Vegetation Changes along Altitudinal Gradients in Human Disturbed Forests of Uttara Kannada, Central Western Ghats

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ABSTRACT This study was carried out along the altitudinal gradients of Uttara Kannada district of Karnataka, representing different agro-climatic zones – coast, hilly and plains. 10 different sectors were selected for the study. Transect based survey resulted in documenting a total of 134 species of trees and 146 species of shrubs. It was found that the sectors 6, 7 and 8, lying in the Western Ghats section, were having semi-evergreen to evergreen forests and had the highest species diversity, percentage evergreen and percentage endemism. The sectors 9 and 10 in eastern plains harbour dry deciduous forests dominated by teak. The coastal sectors have more moist deciduous forests affected by human disturbances except for a patch of sacred grove in sector 1. However, the regeneration of evergreens, especially in the Ghat section areas, can be considered as a good sign for the return of evergreen forests and need to be austerely protected.

INTRODUCTION

The Western Ghats, running almost parallel to the west coast of India, along with Sri-Lanka is one among 34 biodiversity hotspots of the world. It also features among the 200 globally most important ecoregions in the world (Olson and Dinerstien 1998). Covering an area of about 160,000 km^2, this rugged range of hills stretches for about 1600 km from the south Gujarat in the north to nearly the southern tip of the Indian Peninsula (8°N-20°N). The complex geography, wide variations in annual rainfall from 1000-6000 mm, and altitudinal decrease in temperature, coupled with anthropogenic factors, have produced a variety of vegetation types in the Western Ghats. Based on various field-based analysis of vegetation communities and satellite image interpretation, there are four basic forest types found in the Western Ghats: evergreen, semi-evergreen, moist deciduous and dry deciduous. The majority of the area under moist forest types falls within the southern states of Kerala and Karnataka which together account for about 80% of evergreen forest and 66% of moist deciduous forests in the entire Western Ghats (IIRS 2002). The other important vegetation types include scrub jungles, savannahs and shola forests, peat bogs and Myristica swamps. Nearly 4000 species of flowering plants or about 27% of the country's total species are known from the Ghats. Of 645 species of evergreen trees (>10 cm dbh (Diameter at breast height), about 56% is endemic to the Ghats (WGEP 2011; Nair and Daniel 1986). Faunal endemism is also high, in the order of amphibians (78%), reptiles (62%), fishes (53%), mammals (12%) and birds (4%) (Daniels 2003; Gururaja 2004; Sreekantha et al. 2007).

Forest fragmentation in tropical rainforests has been considered as one of the greatest threats to the biodiversity, especially in such species rich ecosystems (Myers 1986; Whitmore and Sayer 1992). The Western Ghats with exemplary biodiversity, also faces severe threats from various anthropogenic activities due to unplanned developmental activities, conversion of native vegetation with plantations of exotic species and encroachment of forests leading to fragmentation of habitats. The disturbances in the forest ecosystems play a central role in shaping the species composition in forests (Canham and Marks 1985) as they directly influence the community and population dynamics by altering resource availability (Denslow et al. 1998), by causing mortality and providing opportunities for recruitment (Canham and Marks 1985), and by influencing the relative competitive status of individuals (Sousa, 1984).The disturbances associated with anthropogenic activities have overruled natural disturbances in many tropical landscapes and once the human induced disturbance starts in a system the degradation will continue pending introduction of some protective measures (Anitha et al. 2009). It has been estimated that between 1920 and 1990, the forest cover in Western Ghats has declined by about 40%, resulting in a four-fold increase in the number of fragments and an 83% reduction in size of forest patches (Menon and Bawa 1997).

STUDY AREA

The Central Western Ghats of Karnataka state comprise a significant portion of the Western Ghats and are bestowed with rich floral and faunal diversity. The Uttara Kannada district, lying between 13.9220° N to 15.5252° N and 74.0852° E to 75.0999° E, is northernmost coastal district of the state and a major chunk of central Western Ghats is embedded in the district. Topographically, the district can be divided into 3 distinct zones namely narrow and flat coastal zone, abruptly rising ridge zone and elevated flatter eastern zone. The district is known for its dense forest cover which encompasses more than 70% of the total geographical area of the district. Taking into consideration various phenological and ecological conditions, the forests of Uttara Kannada can be divided into moist type (evergreen, semi-evergreen and moist deciduous) and dry type (dry deciduous and thorny forest). Champion and Seth (1968) identified the major vegetation of Uttara Kannada as west coast evergreen/ semi-evergreen forest while Pascal (1982) in his vegetation maps (on 1:250000 scale) identified the vegetation of Uttara Kannada as belonging to the *Persea-Diospyros-Holigarna* series of wet tropical forest. The evergreen to semi-evergreen forests forms a major portion of the district especially towards the west which experiences heavy rainfall. As rainfall declines towards the eastern portion, the forests change from moist deciduous to dry deciduous types. Most of the forests towards the western portion are considered to be of secondary nature owing mainly to the slash and burn cultivation practices which were prevalent up to the mid of 19th century and thereafter in an attenuate form until the close of the century. These forests today are in different stages of secondary succession, and in many places appear like the primary forest itself (Chandran 1997; 1998). The current study highlights the vegetation status, diversity and their conservation aspects in the selected forest patches in the Ankola-Yellapur stretch (Uttara Kannada) merging with portions of the Deccan Plateau in the Dharwad district towards the northeast, Shimoga district in the centre and Haveri district representing different altitudinal gradients, and affected by various levels of anthropogenic pressures.

MATERIAL AND METHODS

The study was carried out along altitudinal gradient from the coast (Ankola taluk, Uttara Kannada district) through undulating terrains of Yellapur (in Uttara Kannada district) to plains (Kalghatgi taluk bordering the Deccan plains in the Dharwad district). The vegetation was studied through sampling at 10 (S1, S2, to S 10) different localities using point center quarter (James 2006; William 2006) along the varying to pographies with diverse vegetation (Fig. 1, Table 1). The sampling localities S1 to S4 (Ankola to Ramanguli stretch with lower altitudes) comprised of a variety of terrestrial vegetation types, especially semi-evergreen to moist deciduous forests with several degraded and denuded areas with lateritic surface. The localities S5 to S7, (mid altitudes) located in the Ghats proper comprised of lofty evergreen to semi-evergreen forests forming a mosaic with other forest types such as moist deciduous and scrub savannah, the products of degradation of the original forest type. The samples S8 to S10 (mid altitudes) fall in the eastern plains of Uttara Kannada and in Dharwar district which are mostly dotted with moist deciduous to dry deciduous forests owing to lower rainfall (Fig. 2).

The tree diversity in the sampling sites was studied using Point Centred Quarter sampling technique (Fig. 3) Each linear block of forested tract measured 13 km long area along the Ankola-Yellapur-Kalghatgi direction. Ten such linear blocks, totally covered 130 km long terrain from the coast, crossing the Ghats to the eastern plains (Fig. 1). In each of this 13 km long block, three transects of 500 m length each were laid, thereby covering a survey area of 1.5 km in each sector. In each transect of 500 m

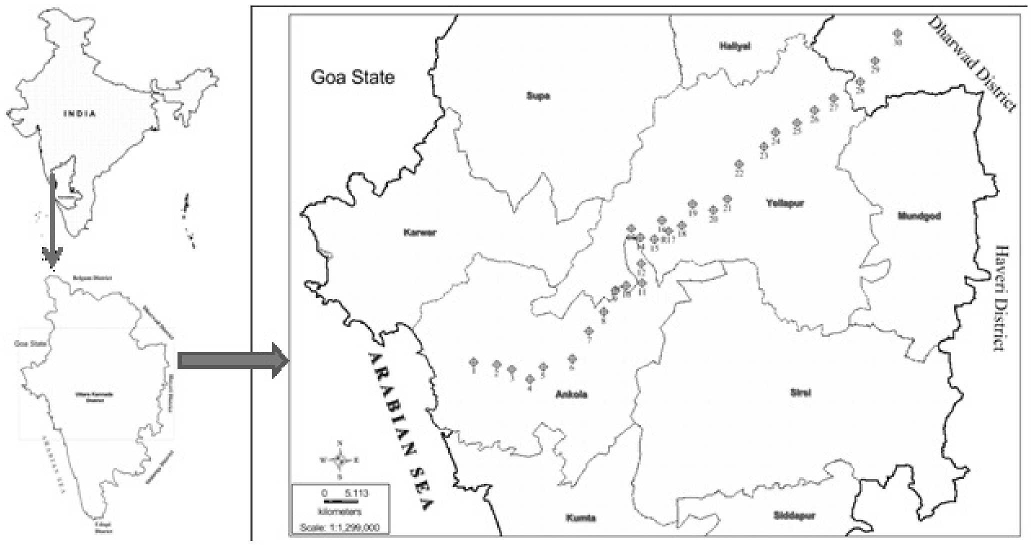

Fig. 1. Study area altitudinal gradient from coast to plains (Uttara Kannada and part of Dharwad district) with vegetation sampling points

Table 1: The geographical co-ordinates and vegetation types of the sectors in study area

S. No.	*Sectors*	*Sampling points*	*Taluk*	*Altitude (m)*	*Habitat type*
1	S1	Kattangadde	Ankola	59	Moist deciduous forest
2		Navgadde	Ankola	108	Evergreen to semi-evergreen forest
3		Agasur	Ankola	56	Semi-evergreen to moist deciduous forest
4	S2	Balaikoppa	Ankola	33	Moist deciduous forest
5		Mundigadde	Ankola	28	Teak mixed moist deciduous forest
6		Badgon	Ankola	28	Moist deciduous forest
7	S3	Hegdekoppa	Ankola	48	Moist deciduous forest
8		Sabguli	Ankola	96	Semi-evergreen
9		Kasinmakki	Ankola	77	Moist deciduous forest
10	S4	Nuglegudda-Vajralli	Yellapur	154	Semi to moist deciduous forest
11		Ramanguli	Ankola	125	Moist deciduous forest
12		Mundegali	Ankola	157	Moist deciduous forest
13	S5	Near Gidgar	Yellapur	455	Semi-evergreen to moist deciduous forest
14		Kattangadde-Tarepal	Yellapur	297	Moist deciduous forest
15		Yammalli	Yellapur	438	Evergreen forest
16	S6	Tarekunte-Mattihakal	Yellapur	394	Evergreen to semi-evergreen forest
17		Birgadde	Yellapur	367	Semi-evergreen to evergreen forest
18		After Mulesal	Yellapur	442	Semi-evergreen forest
19	S7	Arlihonda-Near Idugundi	Yellapur	463	Evergreen to semi-evergreen forest
20		Kumarmane	Yellapur	499	Moist deciduous forest
21		Nandvalli	Yellapur	547	Semi-evergreen to moist deciduous forest
22	S8	Yellapur -Mundgod road	Yellapur	536	Moist deciduous forest
23		Hosgadde	Yellapur	548	Moist deciduous forest
24		Mavalli	Yellapur	547	Moist deciduous forest
25	S9	Kunginkoppa	Yellapur	543	Teak mixed moist deciduous forest
26		Near Kiruwathi	Yellapur	534	Dry deciduous forest
27		After Kiruwathi	Yellapur	524	Teak mixed moist deciduous forest
28	S10	After Sangtikoppa	Dharwad	541	Teak mixed moist to dry deciduous forest
29		Before Devikoppa	Dharwad	533	Teak mixed moist to dry deciduous forest
30		After Devikoppa	Dharwad	530	Bamboo planted area

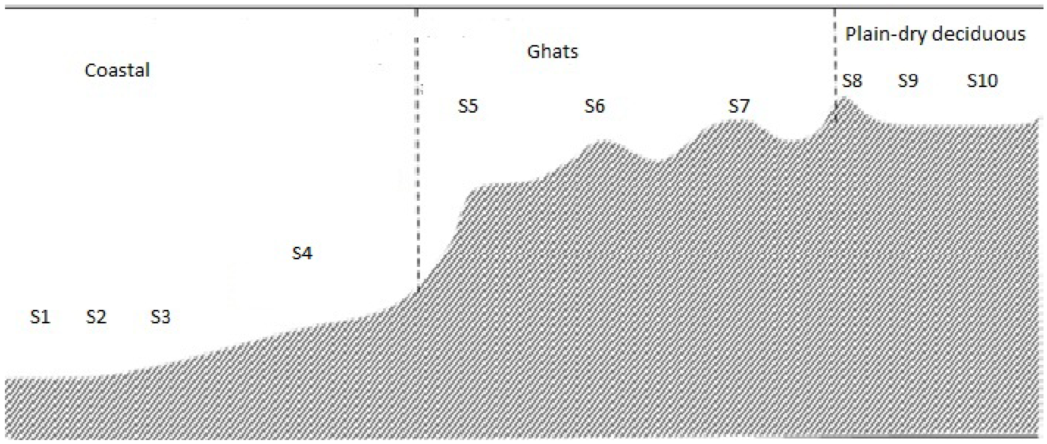

Fig. 2. Topographic features and vegetation associated with different sectors in the study region

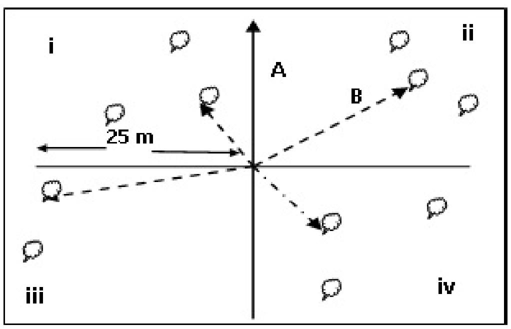

Fig. 3. Point centered quarter (Trees; i, ii, iii, iv- First, second, third and fourth quadrant; A-Direction of transect; B-distance of nearest trees from center of point centered quadrat)

length 10 point centred quarter samples were studied keeping an interval of 50 m between any two points. In each sample, in each of the four quarters demarcated on the ground, the distance to the nearest tree (minimum GBH of 30 cm) from the central point was measured. Thus data was derived on four trees at each point and the distances to these four trees from the central point. The mean distance to the trees was estimated by dividing the total distances to four trees by four from the point. The GBH and the height of the trees were noted down. At every 3rd point, the shrub layer (including shrubs and tree saplings above 1 m height) of 5 x 5 m was studied. The method was used for its fastness in coverage of long stretches of forest vegetation of heterogeneous and fragmented vegetation on account of centuries of human impacts like slash and burn cultivation, pastoralism, clear felling of timber for raising monocultures of mainly teak and *eucalyptus* and *Acacias* in later times and routine extraction of biomass for agricultural and domestic needs. As the method has inherent quality of passing through all grades of forests in case of unbiased application along a longitudinal sampling course, a quick view on vegetation status, especially in terms of tree density and dominant species could be gained in limited time. The tree density was estimated by using the formula: Area/d^2 and expressed in numbers per/ha; d is the average distance to the nearest trees in the four quarters of a cross from its central point, considering the average distances of all such points along any single transect. Other ecological parameters such as Evergreeness, Endemism, Diversity etc., were computed. The various plant species encountered along the transect line and its periphery were also recorded so as not to miss the overall diversity. Other details regarding landscape type, altitude, vegetation disturbances, NTFP collections, fire occurrence, streams etc., were also noted. The revenue lands with cultivation, homesteads and grazing areas were excluded from the forest survey.

RESULTS

The survey along this 130 km long transect passing through three basic vegetation zones from the coast to the mountain and beyond into the plateau, intermittently sampled by point centred quarter, revealed 134 tree species from 106 genera and 43 families and 146 shrub layer species from 128 genera and 58 families (Fig. 4). Sector-7, a mid-altitude transect with a sacred grove accounted for 48 tree species, the highest among all transects. The sector-6, also in a similar region adjoining, was good with 41 species of trees followed by sector-1 with 40 tree species and also having a sacred grove (Fig. 5). The sectors 9 and 10 falling in the eastern plain region had relatively low number of species and dominated by teak.

Shannon diversity index showed that the sectors 6, 7 and 8, falling in the main zone of central Western Ghats, had the highest plant species diversity (Fig. 6). Shannon diversity value was also high for sector 7 (3.47) followed by sector 6 (3.36) and sector 1 (3.3). Sectors 9 and 10 were found to be having the least Shannon diversity values (1.8 and 2).

Highest tree endemism (45%) was in mid altitude Sector 6 (Figure 7), which also had higher evergreeness (87%). Tree basal area/ha and tree density/ha revealed that Sector 6, had both the highest estimated basal area/ha (84.15 m^2) and the highest tree density/ha (598). Sector 10 characterized by degraded teak plantations had the least basal area (2.24 m^2) and lowest tree density (33 trees/ha) (Figs. 7, and 8).

Cluster analysis based on tree and shrub layer species similarity and Important Value Index (IVI) (Fig. 9) reveals three different clusters. The first cluster comprised of mainly low altitude sectors 2, 3, 4 and 5 belonged to the coastal taluk of Ankola. The second cluster included low altitude sectors 1 from the coast and mid-altitude 6, 7 and 8 sector 9 and 10 formed the third cluster.

DISCUSSION

Most of the transects in the coastal sectors were harbouring mainly moist deciduous forests, despite annual rainfall of over 3000 mm. Navagadde of Sector-1, a sacred grove with a shrine, was semi-evergreen, obviously due to the taboo on tree felling on account of its sacredness (Fig. 5). The Sector-7 (Arlihonda near Idugundi) in the mid altitude portion of West-

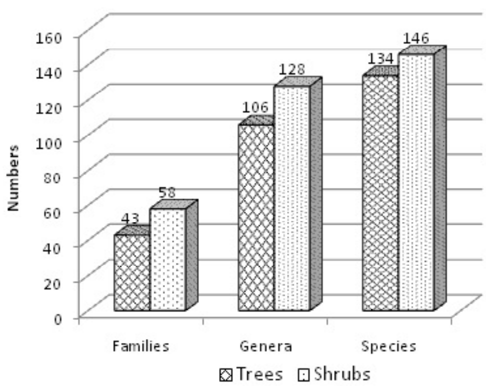

Fig. 4. Total number of tree and shrub species recorded in the study region

Fig. 5. A sacred grove with a shrine in Sector 1

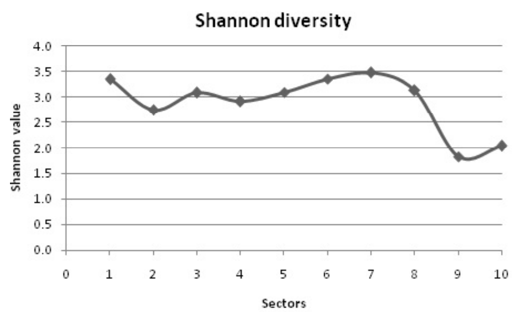

Fig. 6. Shannon diversity index values for the various sectors in the study region

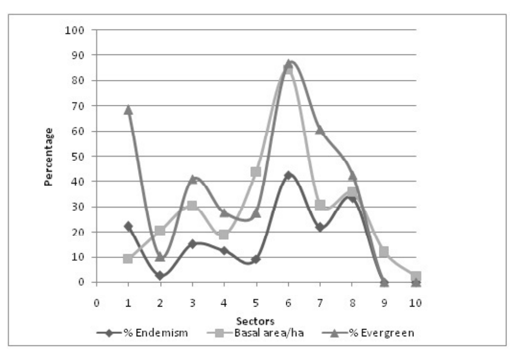

Fig. 7. Percentage endemism, percentage evergreeness and basal area/ha

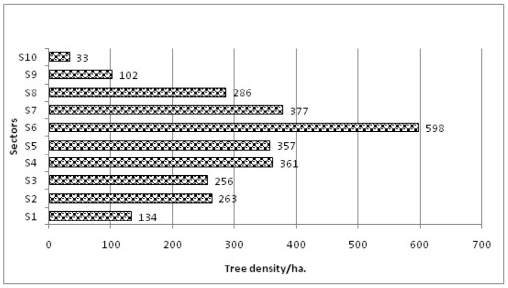

Fig. 8. Tree density/ha values for the different sectors in the study area

ern Ghats proper also had a sacred grove, in much better state of preservation being in an interior thinly populated zone. This sector along with Sector-6 had a mosaic of evergreen to semi-evergreen forest. The Sector-1 having the Navagadde en-route the transect possessed high 40 tree species due to the combination of the semi-evergreen sacred grove with other deciduous zone forests. The eastern plains (Sectors 9 and 10) had relatively low number of species because of the teak dominated deciduous forests in the rain-shadow region.

Shannon diversity index for Sectors 6 and 7 had the highest plant species diversity (Figure 6), mainly due to the semi-evergreen to evergreen forests and relatively lesser human disturbances as compared to the other more approachable sectors. Among the evergreen trees were many Western Ghat endemics like *Knema attenuata, Myristica malabarica and M. dactyloides*. There were as well older individuals of deciduous species such as *Terminalia alata, T. paniculata, Xylia xylocarpa, Lagerstroemia microcarpa*, etc., species which practically had no regeneration under the canopy of the evergreens. These deciduous species might have appeared here during the times of shifting cultivation cycles in the past, over a century ago. Whereas the sectors 9 and 10 were found to be having the least Shannon diversity values because of the over-exploitation of natural resources and domination of teak. Sector 1 also showed a high Shannon diversity (3.3) due to the combined presence of evergreen and deciduous forests. The overall trend of the diversity analysis showed that the diversity was high in the first sector and decreased thereafter until the Ghat section where again the diversity was high and furthermore in the plains, it again reduced.

Evergreenness and Endemism: The percentage of endemism among trees was highest in forests with more percentage of evergreen trees (Fig. 7) particularly in mid altitude Sector 6 (45%). These sectors cover the vegetation of Vajralli – Birgadde villages of Yellapur taluk characterized by the presence of rugged chain of steep hills and narrow valleys with higher evergreen to semi-evergreen forests with lower anthropogenic pressures. More evergreen forests also accounted for relatively higher basal areas and therefore higher carbon sequestration in the biomass. Of the notable endemic species in these evergreen-semi-evergreen zones were *Cinnamomum macrocarpum, Diospyros candolleana, Knema attenuata, Myristica malabarica, Holigarna* spp. etc. As one moves towards the coast or the plains both the evergreeness and endemism drops with lowest in plain area sectors (sectors 9 and 10) which are highly degraded due to high accessibility and anthropogenic pressures coupled with lower rainfall.

Basal Area: Mid altitude forests such as sector 6 with higher evergreeness and endemism also had higher basal area/ha and tree density/ha. They were characterized by lofty evergreen and semi-evergreen species with magnificent individuals of *Lophopetalum wightianum, Persea macrantha, Ficus nervosa*, etc. some with girths of over 400 cm. Sector 10 characterized by degraded teak plantations mixed with highly impacted bamboo mixed scrub with distantly placed deciduous trees had the least basal area (2.24 m^2/ha) and lowest tree density (33 trees/ha) (Figs. 7, and 8). Human impacts such as fire, grazing, logging, encroachment etc., from neighbouring villages (such as etc.,) had contributed to the impoverishment of these forests.

Clustering of Sites: Cluster analysis reveals three different clusters. The first cluster comprised of mainly low altitude sectors 2, 3, 4 and 5 belonged to the coastal taluk of Ankola. They were similar in having highly human impacted secondary deciduous forests. The second cluster included low altitude sectors 1 from the coast (which included the Navagadde sacred grove) and mid-altitude 6, 7 and 8, all of them being mosaic of semi-evergreen to evergreen forests. Sector 1, shows that climax vegetation along the coast could have been more of evergreen to semi-evergreen but for widespread human impacts through centuries. The third cluster in-

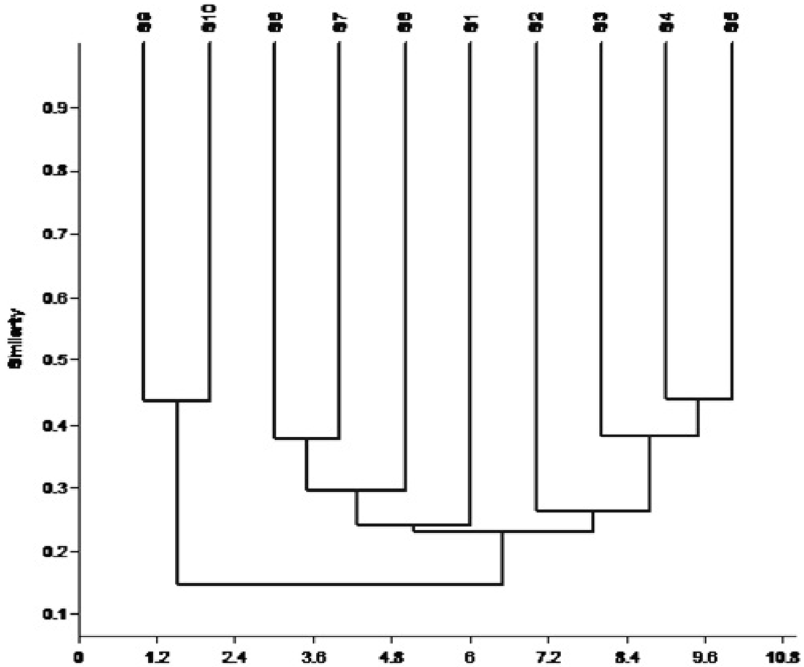

Fig. 9. Cluster analysis using Jaccard's similarity index

cluded mid altitude sectors 9 and 10 and comprised of highly fragmented dry deciduous forests dominated by teak.

The shrub layer studies highlighted that in all the sectors, except sector 6, *Eupatorium* sp., either dominated or was present in large numbers indicating excessive canopy opening and disturbances. However, the presence of the saplings of species such as *Olea dioica, Aporosa lindleyana and Lea indica* in 7 out of 10 sectors indicates the likely return of evergreens in moist deciduous forests, may be due to reduced fire risk. The deciduous tree *Terminalia paniculata* was seen in 9 of 10 sectors and numerically highest in sectors 8 and 9 of deciduous forest zone prone to dry season fires. Sectors 3 and 4 had high presence of *Strobilanthes* sp., which in some places formed large thickets affecting human movements. In the coastal to slightly inland sectors and the lower slopes of the Ghats, *Xylia xylocarpa* showed major presence in the deciduous forests. In the sectors 9 and 10, *Tectona grandis* and *Terminalia paniculata* formed the major part of shrub layer (being juveniles in the ground layer) and the regeneration of other species was poor.

CONCLUSION

Numerous anthropogenic factors such as heavy exploitation, large scale unplanned forest plantations, encroachment of forests were the major causes for transformation of once evergreen forests into deciduous forests today. Forest fragmentation has caused isolation of forest patches leading to species impoverishment affecting especially more sensitive species that require contiguous forest patches for better survival (Niemi et.al. 1998; Laurance et al. 1998). The current study, shows that many forest sites along the coastal zone are worst affected by human impacts with several evergreen trees facing local extinctions. As the evergreeness and endemism decreases, the secondary forests succeeding have lesser carbon sequestering potential. Efforts should be specially made, especially through protection, to promote natural regeneration of characteristic evergreens along the coast. The remaining better forests, especially of the evergreen kind in the Ghats (of the kind occurring in sectors 6, 7 & 8), should be assiduously protected. These forests, through better management practices the basal area/ha from the present <20 sq.m/ha., (those particularly lower altitude coastal forests and mid altitude higher plains), could be raised to the level of 30-40 sq.m/ha, mainly through co-management involving also the local communities.

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