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Tree species diversity, distribution and soil nutrient status along altitudinal gradients in Saptasajya hill range, Eastern Ghats, India

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ABSTRACT: This study analysed the diversity of tree species, their distribution and soil nutrient status along altitudinal gradients of Saptasajya hill range, Eastern Ghats, India. Thirty quadrats of 10m×10m size for trees across the altitude ranges between 81m and 450m were laid. Field sampling were conducted at 3 different elevation sites of the hill range: Site 1- Low Elevation Forest (LEF), Site 2- Middle Elevation Forest (MEF) and Site 3- High Elevation Forest (HEF). A total of 368 individuals which belongs to 48 species among 42 genera and 27 families were recorded in 0.3 ha sampling areas. Maximum numbers of tree species occurred at LEF (35) followed by MEF (34) and HEF (14). The density of tree species varied from 433 ha^{-1} to 390 ha^{-1} with average basal area of 30.64 m^2/ha. The Shannon diversity index (H′) varied among the three sites was 2.19 (LEF), 1.84 (MEF) and 1.29 (HEF). The soil parameters of three forest sites were analysed and correlated with tree species richness, diversity and density. Species richness and tree diversity index were positively correlated with pH (r=0.743 and r=0.829 respectively; $p<0.05$), whereas tree density was negatively correlated with pH (r= -0.597), phosphorous (r= -0.401), organic carbon (r= -0.543) and tree diversity index (r= -0.364). It could be helpful to understand the pattern of vegetation and its relation to soil nutrients in Eastern Ghats of India implicating conservation plan for tree species in tropical moist deciduous forests.

KEY WORDS: Altitudinal gradients; Eastern Ghats; Diversity indices; India; Soil nutrient status; Tropical moist deciduous forest.

INTRODUCTION

Quantitative and qualitative study of vegetation provides all prerequisites to understand the overall structure and function of any ecosystem. The present ecology is stressed in control of alpha diversity and/or protection of coexistence of species at small spatial area (Wright, 2002). Several studies has been accomplished on plant species composition and diversity in order to perform fruitful conservation, effective management under logical exploitation of forests (Andel, 2001; Lovett *et al.,* 2000; Nebel *et al.,* 2001; Chiarucci *et al.,* 2001; Parthasarathy, 2001; Huang *et al.,* 2003; Aubert *et al.,* 2003). Tropical forests are recognised to harbour significant proportion of global biodiversity and are the richest biological communities on earth (Myers *et al.,* 2000; Baraloto *et al.,* 2013). However, most of these forests are threatened by immense anthropogenic disturbances which require integrative interventions in management to retain overall biodiversity for sustainability of natural ecosystem (Kumar *et al.,* 2006). Important ecological services like restriction of soil erosion and species conservation with preservation of habitats for sustainability of life forms are functional aspects of such forests (Armenteras *et al.,* 2009).

The vegetation of any place is the outcome of interaction of many factors such as mesotopographic gradients, elevation, soil, species composition and biotic interferences (Bliss, 1963; Douglas and Bliss, 1977; Billings, 1979). There are many interacting factors which influence the regional species patterns are competition, geographic area, plant productivity, history of evolution and development, regional species dynamics and species pool, environmental variability and importantly the human activities (Criddle *et al.* 2003; Eriksson, 1996; Woodward, 1988; Zobel, 1997). Some other biotic factors include quality of seeds and survivorship of seedling which are among important requirements for maintenance of tree species composition in tropical forest areas (Connell, 1971). According to Mani and Parthasarathy (2006), rapid loss of forest habitat is due to the over exploitation to the resources which has been recognised as the biggest environmental and economic problem around the world. Increase in human population became a major threat which led expansion of agricultural lands and over grazing of live stocks (Anitha *et al.,* 2010). Analysis of the pattern of diversity, causes of diversity loss and its maintenance are the real challenges for present day ecologist, evolutionary and conservation biologist. Gentry (1982, 1995) stated that understandings on biodiversity and interest have been increased within tropics. This is very important in respect to preserve forest resources and to evaluate the complexity within.

Among twelve mega biodiversity countries, India is unique by having diverse habitat and rich vegetation inhabited in them. In India, the highest floral diversity is found in tropical moist deciduous forests which are one of the major forest types of India. The total forest coverof India is about 708,273 km^2 which contributes 21.54% of

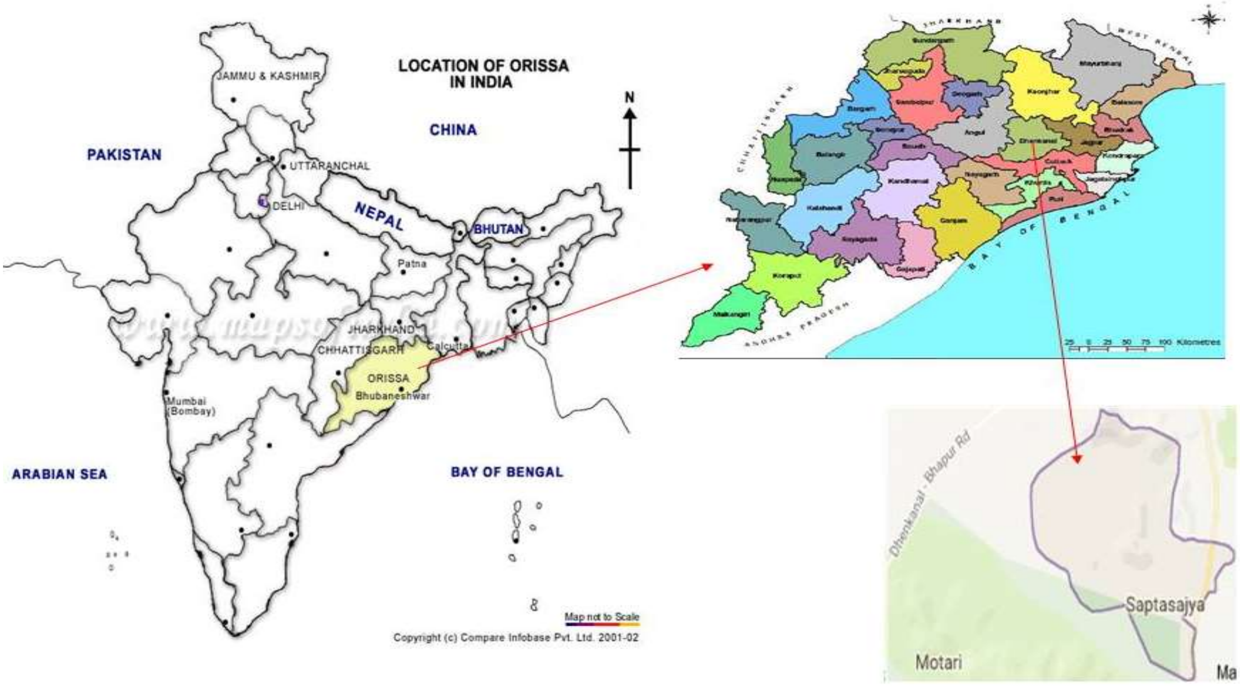

Fig. 1. Map of study area.

the total geographical area of the country (FSI, 2017). The peninsular regions of India i.e. Western Ghats and Eastern Ghats are two major regions of diversity where the anthropogenic pressure made change in vegetation remarkably and still it is continuing at an alarming rate (Parthasarathy, 1999). On the other hand, adequate knowledge on vegetation structure and their dynamics is still lacking (Hubbell and Foster, 1992). So, as suggested by Congdon and Herbohn (1993), it is necessary to understand the forest processes with integrated techniques for impact assessment, disturbances and their effect, optimization of productivity and ecosystem rehabitation is applicable in these areas. The attempt to study phytosociology of Western Ghats (Sukumar *et al.,* 1992; Ganesh *et al.,* 1996; Pascal and Pelissier, 1996; Ghate *et al.,* 1998; Parthasarathy, 1999), Coromandal coast (Parthasarathy and Sethi, 1997) and Eastern Ghats (Kadavul and Parthasarathy, 1999a, b; Sahu *et al.,* 2007; Sahu *et al.,* 2010; Sahu *et al.,* 2012a, b) are significant.

However, phytosociological studies in the forests of Eastern Ghats based on altitude gradients are very poorly explored. There are only a few studies available on altitude-based plant distribution in Eastern Ghats (Bhadra *et al.* 2010a). Therefore, we had made an attempt to quantify the diversity of tree species along altitude gradients in a tropical moist deciduous forest of Saptasajya hill range, Eastern Ghats of Odisha, India. The premeditated objectives of this study were to (1) study the diversity and distribution of tree species along different altitude ranges, (2) correlate the tree species diversity with soil nutrients.

MATERIALS AND METHODS

Study area

Saptasajya hill range is a series of hills present in Dhenkanal district of Odisha, India. It is an idyllic place of scenic beauty and very rich in vegetation. It is located between 20°57′N latitude and 85°54′E longitude (Fig. 1). The entire hill range is spread over an area of 2096.75 hectare. According to Champion & Seth (1968), Saptasajya hill range fall under tropical moist deciduous forest type. In many Hindu Mythological legends, the place finds its mention. According to folklore, its name was derived from surrounding seven hills which represents seven beds or seven home of Saptarishi (Seven Monks). Another mythological story suggests that during the exile of lord Rama, they spent seven days in these seven hills. Due to diversified topography with a stream, the place is having one among the most congenial environment for the growth of plant resources. But these resources suffer severe threat due to over-exploitation by local people, heavy grazing and tourism. The data were collected from three different sites of Saptasajya hill range: Site 1-Low Elevation Forest (LEF) (20°57′N, 85°56′E, Altitude range 81-230m), Site 2- Middle Elevation Forest (MEF) (20°57′N, 85°55′E, Altitude range 231-350m) and Site 3- High Elevation Forest (HEF)(20°57′N, 85°55′E, Altitude range 351-450m) during December to March, 2016-17.

Climate and soil

The hill range enjoys tropical monsoonal climate as it receives most of the rains by south-west monsoon. The climatic condition of the study area is hot & dry sub-humid with an average annual rainfall of 1500 mm. Rain fall rate in this district varies from 1000-1700 mm based on 11 years data (2004-2014) collected from the Forest Department, Dhenkanal. The soil of Saptasajya hill range is mainly red sandy loamy type. Red soils are deficient of nitrogen, phosphates and organic matter. Further, it is tight textured and devoid of carbonates. The average minimum & maximum temperatures are 13ºC and 40ºC respectively. The humidity is generally high varying from 31% to 88%. The hill range also regulates the climate of Dhenkanal city as it is situated very close to it.

Field sampling

Data were collected from three altitudinal gradients of Saptasajya hill range. Low elevation site was between 81-231 m height from mean sea level (msl), Middle elevation site was between 231-350 m height from msl and the high elevation site lies between 350 m and 450m from msl. This study was carried out during December to March, 2016-17. The vegetation was studied via random sampling quadrat method. Ten quadrats, each of 10×10 m^2 were laid on each site of the purpose of studying the trees diversity and distribution. In each quadrat, the girth at breast height (gbh) of each tree (≥10 cm gbh) was measured, and individuals with gbh<10cm were recorded as samplings (Pande *et al.,* 1988). The tree species dominance was determined using the Important Value Index (IVI) of these species. Geographical coordinates of the sites were taken using Global Positioning System (GPS). Identification of tree species was done with the help of regional floras (Saxena and Brahmam, 1994-96; Gamble and Fischer 1915-35). The voucher specimens were preserved in the Biosystematics laboratory, Department of Botany, North Orissa University, Baripada.

Data analysis

Vegetation composition was evaluated by analysing frequency, density, abundance, relative frequency, relative density, relative dominance, basal area and IVI, using the formula given by Curtis and Mclntosh (1951). A girth class analysis was also done to analyse the structural composition of the sites. The distribution data were then used to compute the community indices like Shannon-Diversity Index and Simpson index of the vegetation. Opted formulas for the analysis were:

Frequency = (Total no. of quadrats in which the species occurred/Total no. of quadrats studied)100%

Density =Number of individuals of the species/Total number of quadrates studied

Abundance =Total no of individuals of the species/No. of quadrats in which the species occurred

Relative frequency (%) = (Frequency of the species /Frequency of all the species) 100%

Relative density (%) = (Density of the species /Density of all the species) 100%

Relative dominance (%) = (Basal area of the species /Total basal area of all the species) 100%

IVI = Relative frequency + Relative density + Relative dominance

Diversity indices

Shannon-Wiener diversity index (H′) (Shannon and Weaver 1963):

$$H' = -\sum_{i=1}^{s} pi \ ln \ pi$$

Where s= number of species; p_i =proportion of individuals or abundance of the ith species expressed as a proportion of total cover.

Simpson index (Concentration of dominance) (Simpson 1949):

$$Cd = \Sigma \, (n_i/N)^2$$

Where, n_i and N are the same as those for Shannon-Weiner information function.

Evenness (e):

$$e = H'/\log S$$

Where H′ =Shannon index, S=number of species.

Distributions of tree species were calculated using the ratio of abundance to frequency (Whitford, 1949). If the value lies below 0.025: regular, 0.025 – 0.05: random and if > 0.05 contiguous (Curtis & Cottam, 1956).

Collection of soil sample and analyses

A total of 30 soil samples were collected from 3 study sites (10 from each site and 1 per plot). The three samples of soil from each sampling plot were put in plastic bags and mixed together to make a test sample of soil. The depth of the soil sampling was done at 0–30 cm using auger (Radius = 3.5 cm, Depth = 30 cm) and brought to the soil testing laboratory of Krishi Vigyan Kendra, ICAR, Mahisapat, Dhenkanal. The soil samples were oven dried at 60 degree centigrade and sieved (2mm). These samples were analysed for pH, organic carbon (OC), available nitrogen, available phosphorus and electrical conductivity (EC). Digital pH and EC meter were used to find out soil pH and EC making supernatant saturated suspension of soil and water in the ratio 1: 2.5 respectively. Organic carbon content, available nitrogen and available phosphorus were estimated after cleaning out debris from soil samples by hand. Air dried soil samples were estimated according to the standard method (Maiti, 2003) for organic carbon content by Walkley and Black method, total nitrogen by Micro Kjeldahl method and total phosphorus by Molybdenum-blue method.

Pearson correlation coefficient was studied between soil physicochemical parameters, tree density, species richness and diversity indices at three studied forest sites using MATLAB R2017 software. Further, two-way ANOVA Tukey's multiple comparisons test for soil properties were done using Graphpad PRISM 7 software.

RESULTS

A total of 368 individuals belonging to 48 species (≥10 cm gbh) among 42 genera and 27 families were recorded in 0.3 ha area sampling. Three forest sites, namely LEF, MEF and HEF had shown remarkable difference in vegetation composition among each other. We found 130 individuals belonging to 35 species among 31 genera and 22 families in LEF, 121 individuals belonging to 34 species among 31 genera and 23 families in MEF and 117 individual belonging to 14 species among 14 genera and13 families in HEF. The number of families that included total tree species in three sites of the study area was 27. At LEF, Moraceae had the maximum number of species (6 species) followed by Rutaceae (4 species), Fabaceae (3 species) and so on. At MEF, Moraceae had the maximum number of species (4 species) followed by Rutaceae and Mimosaceae (3 species each), Caesalpiniaceae, Anacardiaceae (2 species each) and so on. At HEF, Anacardiaceae had the maximum number of species (2 species) and other families had one species each. The Important Value Index (IVI) was highest in *Mangifera indica* (112.764) and lowest in *Macaranga peltata* (2.109) at MEF. Similarly, LEF and HEF had highest IVI value of 75.48 (*Mangifer aindica*) and 102.11 (*Shorea robusta*) and lowest of 1.81 (*Pongamia pinnata*) and 2.87 (*Xyliaxylo carpa*) respectively (Table 1). The Shannon diversity index (H′) varied among the three sites was 2.19 (LEF), 1.84 (MEF) and 1.29 (HEF) with Simpson's index value ranging from 0.87 to 0.62. The evenness values for three sites were 0.92 (LEF) followed by 0.80 (MEF) and 0.68 (HEF) (Table 2).

The mean stand density was 409 individuals/ha. The highest stand density was observed in LEF (433 individuals/ha) followed by MEF (403 individuals/ha) and HEF (390 individuals/ha). The basal area ranged from 46.73 (LEF) to 22.21 m^2/ha (HEF) with a mean of 30.64 m^2/ha. Tree girth class wise density was more for the 20-40 cm interval with 55 numbers of individuals at LEF and 61 at HEF whereas >100 cm girth class was more (63) at MEF. The girth class interval 40-60 cm was represented as 36 numbers of individuals at MEF followed by 33 at HEF and 15 at LEF. The girth class study revealed that more numbers of individuals of >100 cm girth class were distributed in MEF and less in HEF. In girth class10-20 cm intervals, there was not a single individual was found at HEF where as MEF and LEF had 1 and 11 individuals respectively (Fig 2 a, b, c).

The present study on distribution pattern of tree species indicated that maximum number of tree species i.e. 18 had contagious distribution whereas 11 species showed random and only 5 had regular distribution pattern at MEF. At LEF, distribution pattern is quite similar to MEF because it had also highest number of contagious distribution (17) along with12 random and 6 regulars. But, at HEF the pattern was remarkably different from LEF and MEF, maximum number of tree species (7) showed random distribution followed by regular (4) and contagious (3).

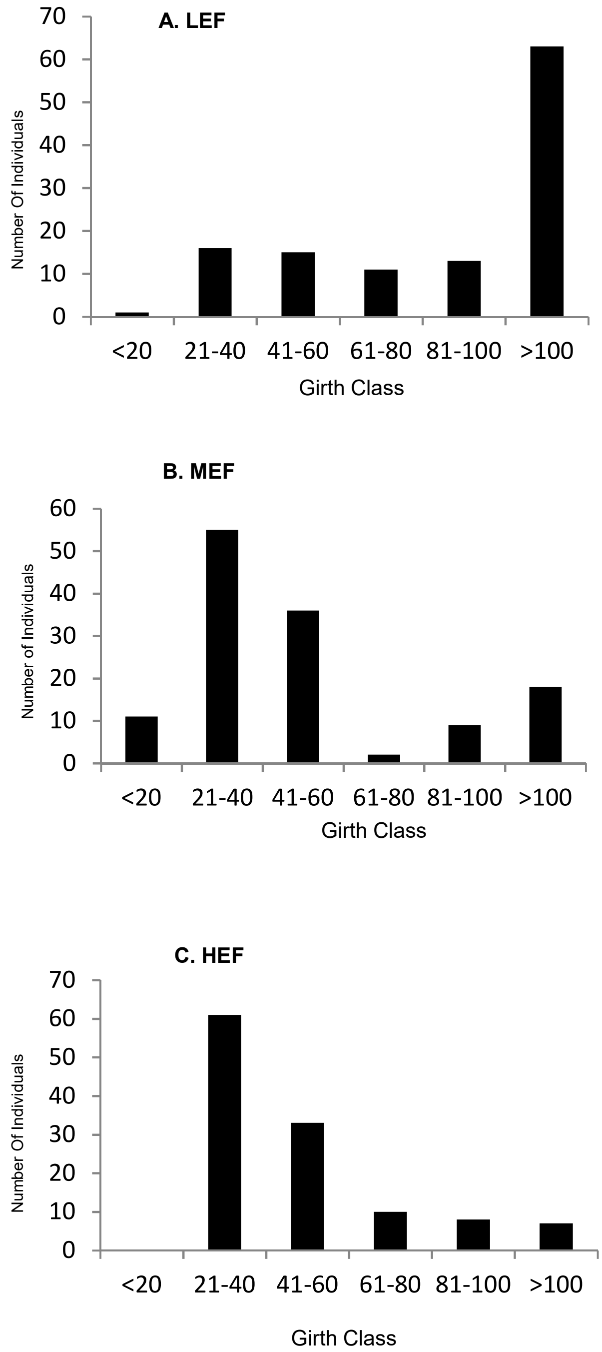

Fig. 2. Contribution of tree stand density based on girth class distribution for three forest sites of Saptasajya hill range, Eastern Ghats of Odisha.

Table 1. Distribution analysis of tree species at three forest sites of Saptasajya hill range, Eastern Ghats of Odisha: LEF-Low Elevation Forest, MEF-Middle Elevation Forest and HEF-High Elevation Forest.

		LEF				MEF				HEF			
Species	Family	F	A	A/F	IVI	F	A	A/F	IVI	F	A	A/F	IVI
Acacia nilotica	Mimosaceae					10	1	0.1	2.109				
Aegle marmelos	Rutaceae	60	1.16	0.019	12.631	20	1	0.05	4.357				
Alangium salviifolium	Alangiaceae	40	1.25	0.031	8.505	10	1	0.1	2.152				
Albizia lebbeck	Mimosaceae	10	1	0.1	3.962	10	1	0.1	3.168				
Alstonia scholaris	Apocynaceae	20	1	0.05	11.604								
Anthocephalus cadamba	Rubiaceae	10	1	0.1	1.858	10	1	0.1	2.175				
Artocarpus integrifolia	Moraceae	20	1	0.05	9.366								
Artocarpus lacucha	Moraceae					40	1	0.025	10.865				
Azadirachta indica	Meliaceae					10	1	0.1	2.309				
Bombax ceiba	Bombacaceae	10	1	0.1	3.635								
Buchanania lanzan	Anacardiaceae					10	1	0.1	2.18	30	1	0.033	10.024
Butea monosperma	Fabaceae					10	1	0.1	2.281				
Caryota urens	Arecaceae	10	1	0.1	3.313	60	1.16	0.019	28.928	10	1	0.1	3.109
Casearia elliptica	Flacourtiaceae					20	1	0.05	4.528				
Cassia fistula	Caesalpiniaceae	60	1.5	0.025	14.878								
Chloroxylon swietenia	Rutaceae	20	1	0.05	3.753								
Cycas circinalis	Cycadaceae	20	1	0.05	3.927	10	1	0.1	2.218	40	2.25	0.056	29.138
Dalbergia paniculata	Fabaceae	40	1.5	0.037	9.237								
Dillenia pentagyna	Dilleniaceae	20	1	0.05	3.69	10	1	0.1	2.164	40	1.25	0.031	12.555
Diospyros embryopteris	Ebenaceae	40	1.75	0.043	10.748	30	1	0.033	6.863	30	1	0.033	12.355
Diospyros melanoxylon	Ebenaceae	10	1	0.1	2.116	10	1	0.1	2.362				
Erythrina indica	Fabaceae	10	1	0.1	2.222								
Ficus benghalensis	Moraceae	10	1	0.1	3.105	10	1	0.1	4.741				
Ficus hispida	Moraceae	10	1	0.1	1.967	10	1	0.1	3.01				
Ficus racemosa	Moraceae	90	2.22	0.024	29.068								
Ficus religiosa	Moraceae	20	1	0.05	6.967	30	1	0.033	7.789				
Leucaena leucocephala	Mimosaceae	20	1	0.05	4.038								
Macaranga peltata	Euphorbiaceae	40	1.25	0.031	8.517	10	1	0.1	2.109				
Madhuca indica	Sapotaceae	10	1	0.1	2.27	50	1	0.02	11.348				
Mangifera indica	Anacardiaceae	90	1.44	0.016	75.48	100	4.5	0.045	112.764	70	1.28	0.018	54.77
Manilkara hexandra	Sapotaceae					10	1	0.1	3.238				
Memecylon edule	Melastomataceae					10	1	0.1	2.562				
Mimusops elengi	Sapotaceae	10	1	0.1	1.906					20	1	0.05	7.087
Murraya exotica	Rutaceae	40	1	0.025	7.366	40	1	0.025	8.52				
Naringi crenulata	Rutaceae	20	1	0.05	3.609	10	1	0.1	2.264				
Pongamia pinnata	Fabaceae	10	1	0.1	1.819								
Pterospermum acerifolium	Sterculiaceae	10	1	0.1	2.119	20	1	0.05	4.43	40	1	0.025	13.817
Schleichera oleosa	Sapindaceae					40	1.25	0.031	10.753	70	1	0.014	28.392
Shorea robusta	Dipterocarpaceae					50	1.2	0.024	11.494	100	6.7	0.067	102.114
Streblus asper	Moraceae	60	1.66	0.027	13.844	30	1	0.033	6.36	20	1	0.05	6.553
Strychnos nux-vomica	Strychnaceae	30	1	0.033	9.913	30	1.33	0.044	7.228	40	1	0.025	11.469
Syzygium cumuni	Myrtaceae	20	1	0.05	3.78								
Tamarindus indica	Caesalpiniaceae					20	1	0.05	4.519				
Tectona grandis	Verbenaceae	70	1.42	0.02	19.221	10	1	0.1	2.425				
Terminalia bellirica	Combretaceae	10	1	0.1	3.973								
Xyliaxylo carpa	Mimosaceae					10	1	0.1	2.178	10	1	0.1	2.874
Ziziphus mauritiana	Rhamnaceae	30	1	0.033	6.109	20	1	0.05	4.226	20	1	0.05	5.736

Table 2. Species richness, number of individuals and diversity indices for three forest sites of Saptasajya hill range, Eastern Ghats of Odisha.

Variables	LEF	MEF	HEF
Number of Individual	130	121	117
Number of Species	35	34	14
Number of Genera	30	31	14
Number of Family	22	23	13
Density	433	403	390
Basal Area (m2/ha)	46.73	22.98	22.21
Shannon Index	2.19	1.84	1.29
Simpson Index	0.87	0.79	0.62
Evenness	0.92	0.80	0.68

LEF= Low Elevation Forest, MEF= Middle Elevation Forest, HEF= High Elevation Forest

Soil analysis

The pH of the soil was found to be slightly acidic in all sites. The average soil pH varies from 5.66 to 6.23. The lowest acidity was found at LEF (pH = 6.25±0.03) and highest acidity was found at HEF (pH = 5.66±0.02). The organic carbon (OC) content ranged in between 0.61% to 0.79%. The highest OC value was reported at MEF whereas lowest value was found at HEF. The nitrogen content (%) of three sites were found to be highest at MEF (0.29±0.01) followed by LEF (0.27±0.01) and HEF (0.26±0.01). This indicates that all the sites contain moderate concentration of nitrogen. The concentration of phosphorous was found to be highest at

Table 3. Two-way ANOVA with Tukey's multiple comparison tests: (using PRISM 7.0)

Parameter	LEF(SITE-I)		MEF(SITE-II)		HEF(SITE-III)		Significant Difference		
	mean	SEM	mean	SEM	mean	SEM	LEF(SITE-I) vs. MEF(SITE-II)	LEF(SITE-I) vs. HEF(SITE-III)	MEF(SITE-II) vs. HEF(SITE-III),
P^H	6.255	0.034	6.235	0.032	5.66	0.027	No, p=0.9942	Yes, p=0.0073	Yes, p=0.0100
EC (dS/m)	0.16	0.005	0.111	0.006	0.16	0.005	No, p= 0.9659	No, p>0.9999	No, p=0.9659
N%	0.27	0.008	0.291	0.008	0.263	0.005	No, p=0.9936	No, p=0.9993	No, p=0.9887
P%	0.12	0.004	0.152	0.010	0.112	0.006	No, p=0.9853	No, p= 0.9991	No, p=0.9771
OC%	0.65	0.005	0.798	0.009	0.61	0.004	No, p=0.7291	No, p=0.9771	No, p=0.6012
C/N	2.430	0.083	2.766	0.100	2.328	0.049	No, p= 0.1996	No, p=0.8587	No, p=0.0657
C/P	5.503	0.255	5.469	0.375	5.656	0.384	No, p=0.9835	No, p= 0.7137	No, p=0.6048
N/P	2.297	0.149	2.025	0.197	2.419	0.136	No, p=0.3482	No, p=0.8059	No, p=0.1108

LEF= Low Elevation Forest, MEF= Middle Elevation forest, HEF= High Elevation Forest (N= 10 for all forest sites)

MEF (0.15±0.01) followed by LEF (0.12±0.01) and HEF (0.11±0.01). The C: N ratio varies from 2.32 to 2.76 at three different sites of forest. The ratio of C: P varies from 5.46 to 5.65 and the ratio of N: P varies from 2.02 to 2.41. Soil analysis of three sites revealed that the concentration of C, N and P were highest in MEF than LEF and HEF (Table 3). The statistical differences of soil nutrients among the three forest sites were calculated with two-way ANOVA Tukey's test by Graphpad prism 7 software. The multiple comparison test shows that there are no statistical difference in soil properties among these three forest sites except the pH value ($p<0.05$).

Species Richness, Tree Density and Diversity Index in relation to soil properties

The correlation of soil parameters with species richness, tree density and diversity index showed some similarity among three elevation ranges (Fig 3). The species richness, tree density and diversity index were positively correlated in all the three sites. In LEF, pH was negatively correlated to phosphorous (r= -0.689; $p<0.05$). In MEF, tree diversity index was positively correlated to nitrogen (r=0.726) and species richness was also positively correlated to nitrogen (r= 0.696). In HEF, tree density was positively correlated to diversity index (r= 0.800) whereas tree diversity index was positively correlated to organic carbon (r= 0.631).

The overall relationship along altitude gradient showed a different picture (Table 4). Species richness and tree diversity index were positively correlated with pH (r=0.743 and r=0.829 respectively; $p<0.05$), whereas tree density was negatively correlated with pH (r= -0.597), phosphorous (r= -0.401), organic carbon (r= -0.543) and tree diversity index (r= -0.364). However, tree density was positively correlated to EC (r= 0.378).

DISCUSSION

The attributes of forest ecosystem like structure, composition and function changes in response to itsassociate edaphic, climatic and topographic conditions, not excluding the anthropogenic disturbances. All these factors including forest succession are simultaneously responsible for variations in forest at both local and landscape level by formation of special heterogeneity (Timilsina *et al.,* 2007). Study of species diversity reveals composition of ecosystem and also variations among different ecosystem. Therefore, our study was aimed at assessing the tree species diversity along altitudinal gradients of Saptasajya Hill range.

A total of 48 tree species were studied from 0.3-hectare area sampling in the moist deciduous forest stands of Saptasajya hill range. The maximum diversityof tree species occurred on the site LEF (35) followed by MEF (34) and HEF (14). Hence, the number of tree species decreases from lower altitude (81m) to higher altitude (450m) level. The result is not satisfying the hypothesis (Hard boundary / Mid domain effect hypothesis) proposed by Colwell and Hurt (1994) which states that mid elevation possess highest species richness. According to the hypothesis, mid elevation peak of species richness is due to increase in overlapping of species ranges towards the centre of total elevation range. This may be due to the unequal segregation made among LEF, MEF and HEF.The numbers of tree species recorded in the study site were found to be lower than the number of species reported by several workers in other tropical forests (Kumar *et al.,* 2006; Jayakumar and Nair, 2013; Kumar *et al.,* 2010; Chowdhury *et al.,* 2000; Fox *et al.,* 1997; Kadavul and Parthasarathy, 1999a, b; Khera *et al.,* 2001). In this study, Shannon diversity index (H′) varied among the three sites i.e. 2.2 in LEF, 1.89 in MEF and 1.29 in HEF which are coming under the previously studied range 0.81- 4.1 at different other tropical forests (Visalakshi, 1995; Sahu *et al.,* 2012a; Sundarapandian and Swamy, 2000). The concentrations of dominance (Simpson's index) were ranged from 0.62 to 0.86 which also corresponded well within several other reports of tropical forests (Parthasarthy *et al.,* 1992; Visalakshi, 1995; Sahu *et al.,* 2007).

The tree stand density of three forest sites ranged from 433 trees/ha to 390 trees/ha which is found lower compared to the report of Kadavul and Parthasarathy (1999a, b) on Kalarayan hills. It was ranged from 640 trees/ha to 986 trees/ha which is much more than our

Table 4: Pearson correlation coefficients between soil properties, Species richness, diversity index and tree density at three study sites.

	pH	EC (µs/cm)	N%	P%	OC%	Diversity index	Species Richness	Tree Density
pH	1							
EC(µs/cm)	-0.29695	1						
N%	0.34899	-0.3451	1					
P%	0.31372	-0.5272**	0.09328	1				
OC%	0.59688**	-0.7257**	0.39879**	0.62086**	1			
Diversity index	0.82976**	-0.0174	0.24986	0.11299	0.30794	1		
Species Richness	0.74325**	-0.0093	0.16276	0.11532	0.24484	0.96591	1	
Tree Density	-0.5972**	0.37817**	-0.3296	-0.4019**	-0.5438**	-0.364**	-0.2883	1

** P- value <0.05

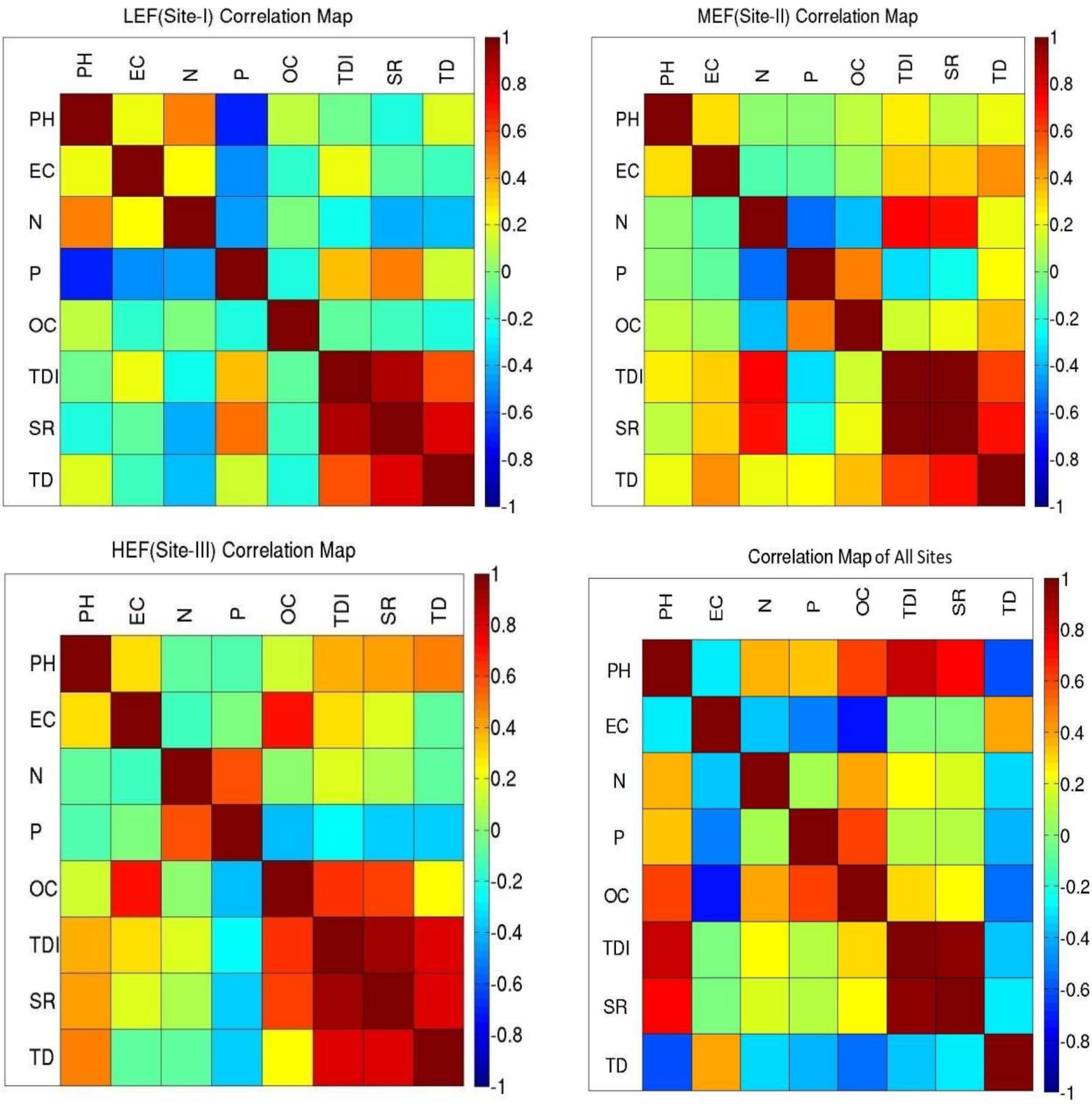

Fig. 3. Correlation map of Pearson correlation coefficients values among different soil parameters and Diversity index, species richness and tree density in different elevation ranges. Here, TD stands for Tree Density, TDI for Tree Diversity Index and SR for Species Richness.

study. Similarly, the density of Eastern Ghats (northern Andhra Pradesh region) (Reddy *et al.,* 2011) and Gandhmardan hills, Eastern Ghats (Sahu *et al.,* 2010) are found more than our study sites. Our result on density resembles closest with the result of tropical dry forest of Deogarh district of Odisha state in India i.e. 479 trees/ha (Sahu *et al.,* 2016). Simultaneously, the mean stand density is well within the range of 276 - 905 stems ha^{-1} reported for trees in other tropical forests (Bhadra *et al.,* 2010b; Nirmal Kumar *et al.,* 2010; Sahu*et al.,* 2007). Girth class-wise frequency structures of trees in three sites were found conformity with several other tropical forests of Eastern and Western Ghats in India are Shervarayan hills Kakachi (Ganesh *et al.,* 1996), (Kadavul and Parathasarthy, 1999a), Kalrayan hills (Kadavul and Parthasarathy, 1999b), Malyagiri hill range (Sahu *et al.,* 2012b), Uppangala (Pascal and Pelissier, 1996). The size class distribution showed decline in number of individuals from lower class to higher class indicating expanding population in HEF and MEF sites where as the LEF forest site was not in this trend. It may be attributed to more anthropogenic activities in lower elevation forest.

The basal area of trees in the moist deciduous forest stands of Saptasajya hill range varied from 46.73 to 22.21 m^2/ha with a mean of 30.64 m^2/ha. The differences in the basal area of tree layers among the three sites may be due to differences in altitude, age of trees, climate and prevailing edaphic factors. This result is comparatively higher than the study made at different forests of India by Naidu and Kumar (2016), Sagar and Singh (2006), Jha and Singh (1990) and Parthasarathy and Sethi (1997).

An analysis of distribution pattern of tree species in three sites of Saptasajya hill range indicated that maximum tree species had contagious distribution although there were a few species that showed random and regular distribution. According to Odum (1971), contagious distribution is common in nature in tropical heterogeneous forests, whereas random and regular distribution is found only under a uniform environment. Contagious distribution has also been reported by various authors from different parts of India (Bhat, 2012; Sahu *et al.,* 2012; Malik *et al.,* 2014).

The soil pH in all sites is found to be acidic. One possible explanation for this could be the weathering of rocks at these sites, because weathering of rock reported to increase pH of soil (Khera *et al.,* 2001). Saptasajya forest with soil pH 5.6 to 6.25 showing sufficient nutrient supply and reduced cation losses in leaching. Species diversity at three points was found to be reduced with the increase in elevation. This may possibly be explained as periodic soil erosion in hill slope and hilltop. The organic carbon (OC) was higher in MEF (0.79%) compared with the sites of LEF and HEF (0.65 % and 0.61%). These values are lowers than the values reported in early studies for organic carbon in dry deciduous forest i.e. 2.23-2.81% in western India (Kumar *et al.,* 2010). In the present study, soil carbon %, total nitrogen % and phosphorus % were found to be high in MEF, and it was observed that these values decreased with the increase in elevation. Our correlation study between soil nutrients with species richness, tree density and diversity index confirms a significant relationship. There were also a significant correlation found by Perroni-Ventura *et al.* (2006); John *et al.* (2007), Juli and Mike (2001) and Sahu *et al.* (2012) among these variables. As studied by Sahu *et al* (2012), pH and OC were negatively correlated with tree density whereas EC, N, P to be positively correlated with the same. But, the present study showed negative correlation between tree density and OC, P, pH but correlation among EC and tree density was positive. Species richness and tree diversity index were positively correlated with pH.

Saptasajya hill range possesses a great heritage of diversity on gene pool of many important tree species as well as valuable medicinal plants. Tree species like *Ficus religiosa*, *Aegle marmelos* and *Streblus asper* are worshiped by the local people. Among medicinal plants *Rauvolfia serpentina, Tridax procumbens, Argemone mexicana* are naturally conserved by the tribal community due to their importance in traditional health care system. Habitat conservation preventing biotic interference and sustainable collection of medicinal plants by the local people is considered as the only effective measure including in-situ and ex-situ conservation of threatened taxa. Threatened medicinal plants should be conserved through ex-situ conservation in the form of botanical garden or nursery to generate more seedlings and planted in their natural habitat. Saptasajya hill range not only increases the beauty of nature but also provide habitat to wild fauna. It is a tourist place and being a source of income for the state. Further, the rich floristic diversity and extensive green vegetation of these hills maintain the ecological balance of the area in moderating weather conditions. Because it acts as a CO_2 sink in the environment. Pollution and other anthropogenic activities are going on and therefore, immediate attention should be given to conserve this forest ecosystem.

CONCLUSION

Vegetation is an essential element of all major ecosystems. The results of our study in Saptasajya hill range highlighted the status of dominant tree species including their diversity indices which will help the policy maker and conservation biologists to plan further on plantation and conservation of the selected tree species. On the other hand, awareness programme should be carried out on proper collection of medicinal plants and other forest products through sustainable collection, so that, the population of threatened medicinal plants will have no risk of extinction. Correlation study between the soil nutrients and tree species parameters reveals that species richness and tree diversity index were positively correlated with pH (r=0.743 and r=0.829 respectively; P<0.05), whereas tree density was negatively correlated with pH (r= -0.597), phosphorous (r= -0.401), organic carbon (r= -0.543) and tree diversity index (r= -0.364). The present study further needs an elaborative research on the relationship of tree species diversity with topographic and climatic variables which has direct implication for conservation and management practices in tropical forest ecosystem.

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