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# Seasonal variation in biomass and nutrient content of the forest floor in a dry tropical forest.

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**Abstract.** Seasonal variations in biomass and nutrient content of the forest floor were studied in a dry tropical forest in India. The range of variations in standing crop of fresh leaf litter, partly decayed litter and wood litter, during different seasons, were 30.8-220.9 g,36.1-115.6 g and 76.4-151.6 g/m$^2$, respectively. The mass of herbaceous live shoots and dead shoots varied 1.4-62.9 g and 3.3-22.9 g/m$^2$, respectively. Nutrient concentration in different forest floor components followed the order: herbaceous shoots > fresh leaf litter > wood litter > and partly decayed litter. Nutrient content in total forest floor mass amounted to (kg/ha): 27.9-39.7 N, 1.7-2.3 P, 12.5-17.1 Ca, 11.1-15.9 K and 1.8-2.6 Na.
*Keywords*:: Dry tropical forest, forest floor, leaf litter, decayed litter, wood litter

## Introduction

Dry forests cover 42% of the forested area in tropics. Highest human population densities have been recorded in the dry forest regions of the neotropics (Murphy and Lugo 1986). Dry deciduous forests constitute the third major regional forest formation in the tropics (Lamprecht 1989) and the most threatened of all major lowland tropical forest types (Janzen 1988). Tropics are characterised by seasonal climates where the annual precipitation is concentrated in one or two rainy seasons, separated by dry spells (Hytteborn and Skarpe 1992).

Organic matter produced above ground accumulates on the forest floor before being transferred to organic matter in soil. The layer of dead and decomposing leaves, woody material, reproductive structures and other organic materials on the surface of the soil is referred to as litter layer or forest floor. Standing crop of litter represents the difference between litter fall and litter breakdown (Spain 1984)

Organic matter present on the forest floor acts as : (i) a nutrient reservoir for intrasystem cycling that regulates forest hydrology (Lang 1974), (ii) a nutrient pool involving input, output, mean nutrient content and turnover rates (Reiners and Reiners 1970), and (iii) an important stage in the cycling of habitat conservation (Ashton 1975); it also helps in forest reproduction. Besides being the substratum for the detritus food web and a nutrient reservoir, litter drastically alters the microenvironment and may affect the structure and dynamics of plant communities

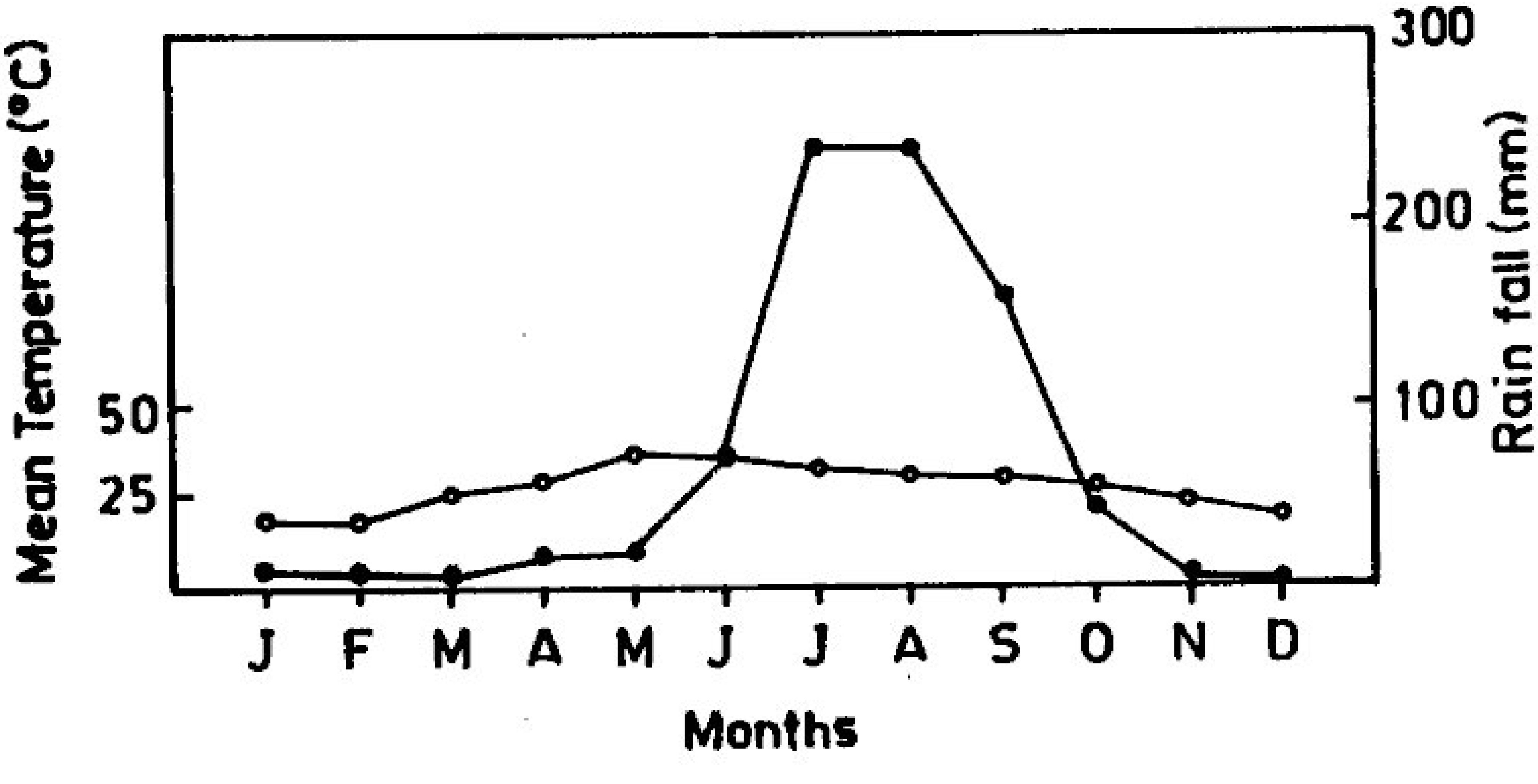


**Fig.1.**Ombrothermic diagram for the dry tropical forest based on eight year data (1982-89). Solid circles represent rainfall and open circles temperature.

| Components | N | P | Ca | K | Na |
|---|---|---|---|---|---|
| Tree leaf litter | 1.00±0.05 | 0.06±0.01 | 0.65±0.10 | 0.32±0.04 | 0.07±0.006 |
| Shrub leaf litter | 1.27±0.11 | 0.07±0.01 | 0.78±0.09 | 0.27±0.02 | 0.09±0.001 |
| Partly decayedlitter | 1.20±0.11 | 0.04±0.002 | 0.28±0.03 | 0.56±0.06 | 0.06±0.005 |
| Wood litter | 0.89±0.06 | 0.06±0.01 | 0.45±0.05 | 0.26±0.02 | 0.07±0.004 |
| Litter layer* | 1.16±0.09 | 0.06±0.01 | 0.38±0.03 | 0.47± 0.13 | 0.07±0.004 |
| Herbaceous live shoot | 1.71±0.29 | 0.16±0.03 | 0.38±0.09 | 1.56±0.32 | 0.09±0.02 |
| Herbaceous dead shoots | 1.36±0.23 | 0.09±0.02 | 0.54±0.09 | 0.39±0.08 | 0.07±0.01 |

**Table 1**. Nutrient concentrations in different components of forests floor (% ± 1 SE). * includes fresh leaf litter plus partly decayed litter plus wood litter.

(Facelli and Pickett 1991).

Studies on the litter layer in dry tropical forests are scarce,( Lugo *et al.* 1978; Brown and Lugo 1982; Proctor *et al.* 1983; Spain 1984; Vogt *et al.* 1986; Lugo 1992; Morellato 1992). The present paper deals with the seasonal variations in dry matter and nutrients of the forest floor in a dry tropical forest.

## Material and methods

### *Study area*

The study area is located between 24° 55′ to 25° 10′ N lat. and 82° 32′ to 83° 45′ N long. in the Marihan range of East Mirzapur Forest Division of Uttar Pradesh, India, on the Vindhyan Plateau (225-525 m altitude). Climate is tropical and is influenced by monsoon conditions. The year is divisible into three seasons: rainy (mid June-September), winter (November-February) and summer (April-mid-June). Mean monthly values for temperature and rainfall, based on eight years of data (1982-89), are plotted in Figure 1. Mean monthly temperature varied from 17.5°C (January) to 35.7°C (May) and the average annual temperature was 27°C ; the average annual rainfall was 821 mm, of which 86% was confined to the rainy season.

Three contiguous sites were selected along a sough facing hill site : Site 1 was located at the summit of the hill; site 2 was the slope of the hill; and site 3 was located at the hill base.

The soil cover on hill-top and mid-slope sites was 28% and 30%, respectively, and the remaining surface area was covered with large boulders and rock outcrops. The hill-base site has depositional soil with no rock outcrops. The Vindhyan plateau is largely an erosional surface. Red-coloured and fine-textured sand (Dhandraul orthoquartzite) are the most important rock types.

Soils are residual ultisols, nutrient poor, and sandy loam in texture (sand 56-69%, silt 24-28%, and clay 4-16%) with moderate water-holding capacity (38-46%). The nutrient status of the soils was already described by Singh and Singh (1991a)

### *Vegetation*

The vegetation of the area belongs to Northern Tropical Dry Deciduous Forest (Champion and Seth 1968). Vegetation characteristics of these sites were described by Singh and Singh (1991b). On the hill base site, the natural forest cover has been altered by the State Forest Department with the plantations of *Acacia catechu* and *Emblica officinalis* which comprised the top story. The second stratum comprised small trees of *Ougeinia oojeinensis* and the shrubs *Ziziphus glaberrima, Ziziphus oenoplia* and *Carissa opaca*. The mid-slope site is dominated by *Acacia catechu* and *Lannea coromandelica* in the overstorey and by the shrubs *Nyctanthes arbortristis, Holarrhena antidysenterica* and *Ziziphus glaberrima* in the second stratum. The Hill top site is dominated by *Boswellia serrata*, and *Acacia catechu*. The second layer is dominated by the shrubs *Nyctanthes arbortristis* and *Ziziphus glaberrima*.

### *Forest floor*

(i) Dry matter

Forest floor samples were collected from eight 50 x 50 cm randomly placed quadrats at monthly intervals for two consecutive years between July 1987 and June 1989. Materials thus collected were categorised, following Pandey and Singh (1981), as (a) fresh leaf litter, (b) partly decayed litter (including fragmented dark material on the soil surface), (c) wood litter (includes reproductive parts also in this study), (d) herebaceous live shoots, and (e) herbaceous dead shoots.

In each quadrat, all the above ground herbaceous live and dead shoots were first harvested at ground level and placed in labelled polyethylene bags. The materials remaining on the forest floof after harvesting the above ground herbaceous mass were then collected, carefully avoiding contamination with soils as much as possible and categorised as described above. The collections were brought to the laboratory separately by category, and oven dry weights were determined. Forest floor estimates on sites 1 and 2 were converted to area-weighted mean values, because these sites comprised rock outcrops as well as soil. Proportions of area covered by rock and by soil were determined by establishing a large number of transects across the sites in each season.

Above ground net production (ANP) of the herbaceous vegetation was calculated according to Singh *et al.* (1975):

$$ANP = \sum_{i=1}^{n} \Delta LS + \sum_{i=1}^{n} \Delta DS$$

Where $\Delta$ LS is increment in herbaceous live shoot biomass and $\Delta$ DS is the corresponding increment in herbaceour dead shoot biomass summded over sampling interval(n).

(ii) Nutrient analysis

Samples of each forest floor component (fresh leaf litter, wood litter, partly decayed litter and herbaceous live and dead shoots) collected at monthly intervals on different sites were pooled in proportion to their volume to represent annual samples. The composite samples of each component of forest floor were oven dried at 80° C to constant weight. The samples were mill ground. Total nitrogen in each component of the forest floor was determined unsing a Perkin-Elmer 240, CHN Auto Analyser. Phosphorus was determined by phosphomolybdic blue colorimetric method,and potassium and sodium by flame photometry (Jackson 1958). Calclium was determined by Atomic Absorption Spectrophotometer (Perkin-Elmer 373 AAS). The nutrient content in each component of forest floor was computed as the sum of products obtained by multiplying dry weights of each component by their mean nutrient concentrations (Table 1). Statistical analyses were performed using SPSS/PC Software (SPSS/PC, 1986).

## Results

*Litter layer*

Temporal fluctuations in the standing crop of fresh leaf litter reflected the variable leaf fall in different months. The standing crop of fresh leaf litter showed marked seasonality. It was maximum during summer and minimum during the rainy season and the range of variation in seasonal averages were 37.3-158.6, 53.8-220.9 and 30.8-140.6 g/m² for sites 1, 2 and 3, respectively (Fig. 2). Analysis of variance (ANOVA) indicated significant differences among sites ($p<0.001$), seasons ($p<0.001$) and site x season interaction for fresh leaf litter.

The range of variation in seasonal mass of partly decayed litter was 64.5-115.6, 58.8-102.3 and 36.1-72.5 g/m² for sites 1, 2 and 3, respectively (Fig. 2). ANOVA indicated significant differences between sites ($p<0.001$) and between seasons ($p<0.001$) for partly decayed litter. However, the values for site x season interaction were not statstically significant.

The variation in seasonal averages for wood litter mass was 93.3-151.6, 83.8-112.5 and 76.4-106.8 g/m², respectively, for sites 1, 2 and 3. Maximum seasonal wood litter mass was observed during rainy season on all sites and the minimum during winter on sites 1 and 2, and in summer on site 3 (Fig. 2). ANOVA indicated significant differences between sites ($p<0.001$), between season ($p<0.001$) and site x season interaction.

*Herbaceous vegetation*

The variation in seasonal averages for biomass of live shoots was 4.1-62.9, 1.5-62.4 and 1.4-51.8 g/m², respectively, for sites 1, 2 and 3 (Fig. 2). Differences between sites and between seasons were significant ($p<0.001$); however,the values for site x season interaction were not significant. The biomass developed rapaidly during the rainy season due to the fast growth of herbaceous vegetation triggered by warm temperatures and accentuated rainfall. The decrease in the biomass of herbaceous live shoots after rainy season resulted from death and shattering of annual plants following mortality. The bulk

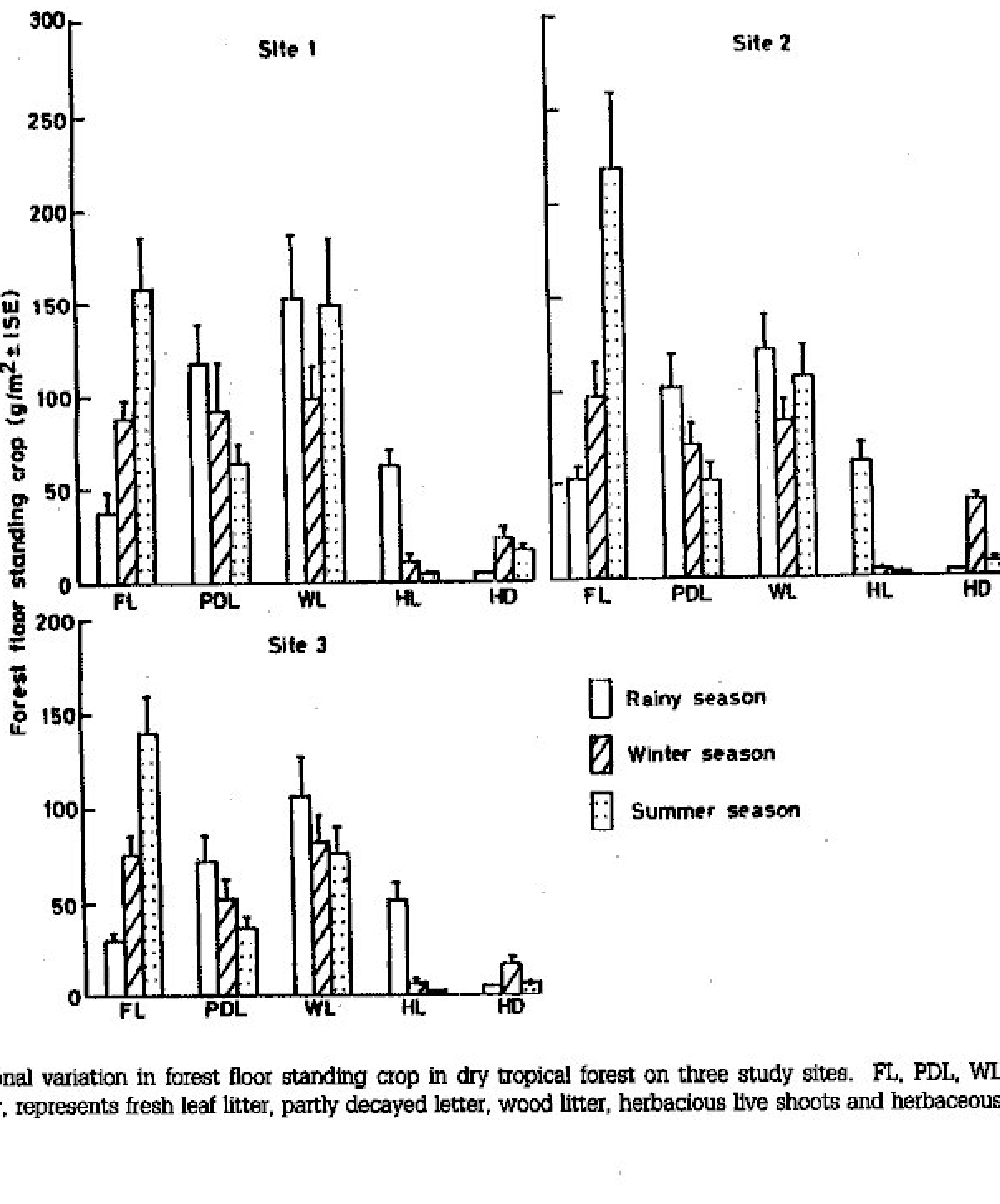


**Fig.2.**Seasonal variation in forest floor standing crop in dry tropical forest on three study sites. FL, PDL, WL, HL and HD respectively, represents fresh leaf litter, partly decayed letter, wood litter, herbacious live shoots and herbaceous dead shoots.

| Components | N | P | Ca | K | Na |
|---|---|---|---|---|---|
| | | | Site 1 | | |
| Fresh leaf litter | 10.6± 2.6 | 0.7±0.2 | 6.7±1.6 | 2.8±0.7 | 0.8±0.2 |
| Partly decayed litter | 10.9±2.5 | 0.4±0.1 | 2.6±0.6 | 5.1±1.2 | 0.6±0.1 |
| Wood litter | 11.8±2.7 | 0.8±0.2 | 5.9±1.4 | 3.4±0.8 | 0.9±0.2 |
| Herbaceous live shoots | 4.4±1.2 | 0.4±0.1 | 1.0± 0.3 | 4.0±1.1 | 0.2±0.06 |
| Herbaceous dead shoots | 2.0±0.3 | 0.1±0.02 | 0.8±0.01 | 0.6±0.1 | 0.1±0.01 |
| Litter layer | 34.9±1.5 | 1.8±0.1 | 11.4±0.5 | 14.2±0.6 | 2.1±0.1 |
| Total forest floor | 39.7 | 2.3 | 17.0 | 16.0 | 2.6 |
| | | | Site 2 | | |
| Fresh leaf litter | 13.8±2.9 | 0.9±0.2 | 8.8±1.8 | 3.7±0.8 | 1.0±0.2 |
| Partly decayed litter | 9.1±1.7 | 0.3±0.1 | 2.1±0.4 | 4.2±0.9 | 0.5±0.1 |
| Wood litter | 9.3±1.7 | 0.6±0.1 | 4.7±0.9 | 2.7±0.5 | 0.7±0.1 |
| Herbaceous live shoots | 3.9±0.6 | 0.4±0.1 | 0.9±0.1 | 3.5±0.5 | 0.2±0.003 |
| Herbaceous dead shoots | 0.1±0.04 | 0.1±0.03 | 0.6±0.2 | 0.4±0.1 | 0.1±0.02 |
| Litter layer | 34.2±2.2 | 1.8±0.1 | 11.2±0.7 | 13.9±0.9 | 2.1±0.1 |
| Total forest floor | 36.3 | 2.2 | 17.1 | 14.6 | 2.4 |
| | | | Site 3 | | |
| Fresh leaf litter | 9.2±1.6 | 0.6±0.1 | 5.9±1.0 | 2.5±0.4 | 0.7±0.1 |
| Partly decayed litter | 6.4±1.2 | 0.2±0.04 | 1.5±0.4 | 3.0± 0.5 | 0.3±0.1 |
| Wood litter | 7.8±2.0 | 0.5±0.1 | 4.0±1.0 | 2.3±0.6 | 0.6±0.2 |
| Herbaceous live shoots | 3.3±0.5 | 0.3±0.1 | 0.7±0.1 | 3.0±0.5 | 0.2±0.03 |
| Herbaceous dead shoots | 1.1±0.2 | 0.1± 0.01 | 0.5±0.1 | 0.3±0.1 | 0.1±0.01 |
| Litter layer | 26.0±1.1 | 1.3±0.1 | 8.5±0.4 | 10.5±0.4 | 1.6±0.1 |
| Total forest floor | 27.9 | 1.7 | 12.5 | 11.1 | 1.8 |

**Table 2.** Amount of nutrients in different forest floor components (kg/ha ± 1 SE).

of live biomass was transferred to the standing dead component during winter season.

The range of variation in seasonal averages for the mass of dead shoots was 4.1-22.9, 3.3-22.0 and 4.4-16.0 g/m$^2$ for sites 1, 2, and 3, respectively (Fig. 2). Significant differences between sites ($p<0.001$) between season ($p<0.001$) and site x season interaction ($p<0.001$) were observed. From rainy to winter season, there was a continuous increase in the dead shoot mass indicatiing continuous transfer of live shoots into this compartment, Consequently, the peak of dead shoots followed that of live shoots.

Since the decomposition is moisture limiting and litterfall of herbaceous shoots occurs after rainy season (Singh 1992), the disappearance of herbaceous materials between two sampling intervals was not significant ($p<0.001$). Total ANP was 110.0, 90.0 and 80.0 g/m$^2$ for sites 1, 2 and 3, respectively with the average of 90.0 g/m$^2$.

*Nutrient concentrations and content*

N, P, Ca, K and Na concentrations in different components of forest floor are summarized in Table 1. The pattern of nutrient concentration in different forest floor components was in the order: herbaceous live shoots> herbaceous dead shoots> shrub leaf litter> litter layer> tree leaf litter> wood litter and> partly decayed litter. However, calcium in tree and shrub litter was greatest among all the components, where as N and K were higher in partly decayed litter as compared to wood litter. The variations in per cent nutrients were 0.89-1.71 for N, 0.04-0.16 for P, 0.28-0.78 for Ca, 0.26-1.56 for K and 0.06-0.09 for Na.

Total forest floor nutrients for different sites ranged 27.9-39.7 for N, 1.2-2.3 for P, 12.5-17.1 for Ca, 11.1-15.9 for K and 1.8-2.6 for Na kg/ha (Table 2). The contribution of different components for different nutrients varied: 18-51% by fresh leaf litter, 19-36% by wood litter, 12-32% by partly decayed litter, 5-27% by herbaceous live shoots and 0.4-5% by herbaceous dead shoots. The variations in litter layer nutrients (kg/ha) were: 25.9-34.9 N, 1.3-1.8 P, 8.5-11.4 Ca, 10.5-14.2 K and 1.6-2.1 Na for different sites (Table 2).

## Discussion

The accumulation of leaf and woody litter on the forest floor are attributed to age, climate, forest type,and species composition (Lugo, 1992). In the present study the seasonal mean total forest floor mass (including herbaceous biomass) was maximum on site 1 (3.58 t/ha) followed by site 2 (3.38 t/ha) and minimum on site 3 (2.52 t/ha). The lowest standing crop on site 3 was on account of low basal cover of trees (5.9 m2/ha) and shrubs (3.1 m$^2$/ha) and low herbaceous biomass. In contrast, site 1 had the maximum basal cover of trees (10.36 m$^2$/ha) and shrubs (4.43 m$^2$/ha), besides maximum forest floor. Site 2 showed lower basal cover of trees (3.84 m$^2$/ha) and higher basal cover of shrubs (7.78 m$^2$/ha) as compared to site 3.

Since the summer season followed peak litterfall period (winter) and the winter season followed the rainy season when the decomposition is most rapid, the pattern of maximum forest floor mass during summer and minimum during

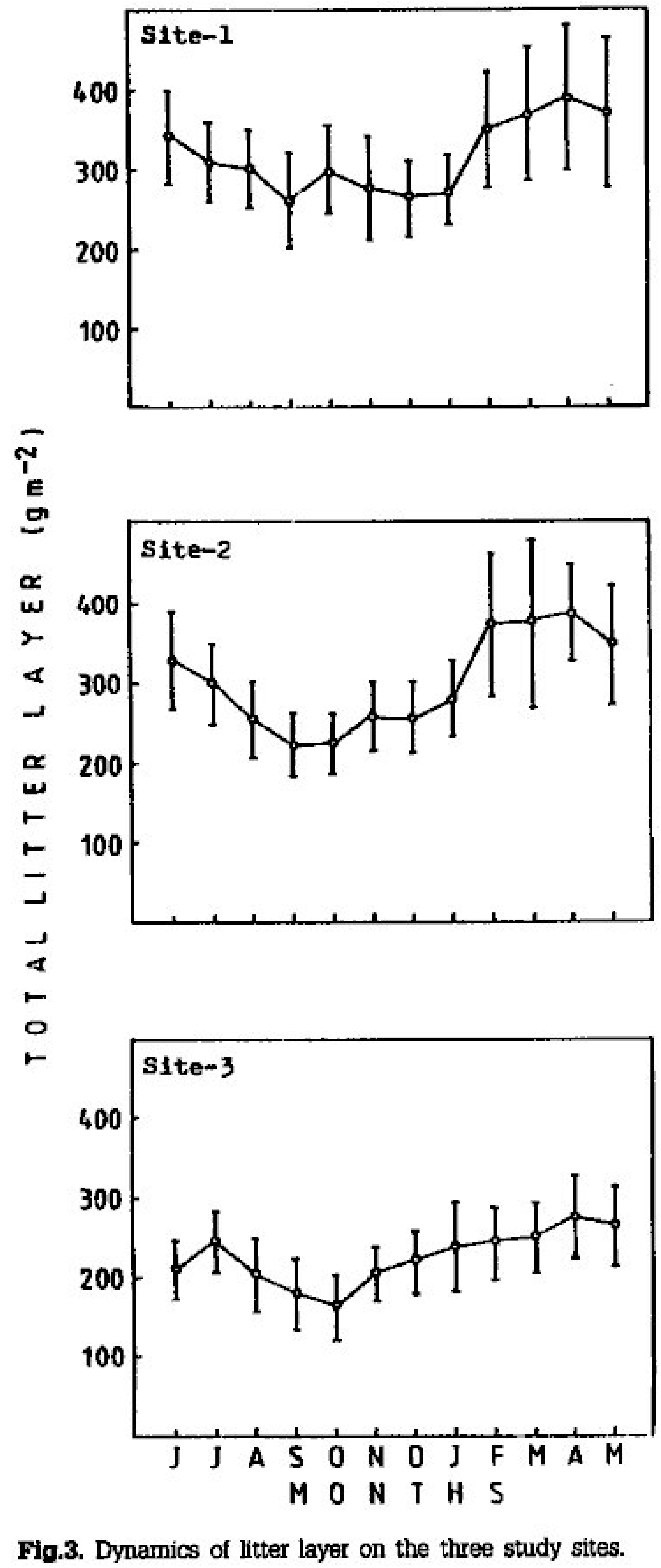


**Fig.3.** Dynamics of litter layer on the three study sites.

winter is expected.

The total quantity of forest floor material varied from season to season on all sites.The minimum forest floor mass on all sites, was obserbed during winter season and the maximum was noted during summer,except site 3 where the maximum amount of forest floor was noted during rainy season. In July,the partly decayed litter contribution was maximum. When averaged for the months, wood litter contributed maximum to the forest floor on sites 1 and 3 whereas fresh leaf litter was maximum on site 2.

Seasonal variations in the standing crops of litter in tropical forests is related to the seasonality of litter fall inputs and the nature of climate. When the climate is monsoon type, breakdown rates are depressed for considerable periods during the dry season (Madge 1965; Swift *et al.* 1981) resulting in the seasonally large standing crops of litter as observed in the present studies (Figs 2, 3). When rainfall is more evenly distributed over the year, breakdown rates are less variable and fluctuations in the standing crops of litter less marked (Ogawa 1978).

Variations in the standing crops of litter in tropical and subtropical forests have been reported. Hopkins (1966) reported annual ranges of 50-480 g/m$^2$ and 180-550 g/m$^2$, respectively, from "dry" and "moist" Nigerian forests. Bernhard (1970) noted seasonal variations in Ivory Coast forests and recorded litter standing crops that ranged from less than 100 to more than 350 g/m$^2$. In the present study seasonal standing crop of litter (fresh + partly decayed + woody litter) showed variation ranging from 246 g/m$^2$ to 335g/m$^2$. Madge(1965) reported that litter accumulation was in the range of 1.7-14.7 t/ha within the tropical zone and of 3.6-39.9 t/ha in the temperate region.

The forest floor mass reported in the present study is in the lower part of the range (2.1-54.0 t/ha) recorded for the tropics (Vogt *et al.* 1986). In gereral, the standing croop of litter in the dry tropical forest studied is comparable with serval other tropical and subtropical dry forests, but distinctly lower than those of tropical rain, tropical montane and tropical moist forests studied elsewhere (Brown and Lugo 1982).

The nutrient content in all the forest floor components increased from hill base to mid slope and hill top. This could be attributed to vegetation structure and litterfall patterns. Hill top site had the maximum forest basal cover and the mid slope showed maximum litterfall (Singh and Singh 1991b; Singh 1992).

It is difficult to make the comparison of litter nutrients beacuse litter is extremely variable in elemental composition, beacause of the variability in the litter composition from forest to forest. Stark (1971) has pointed out that each section of forest floor receives a variety of litter from different species and in different stages of decompostion, and litter comprised of variable percentages of small stem wood, bark, leaves, fruits, dead insects, fungi, and flower parts, all of which contribute to the variability in elemental composition of litter. The variations in litter nutrient (kg/ha) of the forest floor were 27.9-39.7 for N, 1.9-2.3 for P, 12.5-17.1 for Ca, 11.1-16.0 for K and 1.8-2.6 for Na. Lugo (1992) reported that the ranges in nutrient contents were 43.7-140 N, 2.2-4.7 P and 6.6-11.7 K kg/ha for tropical tree plantations and tropical secondary forests.

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