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## COMMUNICATION

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## FOREST EVERGREENNESS AND TREE ENDEMISM IN THE CENTRAL WESTERN GHATS, SOUTHERN INDIA

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**Abstract:** Forests of the Western Ghats are well known for their evergreenness and high endemism. The present study carried out in the Sharavathi River Basin in the central Western Ghats of India is to find the relationship between forest evergreenness and tree endemism. The study was carried out from 2000 to 2006 and the methodology followed is a combination of transect and quadrat method nested with smaller quadrats for shrub layer and herb layer. A total of 51 endemic tree species belonging to 20 families were recorded. The results reveal that the composition of endemic tree population is closely associated with the evergreenness of the forest. With the increase in evergreenness, endemism also increased and almost all the endemic trees of the region occurred in very high evergreen class. Many of them were exclusively found in very high evergreen forests and ground layer data support this observation. Such narrow distribution of endemics makes them most vulnerable to extinction. The present study will be helpful in understanding the association of endemic trees with evergreenness of forest and will be useful in conservation as well as restoration of these endemic trees in their natural habitats.

**Keywords:** Climax forests, evergreenness, paleoendemics, transect, tree endemism, Western Ghats.

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**Author Contribution:** DKM is involved in planning field work, data collection, compilation, analysis of different parameters and preparation of the manuscript. GRH is actively involved in data analysis, preparation of manuscript, discussion and interpretation of results.

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## INTRODUCTION

The Western Ghats, being one of the 35 global biodiversity hotspots (Marchese 2015), is very rich in plant diversity and endemism (Nayar et al 2014). Most of the arboreal taxa (63%) of the Western Ghats are endemic to the region and the evergreen forests are characterised by a very high percentage of endemic species (Ramesh 2001). The evergreen forests in southern peninsular India are mainly restricted to the Western Ghats and the tree endemism in the region shows latitudinal variation with highest endemism in the southern Western Ghats and gradually decreasing through the central Western Ghats to the northern Western Ghats (Pascal 1988). The evergreen forests of the central Western Ghats act as a transition zone forming the northern limit for many evergreen and endemic trees (Mesta 2008). Endemics are of high conservation value, as they are very much restricted in distribution and could be lost forever due to human-induced threats (Nayar 1996; Miara et al. 2018). Like other parts of the tropics, the Western Ghats are also one of the highly human impacted mountainous tracts of the world and various anthropogenic activities have led to the grim biodiversity scenario; pushing many plant species to one or the other category of threat. Most of the red listed tree species of India (53 out of 96) are endemic to the Western Ghats (Nayar & Sastry 1987, 1988, 1990), indicating the heavy threat to them. The present study carried out in the Sharavathi River Basin (SRB) in the central Western Ghats of India aims at finding the relationship of forest evergreenness and tree endemism in the region.

## MATERIAL AND METHODS

### Study Area

The study was carried out in the SRB, one of the major west flowing rivers of the central Western Ghats of Karnataka State, India (13.7–14.43°N & 74.4–75.33°E) (Fig. 1). The forests range from climax evergreen to evergreen, semi-evergreen and moist deciduous through which several major streams and substreams flow out forming the major source of water.

Topographically the river basin includes three belts, a coastal tract with broad winding lagoons, rich plains, and wooded hills running to the sea; a central belt of the lofty Sahyadris covered with magnificent forests; and the eastern upland, which is undulating and thickly wooded in the west and in the east passes into a bare level and thickly peopled plain. The elevations vary from sea level

to about 1,343m at Kodachadri Hill (Mesta 2008).

The rock formation is Archaean complex, the oldest rock of the earth crust (Krishnan 1974). A narrow strip of low land in the western side is covered by alluvium. Lateritic exposure of the tertiary type as well as more recent is common in the river basin especially in the coastal lowland. The soils are basically derivatives of the Dharwar system and the main soil types of the river basin are coastal alluvium and lateritic (Saldhana 1984; Ramaswamy et al. 2001).

The average rainfall received is around 3,500–4,000 mm, extending from June to September. The relative humidity in the coast is 95% where as in the plains it is about 75%. The mean annual temperature ranges between 16°C and 23°C according to altitude (Pascal 1982). The average minimum and maximum temperature is about 15–38 °C.

The major vegetation type in the basin includes evergreen and semi-evergreen climax forests of *Persea macrantha*–*Diospyros* spp.–*Holigarna* spp. type and *Diospyros* spp.–*Dysoxylum malabaricum*–*Persea macrantha* “Kan” type (Pascal 1988). Part of region belongs to *Poeciloneuron* facie of *Dipterocarpus indicus*–*Diospyros candolleana*–*Diospyros oocarpa* type in Kodachadri and Karani. In addition, there are other secondary formations like moist deciduous, savanna to woodland savanna, shola type and various monoculture plantations. The evergreen forests correspond to the

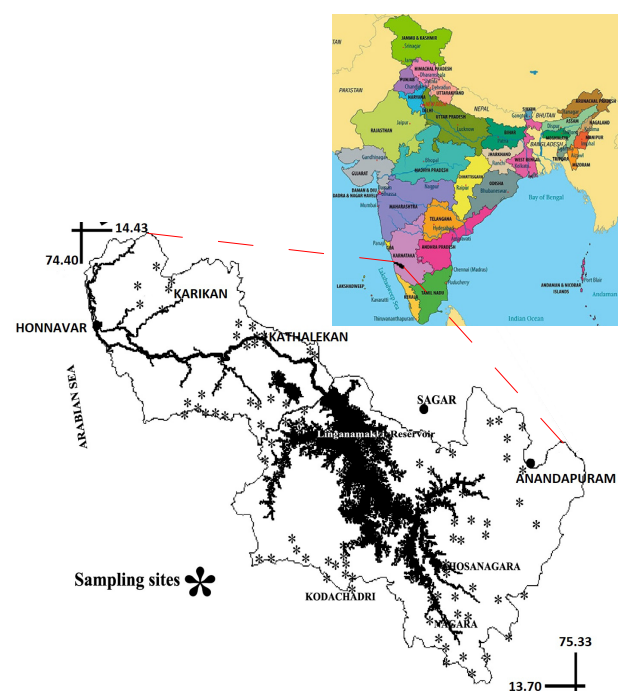


Figure 1. Study area showing sampling sites

“west coast tropical evergreen forests” (Group1/A-C/4) of Champion & Seth (1968).

### Sampling Methods

The tree sampling method followed for the present study is a combination of transect and quadrat method nested with smaller quadrats for shrub layer and herb layer (Chandran & Mesta 2001; Mesta 2008). The transect length ranged from 140–180 m and quadrats of 20x20 m area were laid alternatively left and right along the transect leaving an inter-quadrat distance of 20m throughout the transect. In each tree quadrats, two shrub quadrates of 5x5 m were laid to enumerate tree saplings and four herb quadrats of 1x1 m to enumerate tree seedlings. The number of quadrats laid for each transect was five and in a very few cases it was four, where the forest patch is smaller. Care was taken to distribute the vegetation samples throughout the study area. In each tree quadrat of 20x20 m, all the trees (having a minimum gbh of 30cm) were enumerated thereby getting the actual number of trees in each quadrat. *Myristica* swamps, the relics of primeval forests well known for high endemism, have been excluded from the present study as a detailed study including endemism was reported earlier (Chandran & Mesta 2001).

### Data Analysis

All the sampled transects were classified into five groups based on the percentage of evergreen individuals occurring, as very high (81–100 %), high (61–80 %), moderate (41–60 %), low (21–40 %), and very low (0–20 %) evergreen classes. The endemic as well as nonendemic evergreens have been considered for the calculation of percentage evergreenness. The



Image 1. *Dipterocarpus indicus* Bedd. (Inset: winged fruits)

percentage endemic tree population has been calculated for each evergreen class by pooling all the transect data of respective evergreen class. The endemic trees are listed based on the atlas of endemics (Ramesh et al. 1997) and other regional floras (Cooke 1967; Saldanha 1984, 1996; Dasappa & Swaminath 2000; Mohanan & Sivadasan 2002). The importance value index (IVI), which gives an overall picture of the importance of the species in the community by considering the relative values of density, frequency and basal area in a given sample is calculated by following Elzinga et al. (2001).

## RESULTS

A total of 670 tree quadrats of 400m<sup>2</sup> each were laid along 130 transects accounting for a total sampled area of 26.8ha. In all 203 tree species under 55 families were recorded of which 51 species belonging to 20 families are endemic to the Western Ghats. Of the total 12,404 recorded tree stems, 82% (10,149) of individuals were evergreens while 40% (4,913) were endemic to the Western Ghats. The average value of evergreenness varied from 7% to 91% and the average endemism from 5% to 36% for very low evergreen class to very high evergreen class, respectively (Fig. 2).

### Composition of endemics in different evergreen classes

Very high evergreen class (81–100 % evergreen): Of the 51 endemics recorded, 50 occurred in the very high evergreen class accounting for more than 98% of recorded endemic tree species of the river basin and 18 of them were exclusively found in this class. The dominant endemics found in this evergreen class were *Knema attenuata*, *Hopea ponga*, *Reinwardtiidendron anamallayanam*, *Holigarna grahamii*, *Diospyros candolleana*, *Holigarna arnottiana*, *Ixora brachiata*, and *Flacourtia montana*. The indicator species of climax evergreen forests of Western Ghats like *Palaquium ellipticum*, *Vateria indica*, *Dipterocarpus indicus* (Image 1), *Poeciloneuron indicum*, and *Dysoxylum malabaricum* were found only in this very high evergreen class.

High evergreen class (61–80 % evergreen): The number of endemics drastically decreased from very high to high evergreen class. Of the 51 endemics, 32 (63%) were recorded in this class. Major endemics recorded were *Holigarna grahamii*, *Holigarna beddomei*, and *Polyalthia fragrans*. Other dominant endemics recorded were *Garcinia indica*, *Blachia denudata*, *Dimorphocalyx lawianus*, *Sageraea laurifolia*, *Gordonia obtusa*, *Hydnocarpus laurifolia*, *Drypetes elata*, and *Diospyros*



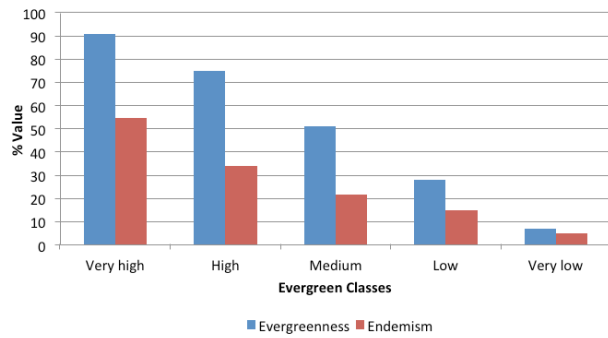


Figure 2. Percentage evergreenness and tree endemism across five evergreen classes

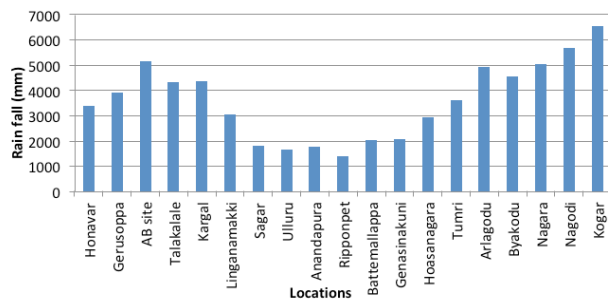


Figure 3. Average annual rainfall for different locations in the river basin

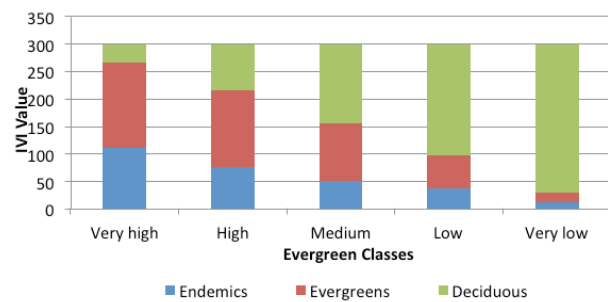


Figure 4. The IVI shared by tree species across five evergreen classes.

*saldanhae*.

Moderate evergreen class (41–60 % evergreen): Totally 17 endemics were recorded here, which is almost 70% less than in the very high evergreen class. Several endemics were absent in this class and the most dominant species recorded in this class were *Holigarna arnottiana*, *Ixora brachiata*, and *Cinnamomum macrocarpum*. Even though *Reinwardtiodendron anamallayanam*, *Diospyros candolleana*, *Beilschmiedia dalzellii* and *Artocarpus hirsutus* occurred in this class, they were less in number compared to their relatively abundant nature in the very high evergreen class.

Low evergreen class (21–40 % evergreen): As the percentage composition of evergreens decreased, the endemics also decreased gradually. Only 8 (16%) endemics were recorded in this class. *Tabernaemontana heyneana* is the only dominant endemic and *Hopea ponga* and *Flacourtia montana* were found in a few numbers; however other species like *Garcinia gummi-gutta*, *Ixora brachiata*, *Vepris bilocularis*, *Knema attenuate*, and *Holigarna arnottiana* were represented by one or two individuals only.

Very low evergreen class (0–20 % evergreen): Only four endemics *Tabernaemontana heyneana*, *Flacourtia montana*, *Calophyllum apetalum*, and *Garcinia gummi-gutta* were recorded here. The latter two were represented by single individuals only.

### Endemic trees in the ground layer

The shrub and herb quadrat data representing tree saplings and seedlings followed the similar trend as in the tree quadrats. The number of endemic tree species in shrub layer across different evergreen classes were 40, 25, 10, 3, & 4 and in herb layer 42, 23, 9, 5 and 6.

### Importance value index (IVI)

The IVI shared by endemics varied from species to species across different evergreen classes. In case of very high evergreen class all the endemic trees together shared the IVI of 112 followed by 76, 51, 38 and 12 for high, moderate, low and very low evergreen class respectively. Major endemics contributing to the IVI in the very high evergreen class were *Knema attenuata*, *Reinwardtiodendron anamallayanam*, *Hopea ponga*, *Holigarna grahamii*, *Diospyros candolleana*, and *Holigarna arnottiana*; in the high evergreen class by *Ixora brachiata*, and *Flacourtia montana*; in the moderate by *Holigarna arnottiana*, *Ixora brachiata*, and *Cinnamomum macrocarpum* and in very low and low evergreen class by the deciduous endemic *Tabernaemontana heyneana*.

### DISCUSSION

The average endemism across the five evergreen classes in SRB ranged from 5% to 36% and most of the endemics were distributed in a very high evergreen class. According to Ghatte et al. (1998) the average endemism for the evergreen forests of the Western Ghats is around 41% and for the closed canopy evergreen forest 55%. Elouard et al. (1997) studying the evergreen forest patch at Kodagu, one of the dense forest areas of the Western Ghats in Karnataka, found 48% of tree endemism.

**Table 1. List of endemics with their composition in different evergreen classes (figure in parenthesis is IVI value)**

	Plant species	Family	Evergreen classes				
			81–100	61–80	41–60	21–40	0–20
1	<i>Actinodaphne angustifolia</i> Nees <sup>1</sup>	Lauraceae	1.16 (3.03)	1.49 (3.46)	1.52 (3.34)		
2	<i>Aglaia lawii</i> (Wight) Sald. <sup>1</sup>	Meliaceae	0.18 (0.04)				
3	<i>Arenga wightii</i> Griff. <sup>3</sup>	Aracaceae	0.10 (0.13)				
4	<i>Artocarpus hirsutus</i> Lam. <sup>1</sup>	Moraceae	1.23 (2.95)	0.74 (3.79)	0.38 (1.41)		
5	<i>Beilschmiedia dalzellii</i> (Meis.) Kost. <sup>2</sup>	Lauraceae	1.17 (3.47)	0.81 (2.15)	0.38 (1.25)		
6	<i>Blachia denudata</i> Benth. <sup>1</sup>	Euphorbiaceae		0.07 (0.16)			
7	<i>Calophyllum apetalum</i> Willd. <sup>1</sup>	Clusiaceae	0.07 (0.25)	0.07 (0.38)	0.19 (0.51)		0.14 (0.36)
8	<i>Cinamomum macrocarpum</i> Hk. f. <sup>1</sup>	Lauraceae	1.05 (2.52)	2.23 (4.98)	3.42 (7.84)		
9	<i>Dimorphocalyx lawianus</i> (Muell.-Arg.) Hk.f. <sup>1</sup>	Euphorbiaceae	0.20 (0.64)	0.27 (0.55)			
10	<i>Diospyros angustifolia</i> (Miq.) Kostermans <sup>1</sup>	Ebenaceae	0.08 (0.11)				
11	<i>Diospyros candolleana</i> Wt. <sup>1</sup>	Ebenaceae	2.49 (5.41)	2.03 (3.96)	1.71 (3.87)		
12	<i>Diospyros paniculata</i> Dalz. <sup>1</sup>	Ebenaceae	0.72 (1.59)				
13	<i>Diospyros pruriens</i> Dalz. <sup>1</sup>	Ebenaceae	1.02 (2.28)				
14	<i>Diospyros saldanhae</i> Kostermans <sup>1</sup>	Ebenaceae	0.06 (0.26)	0.07 (0.12)			
15	<i>Dipterocarpus indicus</i> Bedd. <sup>1</sup> (Fig. 5)	Dipterocarpaceae	1.39 (2.99)				
16	<i>Drypetes elata</i> (Bedd.) Pax & Hoffm. <sup>1</sup>	Euphorbiaceae	0.59 (1.25)	0.07 (0.17)			
17	<i>Drypetes confertiflorus</i> (J. Hk.) Pax & Hoffm. <sup>1</sup>	Euphorbiaceae	0.02 (0.28)				
18	<i>Dysoxylum malabaricum</i> Bedd. <sup>1</sup>	Meliaceae	0.11 (0.34)				
19	<i>Eugenia macrosepala</i> Duthie <sup>1</sup>	Myrtaceae	0.48 (1)				
20	<i>Euonymus indicus</i> Heyne ex Wall. <sup>1</sup>	Celastraceae	0.59 (0.77)	0.07 (0.11)	0.38 (1.05)		
21	<i>Flacourtia montana</i> Grah. <sup>1</sup>	Flacourtiaceae	1.40 (3.17)	3.45 (7.33)	1.52 (2.88)	1.08 (5.86)	0.57 (1.51)
22	<i>Garcinia gummi-gutta</i> (L.) Robson <sup>1</sup>	Clusiaceae	1.13 (2.86)	0.61 (0.97)	0.15 (1.15)	0.72 (1.79)	0.14 (0.37)
23	<i>Garcinia indica</i> (Thouras) Chois. <sup>1</sup>	Clusiaceae	0.01 (0.04)	0.20 (0.35)			
24	<i>Garcinia talbotii</i> Raiz. ex Sant. <sup>1</sup>	Clusiaceae	0.28 (0.93)				
25	<i>Gordonia obtusa</i> Wall ex Wt. & Arn. <sup>1</sup>	Theaceae	0.24 (0.36)	0.14 (0.32)			
26	<i>Holigarna arnottiana</i> Hk. f. <sup>1</sup>	Anacardiaceae	2.46 (5.32)	4.13 (8.95)	5.31 (12.8)	0.36 (4.52)	
27	<i>Holigarna beddomei</i> Hk. f. <sup>1</sup>	Anacardiaceae	0.42 (1.46)	0.20 (0.54)			
28	<i>Holigarna ferruginea</i> March. <sup>1</sup>	Anacardiaceae	0.54 (1.49)		0.19 (0.53)		
29	<i>Holigarna grahamii</i> (Wt.) Kurz. <sup>1</sup>	Anacardiaceae	3.10 (7.62)	2.03 (5.07)			
30	<i>Hopea parviflora</i> Bedd. <sup>1</sup>	Dipterocarpaceae	0.11 (0.62)				
31	<i>Hopea ponga</i> (Dennst.) Mabberly <sup>1</sup>	Dipterocarpaceae	7.42 (11.4)	1.49 (4.16)	0.19 (0.53)	2.16 (3.79)	
32	<i>Hydnocarpus laurifolia</i> (Dennst.) Sleumer <sup>1</sup>	Flacourtiaceae	0.31 (1.34)	0.07 (0.29)			
33	<i>Ixora brachiata</i> Roxb. <sup>1</sup>	Rubiaceae	1.67 (2.95)	4.13 (8.27)	3.80 (8.29)	0.72 (3.17)	
34	<i>Knema attenuata</i> (J. Hk. & Thw.) Warb. <sup>1</sup>	Myristicaceae	10.01 (16.4)	4.06 (8.93)	0.38 (1.05)	0.36 (2.42)	
35	<i>Litsea laevigata</i> (Nees) Gamble <sup>1</sup>	Lauraceae	0.06 (0.27)	0.41 (0.9)	0.38 (0.51)		
36	<i>Mammea suriga</i> (Buch.-Ham. ex Roxb.) Koest. <sup>1</sup>	Clusiaceae	0.04 (0.07)				
37	<i>Mastixia arborea</i> (Wt.) Bedd. <sup>1</sup>	Cornaceae	0.44 (1.47)	0.07 (0.2)			
38	<i>Meiogyne pannosa</i> (Dalz.) Sinclair <sup>1</sup>	Annonaceae	0.13 (0.26)				
39	<i>Myristica fatua</i> var. <i>magnifica</i> (Bedd.) Sinclair <sup>1</sup>	Myristicaceae	0.01 (0.05)				
40	<i>Myristica malabarica</i> Lam. <sup>1</sup>	Myristicaceae	0.92 (2.16)	0.14 (0.25)			
41	<i>Palaquium ellipticum</i> (Dalz.) Baill. <sup>1</sup>	Sapotaceae	0.54 (0.73)	0.07 (0.32)			
42	<i>Poeciloneuron indicum</i> L. <sup>1</sup>	Clusiaceae	1.30 (2.44)				
43	<i>Polyalthia fragrans</i> (Dalz.) Bedd. <sup>1</sup>	Annonaceae	0.68 (1.99)	0.41 (1.27)			
44	<i>Reinwardtiodendron anamallayanam</i> (Bedd.) Sald. <sup>1</sup>	Meliaceae	7.06 (12.26)	2.37 (4.02)	0.95 (1.98)		
45	<i>Sageraea laurifolia</i> (Grah.) Blatt. <sup>1</sup>	Annonaceae	0.18 (0.61)	0.14 (0.34)			
46	<i>Syzygium laetum</i> (Buch.-Ham.) Gandhi <sup>1</sup>	Myrtaceae	0.08 (0.59)				
47	<i>Syzygium travancoricum</i> Gamble <sup>1</sup>	Myrtaceae	0.03 (0.07)				

	Plant species	Family	Evergreen classes				
			81–100	61–80	41–60	21–40	0–20
48	<i>Tabernaemontana heyneana</i> Wall. <sup>5</sup>	Apocynaceae	0.34 (0.89)	1.62 (2.88)	0.76 (2.04)	8.99 (15.91)	3.98 (9.87)
49	<i>Tricalysia apiocarpa</i> Gamble <sup>1</sup>	Rubiaceae	0.01 (0.04)				
50	<i>Vateria indica</i> L. <sup>1</sup>	Dipterocarpaceae	0.44 (1.13)	0.07 (0.16)			
51	<i>Vepris bilocularis</i> (Wt. & Arn.) Engler <sup>1</sup>	Rutaceae	0.51 (1.4)	0.27 (0.53)		0.36 (1.03)	
	<b>Additional endemics recorded outside the sampling area</b>						
52	<i>Gymnacranthera canarica</i> (King) Warb. <sup>1</sup>	Myristicaceae					
53	<i>Madhuca bourdillonii</i> (Gamble) H.J. Lam. <sup>1</sup>	Sapotaceae					
54	<i>Pittosporum dasycaulon</i> L. <sup>2</sup>	Pittosporaceae					
55	<i>Pterospermum reticulatum</i> L. <sup>2</sup>	Sterculiaceae					
56	<i>Semecarpus kathalekanensis</i> Das. & Swam. <sup>4</sup>	Anacardiaceae					

Note: <sup>1</sup>Ramesh et al. 1997; <sup>2</sup>Saldanha, 1984–1996; <sup>3</sup>Mohanani & Sivadasa 2002; <sup>4</sup>Dasappa & Swaminath 2000; <sup>5</sup>Cooke 1901–1908.

Sreekantha et al. (2007) recorded 71% of tree endemism for a forest patch in the SRB. The present study shows that endemism in SRB (except for four transects which had zero endemism) ranged from the lowest of 3% at Chikandagudda to 84% at Tulsani which is exceptionally high compared to any of the evergreen forests of the Western Ghats. Further, several localities in the very high evergreen class have more than 50% endemism.

Apart from the 51 endemics recorded under tree quadrats, an additional five endemics were recorded during the opportunistic visits. They are *Gymnacranthera canarica*, *Madhuca bourdillonii*, *Pittosporum dasycaulon*, *Pterospermum reticulatum*, and *Semecarpus kathalekanensis*. During the present study, seven individuals of *Madhuca bourdillonii* had been recorded close to a steep curve along the roadside of Malemane Ghat. *Myristica* swamps, the relics of primeval forests well known for high endemism, have been excluded from the present study as a detailed study including endemism has been reported (Chandran & Mesta 2001). These swamps in the southern Western Ghats are also known for high endemism (Varghese & Menon 1999). *Gymnacranthera canarica* and *Semecarpus kathalekanensis* are associated with these swamps in the river basin. Even though *Pterospermum reticulatum* is a rare (Nayar & Sastry 1990) and Vulnerable (World Conservation Monitoring Centre 1998) endemic, it is quite frequently seen in the Gersoppa and Malemane Ghats, usually along the forest edges.

The high degree of endemism in the evergreen forests of the Western Ghats can be attributed to the isolation of the ghats from other moist formations and the prevailing drier climatic conditions in the surrounding areas. For the whole of the Western Ghats, the variation in the degree of endemism is determined

by two factors: the increasing number of dry months from south to north and decrease in temperature with increase in altitude (Pascal 1988). But for the SRB there seems to be multiple factors responsible for variation in evergreenness and endemism. In addition to the rainfall and the dry period of 5–6 months, the local topography seems to play an important role. The drainage pattern of the riverbasin indicates higher drainage density towards the ghat region with rugged hills and deep valleys, while the eastern flatter terrain has lower drainage density. Analysis of rainfall data indicates that (Fig. 3) the rainfall increase from west coast to east up to the ghat region, then decrease towards the plains in the east near Sagar and Rippenpet region. Similarly, from north to south it has an increasing trend with maximum rainfall at Kogar. Karthick & Ramachandra (2006) reported that the rainfall is highest in the ghat region and least in the plateau of SRB.

Western Ghats, one of the oldest landmasses of the Earth is related to Gondwana land in origin. Many of the endemic trees of the Western Ghats like *Poeciloneuron indicum*, *Myristica fatua* var. *magnifica*, and *Gymnacranthera canarica* are very old in origin and are called palaeoendemics. They bear testimony to the days when continents like America, Africa and Asia constituted a single landmass called Gondwana. In SRB, such relics of primary forests can be seen in Kathalekan where *M. fatua* var. *magnifica*, *G. canarica*, and *Semecarpus kathalekanensis* were found. Similarly *Vateria indica* and *Poeciloneuron indicum* were found in only two primary evergreen forest patches in the river basin. All such paleoendemics and some indicator species of climax evergreen forests like *Dipterocarpus indicus*, *Palaquium ellipticum*, etc. were recorded only in the very high evergreen class.



The average annual rainfall in the river basin is 3,500–4,000 mm. The rainfall above 2,500mm in Western Ghats support evergreen forests (Pascal 1988) and the evergreen forests in the river basin are restricted to the ghat region whereas the eastern plateau is dominated by moist deciduous forest, since the latter receives less than 2,000mm rainfall. These regions, however, were known to have evergreen ‘Kan’ forests in the past (Brandis & Grant 1868). The drier condition and low rainfall, in association with anthropogenic factors like agriculture, fuel wood collection and cattle grazing through the last many centuries have altered the vegetation of this eastern plateau region. The forests in the lower rainfall areas of the Western Ghats are more fragile and are therefore prone to lose their evergreenness faster than those in the high rainfall areas mainly due to fire. Most of the delicate, thin barked evergreens disappear from such region and only thick barked deciduous trees like *Terminalia* spp, *Xylia xylocarpa*, *Dillenia pentagyna*, *Careya arborea* (Rao 1891) and the deciduous endemic *Tabernaemontana heyneana* can survive the conditions.

The ground layer data reveals that many of the endemics have saplings and seedlings under their preferred evergreen classes; however, there are noticeable numbers of species which do not have saplings or seedlings which is a serious matter of concern (Table 2).

The result shows that the value of IVI shared by endemics is highest in the very high evergreen class (Fig. 4). The major share of IVI in the very high as well as high evergreen class is by endemic and nonendemic evergreen; for moderate evergreen class by nonendemic evergreen and deciduous trees whereas, for low and very low evergreen classes it is by deciduous trees.

### Tree endemism and their habitat preference

Tree endemism is positively related with the evergreenness of forest and most of the endemics recorded in the river basin occurred in the very high evergreen class. The result of Chandran (1997) revealed that the endemism including the shared endemism with Sri Lanka increases with evergreenness. It is interesting that the indicator species of climax evergreen forests like *Dipterocarpus indicus*, *Dysoxylum malabaricum*, *Myristica malabarica*, *Myristica fatua* var. *magnifica*, *Mastixia arborea*, *Palaquium ellipticum*, *Poeciloneuron indicum* and *Vateria indica* were found only in the very high evergreen class (Table 1). More interesting is even in this very high evergreen class, they occurred in the primary evergreen forests with more than 90% evergreenness. These species may be called endemics

of climax forests, as they are the species indicating the climax nature of a forest. Some of these form the habitat and food plants for the survival of rare and endangered flagship species like Lion-tailed Macaque *Macaca silenus* (Ramachandran & Joseph 2000) and Great Pied Hornbill *Buceros biornis* occurring in this region (Ali et al. 2006).

In addition to very high evergreen class, *P. ellipticum* and *V. indica* were recorded even in the high evergreen class also but represented by single individual is exceptional and may be a chance factor. Occurrence of these endemics only in the very high evergreen class indicates that these species prefer the high evergreen, dense canopy forests as their habitat. These species have very low ecological amplitude because of the narrow range of conditions on which their growth depends and such species may be called as habitat specialist. Any alteration in these habitats (forests) such as incidence of fire, logging etc is likely to have an irreparable damage to their existence.

Except *Holigarna grahamii*, *Holigarna beddomei* and *Polyalthia fragrans* all other endemic species are poorly represented in the high evergreen class. This indicates that compared to very high evergreen class, these habitats do not support endemics of high evergreen to flourish. The commonly occurring deciduous tree species in this class were *Terminalia paniculata*, *Lagerstroemia microcarpa* and *Vitex altissima* and most of them are represented by older individuals. These deciduous species probably appeared in this high-rainfall zone because these forests have a history of slash and burn cultivation (Chandran 1997). Banning of shifting cultivation led to the return of the evergreen species and these evergreen species with closed canopy prevented the regeneration of the more light-loving deciduous trees. Denser canopies and thicker litter cover in such forests are known to prevent seed germination. This in turn affect the regeneration of these light seeded deciduous species (Chandrashekar & Ramakrishnan 1994).

Several endemics disappeared from moderate evergreen class. The deciduous endemic *Tabernaemontana heyneana* was represented by very few individuals. The forests in the low evergreen class are susceptible to annual fires which seems to be a major limiting factor for the evergreens and the endemics to come up. Only the fire hardy evergreens *Syzygium cumini* (Hegde et al. 1998) that can tolerate fire to some extent and the pioneer evergreen *Aporosa lindleyana* were recorded. In the very low evergreen class only *Tabernaemontana heyneana* and *Flacourtia montana* had some individuals indicating that, except these two species, no other endemics have the ability

**Table 2. Habitat preference of different endemic trees in tree layer, shrub layer and herb layer.**

	Evergreen classes	Very High			High			Moderate			Low			Very Low		
	Species	TR	SH	HR	TR	SH	HR	TR	SH	HR	TR	SH	HR	TR	SH	HR
1	<i>Tabernaemontana heyneana</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	<i>Flacourtia montana</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	<i>Holigarna arnottiana</i>	+	+	+	+	+	+	+	+	+	+	+	+		+	+
4	<i>Ixora brachiata</i>	+	+	+	+	+	+	+	+	+	+					+
5	<i>Knema attenuata</i>	+	+	+	+	+	+	+	+	+	+					
6	<i>Actinodaphne angustifolia</i>	+	+	+	+	+	+	+	+	+						+
7	<i>Cinnamomum macrocarpum</i>	+	+	+	+	+	+	+	+	+						
8	<i>Diospyros candolleana</i>	+	+	+	+	+	+	+	+							
9	<i>Artocarpus hirsutus</i>	+	+	+	+	+	+	+								
10	<i>Litsea laevigata</i>	+	+	+	+	+	+	+								
11	<i>Reinwardtiodendron anamallayanam</i>	+	+	+	+	+	+	+								
12	<i>Beilschmiedia dalzellii</i>	+	+	+	+		+	+								
13	<i>Euonymus indicus</i>	+			+		+	+								
14	<i>Hopea ponga</i>	+	+	+	+	+	+	+	+		+	+	+			
15	<i>Vepris bilocularis</i>	+	+	+	+	+	+				+				+	
16	<i>Garcinia gummigutta</i>	+	+	+	+	+	+	+		+	+			+		
17	<i>Sageraea laurifolia</i>	+	+	+	+	+	+			+						
18	<i>Diospyros saldanahae</i>	+	+	+	+	+	+									
19	<i>Holigarna grahamii</i>	+	+	+	+	+	+									
20	<i>Polyalthia fragrans</i>	+	+	+	+	+	+									
21	<i>Holigarna beddomei</i>	+	+	+	+	+										
22	<i>Vateria indica</i>	+	+	+	+	+										
23	<i>Drypetes elata</i>	+	+	+	+											
24	<i>Gordonia obtusa</i>	+	+	+	+											
25	<i>Holigarna ferruginea</i>	+	+	+				+								
26	<i>Palaquium ellipticum</i>	+	+	+	+											
27	<i>Dimorphocalyx lawianus</i>	+	+		+	+	+									
28	<i>Garcinia indica</i>	+		+	+		+									
29	<i>Hydnocarpus laurifolia</i>	+			+											
30	<i>Arenga wightii</i>	+	+	+		+										
31	<i>Diospyros paniculata</i>	+	+	+		+										
32	<i>Eugenia macrosepala</i>	+	+	+		+										
33	<i>Mammea suriga</i>	+	+	+		+										
34	<i>Calophyllum apetalum</i>	+	+	+	+			+	+				+	+		+
35	<i>Aglaiia lawii</i>	+	+	+												
36	<i>Diospyros pruriens</i>	+	+	+												
37	<i>Dipterocarpus indicus</i>	+	+	+												
38	<i>Garcinia talbotii</i>	+	+	+												
39	<i>Hopea parviflora</i>	+	+	+												
40	<i>Myristica malabarica</i>	+	+	+	+											
41	<i>Poeciloneuron indicum</i>	+	+	+												

	Evergreen classes	Very High			High			Moderate			Low			Very Low		
		TR	SH	HR	TR	SH	HR	TR	SH	HR	TR	SH	HR	TR	SH	HR
42	<i>Syzygium laetum</i>	+	+													
43	<i>Syzygium travancoricum</i>	+	+													
44	<i>Diospyros angustifolia</i>	+		+												
45	<i>Mastixia arborea</i>	+		+	+											
46	<i>Myristica fatua</i> var. <i>magnifica</i>	+		+												
47	<i>Drypetus confertifolius</i>	+														
48	<i>Dysoxylum malabaricum</i>	+														
49	<i>Meiogyne pannosa</i>	+														
50	<i>Tricalysia apiocarpa</i>	+														
51	<i>Blachia denudata</i>			+	+		+									
Total occurrence		50	40	42	32	25	23	17	10	9	8	3	5	4	4	6

TR -Tree layer; SH - Shrub layer; HR - Herb layer

to tolerate and come up in such conditions. Usually these forests are also prone to frequent and annual fires. In spite of periodic fires and direct sun light (due to canopy openings), presence of *Tabernaemontana heyneana* in such forests indicate that they are capable of tolerating the fire, mainly due to the presence of thick bark and high coppicing ability. This species was also found in the higher evergreen class, but restricted to canopy gaps and forest edges only. According to Hegde et al. (1998) *T. heyneana* must have existed originally in naturally open habitats within climax forest, such as on steep escarpments and later might have spread to more open areas. *F. montana* was also found in all five evergreen classes but it has maximum occurrence in high evergreen class. It means that as soon as the fire stops it starts to appear even in the very low evergreen class or other words it may tolerate fire to some extent so that it occurs even in the deciduous forests.

In general the endemic tree communities of the Western Ghats are mostly evergreen species. Very few deciduous endemics are known to occur in the region like *Terminalia travancorensis*, *Bauhinia phoenicea* and *Tabernaemontana heyneana*. The first one is limited to the south of the Palghat Gap, the second one has wider but sparse distribution in the deciduous forests of Western Ghats and the third one has a wider distribution throughout the Western Ghats including the SRB. It is the *Tabernaemontana heyneana* that contributed the major share of endemism in low and very low evergreen class in the river basin.

## CONCLUSION

In the SRB the tree endemism is positively related to evergreenness of the forest. Most of the tree endemics in the river basin are restricted to very high evergreen class. Out of 51 endemics recorded in the river basin, 50 occurred in the very high evergreen class and 18 of them were exclusive to these high evergreen forests. Because of such narrow distribution they are most vulnerable to extinction. Hence, priority should be given to their conservation and restoration.

The climax species like *Dipterocarpus indicus*, *Vateria indica*, *Poeciloneuron indicum* and *Palaquium ellipticum* are seen only in the very high evergreen class. Any restoration efforts for such climax endemic tree species should be restricted to high evergreen forests. Conservation priority should be given to the high evergreen forests as they are the home for most of the endemic trees.

Uttara Kannada District including part of the SRB was considered as the northernmost limit for many endemic tree species like *Dipterocarpus indicus*, *Poeciloneuron indicum*, *Hopea parviflora*, and *Myristica fatua* var. *magnifica* and the highly threatened tree species *Semecarpus kathalekanensis*, *Syzygium travancoricum* (Chandran et al. 2008, 2010), and *Madhuca bourdillonii*; however, *M. fatua* var. *magnifica*, *S. kathalekanensis* and *S. travancoricum* have been recorded from a *Myristica* swamp further north of Western Ghats in Goa (Prabhugaonkar et al. 2014).

Paleoendemics are the indicators of climax forests, and in SRB, such relics of primary forests can be seen in Kathalekan and Karikan, where *Dipterocarpus indicus*

is found. Similarly *Vateria indica* and *Poeciloneuron indicum* were found in Hessige and Karani, respectively. Conservation priority should be given to such high evergreen forests as they are the home for most of the endemics including the paleoendemics. Therefore, habitat preferred by the endemics should be considered before any restoration programs.

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