

# Riparian Vegetation Dynamics Across Two Different Landscapes Along the River Cauvery in the Kodagu Region of Western Ghats

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**Abstract:** Decades of commercial planting and other anthropogenic processes are posing a threat to the riparian landscapes of the Cauvery river basin, which supports a high floral diversity. Despite this, the habitats in the upstream sections of the River Cauvery are still intact, as they are located in sacred groves. To understand the dynamism of riparian forests exposed to anthropogenic pressures, the upstream stretch of Cauvery extending from Kushalanagara to Talacauvery (~102 km) was categorized into two landscapes: agro ecosystem and sacred (i.e. preserved). The tree species were sampled using belt transects at 5 km intervals and the regeneration status of endemic species assessed using quadrats. A total of 128 species belonging to 47 families, and representing 1,590 individuals, was observed. Amongst them, 65% of unique species were exclusive to sacred landscapes. A rarefaction plot confirmed higher species richness for the sacred compared to the agro ecosystem landscapes, and diversity indices with more evenness in distribution were evident in sacred landscapes. A significant loss of endemic tree species in the agro ecosystem landscapes was found. Overall, this study demonstrates that an intense biotic pressure in terms of plantations and other anthropogenic activities have altered the species composition of the riparian zone in non-sacred areas. A permanent policy implication is required for the conservation of riparian buffers to

avoid further ecosystem degradation and loss of biodiversity.

**Keywords:** Western Ghats; Riparian vegetation; Cauvery River; Sacred grove; Agro ecosystem landscape; Diversity indices; Endemic species.

## Introduction

Riparian areas are important ecosystems because of their complex spatiotemporal processes and functions that support diverse plant and animal communities and maintain a range of ecosystem services (Coroi et al. 2004). Riparian vegetation in mountainous regions is critical for maintaining this diversity, as well as ecosystem resources and services. As riparian corridors are allied with seasonal flooding, high productivity, and geomorphic heterogeneity, it naturally preserves a high degree of floristic and structural diversity (Gregory et al. 1991; Naiman et al. 1993). Riparian vegetation helps to reduce flood water velocities (Sorenson et al. 2009), while the roots of trees and other herbaceous species trap sediments in the riverbank, thereby regulating sediment input and non-point sources of pollution arising from land management practices into the system.

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Alongside its environmental services, riparian vegetation also offers high economic value to local people by reducing floods and controlling soil erosion in the adjacent lands. Most of the world's riparian forests have been degraded by human activities with consequent impacts on river ecosystems (Ryan 1998). Tockner and Stanford (2002) observed that riparian vegetation today is rooted in the most vulnerable and threatened ecosystem of the world, and its conservation is of great importance.

Kodagu (Coorg), a mountainous region located in the central part of the Western Ghats, has diverse vegetation in its landscape with 80% of the geographical area under tree cover (Garcla et al. 2007). The Kodagu district is lauded under the IMFN (International Model Forest Network) due to its unique approach to forest conservation through community participation and management known as "sacred groves", incorporating a broad range of forest values including social, cultural, economic and environmental concerns. For the past 30 years, the district has been the focus of a variety of farming activities, including crop plantations due to the favorable climate offered by forests situated in the uphill patches. The district is the largest coffee producer in the country and has an international reputation as a prominent coffee-producing center (Farooqui 2007). However, massive promotion of farming activity has led to a loss of 30% of species rich forest cover (Garcla et al. 2007), creating a more vulnerable and fragile ecosystem. This anthropogenic pressure has led to forest cover dropping to 45% (Rameshaiah et al. 2002) which is far lower than the 60% minimum required to be preserved in mountain regions according to the National Forest Policy, 1988. The river valley in this mountainous region was also degraded in the past by shifting cultivation (Ramakrishnan et al. 2000), affecting biodiversity (Begum et al. 2009; Nikhil et al. 2010). Smathkin et al. (2002), in their studies on Indian rivers, give a clear indication of the threat experienced by the riparian forest in this region by the expansion of crop plantations. Even under such extreme anthropogenic pressure, 70% of the habitats in the headwater streams of river Cauvery are still in intact (Mittemeier et al. 2003) as they enjoy legal protection.

In tropical countries, riverine habitats are less

investigated and studies are limited due to lack of legislative policies and regulations (Biervilet 2009). So far, inadequate studies have been done on the riparian patches of the Western Ghats, India (Chandran and Mesta 2001; Amitha 2001; Keshava and Krishnakumar 2006). No attempt has been made to explore the riparian vegetation dynamics within and between the sacred grove and agro ecosystem landscapes of the River Cauvery, Western Ghats. The study firstly aimed to analyze the changes in structure, diversity and composition of riparian vegetation in different type of landscapes viz., sacred and agro ecosystem, and secondly, to analyze the impact of these landuse types on native tree species regeneration.

## 1 Study Area

The study area is located in Kodagu district, a central part of the Western Ghats (75° 30' 39.5" E, 12° 22' 37.4" N, 978 m). Cauvery is one of the seven most sacred rivers of the country. Cauvery originates in the Brahmagiri hills, at a place called Talakaveri located at an elevation of 1,340 m above sea level, in Kodagu district which is dominated by moist evergreen and deciduous forests. The upper reach of the basin is covered with hill ranges of the Western Ghats and the sub basin area is broad and open with gently undulating terrain. It flows for ~102 km through forests, plantations, agricultural land and villages in this district. The study area has an elevation ranging from 500 m – 1,500 m and receives 603 cm precipitation primarily from the South West Monsoon. Red loamy soil is the predominant category of soil. Plantations of coffee, silver oak, rubber, cardamom, paddy and areca nut are the major agricultural activities in the district. The coffee plantation dates back to 18<sup>th</sup> century (Ramakrishnan et al. 2000), a life blood of the district economy, and produces nearly one-third of Indian coffee and accounts for the loss of 71% of the original forest area (Ambinakudige and Sathish 2009). Massive landscape fragmentation, habitat loss, and biodiversity depletion have taken place over the last 30 years (Garcla et al. 2007).

The study area harbors sacred groves, a unique concept in nature conservation with community participation and management in the district (Chandrakanth et al. 2010). The sacred grove is

termed as “*Kaveri devarakadu*” locally and is located at the point of river birth, Talacauvery. The sacred landscape extends to an area of 379.85 acres along the main stream of the River Cauvery from its origin point to a village downstream (Cherangala). The village is shaped like a parallelogram with the river Cauvery forming its diagonal. Before reaching the village, the main stream meets four first order streams, all originating from the uphill region.

The riparian zone in the sacred landscape also provides habitat for wildlife such as Asian elephants (*Elephas maximus*), Otter species (*Amblonyx cinereus*) (near threatened) (Kausalya 2005), Endangered Nilgiri langur (*Trachypithecus johnii*) (Sunderraj and Johnsingh 2001), Indian civet (*Viverricula indica*) and so on. The forest landscapes here act as corridors for wildlife, as they are in contiguous with large protected areas such as Nagarhole National Park, Talacauvery, Brahmagiri and Pushpagiri Wildlife Sanctuaries.

## 2 Method

### 2.1 Sampling

The sampling plots chosen for the study extend from Kushalanagara (75° 58' 11.9" N and 12° 26' 51.1" E) to Talacauvery (75° 34' 39.5" N and 12° 25' 37.4" E) covering a distance of ~102 km. This region is replete with different land use practices and has been categorized into two landscapes: agro ecosystem and sacred. Agro ecosystem landscapes are human dominated areas practicing plantation, cultivation and other farming activities in the riparian zone.

To determine the status of the riparian vegetation and the variation in species composition across the two different landscapes, a total of 26 sampling sites were sampled, 16 in agro ecosystem landscapes and 10 in sacred landscapes at every 5 km distance. Of the 10 locations in the sacred grove, two are on the Cauvery river and eight are on its tributaries. A belt transect of 100 m × 50 m was used to record the trees greater than 30 cm dbh and identified following Pascal & Ramesh (1987) and Keshavamurthy & Yoganarasimhan (1990). To measure the endemic sapling density, two quadrats

of 4 m × 4 m were laid in each site.

### 2.2 Vegetation analysis

Species richness, stem density per hectare, and basal area per hectare were estimated to measure the structure and heterogeneity of the riparian vegetation. Importance value index for tree species was calculated following Curtis and Macintosh's (1951) method.

The rank abundance curves were drawn by using the Biodiversity Pro software Ver.2 (McAleece et al. 1996) for visually representing the species abundance between the sacred groves and agricultural ecosystem landscapes. A species-based rarefaction curve was done to compare the species variation between the two landscapes using Biodiversity Pro software Ver. 2. The same software was used for Bray – Curtis similarity group-average clustering to quantify the similarity between the two zones. To compare the species diversity, Shannon Wiener index and the Simpson's reciprocal index (Gimaret et al. 1998; Magurran 2004) were used.

The Shannon Wiener Diversity index ( $H$ ) was computed by using the equation

$$H = -\sum P_i \log(P_i)$$

where,  $P_i = n_i / N$  ( $n_i$  = number of individuals of a species,  $N$  = total number of individuals of all species)

Simpson's index ( $D$ ), which measures the probability that two individuals randomly selected from a sample will belong to the same species (Simpson 1949).

Simpson's index ( $D$ ) was calculated using the equation

$$D = \sum [n_i(n_i-1) / N(N-1)]$$

where  $n_i$  is the number of individuals in  $i^{\text{th}}$  species, and  $N$  is the total number of individuals. The value decreases with increasing heterogeneity. We used reciprocal of  $D$  ( $1/D$ ) in this study, as reciprocal ( $1/D$ ) of  $D$  will rise as the assemblage becomes more even (Dallmeier and Comiskey 1998; Ambinakudige and Sathish 2009).

A two – tailed  $t$  test (XL stat software) was used to compare Shannon's and Simpson's indices for each sampling plot in the categorized landscapes. To quantify the compositional similarity Bray – Curtis similarity group-average

clustering was done by using Biodiversity Pro software.

### 3 Results

From the two landscapes, 1,590 individuals of 128 species belonging to 47 families were recorded. Sacred landscapes harbored the highest number of species (83), from 38 families, while the agro ecosystem landscape supported 74 species from 35 families (Table 1). The sacred landscapes had 65.06 % of unique species within the riparian zone, slightly more than the agro ecosystem landscape (60.8%). Also, 29 species constituting 22.4% of the total were common to both zones. Total basal area cover for the sacred landscapes was 19.8 m<sup>2</sup>ha<sup>-1</sup>, against 10.1 m<sup>2</sup>ha<sup>-1</sup> for the agro ecosystem landscapes.

**Table 1** Vegetation characteristics in Agro ecosystem landscapes (Agro-L) and Sacred landscapes (Sacred-L) of the riparian zone

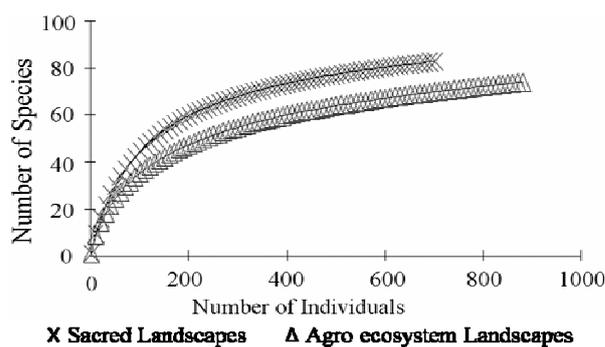
Variables	Agro-L	Sacred-L
Species Nos	74	83
Family Nos	35	38
Genera Nos	57	59
Unique species	45	54
Mean species Nos /plot	12.7 ± 5.9	22.8 ± 4.1
Stem density (trees/ha)	110.6	141
Basal area (m <sup>2</sup> ha <sup>-1</sup> )	10.1	19.8

The rarefaction plot curve for the sacred landscapes remained steeper than the agro ecosystem landscapes, indicating the presence of more diverse vegetation (Figure 1).

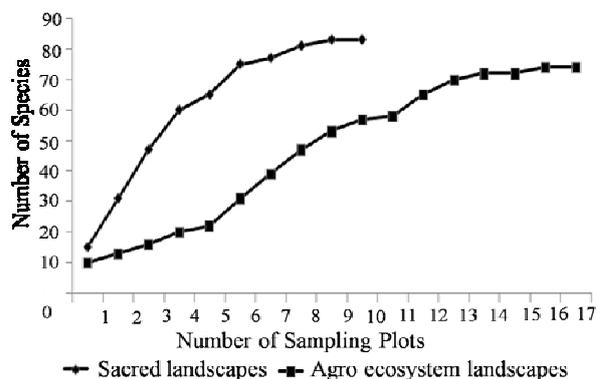
The species area curve (Figure 2) for both landscapes showed saturation at the curve end, indicating that the number of sampling plots performed was sufficient to account for almost all species.

The similarity index for endemic species between the two ecosystems was calculated to be around 36.1%. However, for the saplings of endemic species, the value is 55.4% (Figure 3).

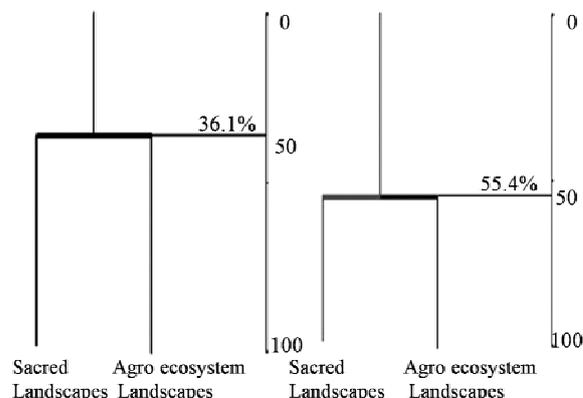
The Shannon Wiener diversity index for the sacred landscape (5.3) is higher than the agro ecosystem (4.4). A lesser degree of standard



**Figure 1** Species rarefaction plot for the two different landscapes



**Figure 2** Species accumulation curve for different landscapes



**Figure 3** Bray-Curtis Cluster Analysis (Single Link) for a) tree species similarity b) species of endemic saplings similarity for two different landscapes

deviation for the two zones signifies nearness of cluster of diversity to their mean. It also signifies more diversity in sacred landscapes. The t-test revealed a non-significant relationship between the two zones at the 0.05% level. According to the Simpson’s reciprocal index, the sacred landscapes (28.9) is more diverse than agro ecosystem (18.8). Also, the t-test for Simpson’s reciprocal diversity

index signifies an significant difference in diversity between the two landscapes. The species evenness calculation confirmed that there was a more even distribution in the sacred landscapes (Table 2).

The rank abundance curve for agro ecosystem landscapes (Figure 4) indicates the dominance of *Coffea arabica* (108) followed by *Mangifera indica* (80), *Hopea parviflora* (79), *Pongamia pinnata* (76) and *Grevillea robusta* (49). The curve also shows that there are 26 rare species with less than two individuals (Figure 4). In the sacred landscapes, *Elaeocarpus tuberculatus* (80) is the most dominant species followed by *Dimocarpus longen* (48), *Garcinia xanthochymus* (34), *Hydnocarpus laurifolia* (28) and *Mangifera indica*

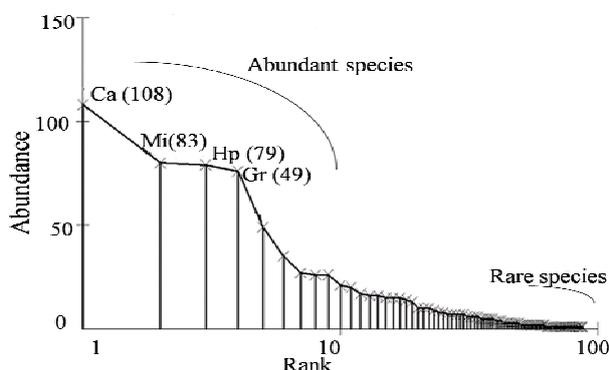
(28). A total of 24 rare species were found in this zone, again represented by less than two individuals (Figure 5).

The sacred landscapes supported the highest number of endemic tree saplings (Table 3) with sizeable number of *Syzygium mundagum* stands followed by *Palaquium ellipticum* and *Litsea mysorensis*. While in agro ecosystem landscapes, *Nothopegia beddomei* shared the highest percentage followed by *Hydnocarpus laurifolia* and *Meiogyne pannosa*.

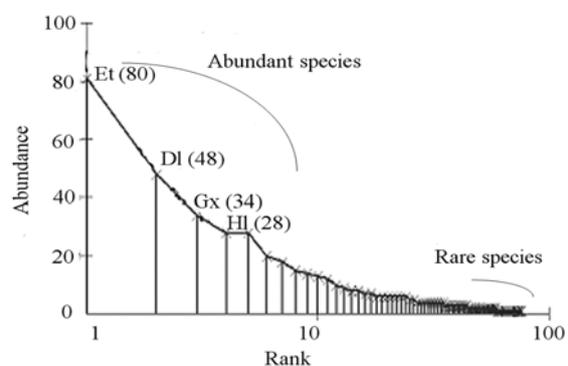
In the agro ecosystem landscape, the ripicole tree species *Hopea parviflora* (38.58) exhibited highest IVI with high relative dominance and frequency followed by *Mangifera indica* (28.3),

**Table 2** Shannon wiener diversity index (DI) and Simpson’s reciprocal index (RI)

Agro ecosystem landscapes					
Shannon – Wiener DI		Simpson’s RI		Evenness	
H	4.4	D	19.3	D	0.72
Mean	2.3	Mean	7	Mean	0.68
SD	0.4	SD	4.2	SD	0.08
Sacred landscapes					
H	5.3	D	29.5	D	0.83
Mean	3.4	Mean	12.9	Mean	0.74
SD	0.3	SD	4.7	SD	0.05
Sacred and Agro ecosystem landscapes					
Difference	-0.433	Difference	-4.581	Difference	-0.025
t (observed value)	-1.957	t (observed value)	-2.546	t (observed value)	-0.765
t  (critical value)	2.064	t  (critical value)	2.064	t  (critical value)	2.064
DF	24	DF	24	DF	24
p-value (two tailed)	0.062	p-value (two-tailed)	0.018	p-value (two-tailed)	0.452
alpha	0.05	alpha	0.05	alpha	0.05



**Figure 4** Rank abundance plot for the species observed in agro ecosystem landscapes. (Ca – *Coffea arabica*, Mi – *Mangifera indica*, Hp – *Hopea parviflora*, Pp – *Pongamia pinnata*, Gr – *Grevillea robusta*)



**Figure 5** Rank abundance plot for the species observed in sacred landscapes (Et- *Elaeocarpus tuberculatus*, Dl – *Dimocarpus longen*, Gx – *Garcinia xanthochymus*, Hl – *Hydnocarpus laurifolia*, Mi – *Mangifera indica*)

**Table 3** Endemic tree saplings per 0.1 ha in riparian stretch of the Sacred landscapes (Agro-L) and agro-ecosystem landscapes (Agro-L)

Species	Sacred-L	Agro-L
<i>Actinodaphne bourdilloni</i>	125	0
<i>Actinodaphne malabarica</i>	0	4
<i>Aphanamixis polystachia</i>	275	8
<i>Artocarpus hirsuta</i>	0	20
<i>Calophyllum apetalum</i>	0	8
<i>Cinnomum</i>	50	8
<i>Cinnamomum riparium</i>	25	0
<i>Diospyros saldhanae</i>	175	0
<i>Garcinia gummi-ghata</i>	50	0
<i>Garcinia indica</i>	150	4
<i>Glochidion ellepticum</i>	150	0
<i>Gordonia obtusa</i>	350	20
<i>Holigarna arnotiana</i>	75	4
<i>Hopea parviflora</i>	75	32
<i>Hydnacarpus laurifolia</i>	75	68
<i>Lasianthus jackianus</i>	275	0
<i>Litsea bourdilloni</i>	225	0
<i>Litsea floribunda</i>	0	8
<i>Litsea laevigata</i>	50	0
<i>Litsea mysorensis</i>	375	0
<i>Meiogyne pannosa</i>	0	44
<i>Nothopegia beddomei</i>	125	152
<i>Olea dioca</i>	275	12
<i>Palaquium ellepticum</i>	425	0
<i>Persea macarantha</i>	50	8
<i>Syzygium heynaenum</i>	0	16
<i>Syzygium laetum</i>	225	16
<i>Syzygium mundagum</i>	1,100	0
Total	4,800	432

*Pongamia pinnata* (22.1) and *Coffea arabica* (18). The planted species *Coffea arabica* has found among top 5 species having highest IVI that surpassed the ripicole species and endemic species (Table 4) such as *Lophopetalum wightianum*, *Hydnocarpus pentandra*, *Madhuca neerifolia* etc. In the sacred landscapes highest IVI for the ripicole species is accorded to *Eleaocarpus tuberculatus* (41.07) and *Vateria indica* (37.5). *Vateria indica* is typified with highest dominance (33) and lesser frequency (1.8), while *Eleaocarpus tuberculatus* stands high among density (11.3) and distribution (4.5). Other ripicole species include *Cinnamomum riparium* (3.0), *Hydnocarpus*

*laurifolia* (4.9), *Pinnanaga dicksonii* (2.9), *Myristica dactyloides* (5.2) with lesser IVI in the forest landscapes.

## 4 Discussion

### 4.1 Floristic composition and stand density

The present study describes the floristic pattern of riparian vegetation composition, structure and species assemblage in the two different landscapes. Though both of the landscapes fall in the same geographical area, a significant difference between stem density and the basal area is observed between the two. The basal area in the riparian forest of agro ecosystem landscapes with monospecific plantations represents a poorer structure of the riparian vegetation than the sacred landscapes. *Hopea parviflora* shared the highest percent of basal area (20.31%) followed by *Mangifera indica* (11.9%) and *Pongamia pinnata* (7.2%). A consistent pattern of reduction in species richness is observed in the agro ecosystem landscapes. Among the observed species 65% are exclusive to the sacred landscapes, with a sizable number of endemic species. Out of 128 tree species across the two zones, 29 belonging to the families Myrtaceae, Moraceae, Fabaceae and Clusiaceae are common to both. The similarity index for the tree species in the two zones indicated a lesser degree of similarity (36.1%) between them. Besides *Coffea arabica* and *Grevillia robusta*, abundant species in the agro ecosystem landscapes, *Mangifera indica*, *Hopea parviflora* and *Pongamia pinnata* were also abundant on freshly deposited sediments in areas exposed to disturbances. *Hopea parviflora* as a mature tree in a few pockets of this zone remained intact despite disturbances. *Elaeocarpus tuberculatus*, a ripicole species, and *Dimocarpus longen* were dominant in the sacred landscapes followed by *Garcinia xanthochymus*, *Hydnocarpus laurifolia* and *Mangifera indica*. Ramachandra et al. (2004) opined that *Elaeocarpus tuberculatus* and *Mangifera indica* represent the key species to maintain the riverine ecosystems and the associated aquatic fauna in the region.

**Table 4** Importance Value Index for the riparian tree species in the two zones

Sacred landscape species	IVI <sub>300</sub>	Agro ecosystem landscape species	IVI <sub>300</sub>
<i>Actinodaphne malabarica</i> Balkr.	0.8	<i>Acacia myanquium</i> Willd.	0.77
<i>Actinodaphne bourdillonii</i> Gamble	3.64	<i>Actinodaphne</i> sp	0.65
<i>Aglaia tomentosa</i> Teijsm & Binn.	1.34	<i>Anogeissus latifolia</i> Roxb	0.73
<i>Antidesma menasu</i> L.	4.66	<i>Aporosa lindleyana</i> (Wt.) Baill.	5.91
<i>Apama siliquosa</i> Lam.	6.89	<i>Ardisia solanaceae</i> Roxb	0.78
<i>Aphanamixis polystachya</i> (Wall.) Parker	5.88	<i>Areca catechu</i> L.	0.89
<i>Aporosa acuminata</i> Thw.	0.75	<i>Artocarpus hirsutus</i> Lam.	3.14
<i>Aporosa lindleyana</i> (Wt.) Baill.	1.44	<i>Artocarpus integrifolia</i> Forst.	6.03
<i>Archidendron monodelphum</i> Roxb	3.96	<i>Bombax ceiba</i> L.	0.77
<i>Artocarpus integrifolia</i> Forst.	0.84	<i>Butea monospermae</i> Lamk.	2.54
<i>Artocarpus</i> sp	2.34	<i>Carallia brachiata</i> (Lour.) Merrill	1.1
<i>Baccaurea courtallensis</i> Muell.-Arg.	2.33	<i>Calophyllum apetalum</i> Willd.	0.66
<i>Bischofia javanica</i> Bl.	2	<i>Canthium dicoccum</i> Gaertn.	0.64
<i>Canarium strictum</i> Roxb.	3.53	<i>Careya arborea</i> Roxb.	2.82
<i>Celtis</i> sp	0.63	<i>Caryota urens</i> L.	1.62
<i>Celtis trimorensis</i> Spanoghe	0.62	<i>Celtis trimorensis</i> Spanoghe	3.09
<i>Chionanthus linocieroides</i> Wt.	3.84	<i>Clausena</i> sp	1.44
<i>Cinnamomum malabaratum</i> Gamble	0.76	<i>Cocus nucifera</i> L.	1.44
<i>Cinnamomum riparium</i> Gamble.	3.1	<i>Coffea arabica</i> L.	18.0
<i>Cinnamomum</i> sp	0.61	<i>Crataeva magna</i> (Lour.) DC	9.0
<i>Citrus grandis</i> L.	0.63	<i>Dalbergia latifolia</i> Roxb.	1.3
<i>Clausena</i> sp	1.86	<i>Dalbergia sissoo</i> Wt.	4.24
<i>Cyathea</i> sp	1.41	<i>Diospyros malabarica</i> Gaub.	6.46
<i>Dillenia pentagyna</i> Roxb.	6.1	<i>Dillenia pentagyna</i> Roxb.	0.69
<i>Dimocarpus longan</i> Lour.	10.5	<i>Diospyros</i> sp	1.05
<i>Diospyros bourdillonii</i> Brand.	0.95	<i>Elaeocarpus tuberculatus</i> Roxb.	1.02
<i>Diospyros saldanhae</i> Kostermans	2.67	<i>Eucalyptus</i> sp	1.09
<i>Diospyros</i> sp	1.65	<i>Ficus glomerata</i> Roxb.	4.31
<i>Elaeocarpus tuberculatus</i> Roxb.	41.1	<i>Ficus racemosa</i> L.	1.41
<i>Ficus glomerata</i> Roxb.	0.9	<i>Ficus religiosa</i> L.	1.59
<i>Ficus</i> sp	1.74	<i>Ficus</i> sp	1.89
<i>Garcinia gummigata</i> L.	2.66	<i>Garcinia gummigata</i> L.	0.64
<i>Garcinia indica</i> (Thouars) Choisy	3.16	<i>Garcinia indica</i> (Thouars) Choisy	1.69
<i>Garcinia morella</i> (Gaertn.)	4.09	<i>Garcinia morella</i> (Gaertn.)	1.56
<i>Garcinia xanthochymus</i> J.Hk.exAnders.	9.17	<i>Gordonia obtusa</i> Wall.	1.31
<i>Gordonia obtusa</i> Wall.	3.54	<i>Gliricidia sepium</i> (Jacq.) Kunth	0.85
<i>Glochidion ellipticum</i> Wt.	5.6	<i>Gmelina arborea</i> Roxb.	4.23
<i>Glycosmis mauritiana</i> Lam.	1.6	<i>Grevillea robusta</i> A. Cunn.	8.67
<i>Glycosmis macrocarpa</i> Wt.	0.63	<i>Hopea parviflora</i> Bedd.	38.6
<i>Grewia</i> sp	0.62	<i>Hopea wightiana</i> Wall.	4.73
<i>Holigarna arnottiana</i> J.Hk.	4.37	<i>Hydnocarpus laurifolia</i> (Bedd.) Warp	2.93
<i>Homonoia riparia</i> Lour.	2.26	<i>Hydnocarpus pentandra</i> (buch.-Ham)Oken	2.78

-To be continued-

-Continued-

**Table 4** Importance Value Index for the riparian tree species in the two zones

Sacred landscape species	IVI <sub>300</sub>	Agro ecosystem landscape species	IVI <sub>300</sub>
<i>Hopea parviflora</i> Bedd.	10.8	<i>Ixora bracheata</i> Roxb.ex Dc	0.69
<i>Hopea wightiana</i> Wall.	0.86	<i>Lagerstroemia lanceolata</i> Wall.	1.4
<i>Hydnocarpus laurifolia</i> (Bedd.) Warp	7.47	<i>Leucaena leucocephala</i>	2.72
<i>Ixora nigricans</i> R.Br.Wt.&Arn	0.61	<i>Litsea bourdillonii</i> Gamble	8.5
<i>Lasianthus jackianus</i> Wt.	6.34	<i>Litsea</i> sp	0.69
<i>Leea indica</i> (Burm.f.) Merr.	1.53	<i>Lophopetalum wightianum</i> Arn.	0.82
<i>Litsea bourdillonii</i> Gamble	2.94	<i>Madhuca neerifolia</i> (Moon) H.J. Lam	6.12
<i>Litsea laevigata</i> Kosterm.	1.88	<i>Mangifera indica</i> L.	28.4
<i>Litsea mysorensis</i> Gamble	2.42	<i>Meiogyne pannosa</i> (Dalz.) Sinclair	1.22
<i>Litsea</i> sp	0.78	<i>Memecylon umbellatum</i> Burm.f.	2.27
<i>Macaranga peltata</i> (Roxb.) Mueller	4.8	<i>Musa paradisiaca</i> L.	4.85
<i>Madhuca neerifolia</i> (Moon) H.J. Lam	1.45	<i>Palaquium ellipticum</i> (Dalz.) Baill.	0.66
<i>Mangifera indica</i> L.	5.94	<i>Persea macrantha</i> (Nees) Kosterm.	2.0
<i>Margaritaria indica</i> L.	1.44	<i>Pongamia pinnata</i> L.	22.2
<i>Meiogyne pannosa</i> (Dalz.) Sinclair	1.39	<i>Psidium guajava</i> L.	0.65
<i>Memecylon umbellatum</i> Burm.f.	1.43	<i>Pterocarpus</i> sp	2.87
<i>Mesua ferrea</i> L.	3.83	<i>Salix tetrasperma</i> Roxb.	6.12
<i>Microtropis latifolia</i> Wt. ex Lawson	2.22	<i>Sapindus emarginatus</i> Vahl.	0.7
<i>Myristica dactyloides</i> Gaertn.	5.26	<i>Schefflera wallichiana</i> Harms	0.67
<i>Myristica fatua</i> Houtt.	3.55	<i>Schleichera oleosa</i> (Lour.) Oken	1.34
<i>Nothopogia beddomie</i> Gamble	1.53	<i>Syzygium cumini</i> (L.) Skeels	2.84
<i>Ochreinauclea missionis</i> (Wall.) Ridsd	1.16	<i>Syzygium hemisphericum</i> (Wt.) Alston	0.71
<i>Olea dioca</i> Roxb.	3.17	<i>Syzygium heyneanum</i> Wall. ex Gamble	4.69
<i>Palaquium ellipticum</i> (Dalz.) Baill.	4.7	<i>Syzygium jambose</i> L. (Alston)	4.41
<i>Persea macrantha</i> (Nees) Kosterm.	2.37	<i>Syzygium laetum</i> (Buch.-Ham.) Gandhi	5.25
<i>Pinanga dicksonii</i> (Roxb.) Bl.	2.96	<i>Syzygium lineare</i> Wall.	8.25
<i>Schefflera wallichiana</i> Harms	2.03	<i>Tectona grandis</i> L.f.	0.68
<i>Schleichera oleosa</i> (Lour.) Oken	2.98	<i>Terminalia bellerica</i> Gaertn.) Roxb.	10.6
<i>Symplocos cochinchinensis</i> Lour	1.08	<i>Terminalia tomentosa</i> Roxb.	3.85
<i>Symplocos racemosa</i> Roxb.	1.3	<i>Trema orientalis</i> (L.) Bl	2.42
<i>Syzygium caryophyllatum</i> (L.) Alston	0.61	<i>Vateria indica</i> L.	5.89
<i>Syzygium gardeneri</i> Thw	4.14	<i>Vitex negundo</i> L.	0.66
<i>Syzygium jambose</i> L. (Alston)	1.14		
<i>Syzygium laetum</i> (Buch.-Ham.) Gandhi	2.56		
<i>Syzygium lineare</i> Wall.	0.77		
<i>Syzygium mundagum</i> (Bourd.) Chitra	3.31		
<i>Tabernaemontana heyneana</i> Wall.	0.61		
<i>Vateria indica</i> L.	37.5		
<i>Viburnum punctatum</i> Ham. ex G.Don	0.63		
UK 1 (Euphorbiceae)	0.61		
UK 2 (Fabaceae)	0.76		

\*UK – Un-known

#### 4.2 Diversity indices

The Shannon – Wiener diversity recorded in the agro ecosystem landscapes corresponds to the values observed in other tropical evergreen forests (Parthasarathy 1999; Parthasarathy 2001; Shastri et al. 2002) and the diversity is not exaggerated by an abundance of non-forest species. Though massive mono-specific plantation is observed, small numbers of native species such as *Terminalia bellerica*, *Artocarpus hirsuta*, *Artocarpus integrifolia*, *Hydnocarpus laurifolia* are retained for the purpose of providing shade to coffee plantations. The Shannon - Wiener diversity for the riparian forest of sacred landscapes corroborates with the diversity values of medium elevation wet evergreen forests (Ramakrishnan et al. 2000). The Simpson's reciprocal index confirmed a greater equitability of species in the sacred landscapes.

#### 4.3 Importance value index

In the agro ecosystem landscapes a ripicole, *Hopea parviflora* (38.5) is the lone evergreen species with highest IVI and relative dominance followed by *Mangifera indica* (28.3). Encroachments for coffee farming and paddy cultivation along the riparian corridor have lead to a decline in ripicole and evergreen species. *Pongamia pinnata* and *Coffea arabica* stand next to the former with an IVI 22.1 and 17.95 characterized with high relative density surpassing the other ripicole species like *Madhuca neerifolia* (6.1), *Vateria indica* (5.8), *Lophopetalum wightianum* (0.82), *Elaeocarpus tuberculatus* (1.01) which are crucial for the riparian zone. As the ripicole species offer a canopy, their exclusion could affect the forest composition and structure (Ramakrishnan et al. 2000) in the riparian corridor. The abandoned areas in the riparian corridors caused by sand mining and paddy cultivation promoted the appearance of deciduous species *Pongamia pinnata* and *Salix tetraspermae*, subsequently posing a threat to the evergreen species that demand sufficient shade and soil moisture in the sapling stage. The two deciduous species are the rapid colonizers in the riparian zones by means of hydrochory. Interestingly, these species also dominated in the lower stretch of the

River Cauvery (Sunil et al. 2010) and could pose a threat to the survival of existing native tree species in the riparian region. The sacred landscapes exhibited highest IVI for the ripicole species *Elaeocarpus tuberculatus* (41.05) and *Vateria indica* (37.5). *Vateria indica* is typified with lesser frequency (1.82) and highest dominance (33.0), where as *Elaeocarpus tuberculatus* has more distribution (4.5) and relative density (11.34). Other ripicole species include *Cinnamomum riparium* (3.6), *Hydnocarpus laurifolia* (4.9), *Madhuca neerifolia* (2.7), *Pinnanaga dicksonii* (1.9), *Myristica dactyloides* (3.4) with lesser IVI in the sacred landscapes.

#### 4.4 Status of native and endemic species

The anthropogenic activities operating in the agro ecosystem landscapes have encouraged exotic species invasion by 20% in the riparian buffer. However, 77% of the native species such as *Hopea parviflora*, *Garcinia indica*, *Ixora bracheata*, *Hydnocarpus laurifolia*, *Artocarpus hirsutus*, and *Vateria indica*, are still retained because they provide valuable services to the local people, as a part of their livelihood in terms of shade, medicinal, fuel wood, fodder and protection from soil erosion. The repository of these native and endemic species in the riparian buffer along the agro ecosystem landscapes is a boon to the adjacent fragmented landscapes lacking native species richness. The natural pollinators like honey bees, bats etc., residing in the coffee plantations play a larger role in the pollination of native species (Ganesh 1996) due to the riparian vegetation buffer. Through this ecologically acceptable process, there is a chance of restoration and recovery of native species in the fragmented landscapes of the Western Ghats.

Sacred landscapes harbored more endemic tree species saplings than the agro ecosystem landscapes. Some proportion of endemic saplings that survived in the riparian corridor have withstood anthropogenic pressures in the agro ecosystem landscapes and ensured the maintenance of riparian buffer, and have also provided a natural habitat for the rare and endemic species. A lower homogeneity (55.5%) of endemic saplings was observed between the two zones. Thereby, endemic species observed in the riparian zone appear to provide key services for the adjacent

terrestrial and riverine habitats. *Syzygium mundagum*, a key and endemic species is preferred by the endangered Nilgiri langur (*Trachypithecus johnii*). The herb *Occhlandra* sp, growing widely here, also attracts elephants to the riparian zone (personal observation).

#### 4.5 Importance of the riparian vegetation buffer in mountainous regions

Riparian vegetation is likely to control many processes related to surface and subsurface flow through its complex physical structures (Tabacchi, 2000). Living and dead vegetation, plant debris, resistant (coarse woody debris) or labile (litter) structures of riparian vegetation can obstruct, divert or facilitate water flow towards downstream by protecting shorelines from erosion caused during heavy run-off. Hence, maintaining the continuity of the riparian vegetation buffer in the study area could also offer other benefits to downstream ecosystems and people. In Karnataka, 3 districts with one urban centre found in the downstream area are dependent on river water for drinking, agriculture and livelihood. Currently, these stakeholders are suffering due to the scarcity of water during summer months. Thus, in order to meet the growing demand of water, protection of riparian vegetation in the mountainous region is an absolute necessity. Besides maintaining water quality, the riparian vegetation in the mountainous regions play a prominent role in maintaining the heterogeneity of endangered fish species like *Barbodes wynaadensis*, *Labio Kontius*, *Silonia childreni* (White cat fish), *Tor Putitora* (Mahseer) (Smakhtin et al. 2007; Lakra et al. 2010). Hence, protection of riparian vegetation is vital to ensure life and function of river ecosystem. In India, there is no principal law for riparian vegetation protection like in other countries like Australia, where several laws such as *Water Act 2000*, *Land Act 1994* and *Nature Conservation Act 1992* etc., were enacted for the protection of riparian zone against disturbances, maintaining physical integrity and placing constraints on clearing of trees in critical areas of riparian zone. In India, National Forest Policy of 1988, a principal legislation for the conservation of state and natural forests of the country articulates the retention of two thirds of forest cover in the hilly areas offers

importance to the riparian vegetation indirectly. The Kodagu region of the study area is also one of the designated hilly regions of India, needs protection and conservation (GOI 2008). Recently Government of India (GOI 2006) has issued guidelines for Environment Impact Assessment (EIA), which stipulate no development up to 100 m from river with the interest of protection of riparian vegetation. However, principal law pertaining only to riparian vegetation in India is necessary to protect the riparian areas for the restriction of activities containing disturbances.

## 5 Conclusion

Recurring anthropogenic impacts have disrupted the diversity of the riparian vegetation in the agro ecosystem landscapes, compared to sacred grove landscapes of the River Cauvery headwaters. Species diversity remains higher in the sacred landscapes, which occupied a small proportion of the study area. The deciduous tree species of the top order in agro ecosystem landscapes pose a major threat for the survival of shade-demanding evergreen and native species. The proportion of endemic species in the study area is not the same in the two categorized landscapes reflecting the stress on the native species regeneration. Maintenance of a minimum riparian buffer of 30 – 100 m wide is imperative to support the quality of habitat and to minimize the impacts of floods on the surrounding agro ecosystem landscapes.

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