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Socio-cultural protection of endemic trees in humanised landscape

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Abstract Culturally protected forest patches or sacred groves have been the integral part of many traditional societies. This age old tradition is a classic instance of community driven nature conservation sheltering native biodiversity and supporting various ecosystem functions particularly hydrology. The current work in Central Western Ghats of Karnataka, India, highlights that even small sacred groves amidst humanised landscapes serve as tiny islands of biodiversity, especially of rare and endemic species. Temporal analysis of landuse dynamics reveals the changing pattern of the studied landscape. There is fast reduction of forest cover (15.14–11.02 %) in last 20 years to meet up the demand of agricultural land and plantation programs. A thorough survey and assessment of woody endemic species distribution in the 25 km^2 study area documented presence of 19 endemic species. The distribution of these species is highly skewed towards the culturally protected patches in comparison to other land use elements. It is found that, among the 19 woody endemic species, those with greater ecological amplitude are widely distributed in the studied landscape in groves as well as other land use forms whereas, natural population of the sensitive endemics are very much restricted in the sacred grove fragments. The recent degradation in the sacred grove system is perhaps, due to weakening of traditional belief systems and associated laxity in grove protection leading to biotic disturbances. Revitalisation of traditional practices related to conservation of sacred groves can go a long way in strengthening natural ecological systems of fragile humid tropical landscape.

Keywords Endemics · Landscape management · Sacred grove · Siddapur · Spatial distribution · Species diversity

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Introduction

Culturally protected forest fragments, popularly known as sacred groves in India are relics of original forests that covered the region before forest cutting and burning initiated with the spread of civilization (Chandran et al. 1998). These preserved forest patches are usually close to human settlement, thus, forming an integral part of traditional rural communities. The growing human intervention in recent times has been modifying the natural system (especially landscape features) to a great extent as observed by many researchers (Achard et al. 2002; Lambin et al. 2003; Echeverria et al. 2006). Deforestation and forest fragmentation are considered as two major drivers of biodiversity loss, changes in climate and ecosystem function (Sala et al. 2000; Wade et al. 2003; Zhu et al. 2004). These changes have an obvious impact on sacred groves existence too that could be identified by their diminishing spatial expanse with time. In an altered landscape grove is often represented either by cluster of trees or small, isolated patches of few acres of land facing diverse disturbance regime which is in sharp contrast to the groves present within reserve forest jurisdiction or institutionalised sacred sites. Despite their size limitations, these fragments conserve local biodiversity and offer important ecological services viz. pollination and seed dispersal by harbouring honey bees and small mammals, species diversity maintenance, avifauna survival etc. (Deb et al. 1997; Malhotra et al. 2001; Ahmed 2004; Bhagwat et al. 2005; Sashikumar 2005; Bodin et al. 2006; Bossart et al. 2006; Ray and Ramachandra 2010; Chandran et al. 2010; Chandrashekara 2011; Hu et al. 2011).The biological significance of many a sacred grove, as evidenced by the presence of rare and endemic species, brought out in several studies highlighting their conservation values (Jamir and Pandey 2003; Chandran et al. 2008; Rao et al. 2011; Sunil et al. 2012; Gao et al. 2013).

Globally, there has been a trend to recognise the importance of remnant patches, woodlands for protection of biodiversity in production landscape. Studies have already emphasized their vital role in providing shelter to a good number of biodiversity elements (i.e. plants, animals and lower group of life forms) in an otherwise modified or converted ecosystems (O'Neal 2004; Aerts et al. 2006; Gardner et al. 2009; Lindenmayer et al. 2009; Cox and Underwood 2011). Sacred groves are unique in this regard as their existence is very much related to cultural and religious life of the community, therefore, enjoying social protection to some extent (Ormsby and Bhagwat 2010).

In India, most studies on sacred groves have encompassed floral and faunal diversity and maintenance of rare threatened and endemic species with limited descriptions of the ecological profiles and disturbance regimes from some regions (Malhotra et al. 2001; Khan et al. 2008). Relatively large groves in Kodagu district of central Western Ghats where the faith in their guardian gods still strong, harbour a good number of forest tree and bird species even outside the forest. In a landscape dominated by cultivated crops, groves have significant contribution in conservation of biodiversity in the coffee-agriculture dominated landscape matrix (Bhagwat et al. 2005; Ambinakudige and Sathish 2009; Page et al. 2010). In Eastern Ghats highlands of southern peninsular India leaving forest areas aside, sacred groves continue to be the most species rich ecosystem in agricultural landscapes (Aiama 2007). However, realizing the groves' presence in diverse ecosystems and varied degrees of management and disturbances they face, it is pertinent to explore their potential and constraints in diverse land use and management scenario.

Despite literature abounding on sacred groves especially the richness of rare and endemic species they harbour, very few studies have uncovered greater details of their population status, reproductive biology, survival strategy (but see Tambat et al. 2005; Pundee 2007; Rajanikanth et al. 2010). These become important in conservation planning and management particularly in humanised landscape as conservation is often tied with livelihood and utilitarian aspects (Cox and Underwood 2011; Mendenhall et al. 2011; Sambuichi et al. 2012). Thus, an understanding of the quantitative details of the ecological correlates is necessary for rare/endemic species persistence as a part of humanized landscape.

In this study, we evaluated the status of woody endemics in sacred groves and contrasted it with the surroundings in a 25 km^2 large landscape located in central Western Ghats of India. We investigated—(1) landuse dynamics of the study area, (2) role of sacred groves in the survival and continuity of endemic tree species in the study landscape and, (3) on potential factors which may affect their future existence.

Study area

The Western Ghats along with Sri Lanka constitute one of the 34 global biodiversity hot spots (Myers et al. 2000; Mittermeier et al. 2005). It harbours forests of varied kinds such as, tropical evergreen, semi-evergreen, moist and dry deciduous types. These forests in many places, because of human impacts through last few millennia have produced secondary kinds of vegetation such as savannah, scrub and grasslands (Pascal 1988). Uttara Kannada is one of the forested districts of central Western Ghats in the state of Karnataka, India. Sacred groves are present throughout the district, under various management systems and in different states of maintenance. The current study is concentrated into 5 km × 5 km area (14°16′48″–14°18′36″N latitude and 74°50′24″–74°54′00″E longitude) (Fig. 1) in eastern part of Siddapur taluk of Uttara Kannada district. The undulating landscape here is characterised by rice fields and small areca nut (*Areca catechu*) gardens interspersed with grassy plains, scrub, degraded secondary forests, monoculture tree plantations and small sacred groves. Rice crop is mainly rainfed and vegetables, ginger and millets are optional crops during dry seasons grown in small portions of the rice fields. The tree plantations mainly consist of the exotic *Acacia auriculiformis* and *Casuarina equisitifolia.*

Methods

The study was carried out during March–October 2010. Knowledge on the focal landscape was gained through the Survey of India topographic maps (48J 15, 1978), Google Earth data (http://googleearth.com) and earlier studies on the sacred groves and general landscape (Chandran and Gadgil 1998; Nagendra and Gadgil 1999; Nagendra 2001).

Study of landuse dynamics

Land use dynamics of the focal region has been studied using data acquired at regular interval through space borne sensors (Landsat Thematic Mapper and IRS-LISS IV [multispectral]). Landsat data of 1989, 1999 and 2010 were downloaded from the public domain (http://www.landsat.org) and IRS data (2010) were procured from the NRSC, Hyderabad (http://nrsc.gov.in). These data were geometrically corrected for the UTM coordinate system of zone 43 using GCPs (ground control points). Land use analysis involved (i) generation of False Colour Composite (FCC) of remote sensing data (bands—green, red and NIR). This helped in locating heterogeneous patches in the landscape (ii)

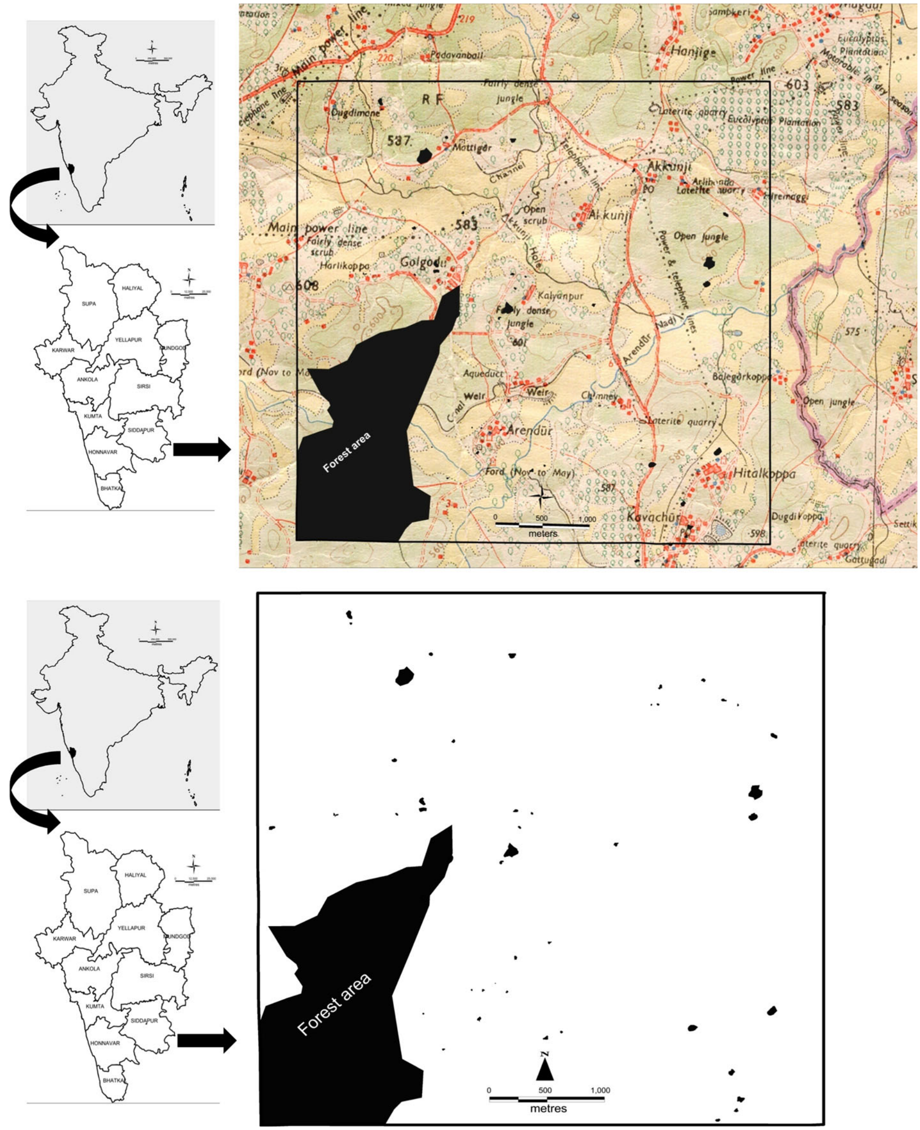

Fig. 1 Location of sacred groves and forest patch (*dark shaded polygons*) in the study area

selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15 % of the study area and uniformly distributed over the entire study area, (iii) loading these training polygons co-ordinates into pre-calibrated GPS, (iv) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, v) supplementing this information with Google Earth (http://googleearth.com) and Bhuvan (http://bhuvan.nrsc.gov.in), and vi) 60 % of the training data has been used for classification, while the balance is used for validation or accuracy assessment (Ramachandra et al. 2012).

Land use analysis was carried out using supervised pattern classifier—Gaussian Maximum Likelihood Classifier (GMLC) algorithm. Remote sensing data was classified using signatures from training sites that include predominant land use types. Mean and covariance matrix were computed using estimate of maximum likelihood estimator. This technique is proved to be a superior classifier as it uses various classification decisions using probability and cost functions (Ramachandra et al. 2012). Spectral classification inaccuracies were measured by a set of reference pixels. Based on the reference pixels, confusion matrix, kappa (κ) statistics and producer's and user's accuracies were computed.

Mapping of current landscape elements

The position of sacred groves and areas covered by each were ascertained using global positioning system (GPS) (Garmin eTrex Vista, USA) and by transferring the data to MapInfo (version 11.0). Other elements of landscape viz, human settlement, forest plantation, forest and agricultural areas were demarcated with the help of the Survey of India topographic maps (1:50,000 scale), Google Earth, village maps and forest maps pertaining to the region.

Status of tree species in sacred groves

Census of tree populations was done grove wise as groves were relatively small in size, the largest one measuring just 18,000 m^2 (i.e. 1.8 ha) and rest were mostly in fractions of a hectare. Species wise abundance was recorded and measurements like girth at breast height (GBH, at 137 cm), height was taken for tree individuals ($\geq$30 cm GBH).

To know the future of endemic tree species within the sacred groves, their saplings (>1 m in height but <30 cm GBH) and seedlings (<1 m in height) were counted in randomly distributed sample plots (5 m × 5 m each) covering 50 % of total area of the larger groves (>5,000 m^2). For smaller groves i.e. <5,000 m^2, the entire forest floor was searched for juvenile members.

Tree species study outside the sacred groves

A small forest patch was present in the south-west corner of the studied landscape. The plant diversity was measured using transect cum quadrat method. The transect had five tree quadrats of 20 m × 20 m size laid alternatively to the right and left, at intervals of 20 m between quadrats, with nested shrub and herb quadrats i.e. 5 m × 5 m and 1 m × 1 m respectively within these tree quadrats. Our sampling covered a total of 2,000 m^2 area.

Endemic tree species hardly occurred in other elements of landscape such as roadside, household gardens and farms. Nevertheless their sightings if any were recorded.

Recording of disturbances

Due to small size, all except the largest three (>5,000 m^2) were fully covered for disturbance measurement. For three largest groves (i.e. Ara39, Kal49 and Mat25), fifty percent of the grove area was covered by 10 m × 10 m plots. The plots were in alternate order along the line transects and were 10 m apart. Seven distinct indicators of disturbance i.e. presence of invasive species, exotic plantation, root exposure (which is an indicator of soil erosion), presence of cattle dung (indicator of grazing), protection status, distance from main road, and grove area were recorded from each studied grove.

For invasive species (e.g. *Lantana camara* and *Eupatorium* sp.), and forest department plantation (*A. auriculiformis*) the degree of presence was categorized on a scale of 1–3: 1 = no presence; 2 = <50 % in edge (for invasive), and presence in edge (for plantation); 3 = >50 % in edge/interior region (for invasive) and interior region (for plantation). In order to measure root exposure (an indicator of soil erosion) the following was adopted: 1 = ≤10 % exposure; 2 = 25 %; 3 = ≥50 %. For cattle dung it was 1 = no/ ≤10 %; 2 = >10 %. Both the measures were taken plot-wise, and then averaged for three largest groves (i.e. Ara39, Kal49 and Mat25). The distance of the groves from main road was measured in MapInfo (version 11.0) and categorized on a scale of 1–3:1 = 0.1–0.4 km; 2 = 0.05–0.09 km; 3 = 0–0.04 km. Grove area was calculated, and categorized based on the size classes (5,000, 2,501–5,000 m^2 and ≤2,500 m^2) for further analysis. Protection status was measured by coding: 1 = presence of fencing; 2 = no fencing.

Data analysis

Sacred grove distribution Distances between the groves and the only forest patch was calculated through Euclidean distance by using open source GIS software GRASS (http://ces.iisc.ernet.in/grass). The area-perimeter ratio of the polygons (corresponding to groves spatial extent) was calculated through MapInfo (Version 11.0).

Endemic population status and disturbances The population data collected on endemic species was categorised into GBH and height classes to understand their distribution pattern. For forest tree species, non-parametric richness indicators and diversity indices were computed through EstimateS version 8.2 (Colwell 2009). The distribution of juvenile members (saplings and seedlings) in the study area was categorised as per land use types based on their abundance data. The severity of disturbance has been measured through scoring method with all disturbance parameters given equal weight. The value was expressed in terms of relative disturbance ({scored value/maximum disturbance value} × 100) (Devar 2008). Due to categorical nature of the disturbance parameters a categorical principle component analysis (CATPCA) was conducted to identify the major disturbance factors and their association with groves (SPSS trial version 17).

Result

Land use dynamics and sacred grove distribution

Temporal land use analysis depicts the landscape status and its transition during 1989–2010. The results show the primeval evergreen forest cover is reduced from 10.22 % (1989) to 7.26 % (2010) due to anthropogenic activities. The region is reflecting intensified agricultural activities and land conversions. The crop land has increased from 45.47 % (1989) to 63.25 % (2010). The built-up area has also increased from 2.22 to 4.40 % by 2010. A total of 14.38 % of area are covered with plantations (exotic plantations 9.38 % and agriculture 5.0 %). Overall accuracy of the classification ranges from 87.38 % (1989), 91.25 % (1999) to 92.47 % (2010). Results of land use analysis are given in Table 1 and depicted in Fig. 2.

Analysis of size class distribution of 53 groves shows that ∼60 % of them are <1000 m^2 (Table 2) and are scattered throughout the study area (avg. distance

Table 1 Temporal changes in the land use pattern in the study area

Category	1989		1999		2010	
	Ha	%	Ha	%	Ha	%
Built-up	**122.87**	**2.22**	**159.17**	**2.87**	**243.73**	**4.40**
Water	19.45	0.35	21.15	0.38	17.55	0.32
Crop land	**2,518.50**	**45.47**	**2,811.96**	**50.77**	**3,503.14**	**63.25**
Open fields	544.54	9.83	348.79	6.30	181.29	3.27
Moist deciduous forest	**258.79**	**4.67**	**309.07**	**5.58**	**207.41**	**3.74**
Evergreen to semi evergreen forest	**566.19**	**10.22**	**474.71**	**8.57**	**402.26**	**7.26**
Scrub/grass	207.70	3.75	179.00	3.23	185.67	3.35
Acacia/eucalyptus/ hardwood plantations	437.92	7.91	453.04	8.18	468.52	8.46
Teak/bamboo/softwood plantations	119.45	2.16	102.78	1.86	51.01	0.92
Coconut/areca nut/cashew nut plantations	729.38	13.17	676.73	12.22	277.06	5.00
Dry deciduous forest	14.04	0.25	2.43	0.04	1.20	0.02
Overall accuracy	87.38		91.25		92.47	
Kappa	0.81		0.86		0.88	

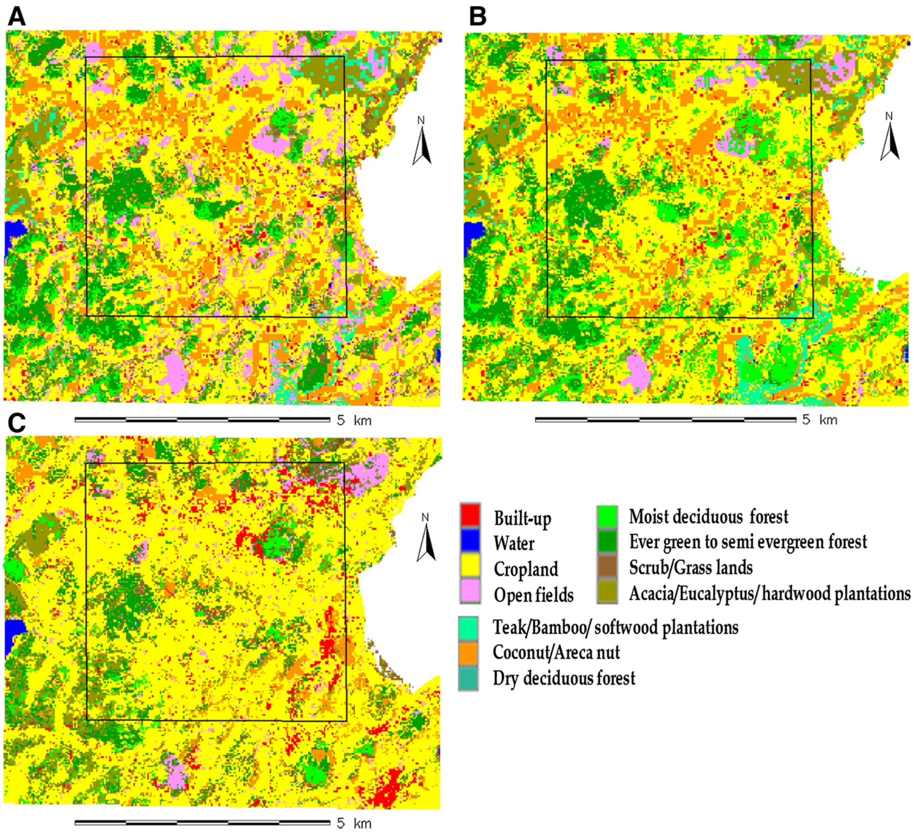

Fig. 2 Land use dynamics in study area **a** 1989, **b** 1999 and **c** 2010

Table 2 Details of the studied sacred groves

Village name (code used)	No. of grove covered	Total area (m^2)	Area range (m^2)
Akunji (Aku)	3	1,315	137–857
Aralihonda (Ara)	6	17,957	205–10,730
Arendur (Are)	11	4,559	36–1,026
Dugimane (Dug)	3	796	46.5–419
Golgudu (Gol)	7	10,296	372–2,230
Harlikoppa (Har)	3	1,900	250.3–1,381
Hittalkoppa (Hit)	2	8,095	3,517–4,578
Kalyanpur (Kal)	6	12,409	330.1–9,264
Kavachur (Kav)	6	8,920	841.5–2,274
Mattigar (Mat)	6	24,341	17.98–18,220

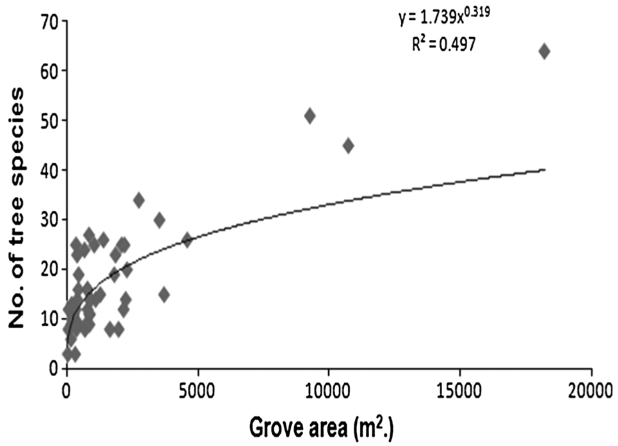

Fig. 3 Species-area curve for studied sacred groves

2.61 km ± 0.57 SD). Groves constitute about 0.36 % and the degraded natural forest about 10.6 % of the study area. The average distance of the groves from the forest patch within the study area is 2.83 km (±1.17) and area-perimeter ratio of the groves is 0.232 (avg.).

Distribution of woody endemics over the landscape

Sacred groves harbour 138 woody species of which 19 (13.7 %) are Western Ghats endemics. Grove area and total species richness show typical species-area relationship in power form (Fig. 3). 14 out of 19 endemics are exclusively confined to the sacred groves, the other five (*Beilschmiedia bourdillonii*, *Holigarna arnottiana*, *Hydnocarpus pentandra*, *Terminalia paniculata* and, *Vateria indica*) occur in forest patch as well as in some other landscape elements (Table 3). All the reported endemics are evergreen trees except *T. paniculata* a deciduous and ubiquitous species present all over south-west India.

Table 3 Distribution of endemic tree species in studied landscape

Endemic tree species (Family)	Species code	Sacred grove	Forest area	Farm/roadside
Actinodaphnae malabarica (Lauraceae)	Act.mal	√	–	–
Artocarpus hirsutus (Moraceae)	Art.hir	√	–	–
Beilschmiedia bourdillonii (Lauraceae)	Bei.bou	√	√	√
Calophyllum apetalum (Clusiaceae)	Cal.ape	√	–	–
Cinnamomum malabatrum (Lauraceae)	Cin.mal	√	–	–
Diospyros assimilis (Ebenaceae)	Dio.ass	√	–	–
Diospyros candolleana (Ebenaceae)	Dio.can	√	–	–
Drypetes confertiflora (Euphorbiaceae)	Dry.con	√	–	–
Flacourtia Montana (Flacourtiaceae)	Fla.mon	√	–	–
Garcinia indica (Clusiaceae)	Gar.ind	√	–	–
Holigarna arnottiana (Anacardiaceae)	Hol.arn	√	√	√
Holigarna grahammi (Anacardiaceae)	Hol.gra	√	–	–
Hydnocarpus pentandra (Lauraceae)	Hyd.pen	√	–	√
Ixora brachiata (Rubiaceae)	Ixo.bra	√	–	–
Knema attenuata (Myristicaceae)	Kne.att	√	–	–
Pittosporum dasycaulon (Pittosporaceae)	Pit.das	√	–	–
Syzygium travancoricum (Myrtaceae)	Syz.tra	√	–	–
Terminalia paniculata (Combretaceae)	Ter.pan	√	√	√
Vateria indica (Dipterocarpaceae)	Vat.ind	√	–	√

Table 4 Diversity study result for forest area

Details of diversity study in forest area	
Observed species richness (within 2,000 m^2 sampling area)	34
Estimated species richness, % of captured species (Chao2)	61, 55.7
(ICE)	53, 64.1
(ACE)	51, 66.6
(Jack1)	48, 70.8
Shannon diversity	3.04
No. of Western Ghats endemics (tree)	3
Five most dominant species (IVI value)	
Aporusa lindlyana (Euphorbiaceae)	60.51
Terminalia tomentosa (Combretaceae)	49.75
Terminalia paniculata (Combretaceae)	32.83
Terminalia bellerica (Combretaceae)	24.84
Vitex altissima (Verbenaceae)	14.08

The non-grove forest patch in the study area shows moderate species diversity and richness (Table 4). We have captured 55–70 % of species diversity from the forest area as estimated by non-parametric richness estimators.

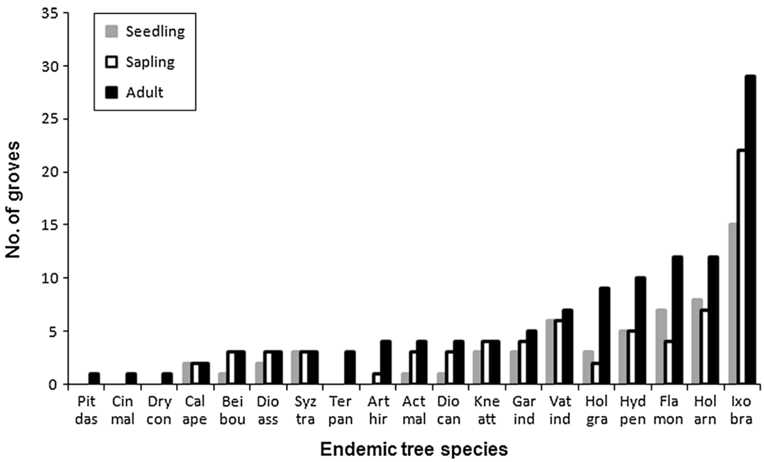

Fig. 4 Distribution of endemic tree population in sacred groves of the studied landscape

Population status and regeneration of the endemics in study area

A total of 19 endemic tree species with 735 individuals have been recorded from the study area of which 14 endemics are exclusive to 39 of the 53 sacred groves. Among these sacred groves three (3) biggest groves harbour 80.53 % of endemic individuals in the entire landscape of 25 km^2. *Ixora brachiata,* a wide spread endemic species along the Western Ghats has highest occurrence (29 out of 39 sacred groves) followed by other stress adapted endemics *Holigarna. arnottiana*, *Flacourtia montana* and *Hydnocarpus. pentandra* in 12, 12 and 10 out of 39, respectively (Fig. 4). Most of the grove and non-grove areas have lower to middle girth class members (distribution follows inverse "J") except for few high girth individuals mainly from sacred groves; the height of trees do not exceed 20 m with few exceptions (Fig. 5a, b). Regeneration profile analysis shows skewed distribution in the studied landscape. A total of 15 endemic species are present in seedling and sapling stages. Devarabatti grove of Mattigar village (Mat25) had highest number of endemic tree species in regeneration stage (13), followed by 11 from Kereamma grove of Kalyanpur (Kal49) and 7 from Kadkod Choudamma grove of Aralihonda (Ara39). *I. brachiata* like its adult members have widespread distribution (15 groves with seedlings and 22 groves with saplings) in comparison to other members (Fig. 4). Apart from sacred grove, endemics from forest area, roads and farms are devoid of juvenile members.

Devarabatti grove at Mattigar village, Kadkod Choudamma grove at Aralihonda and Kereamma grove at Kalyanpur are three largest groves in the studied landscape ($\sim$1.8, 1 and 0.9 ha respectively). Western Ghats tree endemism in these groves ranges from 24.4 % (Kadkod Choudamma grove), 25.3 % (Devarabatti grove), to 25.4 % (Kereamma grove). Endemic population contributes visibly in high girth class members (24.1–37.1 %) and basal area (22.7–45.5 %).

Disturbances over the grove system

We assessed the impact of seven (7) disturbance factors on the groves. Based on the relative disturbance scores groves have been categorised into highly disturbed (76–100 %),

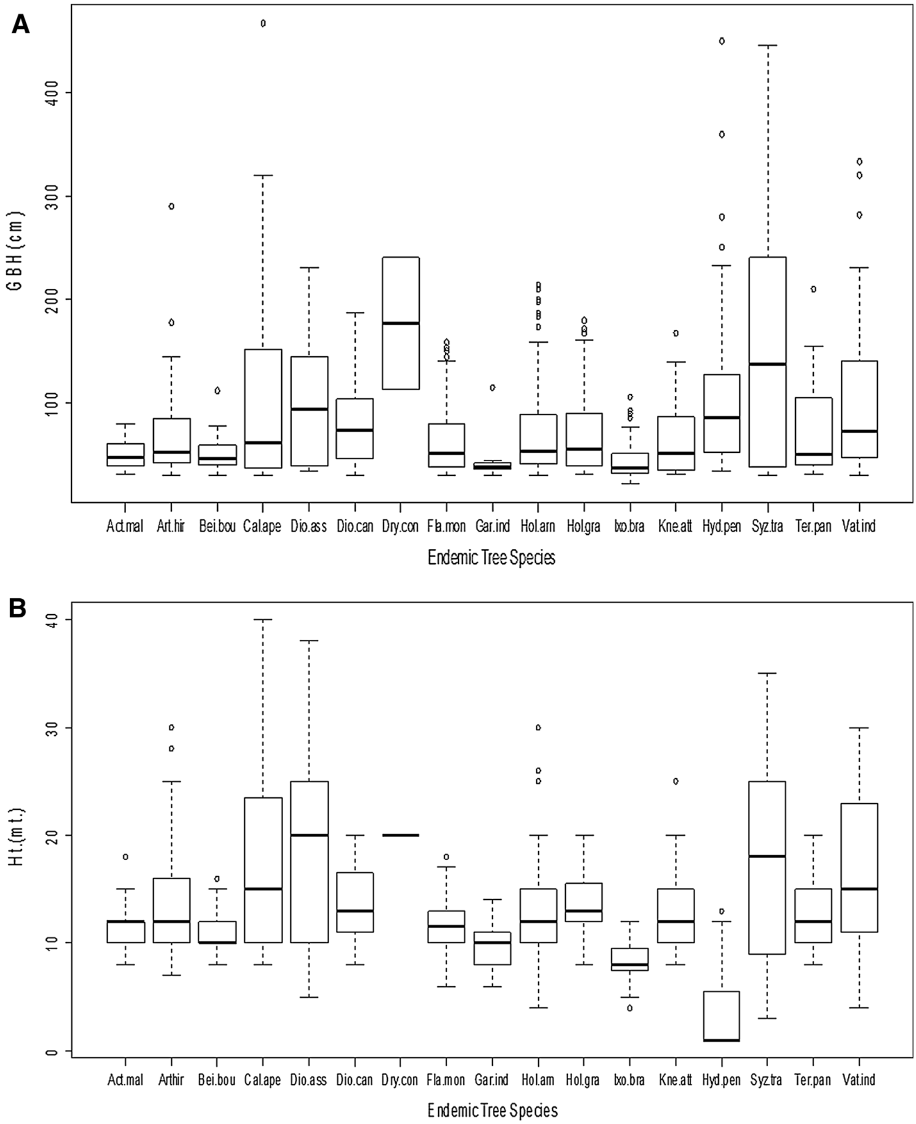

Fig. 5 Girth and height distribution of the woody endemics in study area **a** GBH class distribution. **b** Height class distribution

moderately disturbed (51–75 %), less disturbed (26–50 %) and least disturbed (0–25 %). Disturbance assessment categorised majority of the groves under moderately disturbed category (34) followed by highly disturbed (16) and less disturbed ones (3).

Categorical Principal component analysis (CATPCA) explains 67.76 % of variance through its first three dimensions (Fig. 6). Protection, soil erosion and grazing are found to be major factors for dimension 1 whereas; invasive species and proximity to road dominate dimension 2 and area for dimension 3 respectively. The three largest groves in Mattigar

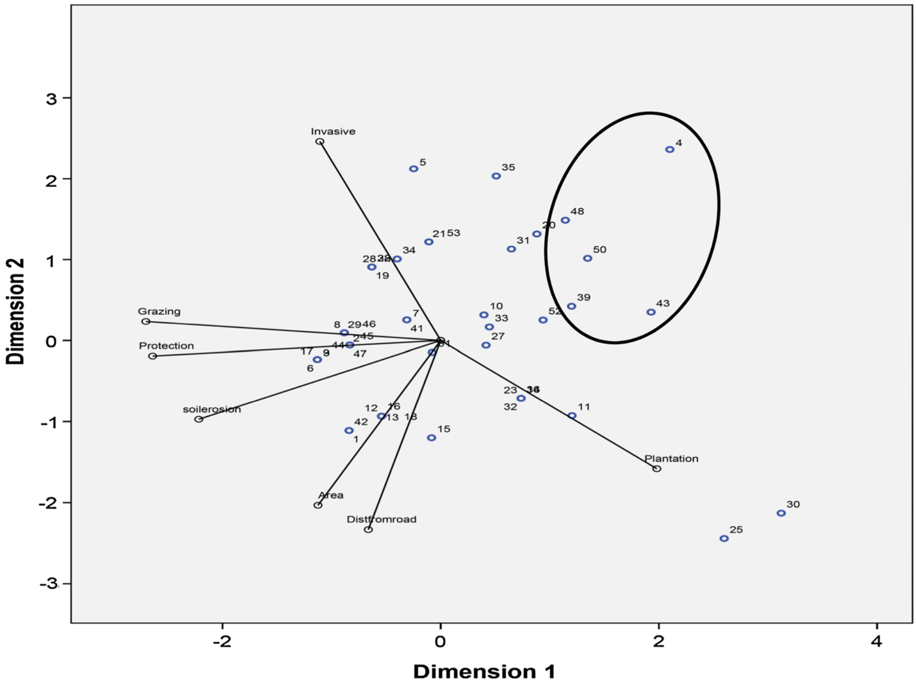

Fig. 6 CATPCA result showing effect of disturbance factors over the sacred groves. *Dimension 1* and *2* explains 30.4 %, 22.3 % variance, respectively. Sacred groves 4, 39 and 48(*three largest groves*) are opposite to all factors indicate their better protection status in the area (See supplement 1 for grove details)

(Mat25), Aralihonda (Ara39) and Kalyanpur (Kal49) are present at the opposite of the axis expressing their better protection status against disturbance factors.

Discussion

Research works from different parts of the world, especially from the humid tropics, indicate that culturally protected fragments are repositories of rare and endemic species which have declined from rest of the local landscape due to anthropogenic pressures (Mgumia and Oba 2003; Bossart et al. 2006; Sukumaran and Raj 2007; Chandran et al. 2008). Similarly, Indian context adequately illustrates the presence of endemic and rare or threatened plants from sacred groves throughout the country (Khan et al. 2008; Chandrashekara 2011). But the future of such relic species in the small sacred groves, often isolated fragments of forests, has been rarely investigated. Past studies on Siddapur sacred groves (Chandran and Gadgil 1998; Nagendra 2001; Gokhale 2004), have primarily focussed on the distribution of these groves in relation to other landscape elements, their vegetation status and socio-cultural aspects. Our study, in the same landscape specifically emphasized on the role of these groves in sheltering the endemic trees and their status of regeneration, a critical aspect closely linked to the future survival of such species in small vegetation patches.

Landuse dynamics

Our study on landuse dynamics corroborates overall landuse change pattern in the Western Ghats as well as in tropical Asia. There is a general trend of deforestation due to establishment of commercial plantation as well as agricultural intensification (Laurence 2007; Giriraj et al. 2008; Joseph et al. 2009; Reddy et al. 2013). Although recent findings emphasize on industry driven forest conversion the deforestation drivers vary according to regional scenario as well as spatial scale (Verburg and Chen 2000; Veldkamp et al. 2001; Rudel et al. 2009; DeFries et al. 2010). The limited extent of the study area offers the opportunity to study the locally active drivers for deforestation which have practical importance for developing mitigation measures. Fragmentation, one of the major consequences of deforestation often associated with increment of forest patch number and reduction of patch sizes which has been evident in many studies conducted throughout the world (Roy and Tomar 2000; Fahrig 2003; Ewers and Didham 2006). The same trend can be observed in our focal area where expansion of agriculture appears to be major driver of deforestation during the study time period and as a result of this cumulative grove area (0.36 %) has also been reduced in comparison to its earlier spatial extent (6 %) (Chandran and Gadgil 1998).

Conservation of woody endemics in sacred groves

We observed that, groves cumulatively support a number of endemic tree species populations despite their small size. The diverse species assemblage including endemics in the groves certainly contributes to maintain the functional diversity of the ecosystem in the otherwise nearly homogeneous landscape of the study area as evidenced elsewhere (Mayfield et al. 2005; Cadotte et al. 2011). In comparison to the 100 % tree diversity captured in sacred grove survey (merely 0.36 % of the study area), 55–70 % of tree diversity was captured from non-grove forest patch. The three largest groves (Mat25, Ara39 and Kal49) jointly contribute 65 % of the woody species diversity in the study landscape.

Among the 19 reported Western Ghats endemics, *I. brachiata*, *H. arnottiana, H. pentandra* have widespread distribution in the Western Ghats (from 8°N lat to almost 20°N) and are comparatively more tolerant to anthropogenic disturbances (Pascal and Ramesh 1997). Even their distribution is better in groves, including very disturbed ones than in the non-grove forests which harbour just few individuals of these tolerant endemics. On the other hand, absence of suitable microenvironment (in terms of moisture, temperature, canopy cover etc.) restricts the distribution of sensitive endemics like *Vateria indica*, *Syzygium travancoricum*, *Calophyllum apetalum, Diospyros assimillis, Knema attenuata*, which are known to be associated with only good evergreen forests (Pascal and Ramesh 1997; Sasidharan 1997; Nair et al. 2007; Chandran et al. 2008). Of these, *V. indica* and *S. travancoricum* enlisted as endangered and critically endangered respectively in the Red List of IUCN (IUCN 2013) are restricted to seven and three groves respectively with their regeneration stocks.

The endemics in general show highly skewed distribution towards relatively bigger groves in the area, however exclusion of three largest groves yields non-significant relationship among the others (Spearman's $r = 0.233$, $P > 0.05$). This finding reiterates the results from the earlier studies in Western Ghats and other areas where species composition, diversity and evenness index have not shown strong relationship with grove/

fragment area indicating importance of the quality of the fragments rather than its spatial extent (Ganeshaiah et al. 1997, Gkaraveli et al. 2001; Sambuichi et al. 2012).

Thirty-nine of the fifty three studied sacred groves have adult endemic individuals, but juvenile stages (seedling and sapling) have been reported from 31 sacred groves either of same as adults or of different species. Although endemics like *I. brachiata*, *H. arnottiana*, *F. montana* are widely distributed in their adult stage many of the groves are devoid of their juvenile stock due to limited spatial expanse and lack of protection. Therefore, often subjected to grazing and trampling by domestic animals. Due to inadequate juvenile stock, the wider distribution of adult members could be attributed to successful seed dispersal by small mammals and birds from neighbouring areas (Vijay 2006) or it could be explained as "Extinction debt" where lack of juvenile stock is an indicator of slow extinction of the species from the area in future (Lindenmayer and Fischer 2006). On the contrary, sensitive endemics like *V. indica*, *S. travancoricum* etc. have better regeneration profile within their limited distribution in the landscape due to some protection provided to their habitats thus maintaining required environmental conditions.

Endemics in forest and other landuse forms

The non-grove forest patch situated in south-west corner of the study area covering about 265 ha is under severe disturbances as observed through its canopy openness, compact soil and dominance of fire tolerant and heliophytic species. This forest is a continuation of the extended portion of the Western Ghats to eastward site and is surrounded by heavily modified landscape. This secondary partially degraded forest although not too far from the groves (average distance 2.83 km.) doesn't seem to play much role in conservation of regional endemic plants.

Roadside and the farm areas are mostly represented by single or a few endemic individuals mixed with other local tree species and often lack juvenile populations. However, their chance survival has not received any support from local land and resource use decisions except for *V. indica*. This species have been used widely in afforestation program by the Karnataka Forest Department since 1996 and planted as an avenue tree in many areas because of its faster growth and wide canopy development.

Disturbances over the grove system

The productive nature of the adjoining landscape have been exerting tremendous pressure on the grove system and causing shrinkage of their spatial extent. Apart from the spatial extent, CATPCA result (dimension 1 and 2) emphasized on the factors like lack of protection, soil erosion, cattle grazing and proximity to road for deteriorating the system. These factors severely affect ground vegetation by damaging juvenile population stock; so do lopping and debarking to the adult trees (Marcial et al. 2001; Chazdon 2003; Tabarelli et al. 2004). The shrinkage of area greatly affects microclimatic condition which results into increment of generalist and invasive species in expanse of specialist and endemic species (Pardini et al. 2009; Anitha et al. 2010; Tabarelli et al. 2010). Earlier study in Siddapur also pointed out that peoples' preference to certain tree species because of horticultural usage can change the floristic composition of the grove system, and can even develop single species dominating vegetation (Gokhlae 2004, 2005).

Larger groves are at least under some form of protection (either fencing or social norms) which ensures their structural integrity as well as ecological attributes due to less disturbed interior part. In contrast, the condition changes along the grove border in terms of light, moisture and soil profile (pers obs.). This drastic change in environment restricts the endemics mostly towards the grove interior except few which prefer open canopy and drier condition (e.g. *H. arnottiana*, *I. brachiata*) (Pascal and Ramesh 1997). There are exceptions however e.g., *S. travancoricum*, though elsewhere found more in interior swampy forests, in our focal area we found it confined to the grove edges that border rice fields. These edges remain water-logged for most periods of the year perhaps favouring the growth of this sensitive Western Ghats endemic.

Despite some limitations (small study area, absence of suitable replicates etc.), the case study attempted here underscores the importance of small scale forest conservation. This, being of an informal kind, has been operating among traditional agricultural communities of Western Ghats, but escapes attention from conservationists. The existing social protection, though may be insignificant (seldom studied systematically), plays a key role in survival of these woody endemics under changing landuse scenario in Western Ghats. The conservation and management of smaller forest fragments has not deserved much consideration so far, and their continued obliteration can be disastrous for this otherwise acknowledged biodiversity centre.

In order to decimate the increasing conflicts between biodiversity conservation and livelihood improvement, sacred groves could continue to play a central role because of their acceptability and veneration for the deities resident in them. However, the groves are dwindling not merely to cater to the needs for biomass and land but also due to transformations in religious attitudes and worldview of local communities who had protected much larger groves in historical times. The local communities and forest administration need to be convinced about the ecological, cultural and historical significance of sacred groves so as to strike a balance between conservation and utilisation of biodiversity.

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