Mysore J. Agric. Sci., 58 (4) : 77-88 (2024)

Accumulation and Decomposition of Litter in Different Agroforestry Systems under Semiarid Condition

A. Kokila, C. Nagarajaiah and D. C. Hanumanthappa
Department of Forestry and Environmental Science, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : kokila95.anbalagan@gmail.com

Authors Contribution

A. Kokila : Conceptualization, investigation and draft preparation;

C. Nagarajaiah & D. C. Hanumanthappa : Conceptualization, framed research proposal, supervision and draft correction;

Corresponding Author :
A. Kokila

Received : July 2024
Accepted : August 2024

Abstract

Agroforestry integrates woody perennials with crops and/or animals, fostering ecological and economic interactions. This study examined litter accumulation and decomposition in seven agroforestry systems such as Teak (*Tectona grandis*), Mahogany (*Swietenia mahagoni*), Malabar Neem (*Melia dubia*) Pongam (*Pongamia pinnata)*, Mango (*Mangifera indica),* Cashew *(Anacardium occidentale)* and Jamun (*Syzygium cumini).* at GKVK, Bengaluru, India, over one year. Litter was collected monthly using traps and analyzed for decomposition rates using litter bags. Results indicated that most of the tree species follow an unimodal pattern of litterfall and have peak litterfall during the months of late rainy and dry seasons. The litter production was significantly higher in *S. mahagoni* and lower in *P. pinnata*. Among the tree species, litter from *P. pinnata* was found to decompose faster with a low half-life period. Litter from *S. mahagoni* and *S. cumini* observed slow rate of decomposition where small portions of litter remained undecomposed. Seasonal fluctuations influenced decomposition, with higher rates in June-August. The study underscores the importance of species selection in agroforestry for effective nutrient cycling and soil fertility.

Keywords : Agroforestry systems, Litter accumulation, Decomposition

Agroforestry is a collective name for a land-use system and technology whereby woody perennials are deliberately used on the same land management unit as crops and/or animals in some form of spatial arrangement or temporal sequence. In an agroforestry system there are both ecological and economical interactions between the various components. It is recommended as a sustainable land use practice for augmentation of biomass production which delimits the opportunities of deforestation, declining soil fertility, occur of droughts and illegitimate use of dangerous chemicals (Nair, 1984 and Kang & Wilson, 1987). It can be an attractive choice for environmental, social and economic development because it improves the environmental quality generating additional income to the farmers (Radhakrishnan & Varadharajan, 2016 and Arya *et al*., 2017).

Litter fall from upper storey trees in agroforestry systems plays a crucial role in maintaining the input-output system of nutrient, the rate at which decomposes controlling the nutrient cycling and the overall improvement (Murovhi *et al*., 2012 and Singh *et al*., 2019). Especially in the tropics where most of the recycling nutrient depends on the amount of litter on the forest floor. Litter production in any ecosystem depends on climatic condition of the ecosystem, the forest type, species composition, the age of the forest and plantation and method of conversion of the original forest to the plantation. Litter cover acts as a protective layer for improving the soil's physical properties like retaining soil moisture, buffering against soil temperature and compaction change and soil conservation from erosion or leaching (Mo *et al.,* 2003 and Bargali *et al.,* 2015). It also provides habitats and substrates for soil fauna and flora (Ruf *et al*., 2006).

The decomposition of litter is an important part of nutrient cycling in forests. The rates at which litter falls and subsequently decay thus in understanding the productivity and nutrient budgeting of these ecosystems (Shivakumar *et al.*, 2014**)**. Decomposition plays an important role in maintaining soil carbon and nutrient pools as well as fertility in a forest ecosystem. The rate of decomposition and nutrient release varies with a number of factors, including rainfall, humidity, temperature, soil moisture, edaphic factors and including the nature of the plant material (Singh *et al*., 1999) (Pandey *et al*., 2006). Meanwhile, their chemical constituents also play a significant role in the amount of nutrient addition through leaf litter decomposition varies from species to species (Mahmood *et al*., 2011). Foliar litter occupies a major fraction of the litter in forest ecosystems and maybe totally decomposed within a year in subtropical and tropical areas. It is thus of importance to evaluate the pattern of litter accumulation, decomposition and its influence on the different agroforestry systems.

MATERIAL AND METHODS

Experiment Site

The experiment was conducted in Agroforestry plot under the maintenance of AICRP (All India Coordinated Research Project) on Agroforestry located in Gandhi Krishi Vignana Kendra (GKVK), the main campus of the University of Agricultural Sciences, Bengaluru, Karnataka. Geographically, the site is located at 12° 58' N latitude, 77°35' E longitude having an altitude of 930 m above MSL. It is located in Eastern Dry Agro-climatic Zone (Zone-V) of Karnataka.

Climatic Conditions

GKVK has a tropical climate with distinct wet and dry seasons. The average annual rainfall of the station is 920 mm. The major portion of it is received during April to November with two peaks in September (196 mm) and October (164.7 mm). The mean maximum air temperature ranges from 26.3 to 33.8p C. The mean monthly relative humidity ranges from 76 per cent in March to 90 per cent in August. Maximum bright sunshine hours are recorded in February (9.6 hr) and lowest in July (4.4 hr) and the mean wind speed is maximum during June (12.2 km/hr) and the minimum in October (5.4 km/hr). The open pan evaporation is directly related to the maximum and minimum temperature of the month and follows the same trend as that of maximum temperature and is maximum during March (7.5 mm per day) and April month (7.4 mm per day).

Experiment Details

The experiment was conducted in the Agro-forestry field unit of AICRP on Agroforestry at GKVK, Bangalore. Here, seven different agroforestry systems *viz.,* Teak (*Tectona grandis*), *Meliadubia*, *Pongamiapinnata*, Mahogany (*Swietenia mahagoni*), Cashew *(Anacardium occidentale)*, Mango (*Mangifera indica) and* Jamun (*Syzygium cumini)* were studied with different intercrops consisting either a cereal or a pulse crop (Table 1). The experiment was carried out for one year (June 2022 to May 2023). Samples were collected at monthly intervals.

Quantification of Litters

Leaf litters of each tree species were collected from agroforestry systems in an area of 1m×1 m using litter traps (Sundarapandian and Swamy, 1999). With three litter traps for each tree species, totally 21 litter traps were established (plate 1). The litters were collected at monthly interval. The collected leaf litters were washed, oven dried and then weighed. The recorded weight was added to quantify the accumulation of litters during the study period.

Litter Decomposition Pattern

The standard litterbag technique was employed for characterising litter decomposition rates (Pinos *et al*., 2017). Twenty grams of leaf litter samples were

TABLE 1

Details of tree species and intercrops in different agroforestry systems (2022-23)

Tree species	Field crop	Year of planting	Spacing
Teak (*Tectonagrandis*)	Fodder Sorghum (*Sorghum bicolor*)	2010	8 m x 3 m
Melia (*Meliadubia*)	Finger millet (*Eleusine coracana*)	2010	8 m x 5 m
Pongamia (*Pongamiapinnata*)	Cowpea (*Vigna unguiculata*)	2017	5 m x 5 m
Mahogany (*Swietenia mahagoni*)	Cowpea (*Vigna unguiculata*)	2010	10 m × 5 m
Cashew (*Anacardium occidenatle*)	Sunnhemp (*Crotalaria juncea*)	2007	10 m x 10 m
Mango (*Mangifera indica*)	Sunnhemp (*Crotalaria juncea*)	2007	10 m x 10 m
Jamun (*Syzygium cumini*)	Sunnhemp (*Crotalaria juncea*)	2007	10 m x 10 m

Plate 1 : Litter traps for litter accumulation study

Plate 2 : Litter bags for litter decomposition study

packed into mesh bags (dimensions: 20x20 cm: 2 mm mesh size) and were sealed. A total of 36 bags were buried in the soil sub-surface of each tree species. At monthly intervals, three bags from each tree species were retrieved from the soil and analysed in the laboratory. The bags were gently rinsed with water to remove the soil and other extraneous materials. The residual litter mass removed from the bags were oven dried at 80°C and weighed to estimate the decomposition rate (plate 2).

Rate of Decomposition Pattern

The litter decomposition rate was compared using litter decay rates, estimated with the commonly used first-order negative exponential decay model (Olson, 1963),

$$X_t = X_0 e^{-kt} ; k = - \ln(X_t - X_0)/ t$$

Where X_0 and X_t are initial and final litter masses, respectively and t is a time interval.

Statistical Analysis

The experimental data obtained during the course of investigation were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) appropriate to the design to test the significance of the overall differences among the treatments. All statistical analyses were carried out using SPSS 16.0 software.

TABLE 2

Litter accumulation (kg/ha) from different agroforestry systems (2022-23)

Months	*T. grandis* +Fodder Sorghum	*M. dubia*+ finger millet	*P. pinnata* +cowpea	*S. mahagoni* +cowpea	*A. occidentale* + Sunnhemp	*M. indica* + Sunnhemp	*S. cumini* + Sunnhemp	Mean
	Tree species							
June	37.25	63.25	75.68	691.60	554.22	223.81	391.53	291.05 [g]
July	83.82	120.00	65.69	684.40	642.09	289.23	512.53	342.54 [g]
August	82.68	190.00	75.68	640.00	735.76	665.34	646.20	433.67 [f]
September	114.15	298.01	79.68	719.40	1201.50	554.25	827.65	542.09 [e]
October	357.24	746.49	86.98	898.65	1305.99	727.53	978.68	728.79 [d]
November	735.10	951.50	112.45	936.20	1285.00	967.38	1492.60	925.75 [c]
December	919.30	1044.25	124.38	1077.10	1250.00	2047.50	1709.15	1167.38 [a]
January	320.80	1231.26	152.75	1432.20	1060.00	1718.40	1927.78	1120.46 [b]
February	204.09	958.50	182.28	1917.60	936.60	886.44	1075.17	880.1 [c]
March	50.69	613.25	146.74	2017.20	696.21	670.62	951.92	735.23 [d]
April	3.42	230.00	108.61	1156.90	612.94	288.67	937.27	476.83 [f]
May	1.11	77.51	94.54	955.30	706.90	398.28	820.92	436.37 [f]
Total	2909.66	6524.02	1305.46	13126.55	10987.21	9437.45	12271.39	
Mean	242.47 [f]	543.69 [e]	108.79 [g]	1093.88 [a]	915.60 [c]	786.45 [d]	1022.62 [b]	

	Months	Species
S.Em±	4.722	6.183
CD (P=0.05)	13.196	17.277

Note : Alphabets in superscript indicate the significance level

RESULTS AND DISCUSSION

Litter Accumulation of Tree Species

The mean litter biomass varied from 108.79 kg/ha to1093.88 kg/ha on the floor of different agro forestry systems where the seasonal pattern of litter biomass was similar (Table 2). The litterfall is in the order; *S. mahagoni* (13126.55 kg/ha) >*S. cumini* (12271.39 kg/ha) >*A. occidenatle* (10987.21 kg/ha) > *M. indica* (9437.45 kg/ha) >*M. dubia* (6524.02 kg/ ha) >*T. grandis* (2909.66 kg/ha) >*P. pinnata* (1305.46 kg /ha). Mean monthly litter was found to be higher in *S. mahagoni* (1093.88 kg/ha) followed by *S. cumini* (1022.62 kg/ha) *and A. occidenatle* (915.60 kg/ha). Lower accumulation has been recorded in *P. pinnata* (108.79 kg/ha) and *T. grandis* (242.47 kg/ha). litter accumulation was higher during the months of low rain and dry seasons.

In *T. grandis*, the overall litter accumulation during the study period was 2909.66 kg/ha. Being deciduous, teak undergoes litterfall in specific seasons, notably in November (735.10 kg/ha) and December (919.30 kg/ha). These months contribute 25.26 per cent and 31.59 per cent, respectively, to the total litter accumulation, showcasing a distinct unimodal litterfall pattern (Fig. 1). The least amount of litterfall was recorded in April (3.42 kg/ha) and May (1.11 kg/ ha). The data showed that the seasonal dynamics of teak litterfall, emphasizing pronounced peaks in late autumn and minimal during the months of summer. The similar litter fall pattern was by reported by Ojo *et al.* (2010). The cumulative litter input had slow increase during rainy months followed by rapid increase in winter and then again slower down during the summer (Jha, 2010).

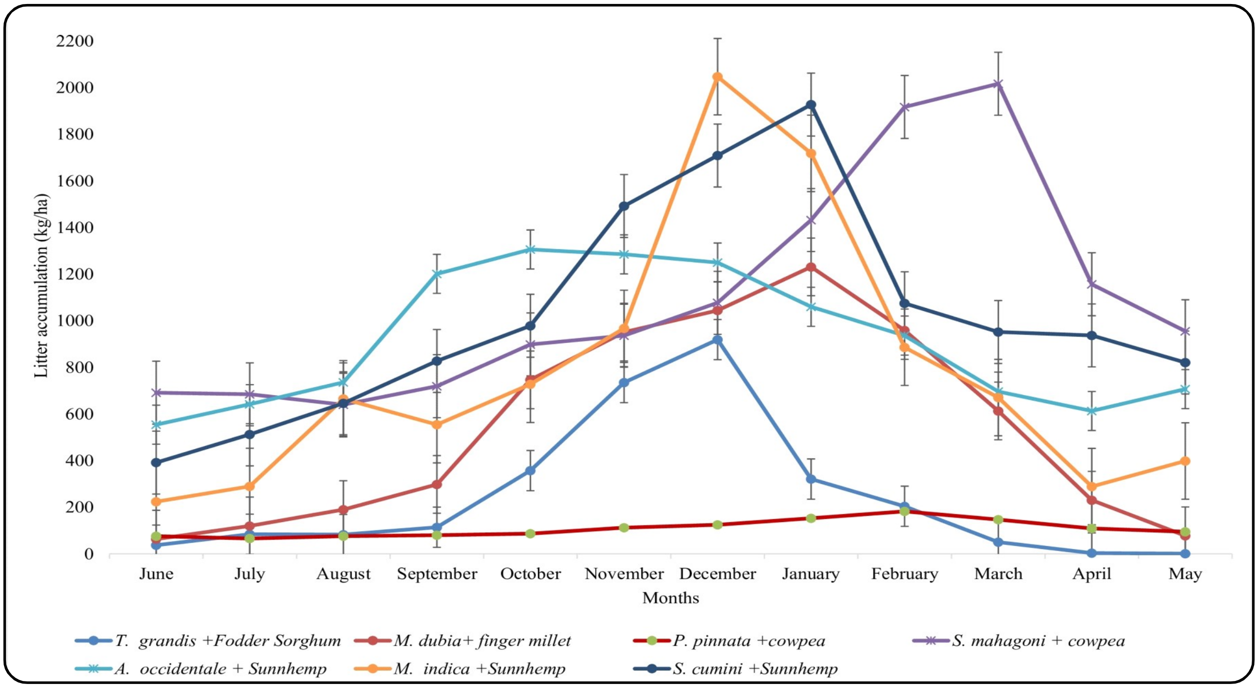

Fig. 1 : Monthly litter accumulation pattern in different agroforestry systems during the study period

M. dubia is also a deciduous tree species having unimodal pattern of litter accumulation. The overall litter accumulation during the study period was 6524.02 kg/ha. The peak of litterfall occurred in the winter months of December (1044.25 kg/ha) and January (1231.26 kg/ha), contributing 16.0 per cent and 18.87 per cent to the overall litter production, respectively. Minimal litter fall was observed during May (77.51 kg/ha) and June (63.25 per cent). As this is a deciduous forest, 100per cent leaf fall occurs each year (Chopra *et al.,* 2023).

In *P. pinnata,* the mean monthly litter was 108.79 kg/ha which is lower compared to other tree species, because of the differences in the age of the tree species. The total litter accumulation during the study period was 1305.46 kg/ha.*P. pinnata*is an evergreen tree species which produces litter throughout the year. It was found that the peak in litterfall was observed during December to March which falls under the winter season. The minimum litterfall was recorded during the summer and rainy season (May to October). Shivakumar *et al*. (2014) studied litter production in *P. pinnata* based agroforestry system which was also observed to have a similar pattern. Litterfall patterns in the majority of Pongamia showed an unimodal distribution, characterized by a clear peak occurring either at the onset or towards the conclusion of the dry period (Cintron and Lugo, 1990).

In *S. mahagoni,* the litterfall followed a unimodal pattern and a distinct peak was noticed during March (2017.20kg/ha). Lower litter production was observed during the months of the rainy season (June to September). Being evergreen, there was a continuous litterfall was noticed during the study period. The mean litter accumulation observed throughout the study period was 1093.88 kg/ha, while the total litter accumulation reached 13126.55 kg/ha.The litterfall from *S. mahagoni* was recorded as 8.3 Mg/ha/yr (Ono *et al.,* 2006) and 3201.65 g/m^2 (Bindu *et al.,* 2014) primarily consisting of leaf litter, with occasional small quantities of bark and small branches falling consistently throughout the year.

In *A. occidenatle,* the total litter production was recorded to be 10987.21 kg/ha during the study period and the mean litterfall was 915.60 kg/ha. As an evergreen tree, litter accumulation was observed consistently throughout the year. The highest litter accumulation occurred in October (1305.99 kg/ha) and November (1285.00 kg/ha), while the lowest accumulation was comparatively recorded in June (554.22 kg/ha). Distinct peaks were observed in November and *A.occidentale* did not register quantifiable amount of reproductive parts in the detritus (Isaac and Nair, 2006).

M. indica exhibited a litter production of 9437.45 kg/ha, with an average litterfall of 786.45 kg/ha. Notably, the highest accumulation occurred in January (2047.50 kg/ha), while the lowest was observed during the early rainy season. Due to its evergreen nature, litter accumulation persisted throughout the entire year. Murovhi *et al.* (2012) observed mean leaf litter production during the 2 year study period, mango produced 6.3 t /ha while seasonal leaf litter production was in late autumn and winter.

In *S. cumini,* the highest amount of litter accumulated in December (1709.15kg/ha) and January (1927.78 kg/ha) and the lowest in June and July (143.21 kg/ha). The overall and mean litter accumulation during the study period was 1221.39 kg/ha and 1022.6 kg/ha respectively. It was observed to have an unimodal pattern of litterfall and accumulated throughout the year because of its evergreen nature. Fontes *et al.* (2014) observed that leaves always represented the largest fraction of litterfall for all cocoa agroforests (mean of 78.1%).

From the study, it was found that peak litter fall of the tree species observed, coincided to the beginning of dry period (December-February). This may be due to water or temperature stress which will activate the synthesis of abscissic acid in the foliage (Kumar and Deepu, 1992). The unimodal litter fall pattern is most common for tropical species (George & Kumar, 1998 and Jamaludheen & Kumar, 1999). The differential accumulation of floor litter biomass among the different agroforestry systems was mainly due to species characteristics followed by annual environmental changes (Tangjang, 2015). Moreover, after spring season or with the onset rainy season, phenological observations do reveal that is a period of newleaf development and expansion for most evergreen species in the area (Singh *et al.,* 2019). So accumulation of floor litter mass during rainy season was less compared with other seasons (Silva *et al.*, 2011; Arunachalam *et al.*, 1998 and Sundarapandian & Swamy, 1999).

Among the various parts of plant that constitute litter leaf tissue accounts for more than 70 per cent of aboveground litter in forests and the rest is composed of stems, small twigs and propagative structures (Robertson and Paul, 1999). In the present study although the segregated litter data is not given, leaf litter is in above mentioned range. The amount and pattern of litterfall varied with the species. It is primarily due to evergreen or deciduous nature of the trees. Deciduous trees, which shed their leaves seasonally, typically exhibit a pronounced peak in litterfall, often occurring in the autumn or winter months. This seasonal shedding is a strategy for conserving water during colder or drier periods and results in a substantial accumulation of leaf litter on the forest floor during these times. Although evergreen trees do shed leaves, the process is more gradual and thus, the contribution to litterfall is more evenly distributed across the seasons. Studies have shown that litter contribution varied with the species, growth, age, tree density, canopy characteristics and seasons (Bhardwaj *et al*., 2001 and Butenschoen *et al.,* 2014). Understanding the patterns and drivers of litterfall is essential for managing forest ecosystems and ensuring their long-term sustainability. The interactions between litterfall and other ecological processes highlight the intricate balance within forest ecosystems, where even small changes in one component can have cascading effects on the entire system.

Litter Decomposition of Tree Species

Litter decomposition was expressed as a dry mass remaining at the end of each month during the study period (Table 3 and Fig. 2). The mean values provide an overall measure of the average litter mass remaining un-decomposed for each species over the entire period.

TABLE 3

Litter mass (g) remained un-decomposed at monthly intervals (2022-23)

Months	Tree species						
	T. grandis +Fodder Sorghum	*M. dubia*+ finger millet	*P. pinnata* +cowpea	*S. mahagoni* +cowpea	*A. occidentale* + Sunnhemp	*M. indica* + Sunnhemp	*S. cumini* + Sunnhemp
June	17.28	17.82	18.40	19.75	18.80	18.20	17.53
July	16.12	16.73	16.80	17.90	16.80	18.20	16.24
August	16.23	14.37	14.40	16.73	14.40	17.20	15.20
September	14.12	13.62	12.20	15.64	13.80	15.80	14.13
October	11.87	12.58	11.80	14.69	12.40	11.80	12.84
November	8.72	9.23	9.60	12.54	11.60	11.40	10.25
December	7.12	7.49	8.20	11.92	10.40	9.20	9.16
January	5.46	6.15	6.20	10.74	9.20	6.80	8.84
February	3.21	4.08	5.20	9.87	7.60	5.60	7.25
March	1.28	3.86	3.60	8.25	6.80	3.60	5.92
April	0.65	2.67	1.80	6.21	5.40	2.20	5.32
May	0.65	1.26	0.80	4.23	3.80	1.80	3.26
Mean	8.56	9.16	9.08	12.37	10.92	10.15	10.50
			Months			Species	
S.Em±			0.062			0.047	
CD (P=0.05)			0.173			0.132	

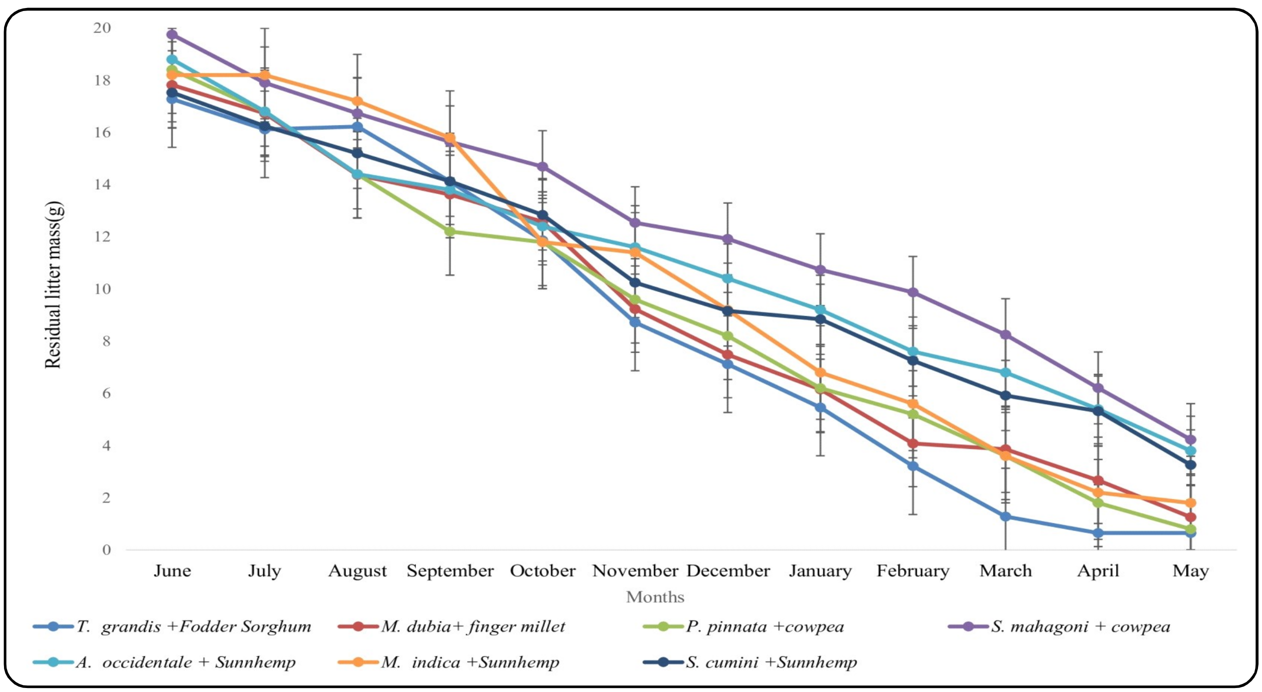

Fig. 2 : Monthly residual litter mass of different agroforestry tree species

Residual litter mass declined exponentially with time for all tree species studied. In *T. grandis* and *A. occidenatle,* nearly 50 per cent of the leaf litter was found decomposed during the first six months of the study while, 40 per cent of *M. dubia, P. pinnata* and *M. indica*; 36 per cent of *S. mahagoni*; 27 per cent of *S. cumini* was decomposed.

There is variability in the litter masses among the different tree species across the months. *S. mahagoni* consistently has higher litter masses compared to other species, indicating slower decomposition for this species. *T. grandis, M. dubia* and *P. pinnata* also show relatively faster decomposition. Litter masses fluctuate throughout the months, suggesting potential seasonal influences on decomposition rates.

T. grandis exhibits moderate litter masses throughout the year, with a mean value of 8.56 grams. There is variability in litter masses across months, suggesting that decomposition rates may be influenced by seasonal factors. *M. dubia* shows relatively consistent and slightly lower litter masses compared to some other species. The mean litter mass for *M. dubia* is 9.16 grams. The consistent litter mass may be indicative of a steady decomposition rate, influenced by factors such as litter quality or microbial activity.

P. pinnata has a moderate litter mass throughout the year, with a mean value of 9.08 grams. *S. mahagoni* consistently maintains higher litter masses undecompesd compared to other species, with a mean value of 12.37 grams. The consistently high litter masses suggest slower decomposition rates for *S. mahagoni*. This species may have leaves with compounds that decompose more slowly or may be less favorable to microbial decomposition.

A. occidentale exhibits variable litter masses, with a mean value of 10.92 grams. The species shows fluctuating patterns, and factors such as litter quality, microbial communities and environmental conditions may contribute to these variations. *M. indica* maintains moderate to high litter masses, with a mean value of 10.15 grams. *S. cumini* generally has lower litter masses compared to other species, with a mean value of 10.50 grams.The lower litter masses may indicate faster decomposition or a lower input of litter from this species.

There is significant variability in the litter decomposition rates among different tree species across the months (Table 4 and Fig. 3). Decomposition rates are given in units of k months^{-1}, representing the proportion of litter decomposed per month.The mean values provide an overall measure of the average decomposition rate for each species over the entire period. *P. pinnata* has the highest mean decomposition

TABLE 4

Litter decomposition rate (k months^{-1}) in different agroforestry systems (2022-23)

Months	Tree species						
	T. grandis +Fodder Sorghum	*M. dubia*+ finger millet	*P. pinnata* +cowpea	*S. mahagoni* +cowpea	*A. occidentale* + Sunnhemp	*M. indica* + Sunnhemp	*S. cumini* + Sunnhemp
June	0.329	0.185	0.470	0.223	0.182	0.385	0.227
July	0.315	0.581	0.582	0.372	0.582	0.508	0.294
August	0.443	0.574	0.574	0.346	0.574	0.523	0.343
September	0.443	0.456	0.514	0.296	0.456	0.412	0.359
October	0.419	0.400	0.421	0.294	0.406	0.354	0.421
November	0.371	0.351	0.390	0.278	0.355	0.328	0.359
December	0.365	0.326	0.353	0.287	0.323	0.325	0.340

Continued....

TABLE 4 Continued....

Months	Tree species						
	T. grandis +Fodder Sorghum	*M. dubia*+ finger millet	*P. pinnata* +cowpea	*S. mahagoni* +cowpea	*A. occidentale* + Sunnhemp	*M. indica* + Sunnhemp	*S. cumini* + Sunnhemp
January	0.335	0.295	0.328	0.261	0.297	0.298	0.323
February	0.313	0.283	0.299	0.247	0.280	0.268	0.296
March	0.293	0.264	0.280	0.232	0.258	0.255	0.280
April	0.269	0.247	0.264	0.224	0.244	0.240	0.262
May	0.247	0.232	0.246	0.212	0.232	0.224	0.242
Mean	0.345	0.350	0.393	0.273	0.349	0.343	0.312
			Months			Species	
S.Em±			0.002			0.002	
CD (P=0.05)			0.006			0.004	

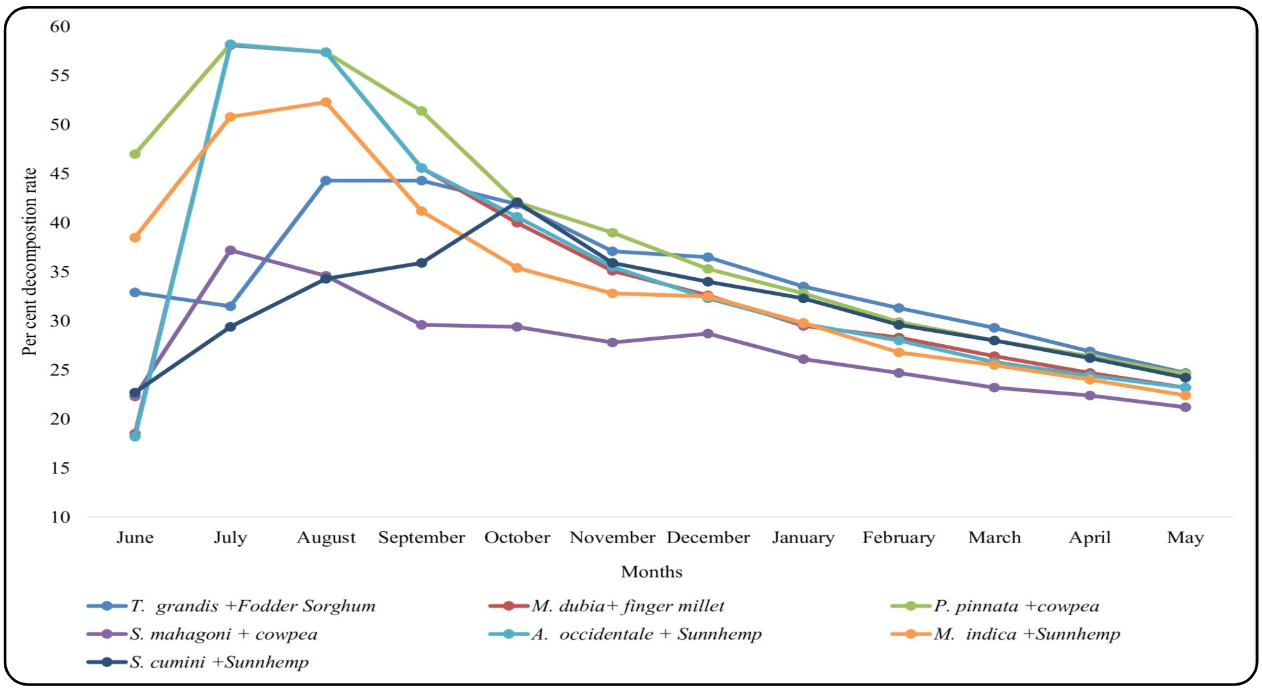

Fig. 3 : Monthly leaf litter decomposition rate across different agroforestry systems

rate, followed by *M. dubia* and *A. occidentale*. *S. mahagoni* has the lowest mean decomposition rate among the species.

T. grandis showed varying decomposition rates, with a mean of 0.345 and it fluctuate, with higher values in June and August. *M. dubia* showed a relatively consistent decomposition rate, with a mean of 0.350 and higher rates were observed in July and August. *P. pinnata* showed variability, with a mean decomposition rate of 0.393. Higher rates are observed in June and July. *S. mahagoni* showed a mean decomposition rate of 0.273, with lower rates compared to other species. Consistent patterns are observed. *A. occidentale* showed variability, with a mean decomposition rate of 0.349. Higher rates are observed in June and August. *M. indica* showed a mean decomposition rate of 0.343, with consistent patterns across the months. *S. cumini* showed a mean decomposition rate of 0.312, with relatively lower rates compared to other species.

Decomposition rates vary seasonally, with some species showing higher rates during certain months. Higher rates during June to August are observed for several species, while rates may decrease during the fall and winter. The different tree species contribute to litter decomposition at varying rates, influencing nutrient cycling and soil health in agroforestry systems. Higher decomposition rates may lead to faster nutrient turnover and potentially influence the availability of nutrients in the soil.

Similar observations were also noticed by Manlay *et al.* (2004). The high rate of decomposition in rainy season was attributed to the optimum moisture, rainfall and microbial population (Sarjubala and Yadava, 2007). Seasonal variations in litter masses suggest that environmental factors, including temperature and humidity, significantly influence decomposition rates. Slower decomposition in some species, especially during summer, may have implications for nutrient cycling and soil health.

The litter decomposition rate was high in initial stages and then it declined gradually due to the influence of environmental factors, litter contents and soil organisms (Das & Mondal, 2016). Also, higher mass loss at the initial stages was due to the decomposition of water-soluble components and relatively slower mass losses at the later stages was due to the presence of recalcitrant constituents such as lignin, cellulose etc., in the residual litter mass along with poor climatic conditions (Hasanuzzaman and Hossain 2014).

The study highlights the critical role of tree litter in agroforestry systems for nutrient cycling and soil health. Significant variability was observed in both litter accumulation and decomposition rates among different tree species, underscoring the influence of species characteristics and seasonal factors. *S. mahagoni* and *S. cumini* were identified as major contributors to litter biomass, while *P. pinnata* and *T. grandis* had lower accumulations. Decomposition rates were highest in *P. pinnata* and lowest in *S. mahagoni*, with seasonal peaks during the summer months. These findings emphasize the importance of selecting appropriate tree species in agroforestry practices to enhance nutrient turnover and soil fertility. By understanding litter dynamics, agroforestry systems can be optimized for sustainable land management, ensuring ecological balance and economic benefits for farmers.

REFERENCES

ARUNACHALAM, A., MAITHANI, K., PANDEY, H. N. AND TRIPATHI, R. S., 1998, Leaf litter decomposition and nutrient mineralization patterns in regrowing stands of a humid subtropical forest after tree cutting. *For. Ecol. Manage*., **109** (1-3) : 151 - 161.

ARYA, S. AND TOKY, O. P. 2017, Biomass production in poplar agroforestry systems in Haryana of North Western India. *Indian J. Ecol.,* **44** (6) : 785 - 787.

BARGALI, S. S., SHUKLA, K., SINGH, L., GHOSH, L. AND LAKHERA, M. L., 2015, Leaf litter decomposition and nutrient dynamics in four tree species of dry deciduous forest. *Trop. Ecol.*, **56** (2) : 191 - 200.

BHARDWAJ, S. D. AND PANWAR AND GAUTAM, S., 2001, Biomass production potential and nutrient dynamics of *Populus deltoides* under high density plantations. *Indian For.,* **127** : 144 - 153.

BINDU, J. P., PARAMA, V. R. AND SRINIVASAMURTHY, C. A., 2014, Changes in nutrient and biochemical constituents on decomposition of leaf litter of selected tree species. *Mysore J. Agric. Sci.,* **48** (3) : 364 - 373.

BUTENSCHOEN, O., KRASHEVSKA, V., MARAUN, M., MARIAN, F., SANDMANN, D. AND SCHEU, S., 2014, Litter mixture effects on decomposition in tropical montane rainforests vary strongly with time and turn negative at later stages of decay. *Soil Biol. Biochem.*, **77** : 121 - 128.

Chopra, N., Tewari, L. M., Tewari, A., Wani, Z. A., Asgher, M., Pant, S., Siddiqui, S. and Siddiqua, A., 2023. Estimation of biomass and carbon sequestration potential of *Dalbergia latifolia* roxb. and *Melia composita* willd. Plantations in the tarai region (India). *Forests*, **14** (3) : 646.

Cintrón, B. B. and Lugo, A. E., 1990, Litterfall in a subtropical dry forest: Guanica, Puerto Rico. *Acta Cient.,* **4** (1-3) : 37 - 49.

Das, C. and Mondal, N. K., 2016, Litterfall, decomposition and nutrient release of *Shorea robusta* and *Tectona grandis* in a sub-tropical forest of West Bengal, Eastern India. *J. For. Res.*, **27** (5) : 1055 - 1065.

Fontes, A. G., Gama-Rodrigues, A. C., Gama-Rodrigues, E. F., Sales, M. V. S., Costa, M. G. and Machado, R. C. R., 2014, Nutrient stocks in litterfall and litter in cocoa agroforests in Brazil. *Plant soil*, **383** : 313 - 335.

George, S. J. and Kumar, B. M., 1998, Litter dynamics and cumulative soil fertility changes in silvopastoral systems of a humid tropical region in central Kerala. *Int. Tree Crops J.*, **9** : 267 - 282.

Hasanuzzaman, M. and Hossain, M., 2014, Leaf litter decomposition and nutrient dynamics associated with common horticultural cropland agroforest tree species of Bangladesh. *Int. J. For. Res.*, **2** (11) : 417 - 430.

Isaac, S. R. and Nair, M. A., 2006, Litter dynamics of six multipurpose trees in a homegarden in Southern Kerala, India. *Agroforestry systems*, **67** : 203 - 213.

Jamaludheen, V. and Kumar, M. B., 1999, Litter of multipurpose trees in Kerala, India: variations in the amounts, quality, decay rates and release of nutrients. *For. Ecol. Manag.*, **115** : 1 - 11.

Jha, K. K., 2010, Litter production and leaf litter decomposition dynamics in an age series *Tectona grandis* Linn. F. plantations of moist Tarai Sal forest. *Indian Forester*, **136** (4) : 433 - 450.

Kang, B. T. and Wilson, G. F., 1987, The development of alley cropping as a promising agroforestry technology. In: Agroforestry: a decade of development. ICRAF, Nairobi, pp. : 227 - 243.

Kumar, B. M. and Deepu Jose, K., 1992, Litter production and decomposition dynamics in moist deciduous forests of Western Ghats in peninsular India. *For. Ecol. Manag.,* **50** (5) : 181 - 201.

Mahmood, H., Siddique, M. R. H., Rahman, M., Hossain, M. and Hasan, M., 2011, Nutrient dynamics associated with leaf litter decomposition of three agroforestry tree species (*Azadirachta indica, Dalbergia sissoo* and *Melia azedarach*) of Bangladesh. *J. For. Res.,* **22** (4) : 577 - 582.

Manlay, R. J., Masse, D., Chevallier, T., Russell-Smith, A., Friot, D. and Feller, C., 2004, Post-fallow decomposition of woody roots in the West African savanna. *Plant Soil*, **260** (1) : 123 - 136.

Mo, J., Brown, S., Peng, S. and Kong, G., 2003, Nitrogen availability in disturbed, rehabilitated and mature forests of tropical China. *For. Ecol. Manage.,* **175** (1-3) : 573 - 583.

Murovhi, N. R., Materechera, S. A. and Mulugeta, S. D., 2012, Seasonal changes in litterfall and its quality from three sub-tropical fruit tree species at Nelspruit, South Africa. *Agrofor. Syst.,* **86** (1) : 61 - 71.

Nair, P. K. R., 1984, Soil productivity aspects of agroforestry. ICRAF, Nairobi, pp. : 164.

Ojo, A. F., Kadeba, T. O. S. and Kayode, J., 2010, Litter mass and nutrient dynamics in a transformed rainforest ecosystem in southwestern Nigeria. *Bangladesh J. Sci. Ind. Res.,* **45** (4) : 351 - 358.

Olson, J. S, 1963, Energy storage and the balance of producers and decomposers in ecological systems. *Ecol.*, **44** : 322 - 331.

Ono, K., Fujimoto, K., Hiraide, M., Lihpai, S. and Tabuchi, R., 2006, Above ground litter production, accumulation, decomposition and tidal transportation of coral reef-type mangrove forest on Pohnpei Island, Federated States of Micronesia. *Tropics*, **15** (1) : 75 - 84.

PANDEY, C. B., SHARMA, D. K. AND BARGALI, S. S., 2006, Decomposition and nitrogen release from *Leucaena leucocephala* in central India. *Trop. Ecol.*, **47** (1) : 149 - 152.

PINOS, J., STUDHOLME, A., CARABAJO, A. AND GRACIA, C., 2017, Leaf litterfall and decomposition of *Polylepis reticulata* in the treeline of the ecuadorian andes. *Mt. Res. Dev.,* **37** (1) : 87 - 96.

RADHAKRISHNAN, S. AND VARADHARAJAN, M., 2016, Status of microbial diversity in agroforestry systems in Tamil Nadu, India. *J. Basic Microbiol.*, **56** (6) : 662 - 669.

ROBERTSON, G. P. AND PAUL, E. A., 1999, Decomposition and soil organic matter dynamics. In: Sala OE, Jackson RB, Mooney HA, Howarth RW (eds) Methods of ecosystem science. Springer, New York, pp. : 104 - 116.

RUF, A., KUZYAKOV, Y. AND LOPATOVSKAYA, O., 2006, Carbon fluxes in soil food webs of increasing complexity revealed by 14C labelling and 13C natural abundance. *Soil Biol. Biochem.*, **38** (8) : 2390 - 2400.

SARJUBALA DEVI, A. AND YADAVA, P. S., 2007, Wood and leaf litter decomposition of *Dipterocarpus tuber culatus* Roxb. in a tropical deciduous forest of Manipur, Northeast India. *Curr. Sci.,* **93** (2) : 25 - 38.

SHIVAKUMAR, S. I., R. REVATHI, R. AND PATIL, S. J., 2014, Litter production in seed sources of *Pongamia pinnata* based agroforestry system in northern transitional zone of Karnataka. *J. int. acad. res. multidis*., **2** (5) : 662 - 670.

SILVA, A. K. L., VASCONCELOS, S. S., DE CARVALHO, C. J. R. AND CORDEIRO, I. M. C. C., 2011, Litter dynamics and fine root production in *Schizolobium parahyba* var. *amazonicum* plantations and regrowth forest in Eastern Amazon. *Plant Soil*, **347** (1) : 377 - 386.

SINGH, K. P., SINGH, P. K. AND TRIPATHI, S. K., 1999, Litterfall, litter decomposition and nutrient release patterns in four native tree species raised on coal mine spoil at Singrauli, India. *Biol. Fertil. Soils*, **29** (4) : 371 - 378.

SINGH, N. R., ARUNACHALAM, A., PATEL, D. P. AND VIYOL, S., 2019, Seasonal dynamics of litter accumulation in agroforestry systems of Navsari District, Gujarat. *Clim. Chang. Environ. Sustain.*, **7** (2) : 123 - 129.

SUNDARAPANDIAN, S. M. AND SWAMY, P. S., 1999, Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India. *For. Ecol. Manage.*, **123** : 231 - 244.

TANGJANG, S., ARUNACHALAM, A., ARUNACHALAM, K. AND DEB, S., 2015, Litterfall, decomposition and nutrient dynamics in traditional agro-forestry systems of northeast India. *Int. J. Ecol. Environ. Sci.,* **41** (1-2) : 43 - 53.