

Spatial variation of soil physico-chemical properties influenced by spatial and temporal variation of litter in a dry tropical forest floor

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Abstract. Natural litter trapping and in situ decomposition in depressions and rocky obstructions of Vindhyan hill tract result in mosaics of patchy microsites, different in appearance from the adjoining non-patchy milieu, in the dry tropical forest floor. Physico-chemical analysis of soil revealed that on both the hill top (ridge) and hill slope, patchy microsites were significantly higher in total organic C, total N and P and fine particle (Silt + clay) proportion than corresponding non-patchy microsites. Monthly maximum litter accumulation is 1,515 g m⁻² litter in April for the patchy microsite compared to a maximum of 927 g m⁻² litter during February in the non-patchy microsites, maximum litter accumulation in hill top site was 888 g m⁻² in February in patchy microsites and 289 g m⁻² in non-patchy microsites during March. Decomposition of leaf litter was studied in nylon net bag for 480 days. The time required for 95% weight loss varied from 441 days for the slope patchy microsites to 651 days for the ridge top or hill top non-patchy microsites. The mean relative decomposition rate varied between 9.12 mg g⁻¹ d⁻¹ in non-patchy microsites of hill top to 9.83 mg g⁻¹ d⁻¹ in patchy microsites of hill slope. Patchy microsites are areas of high litter accumulation + decomposition, within a matrix with comparatively inactive litter processes.
 Key words: Dry forest, patchy microsites, soil properties, litter accumulation, light fraction, decomposition.

Introduction

Litter is a major source of nutrients in dry tropical forests, perhaps second to microbial biomass in importance (Singh *et al.* 1989; Raghubanshi *et al.* 1990; Roy 1992 a,b). The quantitative study of litter is important to describe major pathway for both energy and nutrient transfer in forest ecosystems (Bray and Gorham 1964). Carlisle *et al.* (1966) stated that litter accounted for 60% of the nutrient input to the forest floor. Litter dynamics, particularly litterfall, has been well-studied in deciduous forests (Sykes and Bunce 1970; Huges 1971; Gosz *et al.* 1973) and some tropical forests (Hopkins 1966; Medina and Zelwer 1972; Ewel 1976; Haines and Foster 1977; Whitmore 1978; Proctor *et al.* 1983; Spain 1984; Frangi and Lugo 1985; Dantas and Phillipson 1989; Panday and Singh 1981; Rawat and Singh 1989; Singh and Singh 1991a,b; Singh 1992). However there is a lack of information on litter accumulation pattern on the forest floor of Indian dry tropical forests. The standing crop of litter on the forest floor is determined by the difference between the rates of litterfall and the rates of litter breakdown (Spain 1984).

Litter decomposition, an important component of nutrient cycling, is regulated by two groups of factors, climatic and substrate quality. The present study measures the spatial and temporal dynamics of litter on forest floor as well as the effect of the microsite environment on decomposition.

Study area

The study sites are located at Kotwa in the district

	Hill top		Hill slope		LSD
	Patchy	Non-patchy	Patchy	Non-patchy	
Per cent fine particle (silt+clay)	29.8 ± 2.6	21.22 ± 2.54	34.24 ± 2.1	24.25 ± 1.0	7.18
Bulk density (g cm ⁻³)	1.28 ± 0.02	1.35 ± 0.03	1.24 ± 0.04	1.32 ± 0.02	0.091
Per cent water holding capacity	39.20 ± 0.29	31.49 ± 0.60	56.19 ± 0.65	39.48 ± 1.2	2.49
Per cent organic C	1.82 ± 0.02	0.66 ± 0.059	3.07 ± 0.02	1.62 ± 0.2	0.22
Per cent total N	0.13 ± 0.002	0.045 ± 0.0005	0.21 ± 0.005	0.109 ± 0.0005	0.0091
Per cent total P	0.029 ± 0.001	0.019 ± 0.001	0.036 ± 0.002	0.029 ± 0.001	0.0048
C/N	14.00	14.67	14.62	14.8	
C/P	62.7	34.7	85.27	55.86	

Table 1. Physico-chemical properties of the soil from patchy and non-patchy microsites of the hill top and hill slope (values are mean ± 1 SE). LSD indicates least significant difference between microsites.

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Y	X	r	a	b	p
FP	BD	-0.998	184.14	-120.82	<0.05
Organic C	BD	-0.965	27.7	-19.967	<0.05
WHC	BD	-0.583	164.6	-94.397	<0.05
WHC	Organic C	0.982	23.09	10.32	<0.05

Table 2. Linear correlation ($Y = a+bX$) of bulk density (BD, $g\ cm^{-3}$) with fine particle (FP, %), organic C (%), water holding capacity (WHC, %), and of organic C (%) with water holding capacity (%) across the microsites.

Mirzapur (24°55' to 25°10'N lat. and 82°30' to 82°45' E long.) within the Marihan range of the East Mirzapur Forest Division of Vindhyan mountain range in Uttar Pradesh. Climate is dry tropical with marked seasonality. June to September is rainy, November to February is winter and April to mid June is Summer. October and March comprise transition periods between rainy and winter and between winter and summer, respectively. *Boswellia serrata* dominates the hill top with a basal cover of $8.9\ m^2\ ha^{-1}$ followed by *Acacia catechu* with a basal cover of $1.4\ m^2\ ha^{-1}$. In slope *Acatia catechu* is the dominating species with a basal cover of $1.45\ m^2\ ha^{-1}$ along with *Lannea coromandelica* with a basal cover of $1.88\ m^2\ ha^{-1}$. Details of the study area and its climatic condition have been described by Roy (1992c).

The habitats in both sites are characterized by a variety of depressions of different sizes caused by exposed rocks, boulders and topography (Roy 1992c). These depressions are referred to as patches or patchy microsites (troughs). In these depressed microsites, litter accumulation and subsequent *in situ* decomposition in patches make the soil visually different from the adjoining non-patchy land surface (Flats). The troughs averaged $0.8\ m^2$ in size and 6

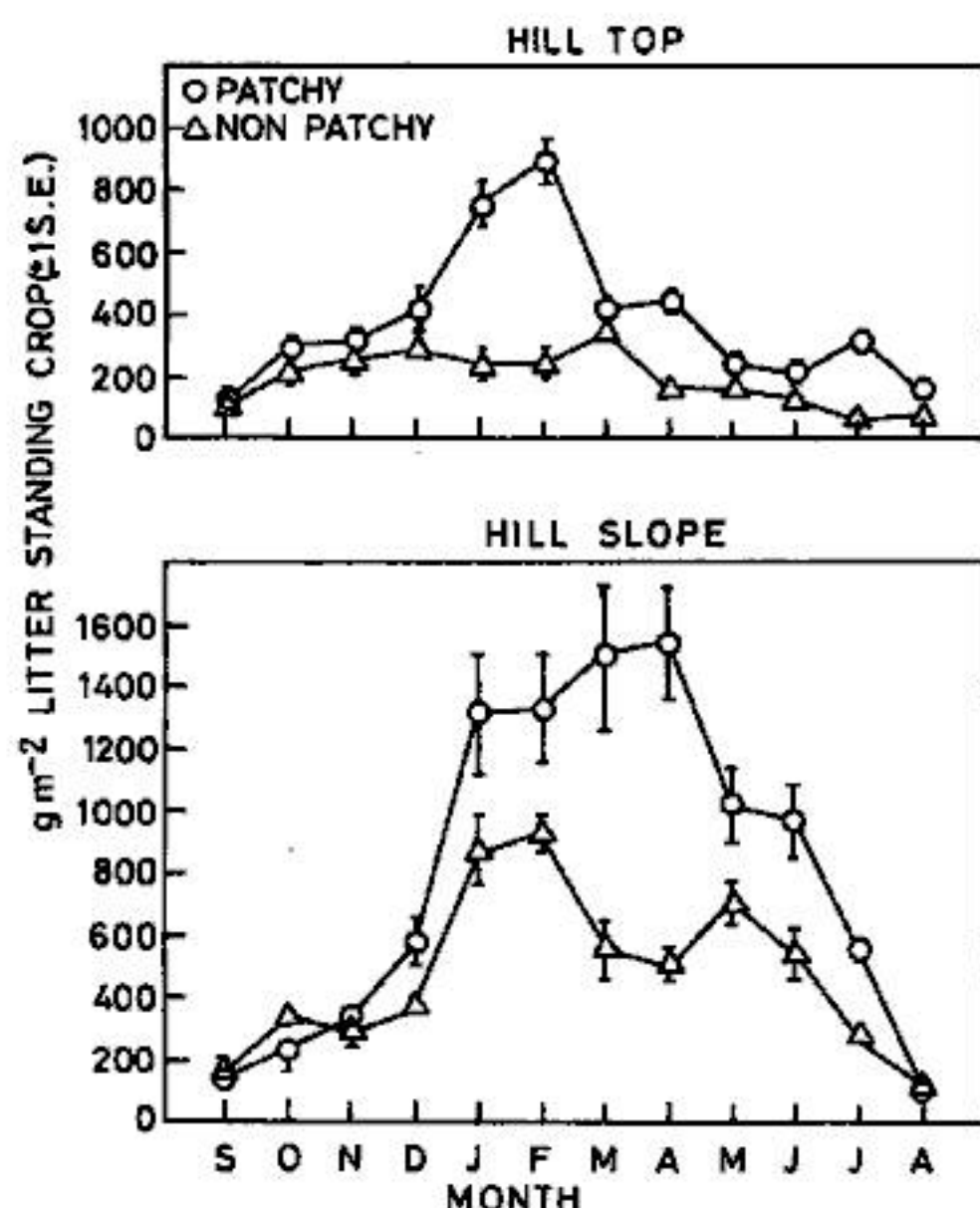


Fig.1. Standing crop of litter in the patchy and non-patchy microsites of the hill top and the hill slope sites in different months. Bars represent $\pm 1\ SE$.

cm in depth.

In the present study one 200 m x 200 m experimental plot was demarcated on the hillslope and another plot of the same size on the hill top. Eight patchy and eight adjacent non-patchy microsites were sampled in each experimental plot.

Methods

Physico - chemical Analysis of Soil

Three soil samples were collected to a depth of 10 cm from each patchy and non-patchy microsite on the hill top and hill slope. The samples were air dried and sieved through a 2 mm mesh. Fine roots were carefully removed.

Mechanical analysis was done by the pipette method (Piper 1944) on unsieved soil samples. Bulk density was determined by using a metal tube of 2.5 cm diameter. Water holding capacity was determined by using a brass box with holes at the bottom.

Chemical analysis was carried out with the sieved soil. Organic carbon was determined by Walkley-Black rapid titration method (Jackson 1958). Total organic N was determined by macrokjeldahl analysis acid extraction (Moore and Chapman 1986).

Quantification of litter accumulation

Litter was collected from three 50 cm x 50 cm quadrats from each patchy and non-patchy microsite on the hill top and hill slope each month for one annual cycle. The samples were oven-dried at 80°C to constant weight. Litter was divided into leaves, flowers, fruits and seeds, woody fraction and trash (i.e. very small partly decomposed parts of a variety of origin) (TSBF 1989). Woody fraction was always less than 10 cm in diameter (considered as the heavy fraction of the litter). Leaves, flowers, fruits and seeds, and trash were considered the light fraction of the litter.

Estimation of litter decomposition

Freshly fallen leaves were collected during February 1990. For the study of the dry matter loss through decomposition all the leaves were washed to remove soil, then air dried. To quantify weight loss due to decomposition, the litter bag technique was used. Nylon net litter bags (15 cm x 15 cm size, 1 mm mesh), containing 5 g air dried leaf litter were placed on the patchy and non-patchy microsites on the hill top and hill slope in the first week of March 1990. A total of 60 litter bags were placed at each microsite. Five litter bags were recovered from each microsite at each sampling date.

	Hill top		Hill slope	
	Patchy	Non-patchy	Patchy	Non-patchy
Winter	686±76	249±16	1077±145	723±93
Summer	296±98	149±10	1143±119	587±47
Rainy	187±24	79±8	268±74	195±29

Table 3. Seasonal averages of the standing crop of litter on the patchy and non-patchy microsites of the hill top and the hill slope ($g\ m^{-2} \pm 1\ SE$).

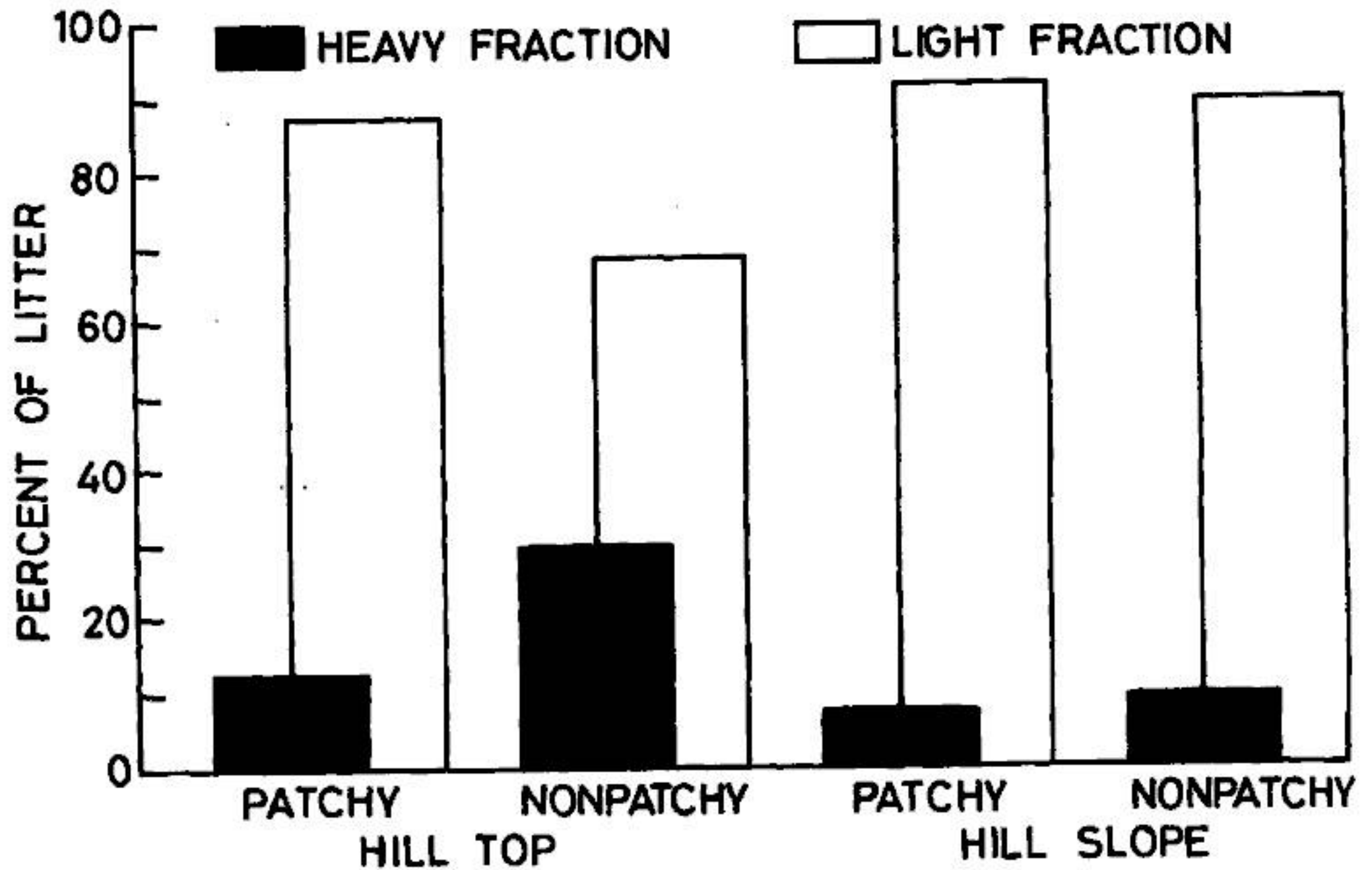


Fig. 2. Percent contribution of heavy and light fraction components to the annual mean standing crop of litter in the patchy and non-patchy microsites of the hill top and the hill slope sites.

The mean relative decomposition rate (RDR) was calculated by using the formula (Singh and Gupta 1977):

$$\text{RDR (g g}^{-1} \text{d}^{-1}) = \text{Ln} (W_1 - W_0 / t_1 - t_0)$$

Where W_0 = weight of litter present at time t_0 ;
 W_1 = weight of litter present at time t_1 ;
 $t_1 - t_0$ = sampling intervals (days).

The daily instantaneous decay rate (K) of litter for the study period was calculated using the negative exponential decay model of Olson (1963):

$$W_t / W_0 = \exp (-Kt)$$

Where W_0 = initial weight and W_t = weight remaining after time t . The time required for 50% and 95% weight loss was calculated as $t_{50} = 0.693/K$ and $t_{95} = 3/K$ respectively.

Results and discussion

Physico - chemical properties of the soil

The patchy microsites had more finer soil particles than adjacent non-patchy microsites (Table 1). This makes the patchy soil capable of holding more moisture. Soils from the patchy microsites had significantly greater water holding capacity and amounts of C, N and P than those from the non-patchy microsites both on the hill top and hill slope (Table 1).

The organic C: Total N ratio was fairly constant and

was within the range reported by Brady (1984). C/N ratio ranged from 14 to 14.62 in the patchy microsites and 14.67 to 14.80 in the non-patchy microsites. C/P ratio ranged from 62.70 to 85.27 in the patchy microsites and from 34.70 to 55.86 in the non-patchy microsites. Singh and Singh (1991b) found that C : N ratio ranged from 9.4 - 12.5 and C : P ratio from 22.81 to 62.50 in the same dry tropical forest of India. This is due to the difference in period of collecting soil samples for C/N ratio determination. For this study C/N ratio was determined from the soil collected at the beginning of active decomposition period during the onset of rainy season. Higher C/N ratios exist in the early stage of decomposition when the micro-organisms involved in the decay are dominant. With the decomposition of the organic matter into simpler forms, C/N ratio is lowered, accelerating mineralization processes as nitrifier population increases (Brady 1984; Pugh 1974).

Bulk density had inverse relation with fine particles, water holding capacity and organic carbon (Table 2). On the other hand, organic carbon showed a positive relationship with water holding capacity of the soil, revealing that accumulation of organic carbon in the soil (patchy microsites) increased the water holding capacity. The greater amount of fine particles in the patchy microsites might also increase its water holding capacity. Soils with high clay content are able to protect organic matter from degradation (Van Veen and Paul 1981).

Litter accumulation on the forest floor

The forest floor starts to get covered with fresh litter in the early part of winter (November and December) and

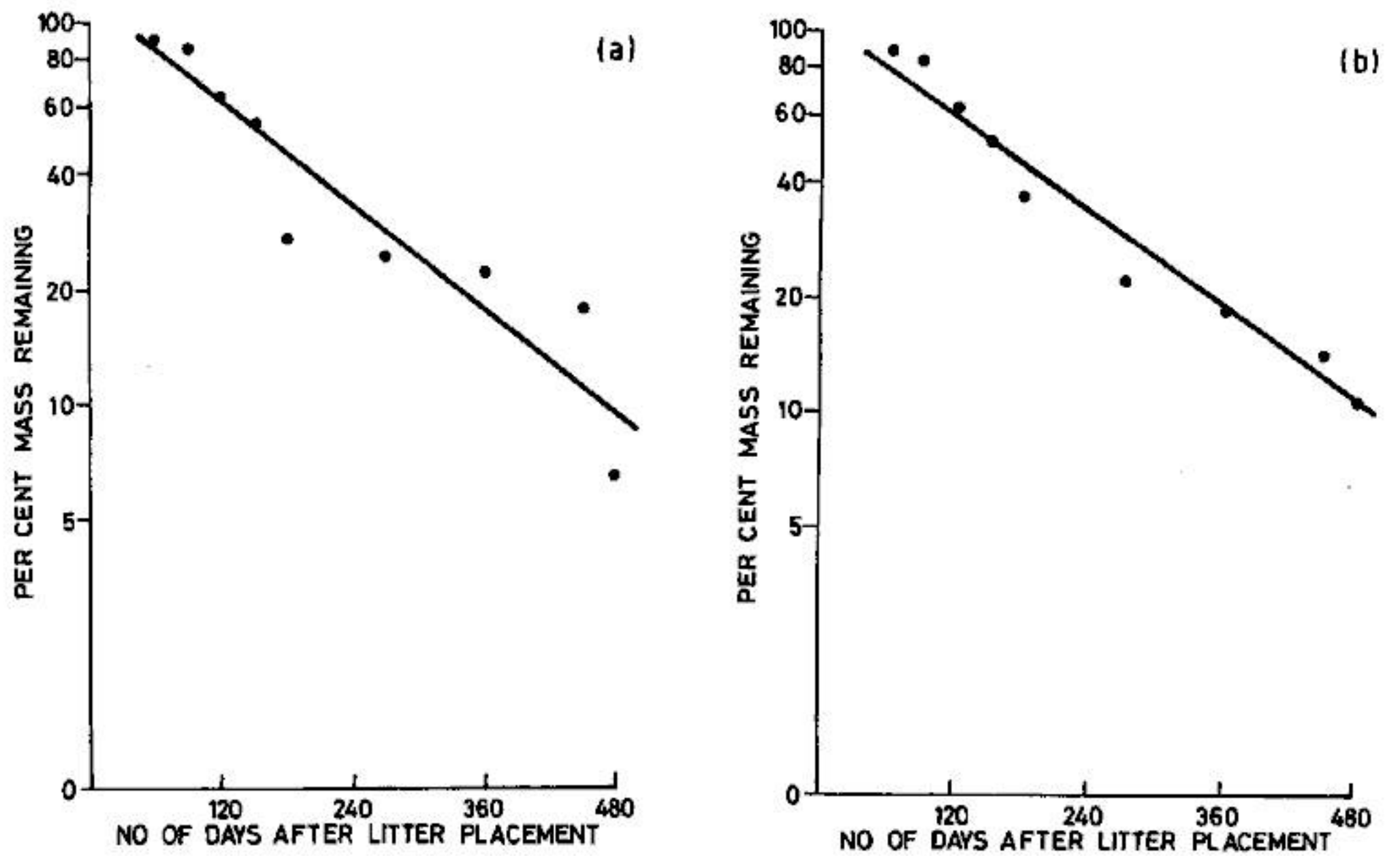


Fig. 3. Relationship between per cent mass remaining of the enclosed leaf litter and time (in days) at the hill top site (a) patchy microsites: The regression equation was $\text{Ln } Y = 4.69 - 0.0051 x$. The relationship was significant at $P < 0.001$ with correlation coefficient of -0.95 . (b) Non-patchy microsites: The regression equation was $\text{Ln } Y = 4.66 - 0.0048 x$. The relationship was significant at $P < 0.001$ with correlation coefficient: -0.986 . In these equations Y is percent weight remaining and X is the number of days after litter bag placement.

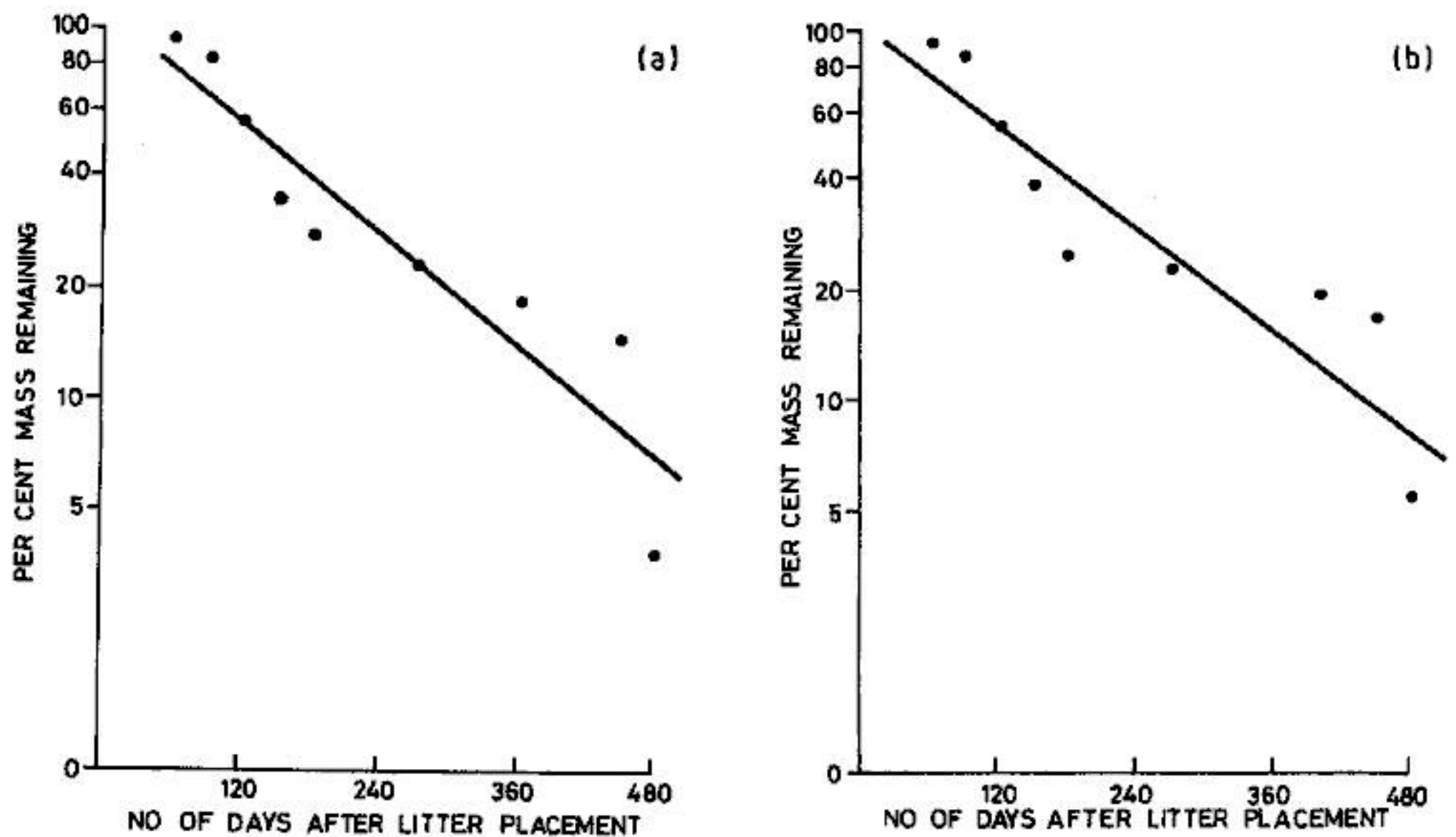


Fig. 4. Relationship between per cent mass remaining of the enclosed leaf litter and time (in days) at the hill slope site (a) patchy microsites: The regression equation was $\text{Ln } Y = 4.70 - 0.0056 x$. The relationship was significant at $P < 0.001$ with correlation coefficient of -0.937 . (b) Non-patchy microsites: The regression equation was $\text{Ln } Y = 4.647 - 0.0053 x$. The relationship was significant at $P < 0.001$ with correlation coefficient: -0.939 . In these equations Y is percent weight remaining and X is the number of days after litter bag placement.

	Hill top		Hill slope	
	Patchy	Non-patchy	Patchy	Non-patchy
Mean relative decomposition rate ($\text{mg g}^{-1} \text{d}^{-1}$)	9.54	9.12	9.83	9.65
Instantaneous decay rate (annual)	2.046	1.68	2.48	2.18
Time (days) for 50% decomposition	124	150	102	116
Time (days) for 95% decomposition	536	651	441	502

Table 4. Dry matter loss of leaf litter in patchy and non-patchy microsites.

litter accumulation reaches its peak by early summer (April). Because moisture is limiting, little litter decomposition occurs during summer. In the present study accumulation of litter was highest in the patchy microsites on the hill slope (Fig. 1), where it ranged from 105 g m^{-2} during August to $1,515 \text{ g m}^{-2}$ during April. In the non-patchy microsites of the hill slope it varied from 146 g m^{-2} in August to 927 g m^{-2} in February. In the patchy microsites on the hill top (Fig. 1) it varied from 126 g m^{-2} during September to 888 g m^{-2} during February. Litter accumulation was lowest in the non-patchy microsites on the hill top and varied from 59 g m^{-2} in August to 289 g m^{-2} in March. The data suggest that litter is redistributed after it falls on the ground as litter accumulation is higher in patchy microsites than non-patchy microsites on both the hill slope + hill top (Fig. 1). Initial distribution of litter on the floor appears to be uniform but later the litter is channeled into the troughs. Singh (1992) estimated that total annual litterfall was $685.0 \pm 99 \text{ g m}^{-2}$ in hill top and $761.0 \pm 130 \text{ g m}^{-2}$ in hill slope and was more or less uniform throughout the forest floor. Strong wind currents during winter and summer sweep dry litter to various depressions and obstructions on the forest floor (Roy 1992b).

The patchy microsites of the hill slope accumulate greater amounts of litter as the litter moves down the slope (personal observation). Analysis of variance revealed that standing crop of litter in patchy microsites was significantly ($P < 0.001$) greater than in the non-patchy microsites at both the hill top and hill slope sites. Differences due to month were significant at $P < 0.001$ for both the microsites, and the interaction (month \times microsite) was significant at $P < 0.01$ for the hill top and at $P < 0.04$ for the hill slope microsites. Both patchy microsites and non-patchy microsites on the hill slope had significantly greater ($P < 0.001$) amount of litter than the corresponding microsites on the hill top. At both hill top and hill slope sites, the accumulation of litter on the patchy microsites was substantially higher than the corresponding non-patchy microsites during all seasons (Table 3).

Singh and Singh (1991a) reported that average forest floor litter mass ranged from 2.24 to 3.22 t ha^{-1} and small litter fall ranged from 4.88 to $6.71 \text{ t ha}^{-1} \text{ yr}^{-1}$ in the same forest. Singh (1989) found that in tropical dry forest in India litter accumulation was $3.6 - 4.0 \text{ t ha}^{-1}$ within a year. Vogt *et al.* (1986) stated that the litter accumulation on the tropical forest floor can range from 2.1 to 54.0 t ha^{-1} in a year.

The litter mass of the patchy microsites had a greater percentage of light fraction than the corresponding non-patchy microsites (Fig. 2). In the patchy microsites of the hill top about 88% of the litter was accounted for by the light fraction, in the hill slope the patchy microsites had 92% light litter fraction whereas the non-patchy milieu had 90% light fraction in the litter. The light fraction, because it has lower mass than the woody fraction, is

easy to move in response to external driving factors such as wind, water and gravitation and can be trapped easily in the depressions and obstructions.

Dry matter loss through decomposition

Significant correlation existed between time (days) and log of per cent mass remaining in all the patchy and non-patchy microsites, according to the equations referred in Figs 3 and 4. It is worthwhile to mention that figures 3 and 4 manifest a relationship pattern, which is a bit curvilinear and is solely due to the sharp seasonal changes in decomposition rates.

Table 4 shows that dry matter loss of leaf litter was faster in the patchy microsites than in their corresponding non-patchy microsites. This indicates that troughs are with more suitable microenvironment of litter decomposition. Roy (1992c) shows that troughs are with more microbial biomass than the flats.

In seasonal forests in Ghana (Nye 1961) and Zaire (Laudelot and Meyer 1954), mean leaf litter decomposition rate of $475\% \text{ a}^{-1}$ and $329\% \text{ a}^{-1}$, respectively were recorded. Madge (1965) reported a dry matter loss from leaf litter between $219\% \text{ a}^{-1}$ in dry season and $548\% \text{ a}^{-1}$ in wet season in Nigerian forests. Tripathi and Singh (1992) reported 151% annual decomposition in the case of leaf litter of Bamboo species in the dry tropical environment in India.

The present study reveals patchiness in the distribution of resource in the forest habitat forming a matrix of troughs and flats. Patchiness in the resource distribution is fundamental to the way organisms exploit their environment (Schoener 1971, Wiens 1976, Mangel and Clark 1986, Pulliam 1989). Higher amount of organic matter in the troughs has resulted in improved physico-chemical environment, conducive for other soil processes. Patchiness provides an efficient nutrient conserving mechanism in this dry tropical forest supported on a nutrient poor soil (Roy and Singh 1994). Microbes release greater amount of nutrients in these troughs during rainy season (Roy 1992c). Tree fine roots have been found to be significantly greater in the troughs than in the flats specially during growth season (Roy and Singh 1994). Troughs in these forests are the microsites of active soil processes and nutrient storage as well as flux, induced by natural channelisation of litter into it and their *in situ* decomposition.

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