VEGETATIONAL CHARACTERISATION AND LITTER DYNAMICS OF THE SACRED GROVES OF KERALA, SOUTHWEST INDIA

M. Rajendraprasad, P. N. Krishnan* & P. Pushpangadan

Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram - 695 562, Kerala, India

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RAJENDRAPRASAD, M., KRISHNAN, P. N. & PUSHPANGADAN, P. 2000. Vegetational characterisation and litter dynamics of the sacred groves of Kerala, southwest India. The sacred groves represent the remnants of the once luxuriant vegetation of Kerala, which are protected on religious grounds. These ecosystems now remain as treasure houses of a large number of endemic flora and fauna. As patches of evergreen forests, the maintenance of the functional dynamics of the sacred groves is always related to a balance in the litter production and decomposition process of its floristic components. In a two-year study, from 1992 to 1994, the vegetational characteristics and litter dynamics of five bioclimatically diverse sacred groves in Kerala, southwest India, were examined. Litterfall and decomposition were measured and are discussed in relation to climatic factors such as temperature and rainfall, and to tree density and basal area. Significant variations with site were found in total litterfall and leaf fall and with season in stem fall. Decomposition rates were low during the rainy season (June to October) and high during the dry season (October to May) and also during the period having interrupted rains (April to May). Tree density and basal area were significantly correlated to litterfall.

Key words: Sacred groves - edaphological factors - Kerala - litter dynamics - bioclimatic conditions - seasonal variations

RAJENDRAPRASAD, M., KRISHNAN, P. N. & PUSHPANGADAN, P. 2000. Pencirian pertumbuhan dan dinamik sarap di kebun suci di Kerala, barat daya India. Kebun suci tersebut mewakili bekas-bekas pokok yang suatu ketika dulu merupakan pokok yang subur di Kerala yang dilindungi atas alasan agama. Ekosistem ini kini kekal menjadi khazanah yang menempatkan banyak endemik flora dan fauna. Sebagai kelompok hutan malar hijau, penyenggaraan fungsi dinamik kebun suci ini selalunya berkaitan dengan keseimbangan dalam pengeluaran sarap dan proses pereputan komponen floranya. Dalam kajian dua tahun, daripada 1992 hingga 1994, ciri-ciri tumbuhan dan dinamik sarap bagi lima pokok suci pelbagai iklim di Kerala, barat daya India telah diperiksa. Jatuhan sarap dan pereputan disukat dan dibincangkan kaitannya dengan faktor-faktor iklim seperti suhu dan hujan, dan juga kaitan dengan ketumpatan pokok dan luas pangkal. Perbezaan yang bererti dengan tapak didapati dalam jumlah jatuhan sarap dan jatuhan daun, dan dengan musim dalam tebangan batang. Kadar pereputan adalah rendah pada musim hujan (Jun hingga Oktober) dan tinggi pada musim kering (Oktober hingga Mei) dan juga semasa tempoh gangguan hujan (April hingga Mei). Ketumpatan pokok dan luas kawasan adalah berkaitan dengan bererti dengan jatuhan sarap.

**Author for correspondence.*

Introduction

The dynamics of plant litter is important in most plant communities (Facelli & Pickett 1991) and is a process that is closely linked to climatic conditions and environmental management. The sacred groves of Kerala (*kavu* in Malayalam) are supposed to be the relics of once extensive evergreen forest of southwest India. These groves occur as isolated patches that have been protected on religious grounds. They range in size from a few square meters to many square kilometres. In Kerala they are mostly associated with temples or old *tharavadus* (houses). These groves can be considered as a unique example of an ecological understanding and sustainable management of natural resources by our ancestors (Rajendraprasad 1995). However, these luxuriant evergreen forest patches are close to extinction due to the high population influx and multifaced development occurring in these areas recently. They are being denuded for fuel, timber, agricultural land and space for construction works. Sacred groves are considered to be productive ecosystems where high net primary productivities have been recorded and where the systems have been self generating and self sustainable (Rajendraprasad 1995). The preliminary studies conducted by Induchoodan (1988), Ramachandran and Mohanan (1991), and Rajendraprasad (1995) revealed that the sacred groves of Kerala constitute a vast array of flora and fauna that include many rare, endangered and endemic species. Unfortunately, a careful examination on the functional dynamics of these virgin, climax evergreen vegetational patches is lacking; such an understanding is a pre-requisite for developing conservation and sustainable resource management plans for biotically rich islands such as these.

Litter production and decomposition rates have great importance for maintaining the fertility of the soil. A substantial portion of the nutrients accumulated by plants is returned to the soil as litterfall followed by its decomposition, i.e. the integrity of an ecosystem is maintained by these transfers of matter and nutrients (Lonsdale 1988). In this context, the quantitative evaluation of litter production and decomposition rates with respect to vegetational characteristics offer an opportunity to understand ecosystem processes and those factors that control dry matter production and its decomposition rates (Bray & Gorham 1964, Singh & Gupta 1977, Pandey & Singh 1981, Chathurvedi & Singh 1982, Ramakrishnan & Das 1983, Spain 1984, Chapman 1986, Vogt *et al.* 1986, Dagar & Sharma 1991, Xiong & Nilsson 1997). However, this type of information is important since these sacred groves are patches of climax vegetation in the midst of urbanised areas, and litterfall dynamics can be used to indicate the health of these remnant forests. This paper is an attempt to study the uniqueness of vegetation in relation to the litterfall dynamics in the sacred groves of Kerala.

Materials and methods

Study areas

Kerala State (8° 2'–12° 8'N, 74° 8'–77° 5'E), located in the southwest corner of the Indian Peninsula, covers an area of 38 864 km^2. The climate of Kerala is tropical, humid, warm and monsoonal. The temperature and humidity are moderate throughout the year. Annual rainfall ranges from 2400 to 3200 mm. Most of the precipitation occurs during the southwest monsoon (June to August) within the period of 8–10 months in a year that receives rainfall (Figure 1). Of the 175 sacred groves visited five bioclimatically divergent sacred groves were selected for in-depth analysis to characterise their flora and litterfall dynamics. All five sacred groves are located in the south, central and northern regions representing the lowland, midland and highland of Kerala. The study discussed here was carried out during the period of December 1992 to November 1994.

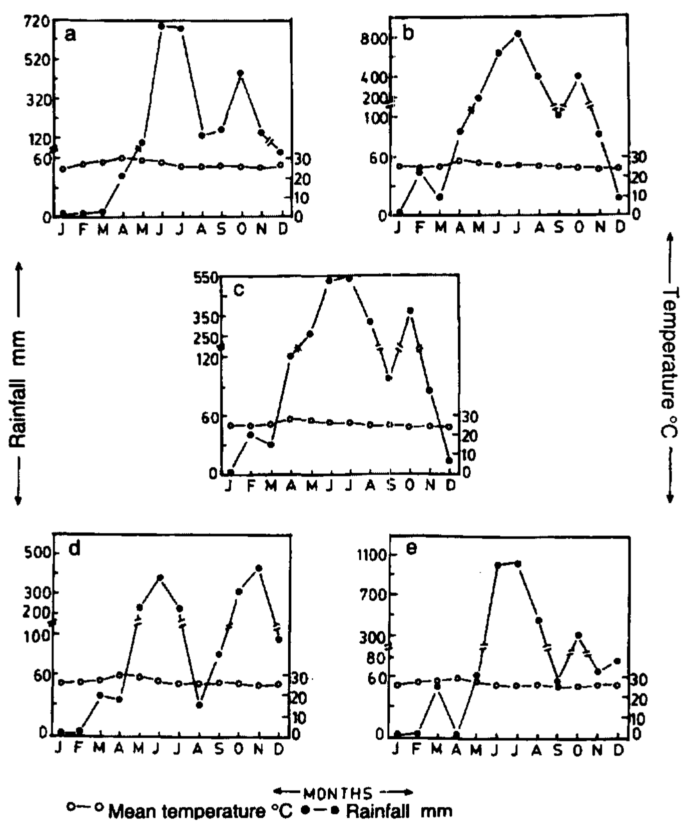

Figure 1. Obro-thermic diagrams of the study sites

a. Vandanam b. Iringole c. Kolani
d. Pachalloor e. Puthiyaparambil

O Mean temperature (°C) ● Rainfall (mm)

Vegetation analysis

Visual observations were made in field trips to sacred groves distributed in all parts of Kerala and various types of vegetation were identified. The physiognomic characters of the different life forms were also given due importance. The various species found in the study site were noted and classified into their appropriate families and characteristics in their distribution pattern were recorded.

Five bioclimatically diverse sacred groves were selected for detailed study. Sites (5 to 10) within each sacred groves were selected and plots of 10 × 10 m (100 m^2) were chosen. All the vegetational forms were counted and listed. Every one was mapped, except for the emerging seedlings. The diameter at breast height was measured for each individual (except for seedling and herbaceous annuals). The following parameters were calculated as described by Pascal (1984), Misra (1968), and Curtis and McIntosh (1950).

$$\text{Relative frequency} = \frac{\text{frequency of the `i' species}}{\text{total frequency of the plots}} \times 100$$

$$\text{Relative density} = \frac{\text{number of individuals of the species `i'}}{\text{total number of individuals in the plot}} \times 100$$

$$\text{Relative dominance} = \frac{\text{sum of the basal area of individuals of the same species}}{\text{total basal area of the plot}} \times 100$$

$$\text{Importance value index (IVI)} = \text{relative dominance} + \text{relative frequency} + \text{relative density}$$

$$\text{Simpson's index} = 1 - \sum_{i=1}^{s} \left[\frac{n_i}{N} \right]^2$$

where n is the number of individuals of a species and N the total number of individuals of all species.

The density of trees was determined using the point centred quadrant method (Barbour *et al.* 1980). Random points were located. The area around each point was divided into four 90° quadrants and the nearest tree of each quadrant was marked. Each tree was identified and its basal area measured. Again, average distance for all trees taken together was computed and converted to total density by the formula,

$$\text{Density} = \frac{10000}{(\text{average distance in meter})^2} \text{ trees ha}^{-1}$$

The biovolume of trees was calculated using formula,

Volume of tree = D^2H (Pascal 1984)
where D is the diameter at breast height and H the height of tree.
Height of the tree was measured using Abney's Scale.

Litter dynamics

Measurements of litter production and turnover rate were carried during the period 1992–1994. Litterfall inputs were measured by placing five to ten permanent litter traps (50 × 50 cm size) in a randomised position at each site. Litterfall was collected at bimonthly intervals and separated into leaf and stem components. All the tissues were dried at 80 °C for 48 h and weighed. The rate of production was calculated. Quadrants measuring 50 × 50 cm were used to collect standing litter from five to eight random locations on the forest floor at intervals of two month. The collected litter was brought to the laboratory and separated into leaf and woody components and all tissues were dried at 80 °C for 48 h and weighed. The turnover coefficient was calculated monthly as the ratio of the difference between the litter on the ground at the beginning plus the litterfall during the month and the litter on the ground at the end of the month to the mean standing crop of litter per month (Jenny *et al.* 1949, Olson 1963, UNESCO 1978). The amounts of decay per month were summed up and the mean rate of litter turnover was calculated. In addition, the time in months for decay of litter on the ground was calculated as the reciprocal of the overall turnover coefficient (for the month).

The meterological data were collected from the nearby meteorological stations during the study period.

Statistical analysis

Randomised block two-way analysis of variance was conducted with seasonal and site to site variations in total, leaf and stem litterfall rate of the sacred groves. The F-ratio obtained was checked for significance level.

Linear regression analysis was done on total litter productions $ha^{-1} y^{1}$ of each site as a function of (1) tree density and (2) basal area following the equation Y=A+Bx, where A is the Y-intercept and B is the slope of regression coefficient (r). The relationship was tested from the calculated r (Sokal & Rohlf 1981).

Results and discussion

Salient features of the study sites

The selected sacred groves of Kerala are characterised by their luxuriant growth of evergreen or semi-evergreen vegetation. The vegetative composition and dominance varies by geographic locations and there is a marked seasonal variation in the dominance of the understorey vegetation.

a. Vandanam kavu (9° 2' N, 76° 20' E; lowland)

This area was once dominated by luxuriant growth of coastal vegetation of Kerala but is now being depleted due to the encroachment of mankind. In total, this sacred grove includes 94 species belonging to 91 genera of 51 families with a floristic diversity of 0.87 (Table 1). The five dominant species according to their importance value indices (IVI) are *Samadera indica, Calophyllum calaba, Gnetum ula, Tabernaemontana alternifolia* and *Carallia brachiata* (Table 2). The dominant tree species are of medium size with umbrella-like crown, branches beginning at 2/3 of the height of the bole. The soil is sandy, acidic and nutrient rich. During the study time, rainfall occurred during a 10-month period with a maximum in June-July due to the southwest monsoon and a second peak due to the northeast monsoon in October (Figure 1a.) The removal of dead material is restricted. The occurrence and activity of associated fauna are very frequent in this sacred grove.

Table 1. Site characterisation and floristic wealth and diversity observed in the different sacred groves of Kerala

Name of sacred grove	Species in 100 m^2 area	Individuals in 100 m^2 area	Individuals/ species in 100 m^2 area	Simpson's index	Density of tree ha^{-1}	Basal area (m^2 ha^{-1})	Biovolume (m^3 ha^{-1})
Vandanam (Lowland)	17	100	5.9	0.87	1423	20.6	516
Iringole (Midland)	25	198	7.9	0.85	1767	78.3	578
Kolani (Highland)	25	231	9.2	0.86	2301	48.7	1222
Pachalloor (South Kerala)	17	107	6.3	0.89	869	18.0	293
Puthiyaparambil (North Kerala)	05	105	20.9	0.22	782	25.3	459

b. Iringole kavu (10° 5'N, 76°°25' E; midland)

It can be considered as a typical example of midland vegetation of Kerala. The vegetation is moderately disturbed by the man. Natural thinning of vegetation is going on especially in the upper canopy members. The floristic richness of this grove showed 124 species from 54 families of 108 genera and the floristic diversity is 0.85 (Table 1). The dominant members include *Artocarpus hirsutus, Hopea ponga, Chasalia ophioxyloides, Mesua nagassarium* and *Xanthophyllum arnottianum* (Table 2). Soil is sandy loam, acidic and humus rich. The removal of dead material is highly restricted.

This site has the typical three stratum structure as found in the typical tropical evergreen forests. The rainfall have two peaks one at June–July due to the southwest monsoon and other at October due to the northeast monsoon.(Figure 1b).

c. Kolani kavu (9° 5' N, 76° 90' E; highland)

This sacred grove is located in Idukki district and topographically represent the highland of Kerala. The flora include about 74 species belonging to 72 genera of 37 families with floristic diversity of 0.86 (Table 1). The important dominant species are *Meiogyne ramarowii, Chasalia ophioxyloides, Artocarpus hirsutus, Nothopegia racemosa, Syzygium heyneanum* and *Polyalthia fragrans* (Table 2). The soil is sandy loam, acidic and humus rich. The vegetation is highly protected from any external disturbance due to the strong religious belief of the local people.

Table 2. The importance value indices of common species of the five sacred groves of Kerala

Name of sacred grove	Species	Family	Importance value index
Vandanam (Low land)	*Samadera indica*	Simarubaceae	196
	Calophyllum calaba	Clusiaceae	168
	Gnetum ula	Gnetaceae	162
	Tabernaemontana alternifolia	Apocynaceae	94
	Carallia brachiata	Rhizophoraceae	49
Iringole (Midland)	*Artocarpus hirsutus*	Moraceae	176
	Hopea ponga	Dipterocarpaceae	125
	Chasalia ophioxyloides	Rubiaceae	131
	Mesua nagassariam	Clusiaceae	113
	Xanthophyllum arnottianum	Xanthophyllaceae	101
Kolani (Highland)	*Meiogyne ramarowi*	Anonaceae	284
	Chasalia ophioxyloides	Rubiaceae	238
	Artocarpus hirsutus	Moraceae	161
	Nothopegia racemosa	Anacardiaceae	135
	Syzygium heyneanum	Myrtaceae	126
	Polyalthia fragrans	Anonaceae	114
Pachalloor (South Kerala)	*Sarcostigma kleinii*	Icacinaceae	49
	Artocarpus hirsutus	Moraceae	32
	Mallotus philippinensis	Euphorbiaceae	29
	Myristica malabarica	Myristicaceae	28
Puthiyaparambil (North Kerala)	*Hopea ponga*	Dipterocarpaceae	271
	Gnetum ula	Gnetaceae	162
	Mangifera indica	Anacardiaceae	71
	Diospyros paniculata	Ebenaceae	34
	Strychnos nux-vomica	Loganiaceae	16

The vegetation can be considered as a typical example of tropical evergreen forest of the Western Ghats, so the structure and composition of vegetation share the similarities. As most of the dominant members are medium-sized trees, the second stratum is more prominent and thick. About 10 months in a year receive precipitation with two peaks one in June–July due to the southwest monsoon and second one in October due to the northeast monsoon (Figure 1c).

d. Pachalloor kavu (8° 60' N, 77° 0' E; south Kerala)

Located in Thiruvananthapuram district, this site represents the southernmost vegetation of Kerala. The flora of this sacred grove includes 72 species, 66 genera from 44 families and the floristic diversity is 0.89 (Table 1) The dominant members are few in number and important among them are *Sarcostigma kleinii, Artocarpus hirsutus, Mallotus philippinensis* and *Myristica malabarica* (Table 2). The soil is sandy loam, acidic and nutrient rich. The grove is surrounded by urbanised area; as a result the vegetation is moderately disturbed.

The structure is similar to that of the Western Ghats forest. The dominant members are representative of second storey; quite naturally this stratum is well developed on this sacred grove. Rainfall is almost equal during the southwest monsoon and the northeast monsoon with the resulting peaks in June and November respectively. Precipitation was recorded during 10 months in a year (Figure 1d).

e. Puthiyaparambil kavu (12° 15' N, 70° 5' E; north Kerala)

This sacred grove represents the northern district of Kerala, viz. Kasargod. The vegetation is undisturbed, due to its religious significance. The whole flora is contributed by 44 species of 43 genera from 33 families and the floristic diversity is 0.22 (Table 1). The low floristic diversity of this sacred grove is due to the abundant establishment of a single species, viz. *Hopea ponga* (about 80% of the vegetation is represented by this single species). The other dominant members in the grove are *Gnetum ula, Mangifera indica, Diospyros paniculata* and *Strychnos nux-vomica* (Table 2). The soil is sandy, acidic and humus rich.

The dominant tree members are representative of the upper canopy, and because of this the upper stratum is well developed, thick and continuous. The second and third strata are also thick and continuous in nature. About 90% of the rainfall occurs during the southwest monsoon in June–July. The northeast monsoon is very weak in this site with a small peak in October (Figure 1e).

Litter dynamics

Even though litterfall occurred continuously throughout the year in all the groves studied, temporal and site to site variations in litterfall among the groves were noticed (Figures 2a & b). The general trend in two peaks in the rate of litterfall observed in tropical forests was also applicable in the case of the sacred groves. Highest rates of total litterfall were obtained in December–January in Vandanam (1.61 g $m^{-2}d^{-1}$), Kolani (2.31 g $m^{-2}d^{-1}$), and Puthiyaparambil (1.79 g $m^{-2}d^{-1}$), but in Iringole the highest rate was recorded in April–May (2.46 g $m^{-2}d^{-1}$) and in Pachalloor it was in August–September (2.09 g $m^{-2}d^{-1}$) (Figures 3a–e). Low rates of litterfall were consistently recorded in June–July. This trend indicates that litterfall rate may vary according to age, structure and type of vegetation, especially of the upper canopy even though generally high amounts of litter input occur during the dry season and low amounts in the wet season. The maximum total litterfall was accumulated in Iringole (6.44 t ha^{-1} y^{-1}), followed by Kolani (6.30 t ha^{-1} y^{-1}), Vandanam (4.85 t ha^{-1} y^{-1}), Pachalloor (4.60 t ha^{-1} y^{-1}) and Puthiyaparambil (4.40 t $ha^{-1}y^{-1}$) (Figure 3f). Leaves were the major fraction of the litterfall in all the groves with their percentage contribution varying from 62.2 to 97.6%. The pattern of leaf fall was the same as that of the total litterfall except in Vandanam, where the lowest amount was recorded in October–November (Figure 3a). Seasonal variation in stem fall was also noticed; it was maximum in February–March in Vandanam, Kolani and Puthiyaparambil, while in Iringole and Pachalloor it was in April–May (Figures 3a–e). But the seasonal variation observed was significant only with stem fall and site to site variation was significant with total litterfall and leaf fall rates (Table 3).

Table 3. Randomised block two-way ANOVA on rate of litter production at various sites in different seasons

Source		Degree of freedom	*F*-ratio	Significance level
Total litterfall	Season	6	1.63	-
	Site	5	3.63	$p > 0.05$
	Error	20		
	Total	29		
Stem fall	Season	6	4.76	$p > 0.05$
	Site	5	0.51	-
	Error	20		
	Total	29		
Leaf fall	Season	6	1.99	-
	Site	5	3.39	$p > 0.05$
	Error	20		
	Total	29		

The amount of standing litter was higher during the dry season and the relative contribution of woody materials and fragmented debris to the total litterfall increased significantly towards the wet period as a result of the fall of large amounts of finely fragmented litter, old twigs, branches and trunks. Moreover, the reproductive structures are also shed during February–March. The lowest value was registered during the rainy season, during the period of June to September.

Litter breakdown and mineralisation is mediated by soil and forest floor micro- and macro-organisms and its rate is regulated by the interaction between these organisms and the litter resource (Anderson & Swift 1983, Rajendraprasad 1995). In the sacred groves, monthly decomposition showed low rates during the monsoon period (June to October—the wet months in Kerala). Thereafter it continuously increased and reached the maximum value in the dry months (Figure 2c.). The mean values of the turnover coefficient of all the study sites showed a seasonal rhythm in the different groves (Table 4). The annual turnover coefficient was 0.71 ± 0.13 in the beginning of the cycle (June–July) and it decreased gradually and reached the value of 0.62 ± 0.03 during September–October. Hereafter it steadily increased and reached maximum value in February–March (0.86 ± 0.02). April–May also recorded a high turnover coefficient (0.84 ± 0.03) (Figure 2c), i.e. 62 to 86% of total litter was decomposed and mineralised during the year-round cycle. Site to site variation in the litter turnover was also remarkable between sacred groves. Among the five sites, the maximum turnover coefficient was observed in Pachalloor (0.82 ± 0.69) followed by Vandanam (0.74 ± 0.11), Iringole (0.72 ± 0.12), Kolani (0.69 ± 0.12) and in Puthiyaparambil (0.67 ± 0.09) (Figure 2d). The turnover time is just the reverse of the value of the turnover coefficient. It is noticed that 1.12 to 1.84 y were required for the complete decomposition of the annual litterfall of the sacred groves.

Table 4. Seasonal variation in the litter turnover coefficient of the five sacred groves of Kerala

Name of sacred grove	Months					
	D/J	F/M	A/M	J/J	A/S	O/N
Vandanam (Lowland)	0.81±0.08	0.85±0.05	0.85±0.02	0.68±0.03	0.58±0.07	0.70±0.08
Iringole (Midland)	0.79±0.03	0.85±0.03	0.84±0.02	0.59±0.09	0.65±0.08	0.59±0.02
Kolani (Highland)	0.77±0.09	0.83±0.03	0.80±0.07	0.59±0.08	0.61±0.04	0.54±0.05
Pachalloor (South Kerala)	0.85±0.04	0.89±0.02	0.87±0.09	0.85±0.09	0.64±0.02	0.79±0.02
Puthiyaparambil (North Kerala)	0.71±0.04	0.86±0.06	0.84±0.01	0.85±0.07	0.61±0.02	0.70±0.06

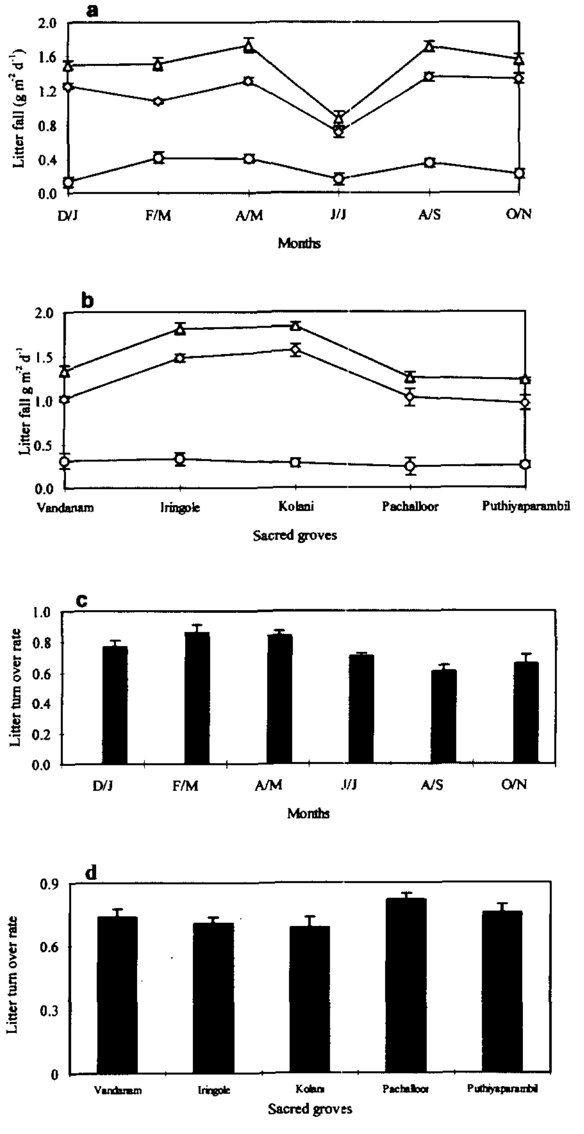

Figure 2. a. Seasonal variation in the total litterfall and its components measured for the two annual cycles in the five sacred groves of Kerala (averaged across all five sites)

b. Site to site variation in the total litterfall and its components measured for the two annual cycles in five bioclimatically divergent sacred groves of Kerala

—◇— Leaf fall —○— Stem fall —△— Total litterfall

c. The seasonal variation in the litter turnover in the sacred groves of Kerala (average of five bioclimatically divergent study sites)

d. Site to site variation in the litter turnover in the five sacred groves of Kerala

As indicated, the dry matter dynamics in the sacred groves of Kerala is strongly determined by monsoon, water regime and temperature of the system (Figures 1, 2a & b). The same observation was made by Reich and Borchert (1984) in the tropical dry forest of Costa Rica. Facelli and Pickett (1991) also reported that in four upland ecosystems, climatic conditions are the major determinant of the litter dynamics. The production and decomposition of dry matter in an ecosystem are also strongly related to light availability during the growing season (Jordan 1971), temperature and precipitation (Vogt *et al.* 1986). The site to site variation observed in the rhythm of the litter production in the sacred groves can be explained as the effect of biotic and abiotic factors of the ecosystems which in turn affect the chemical properties of the soil. This may also affect the selective influence of other biota on the litter (Xiong & Nilsson 1997). Temperature has been considered as one of the most important environmental determinants of litter decomposition, i.e. high temperature can promote litter decomposition and vice versa (Vogt *et al.* 1986, Facelli & Pickett 1991). This may be the possible reason for the high litter turnover during the dry season in the sacred groves of Kerala. The other environmental conditions such as soil temperature, atmospheric temperature and humidity may directly or indirectly influence the moisture status of the system which in turn influences the litter dynamics. Trees growing in sites with low moisture content generally shed their leaves at the end of the wet season (Xiong & Nilsson 1997). This may explain the early shedding of leaves in Pachalloor grove, which showed high litter production in August–September, as this sacred grove, situated in an urbanised area, is moderately disturbed with open canopy and receives low rainfall during these months (after the northeast monsoon in June/July) (Figures 1 & 3d). While the high rate of litterfall during April–May in Iringole grove and December–January in Kolani grove can be explained by the same reason, it must be remembered that all these sacred groves are generally undisturbed with a high above-ground phytomass preventing the direct entry of sunlight to the system and resulting in long-term conservation of water within the system. This type of seasonality in the production of litter has also been reported by Martínez and Sarukhán (1990) for Mexican forest. The effect of soil moisture in leaf phenology of tropical trees has been documented by various authors such as Lieberman (1982), Borchert (1983), Reich and Borchert (1984).

The mean annual total litterfall values obtained from the different groves, ranging from 4.40 to 6.44 t ha^{-1} y^{-1} (Figure 3f), lie within the range reported for tropical rain forests (Proctor 1984, Sanchez & Sanchez 1995). The mean total litterfall was higher in Iringole and Kolani. The reason for this could be related to the soil characteristics, above-ground phytomass, influence of associated fauna, difference in the species diversity, tree density and structure of vegetation. The same was observed by Xiong and Nilsson (1997) in riparian vegetation. The tree density per hectare was 1767 and 2301 in Iringole and Kolani respectively while the basal area was higher in Iringole (78 m^2 ha^{-1}) than in Kolani (49 m^2 ha^{-1}) (Table 1). The other three sites had lower values of basal area and density of trees and a corresponding decline in litter production. Linear regression analysis taking litterfall as a function of tree density and basal area showed a direct correlation and was significant at 5% probability level (Figures 4a & b). A similar relationship between tree density or basal area and litter production has been reported for tropical forests (Martínez & Sarukhán 1990).

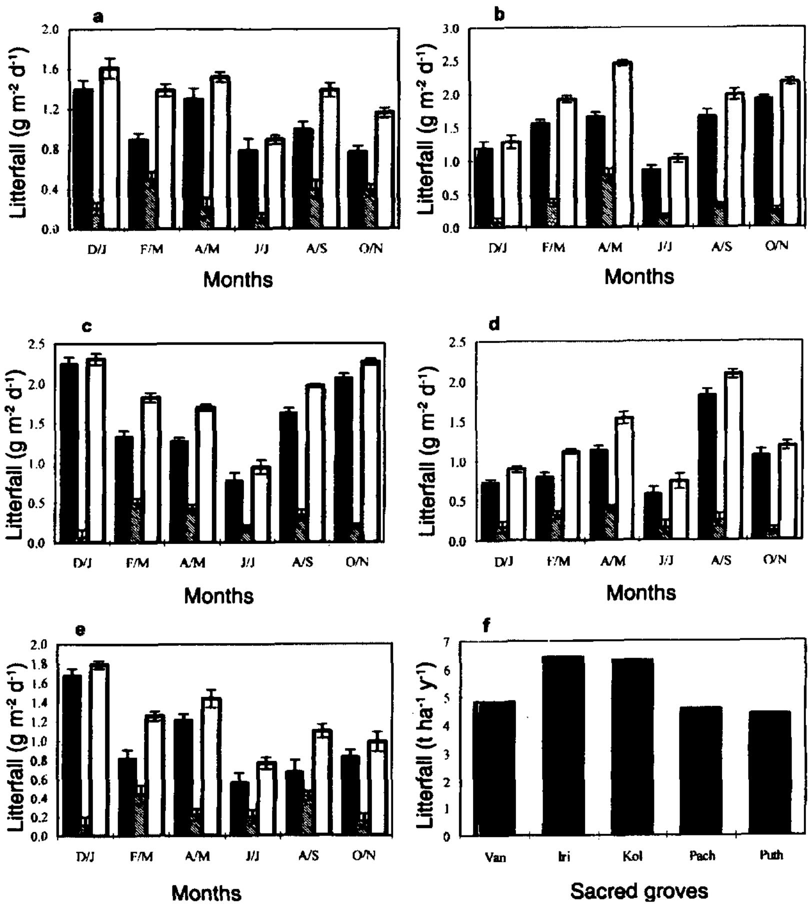

Figure 3. Mean value of litterfall rate measured at two months interval in five bioclimatically divergent sacred groves of Kerala from December 1992 to November 1994

a. Vandanam b. Iringole c. Kolani
d. Pachalloor e. Puthiyaparambil
f. The annual litterfall at five bioclimatically divergent sacred groves

■ Leaf fall ▨ Stem fall □ Total litterfall

The climate of Kerala is tropical, warm humid and monsoonal. The temperature and humidity are moderate throughout the year, rainfall is abundant with rains for nearly eight to ten months in a year. But the major precipitation is restricted to a few months and other rainy days are widely distributed over the rest of the wet months. Soil animals, mainly non-vertebrates such as earthworms, termites, millipedes, centipedes and snails, are more abundant and diverse in the sacred groves during the rainy season (Rajendraprasad 1995). According to Xiong and

Nilsson (1997), such conditions are favourable for microbial activities except during certain months. The microbes may also play a key role in litter breakdown although a low oxygen content in the soil reduces subterranean animal activity (Merritt & Lawson 1980). Low soil temperature during the rainy season may also decrease the activity of microbes (Knapp & Seastedt 1986). In the present investigation also during the heavy rainy period the decomposition rate was low and this could be explained in that, due to the continuous heavy rain, the soil became supersaturated with water, accompanied by low oxygen content and low light intensity, resulting in retarded activity of the micro flora and microbes. Altering wet and dry periods could also be important, since Polunin (1984) suggested that the higher the frequency of change between wetting and drying the greater the potential release of nutrients from the litter. In Miombo, Malaisse *et al.* (1975) noted a seasonal rhythm in the decomposition rate of litter. They suggested that the aerobic digestion of cellulose is inefficient during active rainy season but becomes important during dry season due to the enhanced activity of micro-organisms. These reasons may therefore account for the low turnover rate of litter during the rainy season (June to October), and the high turnover rate of litter during the dry season (October to May) and at the onset of periodical and interrupted summer rains during the months of April–May.

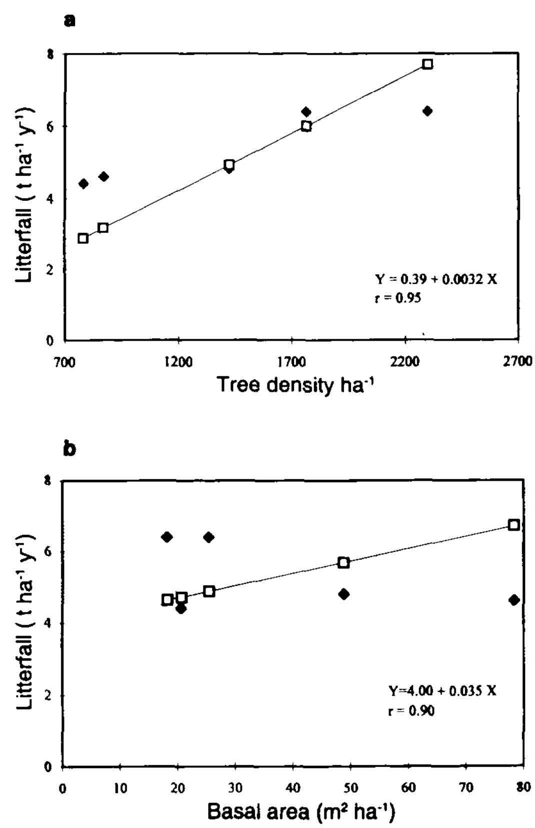

Figure 4. Linear regression analysis taking annual litterfall as a function of (a) tree density and (b) basal area of the five bioclimatically divergent sacred groves

Conclusion

In the sacred groves of Kerala, litter production is directly related to the species richness and diversity. Seasonal variation in the rate of litter production showed two peaks similar to the pattern of litter production in tropical rain forests. Late shedding of leaves in the groves is due to the closed canopy which helps to retain moisture in the system for a longer time. As in the case of other terrestrial ecosystems, the litter breakdown and mineralisation in the sacred groves is mediated by soil dwelling organisms, and its rate is influenced by the nature and activity of the decomposers, the physio-chemical status of the soil, the vegetation structure and the litter resource quality.

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