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Litterfall Pattern and Forest Floor Biomass in Achanakmar-Amarkantak Biosphere Reserve, India

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ABSTRACT
The present study was aimed at assessing the litterfall pattern and forest floor biomass in Achanakmar-Amarkantak Biosphere Reserve. Four sites characterized by varying vegetation attribute and representative of the region were selected. Forest floor biomass was measured by laying random quadrats and litterfall was quantified by litter trap techiniques. The standing crop of fresh leaf litter showed marked seasonality. It was maximum during summer and minimum during rainy season and the seasonal averages varied between 39.0-164.9, 35.8-158.9, 37.3-164.1 and 21-108.5 g m^{-2} on dense, regenerated, medium and degraded, respectively. The highest leaf litter fall values were recorded for dense forest site (523.4 g m^{-2} yr^{-2}) followed by medium forest site (442.3 g m^{-2} yr^{-2}) and the lowest at degraded forest site (298.1 g m^{-2} yr^{-2}). Wood litter fall followed the order: medium site > dense site > regenerated site> degraded site. Annual turnover of litter varied from 66-76% and the turnover time ranged between 1.32-1.51 yrs.
Keywords: *Litterfall, forest floor biomass, turnover rate, turnover time*

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INTRODUCTION
Tropical forests are known to harbor great species richness, vegetation biomass and productivity [1]. As the development of the time these forest were subjected to severe degradation which leads to loss of biodiversity. Because of the higher diversity these forests possess, therefore, much attention has been given towards its conservation and management in recent years [2]. In Indian perspective even protected forests are under threat due to various abiotic and biotic factors affecting the integrity of forest ecosystem's function and associated services. About 86% of the forested area of India is under tropical forests, of which 37% is of the moist deciduous, 53% is dry deciduous and the rest is wet evergreen or semi evergreen [3]. Tropical deciduous forests occur under varied climatic conditions, but essentially with alternate wet and dry period.
Litterfall and litter decomposition are vital processes in tropical forests because they regulate nutrient cycling and source of soil organic matter. Nutrient cycling can be altered by forest fragmentation [4]. Litterfall is an important pathway for nutrient transfer from plants to soil in forest ecosystems. Litterfall sustains forest growth on one hand and exerts a great influence on nutritional and biological characteristics of forest soil [5]. A substantial amount of organic matter returns to the forest floor through litter fall. Leaves constitute about 70-90% of the total litter fall in various forest ecosystems. It plays a significant role in transfer of energy to the major heterotrophs which inhabited in the forest soils. Litter fall, thus, exerts a great influence on physical, chemical and biological characteristics of soil [6]. The cycling of materials is inherent in the functioning of ecosystems and is integral to their structure and functioning. The importance of litter production has been recognized for a long period of time and consequently many studies have been carried out. Litter fall has an important influence on soil formation because it is a major component in the circulation of mineral elements and contains many complex organic compounds, which vary in biological degradability [7]. Litterfall and leaf decomposition represent the main pathway for nutrient cycling in forest ecosystems [8]. Therefore, forest productivity depends on efficient nutrient cycling mechanisms that ensure rapid turnover of litter nutrients [8]. The decomposition of forest floor biomass and litter were determined by temperature of the region. Higher

temperature leads towards faster turn over while the lower temperature reduces the decomposition rate and nutrient release [9].

Estimation of biomass is an essential aspect of studies of carbon stocks and the effects of deforestation and carbon sequestration on the global carbon balance [10-11]. Biomass constitutes a primary data needed for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems [12]. There are only a few studies on litterfall pattern and forest floor biomass in forest ecosystem of Achanakmar-Amarkantak Biosphere reserve. Therefore, the present investigation was carried out to study the litterfall pattern and forest floor biomass in Achanakmar-Amarkantak Biosphere Reserve, India.

MATERIALS AND METHODS

The present study was carried out at Achanakmar-Amarkantak Biosphere Reserve. The study sites are located in 22º15'-22º58' N latitude and 81º25'-82º 5' E longitude having an area of 3835.51 km^2. Climate is tropical and is influenced by monsoon conditions. The mean monthly temperature varies from 17.2^oC (January) to 31.8^oC (May) and the total annual rainfall average 1383 mm, of which 85 % occurs in the rainy season [13]. The soils of the area are generally lateritic, alluvial and black cotton type, derived from granite, gneisses and basalts. The forest is seasonally dry tropical and includes extensive tracts of old growth *Shorea robusta* forest. Forest is classified into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous forests [14]. The former type predominates in the Biosphere Reserve area.

Four sites (Dense, Medium, Regenerating and Degraded) characterized by varying vegetation attributes and representative of the region's vegetation were selected. Data on forest floor were collected from 50 x 50 cm randomly placed quadrats at monthly intervals on each site. The forest floor material was categorized following Singh [15]. The collections were brought to the laboratory separately by category and oven dry weights were determined. The litterfall to the forest floor was measured by placing 10 litter traps (each 50x50x50 cm in size) on the forest floor in each site. The traps were randomly placed on the floor. The litter from each trap was collected at monthly intervals, placed in labeled polyethylene bags and brought to the laboratory, where the samples were separated into leaf and wood litter (which includes also fruits and seeds) and their oven dry weights were determined. The turnover rate (K) of the litter was calculated indirectly following Jenny *et al*. [16]: $K = A/F$, Where, A is the annual increment of litter (i.e. annual litterfall) and F is the amount of the litter at steady state. Turnover time (t) is the reciprocal of the turnover rate and is expressed as $t = 1/K$.

RESULTS AND DISCUSSION

Litter Layer

Fresh Leaf Litter

Within an annual cycle, the standing crop of fresh leaf litter ranged from 0.0-173.50, 0.0-170.0, 0.0-173.0 and 0-118.0 g m^{-2}, respectively on dense, regenerated, medium and degraded forest. Mean standing crop of fresh leaf litter in an annual cycle was maximum in April on dense, regenerated and medium site and in May on degraded site. The standing crop of fresh leaf litter showed marked seasonality. It was maximum during summer and minimum during rainy season and the seasonal averages varied between 39-164.9, 35.8-158.9, 37.3-164.1 and 21-108.5 g m^{-2} on dense, regenerated, medium and degraded , respectively (Table 1).

Partly Decayed Litter

The mass of the partly decayed litter was highly variable and ranged between 46.0 - 185.5, 40.0 - 170.5, 47 - 175.0 and 1.0 - 95.5 g m^{-2}, respectively on dense, regenerated, medium and degraded sites within the annual cycle. Partly decayed litter peaked in July on dense, regenerated and medium forest site, and in August on degraded site and thereafter it declined gradually. Seasonal mass of partly decayed litter ranged between 63.4-116.8, 43.1-102.3, 60.9-112.3 and 31.4-63.1 g m^{-2} on dense, regenerated, medium and degraded forest site, respectively (Table 1).

Wood Litter

Due to the variations in the pattern of wood litterfall several peaks and troughs were observed in the standing crop of this component during annual cycle. However, wood litter was maximum in June on dense in August on regenerated, medium and degraded forest sites. Within the annual cycle the wood litter ranged between 85.0-175.6, 83.5-165.5, 87.0-172.0 and 49.5-72.5 g m^{-2} on sites dense, regenerated, medium and degraded, respectively. Seasonal wood litter mass ranged between 99.85-159.2, 103.3-153, 98.03-155.5 and 51.6-65.7 g m^{-2}, respectively on dense, regenerated, medium and degraded sites. Maximum seasonal wood litter mass was observed during rainy season on all sites and the minimum during winter on dense, regenerated, and medium sites and in summer on degraded site (Table 1).

Litterfall

Annual Litterfall

The total annual litter fall ranged between 421.9 and 701.1 g m^{-2} (mean=570.95 g m^{-2}), (Table 2). The highest leaf litter fall values were recorded for dense forest site (523.4 g m^{-2} yr^{-2}) followed by medium forest site (442.3 g m^{-2} yr^{-2}) and the lowest at degraded forest site 3 (298.1 g m^{-2} yr^{-2}). Wood litter fall followed the order: medium > dense > regenerated > degraded site. The contribution of leaf fall to the total litterfall was 75%, 71%, 68% and 71%, respectively on sites dense, regenerated, medium and degraded. The wood litterfall accounted for 25-32% of the total litterfall. Site to site differences were significant ($p<0.05$) for total litterfall, leaf litter fall and wood litterfall. The differences in the quantity of litterfall due to months and category (leaf, wood) were significant at $p<0.01$. The interaction of month x category was also significant ($p<0.05$) indicating a differential temporal pattern of fall of leaf and wood litter.

Dense Forest Site

The monthly leaf litterfall ranged between 0-120 g m^{-2}, with the peak leaf fall in December. The leaf shedding was concentrated between October and March and did not occur in June-July. The cumulative leaf fall indicated a sigmoid pattern with a hump in October-March, and by the month of May 100% leaf fall was completed. The fall of wood litter among different months ranged between 10.3-25.0 g m^{-2}. The pattern was irregular with multiple peaks and trough. Cumulative pattern of wood litterfall resulted in a continuously increasing curve from the beginning of annual cycle in June to a maximum (100%) in May. The peak total litterfall (leaf + wood) occurred in December and monthly values ranged between 12.0-132.1 g m^{-2}. The shape of curve for cumulative total litterfall was sigmoid and by the end of May 100% total litterfall was completed.

Regenerated Forest Site

The temporal pattern was more or less similar to that on dense forest site. The peak leaf fall occurred in December. The monthly leaf fall ranged between 2.3-139.8 g m^{-2}. The cumulative leaf fall yielded an annual value of 351.6 g m^{-2} and the leaf fall was completed by the month of April. The wood fall among different months ranged between 3.0-26.0 g m^{-2}. The wood fall pattern was irregular though there was peak in May. The cumulative wood fall increased till the end of the annual cycle resulting into a total of 146.1 g m^{-2} yr^{-1}. The total litterfall ranged between 5.3-156.7 g m^{-2} and was highest in December and lowest in August. The cumulative total litterfall yielded an annual value of 497.7 g m^{-2}.

Medium Forest Site

The temporal pattern of litterfall is broadly similar to the patterns on dense and regenerated forest sites. The peak leaf fall occurred in November. The monthly leaf fall ranged between 0-105 g m^{-2}. By the month of April 100% leaf litterfall was completed. The fall of wood litter among different months ranged between 6.1-26.0 g m^{-2}. The pattern of wood litterfall was irregular and the cumulative wood litter deposition resulted into an annual value of 220.8 g m^{-2}. The pattern of total litterfall followed that of leaf litterfall and ranged between 12.0-146.0 g m^{-2}. The cumulative total litterfall yielded an annual value of 663.1 g m^{-2}.

Degraded Forest Site

The peak leaf fall occurred in December. The monthly leaf fall ranged between 0-125 g m^{-2}. By the month of April 100 % leaf litterfall was completed. The fall of wood litter among different months ranged between 2.5-22.5 g m^{-2}. The pattern of wood litter fall was irregular and the cumulative wood litter deposition resulted into an annual value of 123.8 g m^{-2}. The pattern of total litter fall followed that of leaf litter fall and ranged between 4.0-137.5 g m^{-2}. The cumulative total litter fall yielded an annual value of 421.9 g m^{-2}.

Seasonal Pattern of Litterfall

The seasonal pattern of litterfall is illustrated in Table 3. The seasonal pattern of leaf litterfall on all the four sites was similar. The highest value occurred during winter followed by summer and the lowest in rainy season. The maximum seasonal leaf fall, among the sites ranged between 246.3-425 g m^{-2} and the lowest between 3.9-9 g m^{-2}. The calculated daily leaf fall was as expected, highest in winter (2.05-3.54 g m^{-2} day^{-1}) followed by summer (0.38-0.94 g m^{-2} day^{-1}) and rainy (0.03-0.08 g m^{-2} day^{-1}) seasons (Table 4). The pattern of wood litterfall was similar among sites and followed the order: summer > winter > rainy. The wood litterfall ranged between 56-98.6 g m^{-2} in winter, 45.0-66.4 g m^{-2} in summer and 22.8-55.8 g m^{-2} in rainy season (Table 3). The litterfall on per day basis followed the order: winter (except for dense forest site) > summer > rainy. The maximum rate among sites ranged between 0.48-0.82 g m^{-2} day^{-1} in summer and the lowest rates between 0.19-0.46 g m^{-2} day^{-1} in winter season (Table 4).

Turnover of Litter

The values for turnover rage and turnover time for the litter on each site are given in Table 5. The turnover rate on these sites ranged between 0.66-0.76 (x = 0.72) indicating about 66-76% turnover of litter each year. The turnover time of litter ranged between 1.32-1.51 years.

The quantity of forest floor material depends upon canopy closure, altitude and climate. The seasonal mean total forest floor mass was maximum on medium forest site (3.65 t ha^{-1}) followed by regenerated site (3.61 t ha^{-1}), dense forest site (3.46 t ha^{-1}) and degraded forest site (1.95 t ha^{-1}). The lowest standing crop on degraded forest was on account of low density of trees and low herbaceous biomass. In contrast, the other sites had more density of trees thus, more forest floor. Since the summer season followed peak litter fall period (winter) and the winter season followed the rainy season when decomposition is most rapid, the pattern of maximum forest floor mass during summer and minimum during winter is obvious.

The relative contribution of forest floor categories to the total forest floor varied markedly in different months on all the sites. Except for the period of July-October, the contribution of fresh leaf litter category remained greatest in all months on all sites and during August-October the wood litter contributed floor biomass. On an average (across all seasons), the standing crop was maximum for wood litter, fresh leaf litter, partly decayed litter and herbaceous live dead shoots on dense site and for herbaceous dead shoots on regenerated forest site. Lowest values for all categories were recorded on degraded forest site.

The total quantity of forest floor material varied from season to season on all sites. The minimum forest floor mass on all sites occurred during winter season and the maximum during summer, however, on degraded forest site the maximum amount of forest floor occurred during rainy season. In July, the partly decayed litter contributed maximum. When averaged across the months, wood litter contributed maximum to the forest floor on dense, regenerated and medium forest sites and fresh leaf litter on degraded site. The relative contribution of the wood litter on all sites was greatest in rainy, fresh leaf litter in summer and partly decayed litter during rainy season.

Few studies have reported seasonal variation in the standing crops of litter in tropical and sub-tropical forests. Hopkins [17] reported yearly ranges of 50-480 g m^{-2} and 180-550 g m^{-2}, respectively, from 'dry' and 'moist' Nigerian forests. Bernhard [18] noted strong seasonal variation 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) ranged between 249-322 g m^{-2}. Singh [15] reported seasonal standing crop of litter between 246-335 g m^{-2}. Madge [19] has cited data indicating litter accumulation in the range of 1.7-14.7 t ha^{-1} within the tropical zone and of 3.6-39.9 t ha^{-1} in the temperate region.

The forest floor mass in the present study sites is in the lower part of the range (2.07-54.0 t ha^{-1}) reported for the tropics [20]. In general, standing crop of litter in the present study is comparable with several other tropical and sub-tropical dry forests but distinctly lower than those of tropical rain, tropical montane and tropical moist forests studied elsewhere. Present estimated value of forest floor biomass was comparable with the value reported for Sarguja forest division (2.43 to 5.89 t ha^{-1}) in tropics of India [11].

Climate is major determinant of litter production. The influence of climate on litter production was discussed by Bray and Gorham [21]. The average annual total litter production ranged between 1.0 and 3.3 t ha^{-1} in arctic, 3.5 and 4.6 t ha^{-1} in cool temperate, 4.7 and 5.5 t ha^{-1} in warm temperate, and 9.3 and 10.9 t ha^{-1} in equatorial forests. The range of mean annual temperature in these climatic zones is from below freezing point in arctic regions to above 25°C for equatorial forests. The total litterfall in the present study is less than that of the equatorial forests.

Being a deciduous forest 100% leaf fall occurs each year. However, the leaf fall is fairly staggered in time encompassing about 8 months of the annual cycle, but 74-83% leaves fall during the winter season, leaving little foliage to be shed in summer. The tendency of leaf fall to be concentrated during October-February may be related to a combination of decreased temperatures and soil water during this period.

The mean masses of the total litterfall estimated in the present study correspond with the range recorded for other tropical forests. The total litter fall in dry and wet tropical forests ranged between 3-10 t ha^{-1} and 5.0-14.0 t ha^{-1}, respectively [22]. Total litterfall in tropical moist forests ranged from 3.6-12.4 t ha^{-1} yr^{-1} as reported by Vitousek and Sanford [23]. Dantas and Phillipson [24] have reported 8.04 t ha^{-1} yr^{-1} litterfall for primary forest and 5.04 t ha^{-1} yr^{-1} for a secondary forest of Amazon.

The leaf litterfall in the present study accounted for 68-75% of the total annual litterfall. Brown and Lugo [25] reported 69-86% leaf and fruit litter production for tropical forest. Meentemeyer *et al*. [26] calculated 70% leaf litter of total litter production in forests around world. In Central Himalayan forests leaf litterfall accounted for 72-86% [27].

The average annual wood litterfall (1.67 t ha^{-1} yr^{-1}) estimated in this study was lower than the world mean of 3.5 t ha^{-1} yr^{-1} for equatorial forest but comparable to warm temperate forest, 1.9 t ha^{-1} yr^{-1} [21].

The wood litter production in a sub-tropical dry forest was only 0.4 t ha^{-1} yr^{-1} [28]. Mean contribution of wood litterfall to total litterfall ranged between 25-32% in the present study. Wood litterfall accounted for 33% to the total litterfall in tropical climate [21]. In five central Himalayan forests wood litterfall were between 11 and 25% [27]. A cross section of values for the proportion of wood litterfall in total litterfall for tropical forests is 49.3% [29], 10.0% [30], 29.0% [18], 31.5% [31], 23.8% [32], 19.6-31.0% [33], 32.6% [34], 19-25% [35] and 24% [36].

Table 1 Seasonal variation in forest floor biomass on different forest sites (g m^{-2} ± 1 SE)

Forest floor components		Fresh leaf litter	Partly decayed litter	Wood litter	Herbaceous live shoots	Herbaceous dead shoots	Total
Degraded	**Summer**	108.5±19.7	31.4±6.9	51.6±13.8	1.7±1.3	3.8±1.3	197
	Winter	50±10.7	49.1±9.7	56.4±14.6	10.2±4.3	14.9±4.3	180.6
	Rainy	21±4.3	63.1±13.8	65.7±19.2	53.4±0.7	3.8±0.7	207
Medium	**Summer**	164.1±19.7	60.9±6.9	148.9±13.8	3.4±1.3	17.7±1.3	395
	Winter	88.3±10.7	85.3±9.7	98.0±14.6	17.7±4.3	29.9±4.3	319.2
	Rainy	37.3±4.3	112.3±13.8	155.5±19.2	73.2±0.7	3.4±0.7	381.7
Regenerated	**Summer**	158.9±39.5	43.1±9.0	139.75±15.2	6.2±0.3	23±1.7	370.9
	Winter	85.3±17.3	67.3±12.2	103.3±11.7	20.5±0.9	34.3±4.6	310.7
	Rainy	35.8±6.5	102.3±17.4	153±17.2	68.5±10.7	3.9±0.7	363.5
Dense	**Summer**	164.9±28.1	63.4± 10.3	153.2±36.9	4.3±0.7	19.8±2.9	405.6
	Winter	92.6±10.6	88.6±26.0	99.85±18.8	18.4±3.7	29.8±7.2	361.3
	Rainy	39±10.0	116.8±20.8	159.2±34.9	70.9±7.6	4.6±0.6	390.5

Bisht *et al*. [37] reported a total annual litter fall in four communities varied from 2950.00 to 4040.00 Kg ha^{-1} for northwest Himalayan region of India which are closer to lower end of Present study. Kumar and Tewari [38] found total annual litter fall was 538.85 g m^{-2}, of which leaf, wood and miscellaneous litters accounted for 72.35, 23.04 and 4.53% respectively in Kumaun Himalayas. Gairola *et al*. [39] found that the total litterfall (t ha^{-1} yr^{-1}) ranged between 2.6–3.6 and 2.1–2.6 for pristine and degraded stands, respectively in the subalpine forests of west Himalaya, India. Jhariya [40] found the seasonal mean total forest floor biomass across the sites varied from 2.00-3.65 t ha^{-1} and the total litterfall from 4.75-7.56 t ha^{-1} yr^{-1}.

Brown and Lugo [25] developed a predictive equation between total litter production and T/P ratio: y= 16.0 + 16.7 log x-6.5x (where y= total litterfall and x = T/P, T and P represented mean annual temperature and total annual rainfall, respectively). Using this equation the expected total litterfall for the present forest type (T/P= 1.77) is about 8.64 t ha^{-1} yr^{-1}, whereas the actual litterfall (5.71 t ha^{-1} yr^{-1}) is 0.66 times of the predictive value. Bray and Gorham [21] suggested that total net primary production of tropical forests could be estimated by a factor of 3.3. Assuming 100 % turnover of foliage, the total net production for the present forest can be estimated to range between 11.6-14.4 t ha^{-1} yr^{-1}. Brown and Lugo [25] argued that Bray and Gorham's factor should be revised because it can vary between 1.5 - 5.0 depending upon life zones.

Using exponential models of breakdown, Jenny *et al*. [16] and Olson [41] and many others have calculated coefficients based on litterfall input and the standing crop of litter that reflect the turnover of organic matter on the forest floor. Because the assumptions of simple exponential breakdown are unlikely to be met [42], k estimates must be considered as imperfect indices of the turnover of standing crops of litter [43].

The turnover rate (k) in the present study ranges from 0.66-0.76 and lie within the range of values calculated for other tropical forests [42]. Lugo *et al*. [28] reported annual turnover rate of 0.34 for sub-tropical dry forests at Puerto Rico. Turnover rate of litter in three tropical Australian rain forests was 1.4-2.2 [43]. Turnover time in the present study ranged between 1.32-1.51 years and compares with several tropical and sub-tropical evergreen and deciduous forests [20]. The forest floor in present forest is thus highly dynamic. According to Brown and Lugo [25], turnover times are shorter in the Tropical Basal life zone groups (0.57-0.88 yr) than in the sub-tropical groups (0.70-1.86 yr). The present result on litter turnover rate and time were comparable with the value reported by Jhariya [40]. He reported that the annual turnover of litter varied from 70-74% and the turnover time between 1.35-1.43 years of tropical forest of Chhattisgarh.

Table 2 Annual litterfall on different sites. Values in parenthesis are the percentage of the total litterfall

Site	Litterfall (g m^{-2})		
	Leaf	Wood	Total
Dense	523.4(75) ±66.99	177.7(25) ±26.56	701.1±99.76
Regenerated	351.6(71) ±52.04	146.1(29) ±25.30	497.7±57.53
Medium	442.3(68) ±81.03	220.8(32) ±42.45	663.1±114.38
Degraded	298.1(71) ±33.47	123.8(29) ±16.76	421.9±62.65
Average	403.85(71) ±58.38	167.1(29) ±27.76	570.95±83.58

Table 3 Seasonal pattern of litter fall on different forest sites (g m^{-2} ±1SE)

Sites	Leaf litter			Wood litter		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Dense	425.0±49.51	92.4±15.30	6.0±0.92	64.6±7.65	57.4±10.06	55.7±8.48
Regenerated	285.2±40.58	57.4±6.49	9.0±1.14	56±8.63	65±8.00	25.1±3.10
Medium	325.1±56.01	113.3±20.65	3.9±0.67	66.4±7.07	98.6±17.86	55.8±9.84
Degraded	246.3±37.51	45.8±5.66	6.0±0.69	45.0±6.53	56.0±9.08	22.8±4.09

Table 4 Rate of litterfall in different seasons (g m^{-2} day^{-1} ±1SE)

Sites	Leaf litter			Wood litter		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Dense	3.54±0.42	0.77±0.11	0.05±0.01	0.54±0.06	0.48±0.08	0.46±0.08
Regenerated	2.38±0.26	0.48±0.07	0.08±0.01	0.47±0.05	0.54±0.09	0.21±0.04
Medium	2.71±0.38	0.94±0.14	0.03±0.01	0.55±0.09	0.82±0.13	0.44±0.10
Degraded	2.05±0.30	0.38±0.04	0.05±0.01	0.38±0.05	0.47±.09	0.19±0.03

Table 5 Turnover rate (k) and turnover time (t) of litter on the forest floor

Sites	k	T (yr)
Dense	0.72	1.39
Regenerated	0.66	1.51
Medium	0.72	1.39
Degraded	0.76	1.32
Mean	0.72	1.40

CONCLUSION
The study suggests that the high level of disturbance due to over exploitation of trees for timber and firewood had critically affected the litterfall, forest floor biomass and decomposition process. This is evidenced by the very low density, diversity and basal area on degraded site. Litterfall and forest floor biomass are essential from the nutrient cycling perspective which leads toward healthy forest soil. Therefore, appropriate management regime is required to protect the forest from degradation.

REFERENCES

1. Jordan, C.F. (1983). Productivity of tropical rain forest ecosystems and the implications for their use as future wood and energy sources. In: Golley, F.B. (ed.) *Ecosystems of the World. Tropical Rain Forest Ecosystems*, pp. 117-136. Elsevier, Amsterdam, NL.
2. Sahu, P.K., Sagar, R. and Singh, J.S. (2008). Tropical forest structure and diversity in relation to altitude and disturbance in a Biosphere Reserve in central India. *Applied Vegetation Science,* 11: 461-470.
3. Kaul, O.N. and Sharma, D.C. (1971). Forest types statistics. *Indian Forester,* 97: 432-436.
4. Vendrami, J.L, Jurinitz, C.F., Castanho, C.T., Lorenzo, L. and Oliveira, A.A. (2012). Litterfall and leaf decomposition in forest fragments under different successional phases on the Atlantic Plateau of the state of Sao Paulo, Brazil. *Biota Neotrop*., 12(3): 136-143.
5. Shukla, A.K., Srivastava, P.K., Singh, B., Behera, S.K. and Thomas, T. (2017). Litterfall patterns and soil nutrient chemistry in varied tropical deciduous forests. *International Journal of Chemical Studies*, 5(6):1203-1210.
6. Pande, P.K. Meshram, P.B. and Banerjee, S.K. (2002). Litter production and nutrient return in tropical dry deciduous teak forests of Satpura plateau in central India. *Tropical Ecology*, 43(2):337-344.
7. Spain, A.V. (1973). Litter fall in a New South Wales conifer forest: A multivariate comparison of plant nutrient element status and return in four species. *J. Appl. Ecol.,* 10:527-556.
8. Montagnini, F. and Jordan, C.F. (2002). Reciclagem de nutrientes. In Ecología y conservación de bosques neotropicales. LUR, Cartago, p.167-191.
9. Roderstein, M., Hertel, D. and Leuschner, C. (2005). Above- and below- ground litter production in three tropical mountain forests (South Ecuador). *J. Trop. Ecol*., 21:483-492.
10. Yadav, D.K., Ghosh, L. and Jhariya, M.K. (2017). *Forest Fragmentation and Stand Structure in Tropics: Stand Structure, Diversity and Biomass*. *Lap Lambert Academic Publishing*. Heinrich-Bocking-Str. 6-8, 66121, Saarbrucken, Germany. Pp. 116. ISBN: 978-3-330-05287-1.
11. Jhariya, M.K. and Yadav, D.K. (2018). Biomass and Carbon storage pattern in natural and plantation forest ecosystem of Chhattisgarh, India. *Journal of Forest and Environmental Science*, 34(1):1-11.
12. Chaturvedi, O.P. and Singh, J.S. (1987a). The structure and function of pine forest in central Himalaya. I. Dry matter dynamics. *Annals of Botany,* 60: 237-252.
13. Yadav, D.K. (2016). Species structure and diversity in Achanamar-Aarkantak Biosphere Reserve, Central India. *Journal of Applied and Natural Science*, 8(3): 1241-1248.
14. Champion, H.G. and Seth, S.K. (1968). A Revised Survey of the Forest Types of India. Government of India Publications, New Delhi, 404p.
15. Singh, L. (1995). Seasonal variation in biomass and nutrient content of the forest floor in a dry tropical forest in India. *Oecologia Montana,* 4:21-26.
16. Jenny, H., Gessel, S.P. and Bingham, F.T. (1949). Comparative study of decomposition rates of organic matter in temperate and tropical regions. *Soil Sci*., 68:419-432.
17. Hopkins, B. (1966). Vegetation of the Olokemeji Forest Reserve Nigeria. IV. The litter and soil with special reference to their seasonal changes. *J. Ecol*., 54: 687-703.
18. Bernhard, F. (1970). Étude de la litiére et de sa contribution au cycle des elements mineraux en forêt ombiofile de Côte-d'-Ivoire. *Oecol. Plant*., 5: 247-266.
19. Madge, D.S. (1965). Leaf fall and litter disappearance in a tropical forest. *Pedobiologia,* 5:273-288.
20. Vogt, K.A., Grier, C.C. and Vogt, D.J. (1986a). Production, turnover, and nutrient dynamics of above and belowground detritus of world forests. *Adv. Ecol. Res*., 15:303-377.
21. Bray, J.R. and Gorham, E. (1964). Litter production in forests of the world. *Ad. Ecol. Res*., 2:101-157.
22. Murphy, P.G. and Lugo, A.E. (1986b). Structure and biomass of a subtropical dry forest in Puerto Rico. *Biotropica,* 18:89-96.
23. Vitousek, P.M. and Sanford, R.L. Jr. (1986). Nutrient cycling in moist tropical forest. *Ann. Rev. Ecol. Syst.,* 17:137-167.
24. Dantas, M. and Phillipson, J. (1989). Litterfall and litter nutrient content in primary and secondary Amazonian 'Terra Firme' rainforest. *J. Trop. Ecol*., 5:27-36.
25. Brown, S. and Lugo, A.E. (1982). The storage and production of organic matter in tropical forests and their role in the global carbon cycle. *Biotropica,* 14:161-187.
26. Meentemeyer, V., Box, E.O. and Thompson, R. (1982). World patterns and amounts of terrestrial plant litter production. *Bioscience,* 32:125-128.
27. Mehra, M.S. and Singh, J.S. (1985). Pattern of wood litterfall in five forest located along an altitudinal gradient in Central Himalayan forests. *Vegetatio,* 63:3-11.
28. Lugo, A.E., Gonzalez-Liboy, J.A., Cintron, B. and Dugger, K. (1978). Structure, productivity, and transpiration of a subtropical dry forest in Puerto Rico. *Biotropica,* 10:278-291.

29. Kira, T., Ogawa, H., Yoda, K. and Ogino, K. (1967). Comparative ecological studies on three main types of forest vegetation in Thailand IV. Dry matter production with special reference to the Khaochong rain forest. *Nature and Life in South East Asia Kyoto,* 6:149-174.
30. John, D.M. (1973). Accumulation and decay of litter and net production of forest in tropical West Africa. *Oikos,* 24:430-435.
31. Haines, B. and Foster, R.B. (1977). Energy flow through litter in a Panamanian forest. *J. Ecol*., 65:147-155.
32. Klinge, H. and Rodrigues, W.A. (1968). Litter production in an area of Amazonian terra firme forest. I &II. *Amazoniana* 1: 287-302, 303-310.
33. Bernhard-Reversat, F., Huttel, C. and Lemée, G. (1978). Structure and functioning of evergreen forest ecosystems of Ivory Coast. pp. 557-574. In: Tropical Forest Ecosystems, 683 pp. UNESCO, Paris.
34. Malaisse, F. (1978). The Miombo ecosystem. pp. 589-606. *In*: Tropical Forest Ecosystems. UNESCO, Natural Resources Research 14.
35. Gaur, J.P. and Pandey, H.N. (1978). Litter production in two tropical deciduous forest communities at Varanasi, India. *Oikos,* 30:570-575.
36. Singh, R.P. (1979). Primary Production and Energy Dynamics of Tropical Dry Deciduous Forest in Chandraprabha Region, Varanasi. Ph.D. Thesis, Banaras Hindu University, India. pp. 198.
37. Bisht, V.K., Nautiyal, B.P., Kuniyal, C.P., Prasad, P. and Sundriyal, R.C. (2014). Litter Production, Decomposition, and Nutrient Release in Subalpine Forest Communities of the Northwest Himalaya. *Journal of Ecosystems*, Article ID 294867, 13 pages, 2014. Doi:10.1155/2014/294867.
38. Kumar, S. and Tewari, L.M. (2014). Pattern of litter fall and litter decomposition in a *Quercus leucotrichophora* A. Camus forest in Kumaun Himalaya. International Journal of Biodiversity and Conservation, 6(1):108-114. DOI: 10.5897/IJBC2013.0617.
39. Gairola, S., Rawal, R.S. and Dhar, U. (2009). Patterns of litterfall and return of nutrients across anthropogenic disturbance gradients in three subalpine forests of west Himalaya, India. *Journal of Forest Research* 14(2):73-80.
40. Jhariya, M.K. (2017). Influences of Forest Fire on Forest Floor and Litterfall in Bhoramdeo Wildlife Sanctuary (C.G.), India. *Journal of Forest and Environmental Science*, 33(4): 330-341.
41. Olson, J.S. (1963). Energy storage and balance of producers and decomposers in ecological systems. *Ecology*, 44:322-331
42. Bernhard- Reversat, F. (1972). Décomposition de la litiére de feuilles en forêt ombrophile de Base Côte-d' Ivoire. *Oecol*. *Plant* 7: 279-300.
43. Spain, A.V. (1984). Litterfall and the standing crop of litter in three tropical Australian rain-forests. *J. Ecol*. 72: 947-961.

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