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Hydrological importance of sacred forest fragments in Central Western Ghats of India

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Abstract: Sacred groves are patches of forests of special spiritual significance to humans, offering also a diverse range of ecological and environmental services. We have attempted here to understand the local hydrological dynamics of a sacred forest, in terms of the benefits the village community derive, in central Western Ghats region of India. A comparative assessment has been made between two small watersheds in terms of their landscape structure (woody species composition) with soil water properties and availability of water in the respective downstream villages. The result shows that, sacred site with more primeval vegetation has close association with soil moisture in comparison to non-sacred site during dry spell of the year. The higher soil moisture ensures year long availability of water in the downstream village of the sacred site which facilitates farming of commercial crops with higher economic returns to the farmers, unlike the farmers in the other village where they face water crisis during the lean season. The study emphasizes the need for conservation endeavour on sacred groves highlighting its potential for water conservation at local and regional levels.

Resumen: Los bosques sagrados son fragmentos de bosques de especial significado espiritual para los seres humanos, los cuales también ofrecen una amplia gama de servicios ecológicos y ambientales. Hemos intentado aquí entender la dinámica hidrológica de un bosque sagrado, en términos de los beneficios derivados para una comunidad aldeana en la porción central de los Gates Occidentales de la India. Se hizo una evaluación comparativa entre dos cuencas pequeñas en términos de su estructura del paisaje (composición de especies leñosas) con las propiedades del agua del suelo y la disponibilidad de agua en las respectivas aldeas río abajo. Los resultados muestran que el sitio sagrado con más vegetación primaria tiene una relación estrecha con la humedad del suelo en comparación con el sitio no sagrado durante la temporada seca del año.Una humedad del suelo mayor asegura la disponibilidad de agua a lo largo del año en el poblado situado río abajo del sitio sagrado, y esto facilita el desarrollo de cultivoscomerciales y mayores ingresos económicos para los agricultores, a diferencia de los agricultores en el otro pobladoquienes se enfrentan a crisis de agua durante la temporada de carestía. El estudio enfatiza la necesidad de haceresfuerzos de conservación en los bosques sagrados, destacando su potencial para la conservación del agua tanto local como regionalmente.

Resumo: Os bosques sagrados são manchas de florestas de significado espiritual especial para os seres humanos, oferecendo também uma gama diversificada de serviços ecológicos e ambientais. Tentámos aqui entender as dinâmicas hidrológicas locais de uma floresta sagrada, em termos dos benefícios que a comunidade da aldeia obtém, na região central dos Gates Ocidentais da Índia. Uma avaliação comparativa foi feita entre duas pequenas bacias hidrográficas em termos da estrutura da paisagem (composição de espécies lenhosas) com as

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propriedades da água no solo e a disponibilidade da mesma nas respectivas aldeias a jusante. O resultado mostra que o local sagrado com mais vegetação primitiva apresentou uma associação estreita com a humidade do solo, em comparação com local não-sagrado, durante o período seco do ano. A maior humidade do solo garante, no ano, maior disponibilidade de água na aldeia a jusante do local sagrado o que facilita a produção de culturas comerciais com maiores retornos económicos para os agricultores, ao contrário dos agricultores na outra aldeia onde enfrentam crise da água durante o período de escassez. O estudo enfatiza a necessidade de esforço de conservação em bosques sagrados destacando seu potencial para a conservação da água a nível local e regional.

Key words: Ecosystem service, native forest, sacred grove, water conservation, watershed.

Introduction

Landscape constitutes a heterogeneous area comprising of different interacting ecosystems, including land (mountains, hills, soil, forests) and water (streams, rivers, oceans, lakes, etc.). These interactions among the components of ecosystems result in the flow of nutrients, minerals and energy, which contribute to the functioning of the landscape. Watershed, an integral part of any landscape, can be defined as an area that supplies water by surface or subsurface flow to a given drainage system or body of water, be it a stream, river, wetland, lake or ocean (World Bank 2001).

Forests and water are intrinsically intertwined as forested watersheds have significantly different behaviour from non-forested watersheds as the former is more helpful in infiltration of rainfall. The nature of vegetation in the catchment is important in ground water recharge, runoff and soil moisture conditions, soil erosion and soil quality (Biao *et al.* 2010; Bruijnzeel 2004). Despite the fact that the forest-water relationship is not all that simplistic, being an outcome of many factors of climatic, edaphic, geological and biological nature, the importance of forests in water conservation has been accepted globally (Bradshaw *et al.* 2007; Makarieva *et al.* 2006).

India has a well established ancient tradition, more in the highlands, of protection of patches of forests as sacred. Though these forests are devoted to gods with many taboos associated with tree felling in such areas, the intimate association of such sacred forests or sacred groves with water bodies, in the form of streams, rivers, ponds and lakes, swamps or springs, is a well acknowledged fact. Hydrological services to village communities from well preserved sacred groves are highlighted in several studies (Chandran & Gadgil 1998; Gokhale & Pala 2011; Malhotra *et al.* 2001). Based on studies in the Himalayan states of Himachal Pradesh and Meghalaya, Khiewtam & Ramakrishnan (1993) and Singh *et al.* (1998) reported the role of groves in reducing run-off and soil erosion, preventing landslides and in conferring ecosystem stability. Vertical stratification in the untrammelled humid tropical forests along with the extensive root network covered with leaf litter are linked to increased soil percolation, recharge of ground water (Khiewtam & Ramakrishnan 1993). The stored precipitation in the underlying strata (saturated and vadoze zone) are released to the streams making them flow perennially. Natural forest soils with greater porosity and low bulk density retain more moisture for longer duration even after the stoppage of seasonal rains. This fact is evident from the relatively less disturbed sacred groves which are often sources of fresh and clean water for many village communities (Godbole & Sarnaik 2004). The watershed values of especially swampy sacred forests, dominated by members of Myristicaceae, occurring in isolation in Western Ghats of Kerala and Karnataka, are home to several rare and threatened floristic and faunal elements that prefer aseasonal tropical forest conditions (Chandran & Mesta 2001; Chandran *et al.* 2008, 2010). Chandran & Gadgil (1993) emphasized the role of sacred groves as safety forests in otherwise human impacted landscapes of Uttara Kannada district of Karnataka, especially on account of their hydrological and biological importance. The British rulers had shown some consideration of the preservation of the evergreen *kan* forests of Uttara Kannada, on account of their hydrological importance, as reflected in the pronouncement of the Government of Bombay (1923).

All such studies associating perennial water sources with sacred groves were of more of general nature, without any quantifications or evaluations involving local water cycles with biodiversity and livelihoods.

The Western Ghat mountain chain, one of the 34 global hotspots of the world, running parallel to the west coast of the country, is home to numerous sacred groves. Their ecological characters range from evergreen to dry deciduous forests, semi-deciduous and swamp areas thus providing varied ecosystem services (Bhagawat *et al.* 2005; Chandran *et al.* 2010; Gunaga *et al.* 2013; Rajendraprasad *et al.*1998; Ray *et al.* 2012). A large scale land cover change in recent times is altering the ecosystem structure influencing the respective ecosystem's goods and services. Quantification of linkages of ecosystem structure with hydrological and other concurrent services helps in mitigating land cover changes and hence the conservation of ecosystems. In this context, a comparative assessment of two watersheds (with and without sacred forests) through ecological, hydrological and socio-economic parameters was undertaken to understand the linkages of landscape structures of watersheds with hydrological services and also local livelihood.

Methods

Study area

The field investigations were carried out in two neighbouring watersheds with similar topography, one with a sacred grove and the second without a sacred grove, in the Honavar taluk of Uttara Kannada district in the central Western Ghats of Karnataka State. The Karikan hill with a maximum height of about 450 mt. (14° 20.25" - 14° 22.95" N and 74° 29.40" - 74° 31.50" E), covered with a sacred forest of primeval dipterocarps is at the source of a stream that recharges the ground water in the Bangarmakki village in the valley below. In the vicinity of the grove is the Karikanamman temple, a popular place of mother goddess worship in the district. The Karikan watershed is spread over 460 ha, of which about ~178 ha is forest, including the sacred grove. The grove is today part of the State Reserved Forest of Karnataka, and as such has no sharp boundaries to distinguish it from the secondary forest surrounding it.

The second study area was Sambegadde, A hill, also with maximum height of about 450 mt. with a village by same name towards its base (14° 21.54" 14° 22.77" N and 74° 30.50" - 74° 31.58" E). The forest cover on the hill is of secondary nature, and less evergreen than Karikan with several deciduous trees. The forest turned secondary due to slash and burn cultivation in the past and no taboos associated with it regarding resource extraction (Chandran 1997, 1998). A stream draining the watershed enters the Sambegadde village. The total drainage basin covers an approximate area of ~1004 ha of which forest cover is ~239 ha. Both the study areas receive average rainfall 3713.4 mm and the temperature ranges from 15 - 32 °C.

Table 1. Land use under major cultivated crops in the study area.

	Bangarmakki (ha)	Sambegadde (ha)
Areca nut (*Areca catechu*) garden	20.123	10.491
Rainfed agriculture paddy (*Oryza sativa*)	0.111	25.398
Sugarcane (*Saccharum officinarum*)		0.082
Ragi (*Eleusine coracana*)		0.044
Total cultivated land	20.234	36.015

Major land use types in the Bangarimakki village are areca nut (*Areca catechu*) gardens with black pepper (*Piper nigrum*), betel leaf (*Piper betel*), banana (*Musa paradisiaca*) and coconut. Sampegadde has rain-fed rice (*Oryza sativa*) as main crop followed by ragi (*Eleusine coracana*) and sugarcane (*Saccharum officinarum*) as seasonal field crops (Table 1). Garden crops are grown in lesser areas compared to Bangarmakki. The study areas were digitized from Survey of India 1:50,000 toposheets (Fig. 1.)

Vegetation study

Study of the forests covering the drainage basins of the two streams, has been carried out using transect - cum - quadrat method. Each catch-ment was divided into three altitudinal zones viz. low (< 200 m), middle (200 - 400 m) and high (> 400 m). A line transect of 180 m was laid in each altitudinal zone. Five quadrats of 20 m × 20 m for tree (30 cm gbh or more) inventory were laid at equal distances from each other alternately along left and right of this transect covering a total of 2000 m^2 forest area. 5 m × 5 m quadrats, two each

Fig. 1. Study area details (Toposheet (SOI) 48_J_7, 48_J_11). Continuous line indicating watershed boundary and dotted line indicates study forest boundary.

within a tree quadrat, for shrub layer including tree saplings (< 30 cm gbh) and 1 m × 1 m nested quadrat for herbs, two each within a shrub layer quadrat, were laid along the line transect.

Soil study

Soil in the study area is broadly classified under clayey, kaolinitic and ustic kandihumults category (Anonymous 1998). Soil samples (at 0 - 20 cm) were collected for moisture content, bulk density and total carbon. For moisture content, five samples were collected from every altitudinal zone month-wise covering the post- and pre monsoon period (January - May). Therefore, a total of 75 samples were collected from each watershed (5 samples × 3 altitudes × 5 months). Moisture content was analysed through gravimetric method, organic carbon using Walkley-Black method and bulk density through core method (Baruah & Barthakur 1997).

Ground water monitoring

The study period was divided into pre-monsoon (April-May), monsoon (June-September) and post-monsoon (October-March) according to local weather and water availability scenario. The Sambegadde village stream dries up from late post-monsoon in January to May end in pre-monsoon, making villagers entirely depending on open wells for irrigation. The Bangarmakki stream experiences intermittent flows during the pre-monsoon. As ground water level is high villagers better use open wells for water. Therefore, we measured ground water levels in open wells and the quantum of water pumped out of them for farming and domestic needs. We selected 15 wells

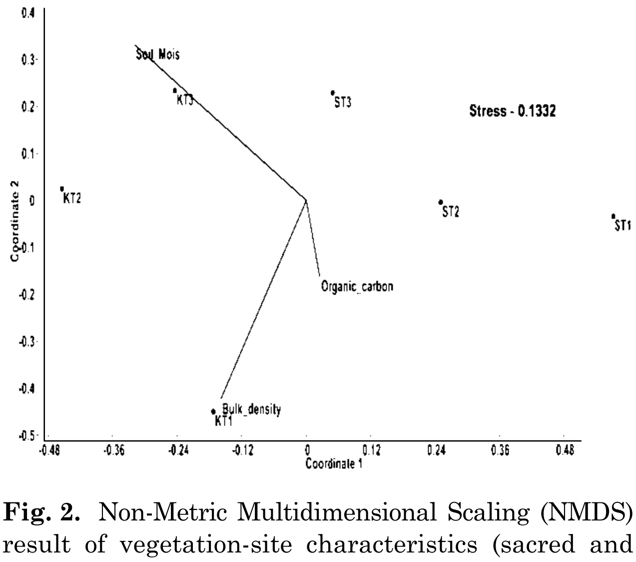
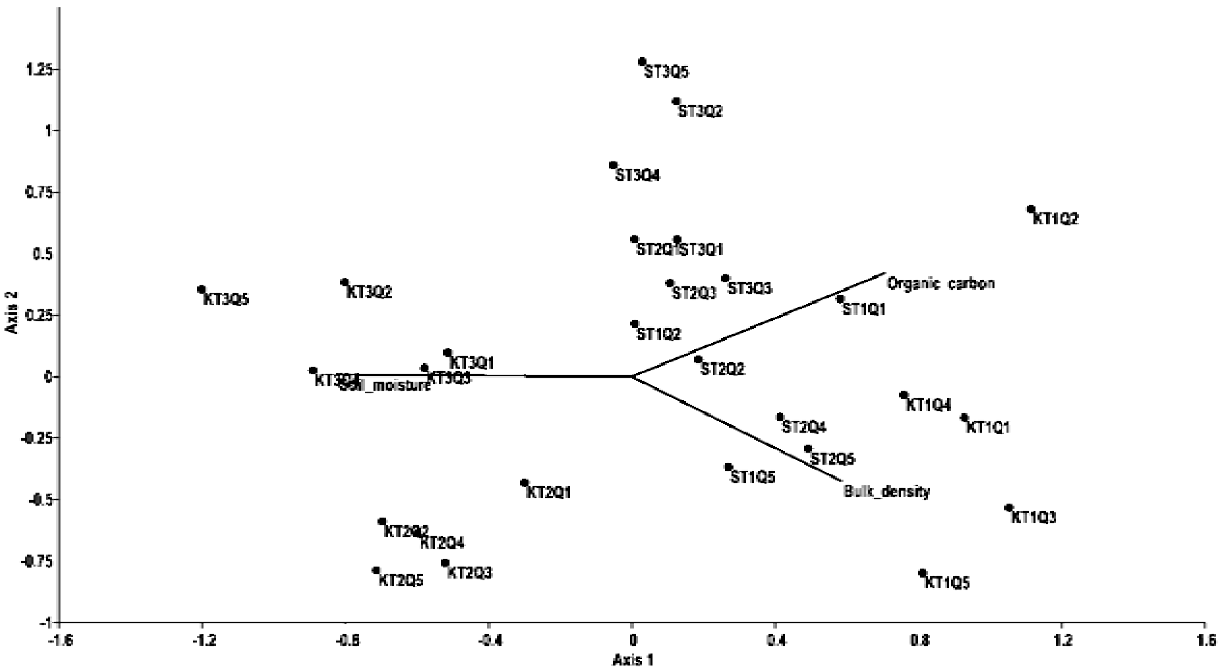


Fig. 2. Non-Metric Multidimensional Scaling (NMDS) result of vegetation-site characteristics (sacred and non-sacred forest sites). KT1, KT2 and KT3 denote sampling groups from Karikan; ST1, ST2 and ST3 denote sampling groups from Sambegadde.

A



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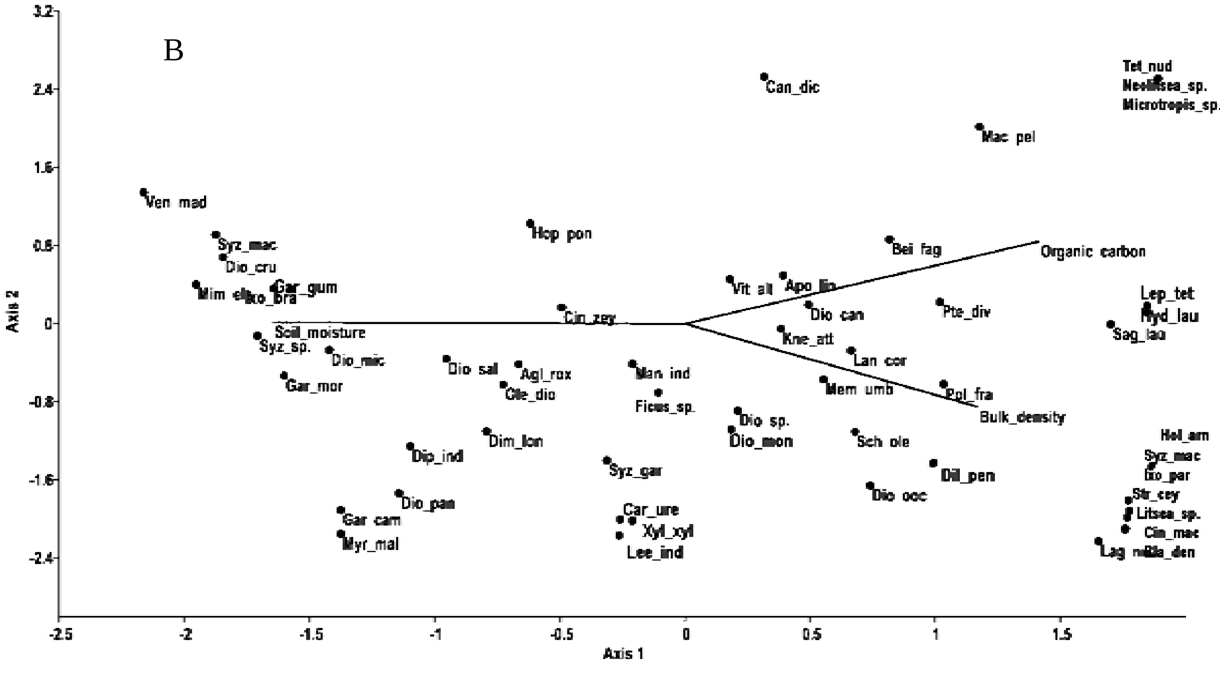

Fig. 3(A). Canonical Correspondence Analysis (CCA) result related to sampling sites and studied soil parameters. Sites prefix with "K" from Karikan and prefix with "S" from Sambegadde. (B) Canonical Correspondence Analysis (CCA) result related to association of species with studied soil parameters.

Table 2. Woody species diversity profile in studied watersheds.

	Karikan	Sambegadde
No. of species observed	44	27
Endemism (%)	38	22
No. of species estimated (% captured)		
Jackknife 1	58.93 (74.66)	38.2 (70.68)
Chao 2	54.18 (81.21)	45 (60)
Diversity index		
Fischer's alpha	13.21	10.11
Shannon	3	2.54
Simpson	12.92	7.57
Three most dominant species (IVI)	*Dipterocarpus indicus* (52.95)	*Hopea ponga* (71.27)
	Hopea ponga (33.03)	*Diospyros candolleana* (29.53)
	Knema attenuata (27.62)	*Aporosa lindleyana* (24.02)

each in Bangarmakki and Sambegadde villages for monitoring ground water for 18 months from January 2009 to May 2010. All these wells were at an average altitude of ~50 - 55 m. The depth to water table was measured manually following standard techniques suggested by World Meteorological Organisation (Anonymous 1994). Data on quantities of water pumped for irrigation and domestic use, was collected through interviews.

Socio-economic survey

Socio-economic survey was conducted in the two villages using structured questionnaire and market price method was used to estimate the cost and benefits of the ecosystem goods i.e. mainly of agricultural and horticultural crops.

Data analysis

Data related to ground water, soil moisture and water usage were analysed for central tendency and t-test was done for comparative analysis. Vegetation data was analysed through multivariate statistical techniques (PAST version 2.14.) (Hammer *et al.* 2001) included Nonmetric Multi Dimensional Scaling (NMDS), Analysis of similarity (ANOSIM) and similarity percentage analysis (SIMPER) for understanding the differences in species composition between the sites. Species richness was estimated through non-parametric richness estimators viz., ACE, ICE, Chao1, Chao2, Jack1 and Jack2 and species diversity-dominance was calculated through several indices like Fischer's alpha, Shannon-Wiener, and Simpson (Estimate S version 8.2) (Colwell 2009). Girth class distribution was compared through Kolmogrov-Smirnov test. Canonical Correspondence Analysis (CCA) was performed with vegetation and soil data to explore the site-species relationship with soil characters. For cost - benefit analysis, expenses related to cost and profit were calculated on data collected from twenty respondents from each site, which was then summed up and averaged. Total cost and benefit were calculated by multiplying this average value with total area under horticultural and crops and the value was expressed in terms of hectare.

Results

Vegetation analysis

Vegetation studies in the focal watershed areas revealed two distinct species composition patterns (Fig. 2.). Whereas 44 tree species were recorded from Karikan forest, only 27 occurred in Sambegadde. The nonparametric species richness estimators, captured 75 - 80 % of species diversity from the study sites (Table 2). Shannon index of diversity was significantly higher for Karikan (3.001) in comparison to Sambegadde (2.54) (*P* - value < 0.000). Girth class distribution is identical reverse "J" shaped in both the areas (K-S test D=0.53333; $D_{critical\ \alpha}$ at 0.05 = 0.6027; $p_{(permutated)}$ = 0.0218), but Karikan shows a good number of high girth class individuals and taller trees, in comparison to Sambegadde. Stark difference was in the average basal area -(53.6 m^2 ha^{-1} in Sambegadde). There are 94 % and 86 % of evergreen tree members and 38.6 % and 22.2 % of endemism in Karikan and Sambegadde respectively.

The overall dissimilarity between the sites is 84.1 % as per ANOSIM analysis (r value 0.342). SIMPER analysis highlighted the major contribution of wet evergreen species like, *Dipterocarpus indicus, Polyalthia fragrans, Syzygium gardneri, Diospyros crumenata, Myristica malabarica, Lepisanthes tetraphylla* etc. in Karikan. Canonical Correspondence Analysis (CCA) with vegetation and soil parameters (pre-monsoon soil moisture, organic carbon and bulk density) has shown distinct groupings in study sites. CCA axes 1 and 2 have explained 70.45 % and 29.54 % variation respectively (Fig. 3 A, B). Species like *Diospyros saldanha, Dipterocarpus indicus, Aglaia roxburghiana, Cinnamomum malabathrum, Myristica malabarica* and *Hopea ponga* are closely associated with high soil moisture, whereas, *Aporosa lindleyana, Vitex altissima, Knema attenuata, Lannea coromandelica* etc., mostly of Sampegadde, form a separate cluster opposite to soil moisture factors. Karikan middle and upper region showed greater association with soil moisture than the very disturbed lower region closer to the Bangarmakki village in the valley. On the other hand, all sampling sites in Sambegadde clustered around bulk density and organic carbon.

Soil analysis

Soil samples collected in three altitude ranges throughout the dry period (January to May) were analysed. In low altitude range (0 - 200 m), Karikan forest has shown gradual reduction in soil moisture from 18.6 % in January to 8.7 % in May. In Sambegadde, soil moisture dropped from 14.4 % to 11.7 % in the same period. In middle altitude range (200 - 400 m), soil moisture content was higher in Karikan than Sambegadde throughout the study period. It was always > 20 % in sacred forest whereas in non-sacred forest it gradually decreased from 17 % in January to 8.8 % in May. In the higher altitude range (> 400 m) of Karikan, soil moisture was 19 - 25 % throughout the study period in comparison to 18 - 20 % in Sambegadde. On the whole sacred forest was found to have more soil moisture in entire study period (Jan - May) 17 - 22 % than non-sacred one 13 - 17 %.

Soil organic carbon in Karikan low altitude was higher (3.79 %) than Sambegadde (2.54 %); but for middle and high altitudes, Sambegadde showed higher value than Karikan. These localities show more or less same bulk density values in all three altitude levels (Fig 4A, B and C).

Ground water monitoring

Ground water monitoring during 18 months (Jan 2009 to May 2010) showed marked differences in two areas (Fig. 5). Bangarmakki, associated with Karikan forest showed lesser decline in water table depth in comparison to Sambegadde during dry spell. However, both the villages showed similar water table profile during monsoon and early post-monsoon periods (July - Dec 2009). The water table at Sambegadde was at its lowest in May 2009 (5.97 m ± 1.60; peak summer) and highest in July 2009 (0.74 m ± 0.72; monsoon). Bangarmakki showed gradual changes in ground water level in comparison to drastic changes in Sambegadde (rising and receding faster during wet and dry seasons). The maximum difference between these two areas was found during March 2009, when the mean water table was 2.46 m. lower in Sambegadde than in Bangarmakki.

Crop pattern

Bangarmakki, the hamlet near Karikan sacred forest has dominance of horticultural crops (99.4 %) in its land under cultivation. Mainly higher income yielding cash crops like areca nut, coconut, banana, beetle leaf and pepper vines are grown there. In contrast to that horticultural crops cover only 29 % of total cultivated area in Sambegadde, while the rest was mainly under rain fed paddy and to a smaller extent sugarcane and ragi cultivation. Land holdings are small in both the study areas (mean 0.8 ha ± 0.424) (Table 1).

Water usage

Pumping schedule during late post- and pre-monsoon season showed more liberal usage of water in Bangarmakki than in Sambegadde. In the former average of 1862 Kilolitres ha^{-1} of water was pumped in January, which got reduced to 136 Kilolitres ha^{-1} in May, the peak of summer. Similar data for Sambegadde (947 Kilolitres ha^{-1} in January to 37 Kilolitres ha^{-1} in May) were significantly lower (Fig. 6). Withdrawal of water during lean seasons (non-monsoon) is linked to the quantum of recharged water at regular interval. Geology of the terrain (of both regions) are similar and there is no scope for further deepening of wells as in Sambegadde village compelling farmers to restrict to rain-fed rice than water demanding garden crops.

Cost-benefit analysis of plantation and agriculture products

Both plantation and agricultural crops have been considered for the valuation. In Bangarmakki, plantation crops (viz. areca nut, coconut, banana, beetle leaf and pepper) are the major income generating products. A total amount of Rs. 3,11,701 ha^{-1} $yr.^{-1}$ (year 2009-10) gross average income was generated from the plantation crops against an average expenditure of Rs. 37,043 ha^{-1} yr^{-1}, (mainly for plantation maintenance), yielding a net profit of Rs. 2, 74,658 ha^{-1} yr^{-1}. On the contrary, for Sambegadde, (where both plantation and rice

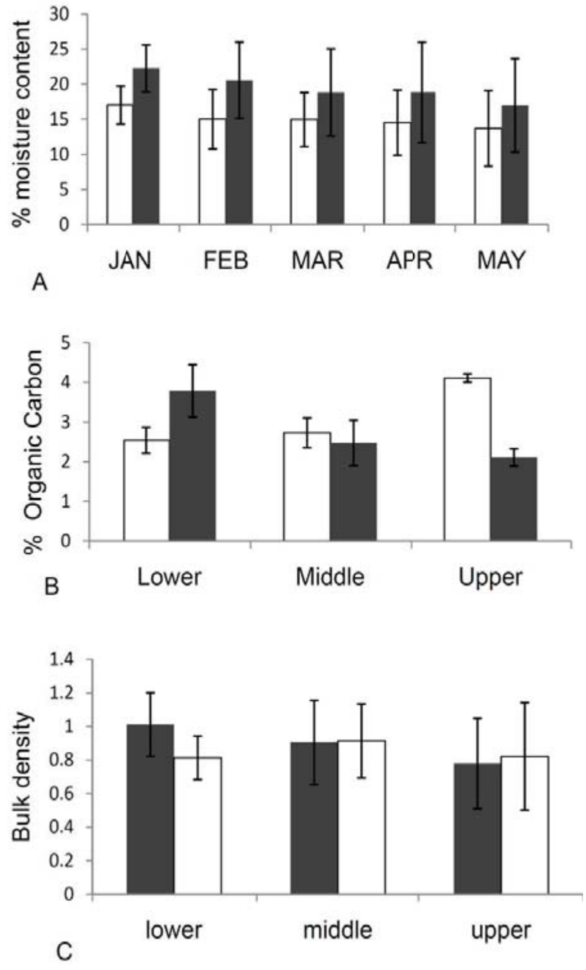

Fig. 4. Soil analysis result from sacred and non-sacred sites.

(Karikan ■ Sambegadde □)
A = soil moisture at dry period (Jan-May)
B = % of organic carbon at three altitudes
C = Bulk density at three altitudes.

fields were considered for income calculation) the average gross income generated was Rs. 1, 50,679 ha^{-1} yr^{-1} against expenditure of Rs. 6474.10 ha^{-1} yr^{-1} for plantation maintenance and field preparation. The maintenance cost was lower here as major land use was rain-fed rice. Therefore, net profit per hectare of cultivated land was only Rs.1,44,204 ha^{-1} yr^{-1}, against a sum of over Rs. 2,74,658 ha^{-1} yr^{-1} from Bangarmakki.

Discussion

The importance of forested catchment area in hydrological cycle is a well explored topic which has been under extensive reviewing from time to time (Bruijnzeel 2004; Chomitz & Kumari 1998; Hamilton 2008; Makarieva *et al.* 2006). Forest type (native/ plantation / primary / secondary), edaphic factors and ground water recharges are some of the major factors which have been investigated by many workers (Brauman *et al.* 2011; D'Odorico *et al.* 2010; Kagawa *et al.* 2009; Muñoz-Villers *et al.* 2011; Smerdon *et al.* 2009). Forest cover has defi-nite role in water conservation by soil moisture retention (through humus and thick litter layer) and maintaining microclimate thus reducing evapo-transpiration demand (Sikka & Selvi 2006; Thomas & Sankar 2006). Similarly studies have also addressed the effect of afforestation and land conversion in relation to hydrological cycle (Purandara *et al.* 2006; Sikka & Selvi 2006).

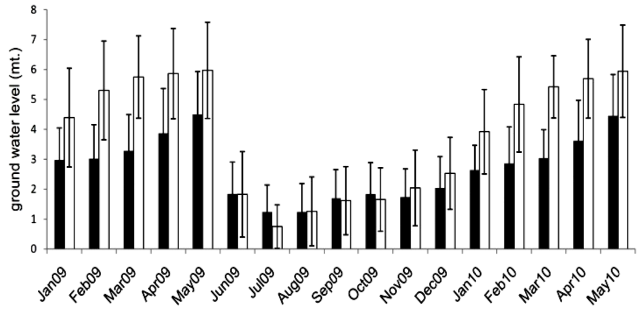

Fig 5. Groundwater profile at two sites (January 2009 - May 2010).

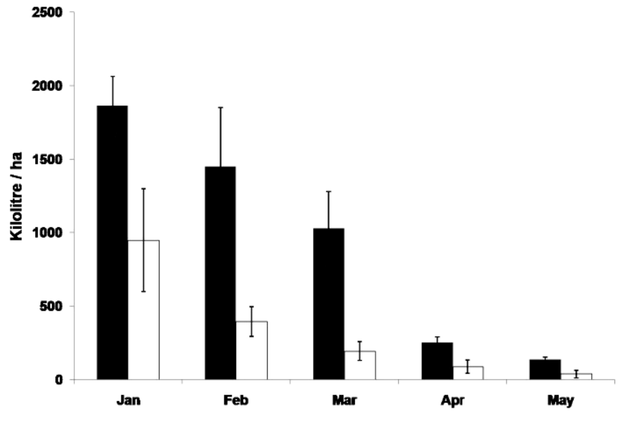

Fig. 6. Water usage in study areas during dry period (January-May).

Ecologically, the sacred groves in central Western Ghats region often represent relic primary forests or other old growth forests, usually characterised by large trees (higher basal area), rich litter cover and less compact soils. However, their ecological status is too much varied as per management condition and changing land use practices in the region from British colonial time period (Chandran & Gadgil 1998). Both sacred and non-sacred hill slopes of the current study sites, separated from each other by a single hill, are part of the central Western Ghats. Therefore, overall temperature, precipitation and gross geological pattern are similar for both the study areas. However, differences would certainly exist in microclimate level as reflected in plant species diversity, endemism, periodic soil moisture level and ground water recharge.

Karikan sacred grove occupies south-west slope of the hill and is the source of perennial streams in the locality. The old growth evergreen to semi-evergreen nature of the Karikan forest is in sharp contrast to its neighbouring forested areas which are secondary with more deciduous tree elements. These deciduous elements in a heavy rainfall zone are the results of slash and burn cultivation system of the past. Ever since this system was prohibited by the British over a century ago, the practice of setting fire to the forests diminished in the region, favouring the return of the evergreens in a big way as is evident from the greater numbers of the endemic evergreen trees like *Hopea ponga* and *Diospyros candolleana.* Nevertheless, the tree basal areas in the secondary forests of Sambegadde are far less from that of the Karikan hill. NMDS analysis also reveals distinct species composition pattern in two areas. Tree population study in Karikan shows considerable presence (31 %) of high girth class members (> 90 cm GBH) and upper strata at ≥ 30 mt, typical structural characteristic of tropical old growth forest as reported from other parts of Western Ghats and elsewhere in tropics (Chandrashekara & Ramakrishnan 1994; Pascal & Pelissier 1996; Uuttera *et al.* 2000). Although not saturated, the diversity study has captured 74.66 % and 81.21 % (Jackknife 1 and Chao1) of species diversity from the study area. High species richness among trees with 38 % Western Ghats endemism indicates favourable microclimate especially for diverse endemic species. Presence of typical wet evergreen species like, *Dipterocarpus indicus, Polyalthia fragrans, Diospyros saldanha, Knema attenuata, Myristica malabarica* etc. (Western Ghats endemics), in Karikan also confirms this contention. Although the non-sacred forest site in the Sambegadde hill has shown less species richness and endemism (22 %), estimators assume more species to be found. Tree population structure shows dominance of younger members (86 %) i.e. girth class < 90 cm GBH and lower height level (~20 - 25 mt) which indicates comparatively younger age of the forest stand, in contrast to the large girth trees with several reaching 30 - 40 m in Karikan. The dominant species are *Hopea ponga, Diospyros candolleana, Aporosa lindleyana, Schleichera oleosa* etc. (as per IVI value) of which *Hopea ponga* (though an ever-green dipterocarp) and *Aporosa lindleyana* are well recognised disturbance indicators of the forests of the high rainfall areas of South Indian Western Ghats (Gokhale 2005; Pascal & Ramesh 1997).

CCA has found close association between Karikan middle and upper region with soil moisture which could be justified by presence of undisturbed interior, large sized evergreen trees and litter covered forest floor whereas, the difference in lower region is mainly due to disturbances like, widespread tree cutting, lopping and encroachment (for plantation crop establishment) etc. Although this lower region has some wet evergreen species like *Sageraria laurifolia, Hydnocarpus laurifolia, Polyalthia fragrans* and *Pterospermum diversifolium* they are more restricted to adult population with minimal representation in the juvenile group. Non-sacred sampling sites in Sambegadde forest are present in close association with each other in relation to factors like bulk density and soil organic carbon but standing apart in soil moisture conditions. Similarly, tree species also form separate clusters corresponding to soil moisture. Wet evergreen species like *Diptero carpus indicus, Myristica malabarica, Dyospyros saldanha, Cinnamomum macrocarpum,* are clustered in the vicinity of soil moisture variable which confirms their inclination towards moist microclimatic conditions of Karikan. These species are more abundant in southern Western Ghats which enjoy more rainy months (usually 7 to 9) than in the central Western Ghats of Uttara Kannada with 5 - 7 rainy months (Pascal & Ramesh 1997).

Dry season soil moisture profile for top soil layer (0 - 20 cm) was analysed as it is one of the important determinant factors for species composition in any area (D'Odorico *et al.* 2010; Jirka *et al.* 2007). Moisture level at top soil layer is an indicator of water retention potential of entire soil mass especially at lean season. In clayey soil, the top soil layer (10 - 30 cm) is considered as soil moisture control section which plays important role in maintenance of above ground biomass (Anonymous 1999). As long as the top soil layer is wet there is a clear indication of water availability in the area. The study shows significantly higher soil moisture profile throughout the pre-monsoon season in Karikan which could be attributed to its dense canopy cover of evergreen trees and rich litter cover on the soil, not tampered with at least in the sacred grove proper. Many studies have established linkages of old growth trees in tropical forests as adapted to several physiological changes like less water usage, decreased stomatal conductance and protection of soil from direct solar radiation which promote water conservation in the nearby localities (Kagawa *et al.* 2009; Macfarlane *et al.* 2010; Singh & Mishra 2012; Vertessy *et al.* 2001).

The typical old growth forest structure (i.e. higher basal area, height, high evergreenness and endemism) and soil moisture profile in Karikan have obviously combined effect on water availability in downstream area. Bangarmakki shows comparatively slower decline in water table in dry months than Sambegadde indicating higher recharging capacity. The landscape with good vegetation cover allows higher infiltration of water and groundwater recharge. This also helps in sustaining water in the streams during lean seasons due to lateral flow from vadoze zone and from aquifer. The partial presence of water in stream bed in May in the Bangarmakki valley indicates stable presence of ground water in the area even in dry summer period, despite having heavy use for horticultural crops. Increment in water table is more drastic in Sambegadde compared to Bangarmakki due to its completely dry stream bed and sharp decline in the ground water table during summer.

Here we find the hydrological significance of a natural sacred site (Karikan) benefitting immensely the farming community in the valley downhill. The predominance of water demanding plantation crops at Bangarmakki indicates year long water availability in the region whereas, Sambegadde shows dominance of rain-fed cultivation mainly of paddy, (64 % of total cultivable area) with less plantation crops (29 % of total cultivable area). The availability of water for longer period (lean seasons) is also reflected in water usage pattern. Monthly water utility in dry period (January to May) shows that Bangarmakki has more water availability as reflected in the usage (1862 - 136 Kilolitres ha^{-1}) than Sambegadde (947 - 37 Kilolitres ha^{-1}). Similarly, a conservative monetary assessment on farm production has also highlighted the contrast between the areas. Constant availability and higher market prices of horticultural products keeps the Bangarmakki farmers in better economic situation in comparison to Sambegadde farmers. The farmers in Sambegadde, obviously, not backed to that extent by supporting forests like a primeval sacred grove, have to subsist mainly on rainfed rice. They are also required to grapple with fast depleting water table in the dry months throwing challenges for maintenance of cash crops in their gardens.

Conclusions

Comparative analysis of water yields from the watersheds of sacred forest dominated Karikan hill of Bangarmakki village and secondary forest dominated Sambegadde hill fortifies the contention of many investigators alluding to the intimate linkages between sacred groves and water conservation. Despite the smallness of this empirical study, confined to merely two forested watersheds, it illustrates the possible link of water availability in the watershed with the preservation of native primary forests to some extent. The retention of native forests as sacred groves, as reflected in their vegetation dominated by relic species, has added significance in the form of better status of soil moisture and ground water. That such forests were protected as integral to the cultures of the region highlights the need for more studies on the eco-centric societies and their conservation practices in the Western Ghats, one of the global biodiversity hotspots.

This finding has also much bearing on conservation and management of the last remains of primeval forests of the Western Ghats. Many of these forests, the sacred groves which had greater ecological and cultural roles in the rural land-scapes of the bygone days, are being increasingly targeted for development of hydroelectric projects or being reclaimed for cultivation and other alternative land uses by the local communities themselves who are under the throes of a cultural change that is distancing them from their age old traditions of worship associated with natural sacred sites. It is time that the waning sacred groves of central Western Ghats, which once con-stituted major landmarks of the pre-colonial villages, and functioned as decentralised water conservation systems, are resurrected through an active conservation program designed to ensure their long term survival and benefit to local liveli-hood.

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