 2 : Similarity in species composition (Jaccard diversity index) among populations of Dipterocarp forests in Karnataka

Populations	**Devimane**	**Gundya**	**Kattalekan**	**Makuta**	**Mudigere**	**Sakleshpura**	**Sampaje**	**Sringeri**
Devimane	1	-	-	-	-	-	-	-
Gundya	0.56	1	-	-	-	-	-	-
Kattalekan	0.57	0.59	1	-	-	-	-	-
Makuta	0.55	0.57	0.56	1	-	-	-	-
Mudigere	0.55	0.58	0.57	0.56	1	-	-	-
Sakleshpura	0.56	0.57	0.56	0.58	0.59	1	-	-
Sampaje	0.57	0.60	0.58	0.57	0.57	0.57	1	-
Sringeri	0.57	0.53	0.55	0.53	0.54	0.55	0.53	1

Table 3: Similarity in families composition (Jaccard diversity index) among populations of Dipterocarp forests in Karnataka.

Populations	Devimane	Gundya	Kattalekan	Makuta	Mudigere	Sakleshpura	Sampaje	Sringeri
Devimane	1	-	-	-	-	-	-	-
Gundya	0.59	1	-	-	-	-	-	-
Kattalekan	0.60	0.61	1	-	-	-	-	-
Makuta	0.59	0.59	0.57	1	-	-	-	-
Mudigere	0.58	0.59	0.57	0.60	1	-	-	-
Sakleshpura	0.59	0.61	0.58	0.60	0.60	1	-	-
Sampaje	0.59	0.62	0.58	0.59	0.60	0.62	1	-
Sringeri	0.61	0.56	0.57	0.55	0.57	0.58	0.56	1

Table 4: Ten dominated regenerating species among populations of Dipterocarp forests in Karnataka

Species	Devimane		Gundya		Kattalekan		Makuta		Mudigere		Sakleshpura		Sampaje		Sringeri	
	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank
Miliusa wightiana	20.89	1	-	-	23.34	1	-	-	-	-	-	-	-	-	-	-
Dipterocarpus indicus	16.52	2	–	-	19.99	2	16.41	4	19.93	2	20.85	1	-	-	14.43	5
Hopea ponga	14.11	3	15.88	3	15.01	5	-	-	-	-	-	-	7.24	8	12.96	6
Caryota urens	13.39	4	-	-	-	-	-	-	-	-	-	-	-	-		
Hopea parviflora	10.36	5	-	-	12.09	7	11.16	7	-	-	5.99	9	6.98	10	14.73	4
Myristica fatua	10.36	6	-	-			-	-	-	-		-		-		
Dimocarpus longan	8.57	7	13.67	4	11.95	9	-	-	7.77	9		-	18.79	1	7.07	10
Memecylon umbellatum	7.32	8	-	-	-	-	-	-	-			-		-		
Chionanthus mala-elengi	6.07	9	-	-	-	-	-	-	-		12.79	3		-	7.95	9
Cinnamomum malabaricum	6.07	10	-	-	-	-	-	-	8.20	8	8.79	6	17.77	2	-	-
Kingiodendron pinnatum	-	-	21.33	1	-	-	11.85	6	20.60	1	14.02	2	17.07	3	-	-

*IVI- Important value index

Table 5: Ten dominated families of regenerating species among populations of Dipterocarp forests in Karnataka

Families	Devimane		Gundya		Kattalekan		Makuta		Mudigere		Sakleshpura		Sampaje		Sringeri	
	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank	IVI	Rank
Dipterocarpaceae	46.25	1	47.27	1	48.72	1	35.62	1	27.47	1	32.26	1	23.35	3	47.79	2
Anonaceae	27.5	2	18.18	4	30.77	2	10.96	7	24.18	4	-	-	20.30	5	-	-
Lauraceae	16.25	3	3.63	10	-	-	20.55	4	15.38	5	16.13	4	28.43	1	-	-
Clusiaceae	15	4	-	-	6.41	8	5.48	10	26.37	3	24.19	2	-	-	15.93	4
Sapindaceae	15	5	14.54	6	11.54	7	-	-	7.69	7	-	-	22.34	4	-	-
Arecaceae	12.5	6	-	-	21.79	3	-	-	-	-	-	-	6.09	9	-	-
Myristicaceae	12.5	7	12.12	8	20.51	4	8.22	8	14.29	6	14.52	5	-	-	-	-
Anacardiaceae	7.5	8	-	-	-	-	-	-	-	-	6.45	9	-	-	3.54	10
Memcylaceae	7.5	9	-	-	12.82	5	-	-	-	-	-	-	-	-	49.56	1
Rubiaceae	6.25	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*IVI- Important value index

distribution range (200 – 900) may have got more rainfall and fewer disturbances. Therefore, these populations are being less accessible by inhabitants and their animals. Rahbek (2005) reported that the altitudinal patterns in species richness vary between mountains and regions. Sun (2011) reported that differences in longitude, altitude, slope, slope aspect, nutrient availability and human disturbance all likely contribute to the variability of species diversity. Wangda and Ohsawa (2006) reported that the major human settlements are located around the bottom of dry valleys.

The inhabitants are using the nearby forests for timber, firewood, grazing and litter for cattle bedding. The cumulative disturbance of these has resulted in an increased canopy opening and incoming solar radiations promoting the establishment and survival of pioneer and light demander tree species.

The less or poor natural regeneration in population of Sringeri could be due to the influence of both human disturbance and environmental factors on seed dispersal mechanism, fruiting and seed germination of tree species. The less regenerated tree species < 40 cm height indicate that the seed sources were depleted through harvesting of mature trees (Fig. 2). Sagar *et al.* (2008) inferred that the diversity of both over-storey and under-

Table 6 : Average disturbance parameters among populations of Dipterocarp forests in Karnataka

Disturbance	Makuta	Gundya	Kattalekan	Sampaje	Sakleshpura	Mudigere	Sringeri	Devimane	ANOVA
Lopping	1.625	1.625	1.875	1.75	1.75	1.5	2.125	1.875	NS
Cut stumps	1.5	1.625	2	1.625	1.5	1.25	2.125	2	NS
Litter collection	1.125	1.125	1.375	0.875	1.375	1	2	1.25	p<0.05
Soil removal	1	1	1.25	0.75	1.5	1.125	1.5	1.125	NS
Grazing	2.125	2	1.875	2.875	1.875	1.25	2.75	2.25	p<0.05
Fire	1.125	2	1.625	1.375	1.125	1.25	2.25	1.5	p<0.05
Weeds	1.375	1.5	1.875	1.875	2.375	1.75	1.875	2.375	p<0.05
Footpath	1.875	2.25	2	1.75	2.125	2.125	2.125	2.125	NS
DAD	2.375	2.25	2.5	1.875	1.250	1.625	2.125	2	NS
WAD	2.25	2.75	2.625	2	2.125	2.125	2.375	2	NS
Canopy opening	1.75	2.375	2.875	2.625	3.25	2.125	2.75	3.125	p<0.05
CDI	1.65	1.86	1.99	1.76	1.16	1.56	2.18	1.97	1.65

CDI : Cumulative disturbance index, DAD : Domestic animals dung and WAD : Wild animals dung

Table 7: Correlation matrix between regeneration and disturbance parameters

	Lopping	Cut stumps	Litter collection	Soil removal	Grazing	Fire	Weeds	Footpath	DAD	WAD	Canopy opening
Species richness	-0.652*	-0.779*	NS	NS	-0.565*	-0.820*	NS	NS	NS	NS	-0.765*
No. of individuals	-0.580*	NS	-0.865*	-0.864*	-0.867	NS	-0.587	NS	NS	NS	-0.689*
Density	-0.600*	NS	-0.868*	-0.855*	-0.645	NS	-0.698	NS	NS	NS	-0.786*

Significance association @ 0.05, p level (r= ± 532) DAD : Domestic animal's dung, WAD : Wild animal's dung.

storey strata decrease significantly with disturbance intensity. The intermediate disturbances may have increased the number of seedlings and density of regenerated tree species and families. These could be due to the moderate canopy opening lopping and other disturbance parameters as observed in the populations of Mudigere and Sampaje (Tables 1). Eilu and Obua (2005) found that the higher stem densities were found in undisturbed and lightly disturbed forest types compared to heavily or completely disturbed types. Tree species richness and diversity were highest in lightly disturbed forest. Similarly, Yadav and Gupta (2009) stated that local people reduced the seed production of various tree species to 34 to 94 % in different disturbed areas because of the frequent felling and lopping of trees.

The similarities in population structure and species composition of Sampaje and Gundya could be attributed to similar environmental gradients and human pressures which may also determine the regeneration of the other tree species.

Dipterocarpus indicus was found to be dominant among the regenerated tree species in all study sites except in the populations of Gundya and Sampaje. It ranked first in the populations of Sakleshpura with IVI value of 20.85 and second in the populations of Devimane (16.52), Kattalekan (19.99) and Mudigere (19.93). *Miliusa wightiana* topped the list of dominant tree species in the populations of Devimane and Kattelakan with IVI values of 20.89 and 23.34, respectively and not found in other populations. *Kingiodendron pinnatum* ranked first in the populations of Gundya (21.33) and Mudigere (20.60), and ranked second and third in the populations of Sakleshpura and Sampaje and not recorded in the populations of Devimane, Kattalekan and Sringeri (Table 4). Dipterocarpaceae was the top ten dominated tree families with IVI value of 46.25, 47.27, 48.72, 35. 62, 27.47 and 23.26 in the populations of Devimane, Gundya, Kattalekan, Makuta, Mudigere and Sakleshpura, respectively (Table 5). Further, it was ranked second and third in the populations of Sringeri with IVI value of 47.79 and Sampaje 23.53. Anonaceae ranked second in the populations of Devimane and Kattalekan with IVI values (27.50 and 30.77 respectively) and ranked fourth in the populations of Gundya and Mudigere (18.18 and 24.18 respectively). Also other families were found to be less dominant with different rank and IVI value in different populations. The dominance of *Dipterocarpus indicus* and Dipterocarpaceae family may be attributed to their density with big girth class, which increases the relative dominance per ha. The consequence of the frequency of its members increased the chance to be dominant family in these populations, though it is considered as a common tree species and more adapted to different populations with vast environmental gradients. Al-sagheer *et al.,* (2009) attributed the dominance of species to their ability for adaptation with disturbance and environment gradients.

Regeneration classes : The regeneration of tree species in these types of forests showed inverse J shaped curve. The frequency of seedlings in the first regeneration class was highest compared to the frequency of seedlings in the second, third and fourth regeneration classes (Fig. 2). This could be due to continued process of regeneration initiated from seeds formations, dispersal, germination and establishment. This suggested that the regeneration structure is good and may possibly give stability to the population in the future if the disturbance doesn't exceed the present level. The results of the

Table 8: Correlation matrix between regeneration and geoclimatic factors

	Species richness	No. of individuals	Density
Latitude	-0.884*	-0.724*	NS
Longitude	NS	NS	NS
Altitude	-0.837*	NS	NS
Temperature	NS	0.824*	0.815*
Rainfall	0.777*	0.764*	0.877*

Significance association @ 0.05, p level (r= ± 707).

present study are in agreement with studies of Shankar (2001) who reported that 20.4% showed good regeneration, 10.8% fair, 30.1% poor and 17.2% lacked regeneration out of 93 regenerated species.

Disturbance parameters: The average values of litter collection, grazing, fire, weeds and canopy opening showed significant difference among different populations of Dipterocarp forests (Table 6). The highest average disturbance parameters were recorded at the populations of Sringeri (2.18), Kattalekan (1.99) and Devimane (1.97) whereas the lowest average disturbance was recorded at the populations of Mudigere (1.56) and Makuta (1.65). The correlation matrix showed that the disturbance had profound impact on regeneration of population (Table 7). Species richness, the number of individuals and density decreases with increasing the loping, cut stumps, grazing, fire and canopy opening. Similarly, species richness and the number of individuals were found to be negatively correlated with latitude (r=-0.884, and r=-0.724). The rainfall was found to be positively correlated with species richness (r=0.777), the number of individuals (r= 0.764) and density (r= 0.877) (Table 8). The significant variation among some of the disturbance parameters (litter, grazing, fire and canopy opening) may be due to the variation in pressure that occurred among different populations. The pressures on these populations may have resulted from the fact that most of dwellers are living inside and around the forests. The populations of Kattalekan, Devimane and Sringeri are located at low elevations where the dwellers are settled. Uma Shankar *et al.* (2003) explained the ecological consequences of human dependence on the forest and it was inferred that forest sites proximal to human settlements were relatively more disturbed than the sites distant from the settlements. This assumption depends on the fact that the cost of harvesting forest resources decreases with distance from the settlement (Al-Sagheer *et al.*, 2009). Disturbance may alter the species composition and had adversely proportion with species richness, diversity and density. Furthermore, these populations received a moderate amount of precipitation with high average of disturbance resulting in reduction of the regenerated tree species. Sinha and Bawa (2001) stated that the higher dependence on forest was however not without an ecological cost and had been shown to affect forest structure and dynamics at a various level. Mehta *et al.*, (2008) stated that Indian forests provide a multitude of services to vast populations. Based on the present study, it is concluded that the species richness and diversity may vary among different populations due to the variations in environment gradient and cumulated disturbance parameters.

Acknowledgements

This research work was supported with funds recieved from the Ministry of Higher Education and Scientific Research, Republic of Yemen. One of the authors (Nageeb, A.A l-Sagheer) thanks the Agriculture Research Authority in Yemen for providing the chance for this research.

References

Al-Sagheer, N.A., A.G.D. Prasad and N. A. Prakash: Impact of anthropogenic pressures on forest structure and species composition of moist deciduous forest in Thithimathi range of Western Ghats, India. *Int. J. Appl. Agri. Res*., **4,** 131-149 (2009).

Arunachalam, A.: Dynamics of soil nutrients and microbial biomass during first year cropping in an 8-year jhum cycle. *Nutr. Cycl. Agroecosys*. **64,** 283–291 (2002).

Brockington, D., R. Duffy and J. Igoe: Nature unbound: Conservation capitalism and the future of protected areas. Earthscan, London (2008).

Chapin, M.: A challenge to conservationist. *World Watch Magazine*., **17**, 17-31 (2004)

Cincotta, R.P., J. Wisnewski and R. Engelman: Human population in the biodiversity hotspots. *Nature*, **404**, 990-992 (2000).

Curtis, J.T. and R.P. Mcintosh: An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecol*., **32**, 476-496 (1951).

Duchok, R., K. Kent, A. D. Khumbongmayum, A. Paul and M. L. Khan: Population structure and regeneration status of medicinal tree *Illicium griffithii* in relation to disturbance gradients in temperate broad-leaved forest of Arunachal Pradesh. *Curr. Sci.,* **89**, 673-676, (2005)

Eilu, G. and J. Obua: Tree condition and natural regeneration in disturbed sites of Bwindi Impenetrable Forest National Park, southwestern Uganda. *Trop. Ecol.,* **46**, 99-111 (2005)

Gunawardene, N.R., A.E. Dulip Daniels, I.A.U.N. Gunatilleke, C.V.S. Gunatilleke, P.V. Karunakaran, K. Geetha Nayak, S. Prasad, P. Puyravaud, B.R. Ramesh, K.A Subramania and G. Vasanthy: A brief overview of the Western Ghats-Srilanka biodiversity hotspot. *Curr. Sci*., **93**, 1567-1572 (2007).

Keshavamurthy, K.R. and S.N. Yoganarasimhan: Flora of Coorg. Vimsat Publishers, Bangalore, (1989)

Kumar, R. and G. Shahabuddin: Effect of biomass extraction on vegetation structure, diversity and composition of forests in Sariska Tiger Reserve, India. *Environ. Conserv.*, **32**, 1-12, (2005)

Larpkern, P., S.R. Moe and O. Totland: The effect of environmental variables and human disturbance on woody species richness and diversity in a bamboo-deciduous forest in northeastern Thailand. *Ecol. Res*., **24,** 147 -156 (2009).

Mehta, V.K., P.J. Sullivan, M.T. Walter, J. Krishnaswamy and S. D. DeGloria: Ecosystem impacts of disturbance in a dry tropical forest in southern India. *Ecohydrol.,* **1**, 149-160 (2008)

Menhinick, E.F.: A comparison of some species-individuals diversity indices applied to samples of field insects. *Ecol*., **45,** 859 - 861 (1964).

Mittermeier, R.A., P.R. Gil, M. Hoffmann, J. Pilgrim, T. Brooks, C.G. Mittermeier and J. Lamoreux: Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. CEMEX. Retrieved, 392 (2005)

Pascal, J.P. and B.R. Ramesh: A field key to the trees and lianas of evengreen forest of Western Ghats (India). Institute Franxaise De pondichery, Sri Aurobindo Ashram Press, Pondicherry, India (1987)

Pielou, E.C.: An introduction to mathematical ecology. New York, Wiley (1969)

Rahbek, C.: The role of spatial scale and the perception of large-scale species-richness patterns. *Ecol. Lett*., **8**, 224–239 (2005)

Ramesh, B.R.: Biodiversity conservation and management. *Trop. Ecol*., **44**, 85-91 (2003)

Sagar, R., A.S. Raghubanshi and J.S. Singh: Comparison of community composition and species diversity of understorey and overstorey tree species in a dry tropical forest of northern India. *J. Environ. Manage.,* **88,** 1037-1046 (2008).

Saldanha, C.J.: Flora of Karnataka, **Vol I**. Oxford and IBH publishing Co. Pvt. Ltd., New Delhi, (1984)

Saldanha, C.J.: Flora of Karnataka, **Vol II**. Oxford and IBH publishing Co. Pvt. Ltd., New Delhi (1996)

Shankar, U.: A case of high tree diversity in a Sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Curr. Sci.,* **81**, 776-786 (2001)

Shannon, C.E. and W. Weaver: The mathematical theory of communication. Urbana, IL, University of Illinois press (1949).

Sinha, A. and K.S. Bawa: Impacts of anthropogenic pressure on population dynamics, demography, and sustainable use of forest species in the Western Ghats, India. In: Tropical Ecosystems: Structure, Diversity and Human Welfare (Eds.: Ganeshaiah, K. N. Uma Shankar, R. and Bawa, K.S.). New Delhi. Oxford and IBH. pp. 101 - 3 (2001).

Stohlgren, T.G., G.W. Chong, M.A. Kalkhan, L.D. Schell: Rapid assessment of plant diversity patterns: A methodology for landscapes. *Environ.Monit.Assess*., **48**, 25-43 (1997)

Sun, J., X.Z. Lia, X.W. Wanga, J.J. Lva, Z.M. Lia and Y.M. Hua: Latitudinal pattern in species diversity and its response to global warming in permafrost wetlands in the Great Hing'an Mountains, China. *Russ. J. Eco.,* **42**, 123–132 (2011)

Synnott, T. J.: A manual of permanent plot procedures for tropical rainforests. Tropical forestry papers Commonwealth forestry institute, University of Oxford. **10**, p 45 (1979).

Uma Shankar, R., K.N. Ganeshaiah, R.M. Nageswara, and G. Ravikanth: Genetic diversity of NTFP species: issue and implication: In proceedings of International workshop on policies, management, utilization and conservation of NTFPs in the South Asia region (Eds.: Hiremath, A.J. Joseph, G.C. and Uma, S.R.). 40-44 (2003).

Uniyal, P., P. Pokhriyal, S. Dasgupta, D. Bhatt and N.P. Todaria: Plant diversity in two forest types along the disturbance gradient in Dewalgarh watershed, Garhwal Himalaya. *Curr. Sci*., **98**, 938-943 (2010)

Wangda, P. and M. Ohsawa: Structure and regeneration dynamics of dominant tree species along altitudinal gradient in a dry valley slopes of the Bhutan Himalaya. *Forest. Ecol. Manage.* **230**, 136-150 (2006).

Yadav, A.S. and S.K. Gupta: Natural regeneration of tree species in a tropical dry deciduous thorn forest in Rajasthan, India. *Bull. Nat. Inst. Ecol.,* **20**, 5-14 (2009)