

Habitat similarity and species distribution analysis in tropical forests of eastern ghats, Tamilnadu

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Abstract: Sørensen similarity index and Coles association coefficient were computed to analyse the similarity between forest types and association between individual plant species in the Pacchaimalai hills of the eastern ghats of Tamil Nadu, South India. Sørensen index shows that the higher similarity existed between the evergreen and semievergreen, the semievergreen and dry mixed deciduous, the dry mixed deciduous and the dry savannah with the dry deciduous scrub, the southern thorn scrub and the southern thorn forests. Chi-square values are found to be significant between *Santalum album* with *Dodonaea viscosa*; *Cycas circinalis* with *Cleistanthus collinus*, *Combretum albidum*, *Pongamia pinnata* and *Symphorema involucratum*; *Nothopegia colebrookiana* with *Tarenna asiatica*; *Pterospermum xylocarpum* with *Doryopteris concolor*; *Smilax zeylanica* with *Acacia torta*; *Canarium strictum* with *Aglaia lawii* and *Dicliptera cuneata*; *Cymbopogon citratus* with *Grewia hirsuta* and *G. tiliifolia*. This study contributes to the growing body of evidence suggesting that many species of tropical trees are differentially distributed with respect to habitat variables, in this case to different forest types.

Resumen: El índice de similitud de Sørensen y el coeficiente de asociación de Coles fueron calculados para analizar la similitud entre tipos de bosque y la asociación entre algunas especies de plantas en las Colinas Pacchaimalai de los Gates Orientales de Tamil Nadu, sur de la India. El índice de Sørensen mostró que la similitud más alta existe entre los bosques perennifolio y subperennifolio, los bosques subperennifolio y mixto seco caducifolio, y entre el bosque seco mixto caducifolio y la sabana seca con el matorral seco caducifolio, el matorral espinoso sureño y el bosque espinoso sureño. Los valores de χ^2 fueron significativos para *Santalum album* con *Dodonaea viscosa*; *Cycas circinalis* con *Cleistanthus collinus*, *Combretum albidum*, *Pongamia pinnata* y *Symphorema involucratum*; *Nothopegia colebrookiana* con *Tarenna asiatica*; *Pterospermum xylocarpum* con *Doryopteris concolor*; *Smilax zeylanica* con *Acacia torta*; *Canarium strictum* con *Aglaia lawii* y *Dicliptera cuneata*; *Cymbopogon citratus* con *Grewia hirsuta* y *G. tillifolia*. Este estudio contribuye al creciente cuerpo de evidencia que sugiere que muchas especies de árboles tropicales están distribuidos diferencialmente con respecto a variables de hábitat, en este caso diferentes tipos de bosque.

Resumo: O índice de semelhança de Sorenson e o coeficiente de associação de Coles foram calculados para analisar a semelhança entre tipos florestais e associação entre espécies vegetais individuais nas colinas de Pacchaimalai nos ghats orientais de Tamil Nadu no Sul da Índia. O índice de Sorenson mostrou existir elevada semelhança entre a sempreverde e a semi-sempreverde, a semi-sempreverde e a decídua mista seca, a decídua mista seca e a savana seca com a arbustiva decídua seca, a arbustiva espinhosa do sul e a floresta espinhosa do sul. Os valores do Chi-quadrado encontrados eram significativos entre a *Santalum album* com a *Dodonaea viscosa*; *Cycas circinalis* com *Cleistanthus collinus*, *Combretum albidum*, *Pongamia pinnata* e *Symphorema involucratum*; *Nothopegia colebrookiana* com *Tarenna asiatica*; *Pterospermum xylocarpum* com *Doryopteris concolor*; *Smilax zeylanica* com *Accacia torta*; *Canarium strictum* com *Aglaia lawii* e *Dicliptera cuneata*; *Cymbopogon citratus* com *Grewia hirsuta* e *G. tillifolia*. Este estudo contribui para o aumento do corpo de evidência sugerindo que muitas espécies de árvores tropicais estão diferenciadamente distribuídas em relação às variáveis do habitat e, neste caso, com os diferentes tipos florestais.

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Key words: Coles association, eastern ghats, forest types, quadrat sampling techniques, satellite digital data, similarity index.

Introduction

Populations in a natural community are not distributed independently (Misra & Misra 1981) except in associations. Plant or animal species may exhibit positive and/or negative association among themselves because of interaction between the species or of the similar responses of the species to the same environmental variables. The pattern of distribution of a population of plants or of animals is a fundamental characteristic of that population (Clark & Evans 1954). The study of relational patterns in vegetation has developed rapidly since 1960s as an important method of studying community organization and species interrelation-ships (McIntosh 1962).

Biotic relationships are measured at three levels i.e. geographic, communal and interspecific (Brey 1956). At the community level, similarities between different communities (habitats) were analysed in terms of total species composition (Culberson 1955; Gleason 1920; Goodall 1952; Hanson 1955; Hopkins 1957; Sörenson 1948; Webb 1950; Whittaker 1952). The association of different species within a community forms the basis of the floral community classification. This interaction has been termed as interspecific association and measured by Dise (1948) followed by Cole (1949), who formulated C_7 , a coefficient of interspecific association. Since then many animal and plant ecologists (Beals 1965; Beaman & Anderson 1966; Cook & Hurst 1963; Greig-Smith 1952; Hurlbert 1969; Kershaw 1958, 1959; Macan 1954; Maguire 1963; Mall 1961; Mall & Das 1973; Nash 1950; 1963; Risser & Rice 1971; Singh 1969; Smith & Cottam 1967; Vasilevich 1961, Vessby *et al.* 2002) have studied association between plants and animal species.

However, the study of association between plant species within a community did not get enough attention by scientists except a few such as those of Goodall (1952), de Vries (1953) and Hale (1955). Knowledge on association between plant species has been applied to identify overall biodiversity by conservation biologists (Faith & Walker 1996; Noss 1990; Pharo *et al.* 1999). Similarly, distribution of birds, tiger beetles and butterflies serve as indicators to many other taxa (Blair 1999; Kremen 1992; Pearson & Cassola 1992). This study aims at analysis of similarity among different forest types with the help of

Sörenson index and analysis of interspecific association of *Santalum album*, *Gnetum edule*, *Psydrax dicoccos* (endangered), *Celastrus paniculatus* and *Cycas circinalis* (Vulnerable), *Gloriosa superba*, *Pterospermum xylocarpum* and *Smilax zeylanica* (Lower risk near threatened), *Elaeagnus indica*, *Nothopegia colebrookiana* and *Canarium strictum* (endemic to Peninsular India) (Ahmedullah & Nayar 1986; Nayar & Sastry 1987, 1988, 1990; Thinagaran & Ramanathan 1999). The positively associated species surely would help to conserve the above red listed species and the associated species which would help for their better survival.

Materials and methods

Study area

The Pacchaimalai hills (Fig. 1) are situated to the north of Turaiyur taluk of Tiruchirappalli districts, at latitudes $11^{\circ} 09' 00''$ to $11^{\circ} 27' 00''$ N and longitudes $78^{\circ} 28' 00''$ to $78^{\circ} 49' 00''$ E and occupy an area of about 527.61 sq. km. Climate is tropical with temperature ranging from 25 to

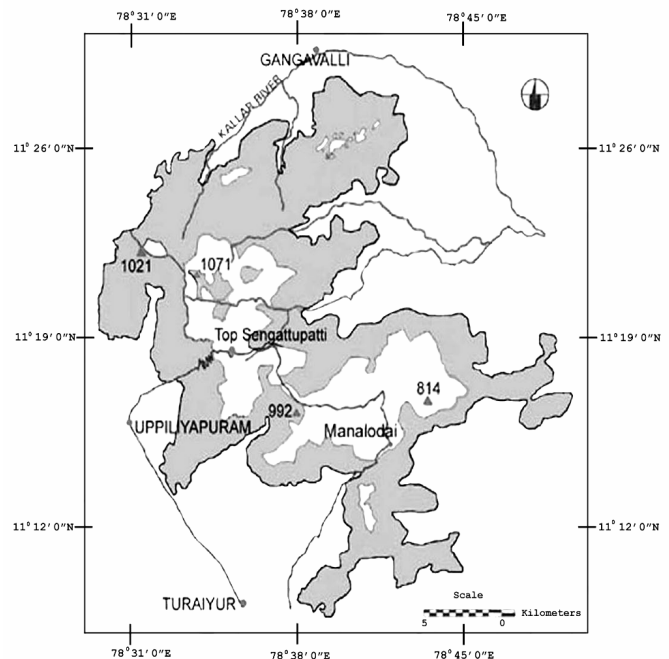


Fig. 1. Location map of the Pacchaimalai hills. Shaded region indicates protected area and numbers indicate altitude in m (mean sea level)

30°C and annual rainfall of 800 to 900 mm. The area is marked by the presence of crystalline rocks of the Archaean age comprising gneisses, charnockites and granites with little soil cover of red loamy and black. The crystalline terrain exhibits multispectral and poly metamorphic complexity. Natarajan (1998) differentiates three types of sedimentary rocks based on their period of origin. Pacchaimalai hills are drained by Swedanadi at northern part, Kallar river at north eastern part and Aiyar river in southern parts. The drainage pattern in the hills is dendrite and radial.

Vegetation mapping

Cloud-free IRS 1C LISS III Satellite digital data of Path 101 row 65 and 66 on February 1999 and Survey of India toposheets of 58 I / 7, 11, 12 and 15 were used for the study. Vegetation mapping was carried out using Erdas Imagine 8.3.1 and Arc dak (GIS) software (Driese *et al.* 1997; Radhakrishnan *et al.* 1996; Trisurat *et al.* 2000).

Data collection

Data collection was carried out following quadrat sampling techniques (Cottam & Curtis 1956). Different size quadrats are laid for trees 20 x 20 m, shrubs 5 x 5 m and herbs 1 x 1 m. From each quadrat, number of species and girths of trees were recorded. These field data were used to explore the Coles index of coefficient association of species and similarity coefficient of different forest types.

Community interaction

Similarity coefficient of different forest types was calculated using Sørensen index (Janson & Vegelius 1981).

Sørensen index (C_s) = $2j / (a+b)$

where, j = the number of species found in both sites, a = the number of species found in site A and b = the number of species found in the site B. Obtaining value 1 postulates complete similarity while 0 indicates complete dissimilarity.

Species association

Relevant informations can be obtained from analysis of field data such as interrelationships between different species by counting the number of quadrats out of the total in which one or both of pair of species are found. The data obtained are tabulated in conventional 2 x 2 contingency table (Hurlbert 1969).

Chi-square value estimation

Max χ^2 values are calculated as follows (Billore & Mehta 1975) and Observed χ^2 value (Obs χ^2) is calculated using the formula (Kershaw 1973)

$$\text{Obs } \chi^2 = \frac{(ad - bc)^2 n}{(a + b)(a + c)(b + d)(c + d)}$$

where, a = number of sampling units in which both the species A and B occur,

b and c = the number of sampling units having only species B or species A, respectively.

d = number of sampling units in which both the species are absent

n = total number of sampling units.

The χ^2 value shows whether the difference between the observed and expected numbers of quadrats is significant or merely due to a chance fluctuation. The significance was estimated at 5% level of degree of freedom.

Coles index

$$C_7 = \frac{ad - bc}{|ad - bc|} \sqrt{\frac{\text{Obs } \chi^2}{\text{Max } \chi^2}}$$

The coefficient varies from 0 (independent distribution) to +1 (complete positive association) and -1 (complete negative association).

Results and discussion

Similarity index of different forest types

Similarity index does not underestimate the uniqueness of each forest type rather deciphers the interrelatedness and enables to understand the hidden process of succession of different forest types. Species composition of different forest types was analysed in terms of Sørensen similarity index (Table 1). Dry evergreen forest shows maximum (0.5 value) similarity with the semi evergreen forests confirming the fact that the latter is the degraded form of the former. Forty one species are encountered only in the dry evergreen forest of Pacchaimalai hills, which strengthens the uniqueness of this forest type.

The semievergreen type shows greater similarity with tropical dry mixed deciduous forest (0.52) than any other forest types. This change which is irreversible proves that once intact forest patch is disturbed, it is subjected to invasion by types such as deciduous ones and is conducive to evolve to the next possible stages of

Table 1. Sörenson's similarity index between different forest types.

	Dry evergreen	Semi evergreen	Dry mixed deciduous	Dry savannah	Dry deciduous scrub	Southern thorn scrub	Southern thorn forest
Semi evergreen	0.5	---	---	---	---	---	---
Dry mixed deciduous	0.28	0.52	---	---	---	---	---
Dry savannah	0.128	0.23	0.34	---	---	---	---
Dry deciduous scrub	0.125	0.28	0.51	0.65	---	---	---
Southern thorn scrub	0.117	0.24	0.43	0.27	0.55	---	---
Southern thorn forest	0.173	0.29	0.44	0.24	0.25	0.545	---
Dry grassland	0	0.04	0.08	0.1	0.136	0.267	0.19

successions. Among the 17 species found only in semievergreen forests, *Glyptopetalum lawsonii*, *Dalbergia sissoides*, *Thunbergia alata*, *Neonotonia wightii* and *Tephrosia pulcherrima* are prominent.

The tropical dry mixed deciduous forest shows maximum similarity with dry deciduous scrub (0.51) followed by the southern thorn forest (0.44) and the least with the dry grassland (0.08). The above similarity could be attributed to the species composition which is by and large composed of deciduous trees, shrubs and herbs, while the difference between these two types is the absence of specific tree species such as *Diospyros melanoxylon*, *Careya arborea*, *Buchanania axillaris*, *Hymenodictyon orixense*, *Firmiana colorata* and *Helicteres isora* that are peculiar to the dry mixed deciduous forest.

The dry savannah forest has more similarity with dry deciduous scrub (0.65) owing to their single origin of succession from the dry mixed deciduous forest due to degradation. The major difference among them was the presence of *Cymbopogon citratus* in the former while it is completely lacking in the latter. The dry deciduous scrub shows high similarity with the southern thorn scrub (0.55) due to the occurrence of similar shrub and herbaceous composition. Southern thorn forest and southern thorn scrub are distributed adjacent to each other, however, the former type differs by having dense crown cover contributed by *Diospyros ferrea* whereas, the latter sustains numerous herbaceous vegetations alone.

Species such as *Lantana camara*, *Zizyphus oenoplia*, *Pterolobium hexapetalum* and *Hybanthus enneaspermus* are encountered in all forest types, since they withstand different climatic and environmental conditions as stated by Wilson & Agnew (1992) and Hacker & Gaines (1997) that the plants could modify their own environment turning them more favorable to other species through positive feed back

mechanisms. Besides these, 17 species were found to prevail in six forest types, a few of them: *Tarennia asiatica*, *Diospyros ferrea*, *Carissa carandas*, *Jasminum angustifolium*, *Ixora pavetta*, *Chloroxylon swietenia*, *Pleiospermium alatum* and *Stenosiphonium parviflorum*. These species were not encountered in dry savannah and dry grassland. In one way their presence in many forest types portrays their plasticity and on the other hand their absence from these two forest types make us ponder over the possible causes. It could be because these species being trees and shrubs are unable to withstand low depth soil condition or because the environmental condition of *Cymbopogon citratus* varies to such an extent that the above species fail to thrive. In other words there seems to prevail a certain amount of negative correlation between the grass community and the above cited species. Occurrence of 27 species in five, 39 species in four, 72 species in three and 122 species in two forest types are a reflection of their adaptability to varied climatic and environmental conditions. However, presence of 183 species to any one of the forest types refrains us from making such drastic absolute statement that all of them are highly adaptable to all climatic conditions.

Interspecific association

Chi-square values and Coles index values for 216 species were analyzed while giving importance to endangered and endemic species. Most of the species pairs showed low Chi-square and Coles coefficient value while a few showed negative associations. Hence the species with Coles value of >0.2 are shown in Table 2. This finding supports Whittaker's (1970) statement that correlation or associations between species are for the most part not strong and many pairs of species in a community may show none. Brey (1956) stated that the basis of interspecific association is that if species are indifferent to each other (i.e. independent), they will occur

Table 2. Coles index of associated species. Significant at 5% degree of freedom

Target species	Associated species	χ^2 Value	Coles index
<i>Santalum album</i>	<i>Acacia torta</i>	3.745	0.317
	<i>Dodonaea viscosa</i>	3.953*	0.228
	<i>Lantana camara</i>	3.225	0.256
	<i>Smilax zeylanica</i>	2.733	0.245
	<i>Memecylon umbellatum</i>	3.226	0.439
<i>Cycas circinalis</i>	<i>Cleistanthus collinus</i>	10.667*	0.444
	<i>Combretum albidum</i>	8.694*	0.453
	<i>Pongamia pinnata</i>	5.559*	0.462
	<i>Symphorema involucratum</i>	5.55*	0.462
	<i>Sapindus emarginatus</i>	3.184	0.283
<i>Gloriosa superba</i>	<i>Cocculus hirsutus</i>	1.234	0.239
	<i>Memecylon umbellatum</i>	2.667	0.222
	<i>Scleria lithosperma</i>	2.667	0.223
	<i>Stenosiphonium parviflorum</i>	2.077	0.231
	<i>Maytenus heyneana</i>	1.433	0.212
<i>Nothopegia colebrookiana</i>	<i>Elaeagnus indica</i>	0.009	0.033
	<i>Glycosmis mauritiana</i>	0.242	0.201
	<i>Mallotus philippensis</i>	0.461	0.211
	<i>Murraya koenigii</i>	0.345	0.2
	<i>Sageretia filiformis</i>	0.247	0.2
	<i>Tarenna asiatica</i>	8.868*	0.441
	<i>Diospyros ovalifolia</i>	0.821	0.21
	<i>Psydrax dicoccos</i>	0.016	0.024
	<i>Cayratia pedata</i>	0.499	0.188
	<i>Diospyros ovalifolia</i>	3.207	0.212
<i>Pterospermum xylocarpum</i>	<i>Doryopteris concolor</i>	1.466	0.258
	<i>Hemionitis arifolia</i>	4.069*	0.367
	<i>Psydrax dicoccos</i>	0.088	0.04
	<i>Acacia torta</i>	4.83*	0.331
	<i>Cyclea peltata</i>	4.83*	0.33
	<i>Santalum album</i>	2.733	0.245
	<i>Psydrax dicoccos</i>	1.887	0.129
<i>Canarium strictum</i>	<i>Celastrus paniculatus</i>	2.655	0.203
	<i>Aglaia lawii</i>	4.069*	0.205
	<i>Beilschmeidia</i> sp.	6.436*	0.389
	<i>Dicliptera cuneata</i>	3.55	0.337
	<i>Artocarpus heterophyllus</i>	6.368*	0.343
<i>Gnetum edule</i>	<i>Streblus taxoides</i>	2.001	0.652
	<i>Syzygium cumini</i>	2.001	0.652
	<i>Acacia torta</i>	1.466	0.258
	<i>Dicliptera cuneata</i>	2.328	0.285
	<i>Vitex altissima</i>	2.328	0.285
	<i>Symphorema involucratum</i>	1.666	0.201
	<i>Nothopegia colebrookiana</i>	0.113	0.067

together more or less by chance, while if they are not indifferent (i.e. dependent) they will occur together more often or less often than can be expected by chance, which is expressed in terms of Coles index. As we have encountered in this study, many species do not express any significant association with each other, while some showed negative interaction and very few showed positive association. Zaal (1993) speaks of two types of negative interactions and the first type is due to competition between ecologically equivalent species, where one species exclude the

other in a community and the second type reflects the substitution of species during succession and is connected with niche differentiation. The positive association between species are brought about by different conditions such as habitat suitability (Hubbell & Foster 1983; Misra & Misra 1981; Tilman & Pacala 1993), requirement of shade by herbaceous species (Billore & Mehta 1975; Franco & Nobel 1988, 1989; Franco-Pizaña *et al.* 1995; Silvertown & Wilson 1994; Valiente-Banuet & Ezcurra 1991; Valiente-Banuet *et al.* 1991; Yeaton & Manzanares 1986) and

requirement of light, space and nutrition (Misra & Misra 1981). According to Hurlbert (1969) Coles index (C_7) does not measure the degree to which two species occur jointly but rather indicates the degree to which their joint occurrence is more frequent or less frequent than to be expected on the basis of chance. Pielou (1969) argues that it is possible that when two species are found to be positively associated it may be due to (a) one of the species has a beneficial effect on the other, either directly or by modifying the environment in a way favorable to it or some independent environment factors are variable over the area and (b) because of the two species have identical or overlapping tolerance ranges for the factors, both are forced to occupy coincident or overlapping areas.

Santalum album, a species that is highly endangered and has high economic value is closely associated with *Acacia torta*, *Dodonaea viscosa*, *Lantana camara*, *Smilax zeylanica*, *Tephrosia pulcherrima* and *Memecylon umbellatum*. This association reveals that *Santalum album* flourish well in the degraded lands as it provides optimum growth condition. *Dodonaea viscosa* as an aggressive colonizer on disturbed ground (Matthew 1983), indicates the extent of wanton destruction of primary forests without any significant use being made subsequently. *Lantana camara* again, an indicator species of disturbed area as described by Chandrasekaran & Swamy (1995) and Britto *et al.* (2001), confirms to the fact that *Santalum album* is frequent at disturbed area. Moreover, the highly associated species are shrubs and light demanding, hence, it is likely that this species also requires similar conditions.

Cycas circinalis, an endangered Gymnosperm has significant association with *Cleistanthus collinus* (0.444), *Combretum albidum* (0.453), *Pongamia pinnata* (0.462) and *Symphorema involucreatum* (0.462). This significant association could be possible because these species may facilitate and buffer the former from the environmental extremes (Callaway & Walker 1997). This strong association discloses the fact that *Cycas circinalis* is frequently associated with stream bed habitats of dry deciduous forest types requiring high temperature (30–40°C) and high soil moist conditions and their distribution is very much restricted. *Gloriosa superba* an endangered species frequently occur in the southern thorn and dry deciduous forest types which has high association with *Cocculus hirsutus*, *Memecylon umbellatum*, *Scleria lithosperma*, *Stenosiphonium parviflorum* and *Maytenus heyneana*. This is a special case where the study

of association is much dependent on the period of field studies because this species persists in the summer season in the form of underground tubers and flourish lavishly after monsoon.

Nothopegia colebrookiana has high chi-square value with *Tarenna asiatica*, however, the latter being distributed in many other types, this significance is nullified. *Nothopegia colebrookiana* has high Cole's values with *Mallotus philippensis*, *Diospyros ovalifolia* and *Psydrax dicoccos* of tree species, besides the straggler species *Sageretia filiformis* and *Elaeagnus indica*. All these species are confined to the evergreen and the semievergreen forest types.

Pterospermum xylocarpum has significant association with *Hemionitis arifolia*, where the latter is a shade dependent Pteridophyte (Billore & Mehta 1975). Besides, *Diospyros ovalifolia* and *Psydrax dicoccos* the tree species and *Cayratia pedata*, a vine has high Coles value owing to their similar habitat requirements. *Smilax zeylanica* has high significant association with *Acacia torta*, *Cyclea peltata* both climber species. Its high Coles value with *Psydrax dicoccos*, *Santalum album* and *Celastrus paniculatus* exhibit that *Smilax* occurs frequently in degraded high altitude conditions or at the edges of intact forests, revealing their light requiring nature.

Canarium strictum has significant chi-square values with *Aglaia lawii* and *Artocarpus heterophyllus*. Besides this, it has got high Coles value with *Sygygium cumini*, *Streblus taxoides* and *Dicliptera cuneata*. All of them are evergreen species; even more significant is that they are distributed only in Kannimar shola RF of the Pachchaimalai hills. The significance can be attributed to the favourable conditions, provided by the species for the germination and growth of the plants (Zaal 1993). *Gnetum edule*, a member of Gymnosperm liana is closely associated with *Vitex altissima*, *Dicliptera cuneata*, *Acacia torta*, *Nothopegia colebrookiana* and *Symphorema involucreatum*. *Cymbopogon citratus*, a constituent of dry savannah forest has high association with *Grewia hirsuta* and *G. tiliifolia*, may be because they will have different needs or the same need at different times (Smith & Cottam 1967).

If we understand association in terms of dependence as in the case of parasite with host, symbiotic organism and similar ones, then this is not the case in higher plants of this study. However, if association is understood in terms of sharing of optimum habitat requirement by different species, then Coles intrespecific coefficient has thrown light on a few findings. The study of pattern in vegetation obviously relates to the distribution of environmental factors, the

relationship of species to the environment and to the problem of the recognition (Greig-Smith 1952) and classification of plant communities (Legris & Meher-Homji 1968). Association can be explained as the relationship between the plant species in its community which is dominated by more than one species and this association has been used to classify the community based on the species composition (Lal 1992).

a) Evergreen forests

i) *Canarium strictum*–*Artocarpus heterophyllus* – *Aglaiia lawii*–*Syzygium cumini* series in Kannimar shola RF.

ii) *Pterospermum xylocarpum*–*Chukrasia tabularis* – Putranjiva roxburghii series in Solaimatti RF.

iii) *Nothopegia colebrookiana*–*Diospyros ovalifolia* –*Psydrax dicoccos* series in Peria shola RF, Manmalia RF. Degraded dense forests *Santalum album*–*Dodonaea viscosa*–*Smilax zeylanica* series in Vengamudi RF and Part of Periya shola RF.

b) Dry mixed deciduous forests

i) *Hymenodictyon orixense*–*Garuga pinnata*–*Commiphora caudata* series in Nagur RF.

Commiphora caudata – *Drypetes sepiaria*–*Albizia amara* series in Sengattupatti RF.

Dry savannah forests

i) *Cymbopogon citrates* –*Grewia hirsuta*–*Grewia tiliifolia* –*Dalbergia lanceolaria* series in Manmalai RF.

d) Dry deciduous scrub forests

Euphorbia antiquorum–*Albizia amara*–*Chloroxylon swietenia* series in many RFs.

e) Southern thorn forests

i) *Commiphora berryi*–*Benkara malabarica*–*Grewia flavescens* series in Manmalai RF, Palamalai RF and Nesakkulam RF.

ii) *Commiphora berryi*–*Rhus mysorensis*–*Flacourtia indica*–*Canthium parviflorum* series in Palantankarai RF, Gangavalli RF. etc.

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