

Litter Production and Decomposition in Agro-ecosystems of Aleta Chuko District of Sidama Region, Ethiopia

Zenebe Argado (✉ zeneshu112@gmail.com)

Wondo Genet College of Forestry and Natural Resource, Hawassa University

Ambachew Wele

School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University

Tesfaye Amdie

School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University

Article

Keywords: litter fall, decomposition, nutrient dynamics, agro-ecosystems, agroforestry

Posted Date: February 7th, 2024

DOI: <https://doi.org/10.21203/rs.3.rs-3715100/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: There is **NO** Competing Interest.

Abstract

Litter fall and decomposition in agro-ecosystems varies by tree species where indigenous and exotic species were mixed. In such diversified species, litter decomposition and nutrient dynamics are not well understood in Aleta Chuko. This study was aimed at measuring litter fall of seven abundant woody species in Coffee-*Enset* based agroforestry (CEA) and *eucalyptus camaldulensis* woodlots; determining decomposition rate and nutrient contents of leaf litter. Three replicates for each species which were distributed over three transect lines, were used for litter fall and in situ decomposition experiment for one year by using litter traps and nylon-mesh litter-bag respectively. Mean monthly litter fall ranges from 40.9 for *M. indica* to 79.7 g m⁻² for *O. kenyensis* in CEA while it was 54.8 g m⁻² for *E. camaldulensis*. There was a significant difference in litter production among studied species ($P < 0.05$). Also, there was a significant difference in decay constant among studied species ($P < 0.05$). Indigenous species such as *C. arabica*, *C. africana* and *M. ferruginea* showed greater value of decay constant as compared to exotic species such as *E. camaldulensis*, *P. americana* and *M. indica*. *C. arabica* showed fastest decomposition with decay constant of 2.4 while it was 1.1 for *E. camaldulensis*. There was a significant loss of initial litter Ca, K and Mg contents within annual decomposition for all studied species. Whereas loss-gain condition of P, Na and N contents vary by woody species. Further research is required on nutrient dynamics of diverse plant species; particularly on factors responsible for increase or decrease in nutrient contents.

Introduction

Litter production is a key ecological pathway for carbon cycle as it is an input for soil organic matter thereby carbon is stored in the soil. The litter production is influenced by land use change and agricultural intensification processes that decline plant diversity, tree density and soil microbial biomass (Kagezi et al. 2016). Such processes cause not only loss of plant species but also replacement of native species by exotic ones which influence litter production, turnover time and nutrient cycle (Jo et al. 2017; Bohara et al. 2019).

Litter biomass is the largest source of decomposable organic material from the vegetation into the soil where carbon enters a long-lived pool. Litter decomposition is a valuable ecosystem process involving energy transfer, carbon sequestration and nutrient cycling in agro-ecosystems (Wang et al. 2008; Bradford et al. 2016; Li et al. 2020). The production and decomposition of litter differs by tree species (Becker et al. 2015). Land use practice induces modification of native vegetation that is expected to affect litter turnover time and carbon cycle (Carvajal et al. 2013). There is a scientific query to shed light on the nutrient dynamics in agro-ecosystems that is impacted by the type of plant species in tropics (Batish et al. 2008; Petit-Aldana et al. 2019).

There are three dominant land use types in Aleta Chuko district, namely 1) Coffee-*Enset* based agroforestry (CEA), with a mixed of dominantly native woody and herbaceous species; 2) Woodlots, which are dominated by few or single planted woody species particularly *eucalyptus*; and 3) *Chat* mono-cropping with rare tree species. *Eucalyptus* and *Chat* mono-cropping are expanding land uses at expense of traditional agroforestry which is age-old practice in Aleta Chuko that has been sustaining livelihoods and the natural environment.

There are few studies on litter falls and decomposition in Ethiopia to mention some: Lisanework and Michelsen (1994); Demessie et al. (2012); Seta et al. (2016), Tesfay et al. (2020) and Kassa et al. (2022). Litter fall, decomposition and its nutrient dynamics study in Ethiopia differ in many ways: some focus on C and N investigation (Demessie et al. 2012; Negash and Starr 2013); differ by plant species and/or land use (Lisanework and Michelsen 1994; Demessie et al. 2012; Tesfay et al. 2020); consider only initial nutrients but not investigate nutrient content after decomposition (Tefay et al. 2020; Kassa et al. 2022) and differ by agro-ecology (Seta et al. 2016). Accordingly, current study considered litter fall, decomposition rate, and initial and decomposed litter macro nutrients that is useful to predict nutrient input into the soil from litter source in agro-ecosystems.

Although plant litter production and decomposition is an important source of organic matter in the managed land use systems, the litter production and decomposition pattern, leaf litter nutrient contents is not yet established for Aleta Chuko district. Therefore, objectives of this study were to measure litter fall for abundant woody species in coffee-*Enset* based agroforestry

and *eucalyptus camaldulensis* Dehnh. in eucalyptus woodlots; to determine decomposition rate and nutrient contents of leaf litter.

Materials and Methods

2.1. Site Description

2.1.1 Location

This study was conducted in Aleta Chuko district of Sidama region, Ethiopia. The site is situated in the western escarpment of South Eastern Highlands. The study district is 340 km away from the national capital, Addis Ababa. Seventy percent of the district is agro-ecologically *Woina Dega* (warm- tropical) type of climate. The altitude of the district ranges from 1400 to 2000 m.a.s.l (Agricultural and Natural Resource Office of Aleta Chuko district 2020). The representative sites selected for the study were three kebeles namely Rufo Waeno, Korke and Dongora having similar biophysical environments. The sites are located between 6° 33' 27"N to 6° 38' 54"N latitude and 38° 18' 53"E to 38° 21' 6" E longitude. Samples plots were taken from elevation ranges of 1825 to 1838 m.a.s.l.

2.1.2. Topography and Soils

The topography of the areas has features of flat lands, undulating terrain (dominant topography) and small hills with moderate to steep slopes. Sandy clay loam, clay loam and clay soils are the dominant soil textures in the study area. The soils are locally named by their color as '*keyi afer*' (meaning red soil) and '*Koticha*' (meaning black soil) (Agricultural and Natural Resource Office of the district 2020).

2.1.3. Land Uses and Management

Sidama traditional agroforestry is a highly developed and complex agroforestry practice of long history (Asfaw and Agren 2007) though its origin has not been specified in the literature. The people of Gedeo and Sidama are among the first people who cultivated *Enset*-coffee agroforestry more than 3000 years ago, the ancestor of agroforestry (Kanshie 2002). Being neighbors, aspects of Gedeo and Sidama land use and farming practices are closely similar (Ibid). Sidama agroforestry practices include *Enset*-coffee, tree-*Enset*, *Eucalyptus camaldulensis* woodlots, scattered/parkland trees in maize fields, boundary planting, and scattered trees on grazing fields (Molla and Asfaw 2014). Aleta Chuko district is characterized by major land uses such as *Enset*-Coffee based agroforestry, Coffee- *Enset* based agroforestry (CEA), Coffee based agroforestry, *Enset* based agroforestry, seasonal cropland, emerging land use i.e Chat mono-cropping (CM) and woodlots either *Eucalyptus* monoculture woodlot (EW) or *Eucalyptus* with other species (Abebe 2005). This was also confirmed by the preliminary survey in the study area.

CM land use is expanding alarmingly at the expense of traditional agroforestry, woodlots and over a few available grazing areas. Chat cash crop farm requires frequent tillage from 3 to 5 times a year and it can be harvested from 3 to 4 times a year. Woodlots are areas where farmers set aside part of their land for growing planted and/or conserved trees (Bekele 2011). Woodlots are established from either *Eucalyptus* monoculture or a mixture of other tree species including a few natives. The woodlots are also used as grazing areas by farming communities. *Eucalyptus* is harvested commonly from 5 to 12 years as a construction material as well as for fuel wood. Despite their environmental liability, these two land uses have a vital economic role to generate income for smallholder farmers.

Woody and herbaceous species are also planted in Coffee-*Enset* based agroforestry as hedge-rows that serve many purposes such as fuel-wood, fencing and construction materials. However, big trees are traditionally conserved as threatened species that are valued as precious community resources. Tree management practices in agroforestry systems includes pruning, pollarding, lopping or trimming, whereas eucalyptus is harvested by means of coppicing as it has the ability to resprout after cutting down its stem. The farming community of Aleta Chuko practices seasonal shallow tillage and maintains soil fertility in Coffee-*Enset* based agroforestry through application of animal dung, crop residues, and domestic organic wastes.

2.2. Sampling Design and Data collection

Prior to litter production measurement, plant species diversity was assessed in three *kebeles* namely Rufo Waeno, Korke and Dongora since they have similar biophysical environments that enable comparison of litter production and decomposition among abundant woody species. The inventory was done in the three east-west aligned transect lines, which were drawn based on spatial analogue design over the gentle slopes (Buckland et al. 2007). An inventory includes three major land uses such as Coffee-*Enset* based agroforestry (CEA), Chat mono-cropping (CM) and *eucalyptus camaldulensis* monoculture woodlot (EW) within 20 x 20 m plot. Litter production and decomposition measurements were conducted only in two land uses namely CEA and *eucalyptus camaldulensis* (EW) plantation since in *chat* mono-cropping tree species found in the form of pruned stems and chat litter production is not measurable as the chat is harvested at basal height. A woody species diversity assessment was done to determine the most abundant species in the sites. Accordingly, seven most abundant woody species were selected from CEA for litter production and decomposition experiment. *Eucalyptus camaldulensis* was included from the woodlot since there are no other tree species suitable for litter collection in such woodlots except undergrowth in the lower story. A total of eight woody species with three replicates, which were distributed over three transects, were used for litter fall measurement and decomposition experiment. Tree diameter at breast height was measured with a diameter tape and mean crown area with tape meter (crown diameter measured in two perpendicular directions) (Negash and Starr 2013).

Litter fall data collection

To determine annual litter fall, samples were collected per month for a one year period from January 2022 to December 2022. Twenty four (24) a 2 x 2 mm nylon mesh litter traps with a 1 m x 1 m mini-frame plots were suspended at the height of 1 m above the ground and wood poles were used to collect litters of each species monthly. To measure each species litter fall, litters from other species were sorted out and removed from each trap. Collected litters were air-dried for 2 days; oven-dried at 70°C for 24 hours and mass of each sample were recorded. Air dry and oven dry weights were recorded. Then the conversion factor was used per woody species to get oven-dry weight for every month's litter fall records. The fraction of conversion factor was obtained by dividing oven-dried weight to air-dried weight.

Litter decomposition

Leaf litter decomposition experiment was done by using a standard nylon-mesh litter-bag for one year, from the beginning of February 2022 to January 2023. Eighty (80) grams of oven-dried fresh leaf litter samples were placed in 1-mm size nylon mesh with 25 x 25 cm litter bags. A total of twenty four (24) litter bags, three replicates for each species, were pegged onto the site floor near the installed litter fall traps. The litter bags were retrieved monthly, roots and other spare materials were removed, briefly washed with a tap water to clean soil (Motsara and Roy 2008), air-dried for 2 days and then transported to the laboratory to be oven-dried at 70°C until constant weight in paper bags. Finally, the mass of each sample was weighed and recorded.

Nutrient analysis

To determine initial and annual decomposed litter nutrient dynamics, the nutrient analysis was done at the beginning and end of the decomposition experiment. The leaf litter collected at the second month was used for initial nutrient analysis, the fresh leaf litter samples collected from litter traps were air-dried under shade for one week and then oven-dried at 70°C until constant weight was achieved, using Khaki paper bags. The three replicates of each species litter were ground/powdered using a grinding mill to take samples for nutrient analysis. At the end of the decomposition experiment remaining litter mass in the litter bags were retrieved, air-dried for 2 days and the same procedure was followed for nutrient analysis.

Macronutrient contents of leaf litter were extracted with respective relevant methods: Organic carbon and Nitrogen were determined by Walkley-Black (1934) and Kjeldahl methods respectively; Mg, K and Ca were extracted by atomic absorption method; P and Na by Olsen and flame photometer methods respectively (Motsara and Roy 2008). All nutrients were extracted at the Wondo Genet College of Forestry and Natural Resource laboratory except nitrogen which was extracted at college of agriculture, Hawassa University.

2.3. Measurement and Calculations

Leaf litter mass loss was measured using Eq. 1. by Olson (1963) method

$$\% \text{ Mass Loss} = 100 * (X_0 - X_t) / X_0 \dots\dots\dots \text{Eq. 1}$$

Where:

X_t is the mass of litter at time t , and X_0 is the initial litter mass at time zero.

Litter mass remaining in the litter bag was calculated using Eq. 2

$$\text{Mass remaining in the litter bag} = 100 - \% \text{ Mass Loss} \dots\dots\dots \text{Eq. 2}$$

Leaf-litter decomposition rate constants (k) was calculated using the negative single exponential using Eq. 3 by Olson (1963) procedure

$$Kt = -\ln (X_t/X_0) \dots\dots\dots \text{Eq. 3}$$

Where:

K is the decomposition constant (in year), and

X_t and X_0 are the same as above, t is decomposition time (in years).

Mean residence time (R_t) of leaf-litter was estimated by the inverse of k using Eq. 4 by Olson (1963) formula.

$$R_t = 1/k \dots\dots\dots \text{Eq. 4}$$

Where:

R_t is mean residence time.

Half-life periods $t(0.5)$ of decomposing litter samples was estimated from k values using Eq. 5 by Olson (1963) formula

$$t(0.5) = \ln(0.5)/(-k) = -0.693/(-k) \dots\dots\dots \text{Eq. 5}$$

The percent of nutrient loss between time of litter fall and after one year decomposition was estimated using Eq. 6 by Huang *et al.* (2007) methods as described in Demessie *et al.* (2012).

$$\text{Nutrient loss (\%)} = ((G-L)/G) * 100 \dots\dots\dots \text{eq.6}$$

Where:

G is initial nutrient concentration of fresh mature leaf litter and

L is nutrient concentration of decomposed litter after a year.

Statistical analysis

Each variable of collected information was entered into Excel and exported to IBM SPSS software version 26 for statistical analysis. Kruskal-Wallis Test was used to test for significant differences for mean monthly litter fall among woody species; annual litter decay rate constant, half-life and residence time among woody species at alpha 0.05. Mann-Whitney Test was used to test significant differences between initial and decomposed litter nutrient contents for each woody species at alpha 0.05.

Results and Discussion

Litter production

Litter fall production was collected from seven most abundant woody species in CEA, namely *Podocarpus falcatus* (Thunb.) Mirb., *Coffea arabica* Benth., *Persea americana* Mill., *Cordia africana* Lam., *Millettia ferruginea* Hochst. Bak., *Ocotea kenyensis* Robyns. Wilczek, and *Mangifera indica* L. while *eucalyptus camaldulensis* Dehnh. from eucalyptus woodlots. Litters collected include leaves, fruits, flowers and twigs with diameter ≤ 2.5 cm. Annual litter fall ranges from 4.9 for *C. arabica* to 9.6 $\text{Mg ha}^{-1} \text{y}^{-1}$ for *O. kenyensis*. The higher litter fall was recorded during the dry season from December to February while low litter falls was recorded during the rainy season from May to July. Seasonal variation of litter fall is shown in Fig. 3. Annual litter fall production per unit area for each species is given in Table 1.

There is a significant difference in litter fall of studied species ($P < 0.05$). A significant difference exist between higher litter fall producing species group such as *O. kenyensis*, *C. africana* and *P. americana*; and lower litter fall producing group of species such as *C. arabica*, *M. ferruginea*, *M. indica*, *P. falcatus* and *E. camaldulensis* (see Table 1). Mean monthly litter fall for *C. arabica* and *M. ferruginea* was higher than the similar study in Gedeo agroforestry; while it was lower than for *M. indica* and *C. africana* but consistent for *P. americana* (Negash and Starr 2013). Litter fall for *E. camaldulensis* in this study was lower than the result reported by Demessie et al. (2012) in Gambo District, southern Ethiopia.

Table 1
Showing mean monthly and yearly litter fall per species.

Woody species	Mean dbh(cm)	Mean crown area (m^2)	$\text{Mg ha}^{-1} \text{y}^{-1}$	Mean monthly litterfall (g m^{-2}) (Std.)
<i>O. kenyensis</i>	41.0	32.1	9.6	79.7 (± 19.9) ^a
<i>C. africana</i>	38.7	91.1	7.9	66.1 (± 15.7) ^a
<i>P. falcatus</i>	42.2	33.4	5.6	46.5 (± 20.7) ^b
<i>E. camaldulensis</i>	29.0	14.2	6.6	54.8 (± 11.4) ^b
<i>P. americana</i>	38.9	68.2	7.9	65.8 (± 19.3) ^a
<i>M. indica</i>	27.3	7.4	5.3	43.9 (± 9.9) ^b
<i>M. ferruginea</i>	36.6	33.2	5.3	43.9 (± 13.8) ^b
<i>C. arabica</i>	7.1	4.4	4.9	40.9 (± 16.3) ^b
Mean monthly litterfall indicated by the same letter is not significantly different ($P < 0.05$, $n = 3$)				
m^2 = square meter, dbh = diameter at breast height, cm = cent meter, Mg = mega gram, ha = hectare				

Litter decomposition

The loss of leaf litter mass showed the pattern of exponential decay with variation of decomposition between time intervals. Litter mass loss was negligible during the first two months for all studied species. This can be related to low moisture as the experiment was started in the dry season. In such conditions soil microbial activity is slothful that ingrowth of microbial biomass and subsequent splintering through penetration into leaf litter require sufficient moisture (Paudel et al. 2015; Seta et al. 2016; Bohara et al. 2019; Berg and McClaugherty 2020, and Orrego et al. 2022) that the initial stage of decomposition is strongly controlled by climate conditions than other factors such as litter quality and nutrient concentration (Berg and McClaugherty 2020).

But the mass loss was swift from 3 to 9 months in this study due to higher moisture in this period and higher nutrient concentration (Bradford et al. 2016; Huang et al. 2023). Then again litter mass loss was showed steady-state from 9 to 12 months (Fig. 4). The rate of decomposition was fast for species containing higher P, N and K such as *C. arabica*, *C. africana* and *M. ferruginea* (Table 3). The steady mass loss in the latter stages is attributed to the concentration of recalcitrant fractions such lignin, waxes, fats and tannin in leaf litter as decomposition progresses (Berg and McClaugherty 2020; Giweta 2020).

The decay rate of constant varies by species (Table 2). Decay rate constant of *M. indica* in this study was consistent with the result reported by Hasanuzzaman and Hossain (2014) in Bangladesh. Decomposition half-life and residence time for *E.camaldulensis* was consistent with the result reported by Demessie et al. (2012) in Gambo district, Ethiopia. The range of annual decay constant for seven considered species in this study was consistent with the result obtained for organic and conventional cocoa farms at Suhum, Ghana. But the decay constant for *C. arabica* is greater than the cocoa (Asigbaase et al. 2021).

Indigenous woody species such as *C. arabica*, *C. africana* and *M. ferruginea* showed the faster decay rate constant than exotic species such as *P.americana*, *M. indica* and *E.camaldulensis*. However, *P. falcatus* and *O. kenyensis* were slow decomposing litter among studied indigenous species. Finally, *E. camaldulensis* litter was the mildest of all studied species.

Table 2
Leaf litter decay rate constant, half-life t (0.5) and residence time (year unit).

Woody species	Decay rate constant (k)	Half-life t(0.5)	Residence time (Rt)	Origin (exotic or indigenous)
<i>P. falcatus</i>	1.5 ^c	0.4 ^b	0.6 ^b	Indigenous
<i>C. arabica</i>	2.4 ^a	0.3 ^c	0.4 ^c	Indigenous
<i>P.americana</i>	1.5 ^c	0.5 ^b	0.7 ^b	Exotic
<i>C. africana</i>	1.7 ^b	0.4 ^b	0.6 ^b	Indigenous
<i>M. ferruginea</i>	1.7 ^b	0.4 ^b	0.6 ^b	Indigenous
<i>E.camaldulensis</i>	1.1 ^d	0.6 ^a	0.9 ^a	Exotic
<i>O. kenyensis</i>	1.5 ^c	0.5 ^b	0.7 ^b	Indigenous
<i>M. indica</i>	1.6 ^b	0.4 ^b	0.6 ^b	Exotic

Column values with the same letter not significantly different ($P < 0.05$, $n = 3$).

Nutrient Dynamics of Leaf Litter Decomposition

The initial nutrient content of freshly fallen leaf litter was analyzed during the starting of the decomposition experiment and then decomposed litter nutrient was measured at the end of the decomposition experiment. The magnitude of nutrient release varied among studied species and across nutrient types in one year decomposition. There was no significant difference in carbon content for *P. falcatus*, *C. arabica* and *C. africana* but for the rest of five species. However, decreasing features of the carbon content was reported by several studies (Kim 2007; Demessie et al. 2012; Bohara et al. 2019).

Phosphorus significantly increased for *E.camaldulensis*, and this is supported by the study of Bohara et al. (2019) who showed significant decrease for the species. Decreasing tendency of Phosphorus was also reported in Boter-Becho Forest, Southwestern Ethiopia by Seta et al. (2016). Sodium content was increased for seven species but for *P. falcatus*. Increase in sodium during annual decomposition is also reported by Yue et al. (2016) that is due to litter decomposers balancing sodium content for their own consumption of litter. Nitrogen content was significantly increased for the seven species, except *M. ferruginea* (table, 3). An increasing tendency of nitrogen content during decomposition period was also reported by Kim (2007) and Taylor (1998). This is due to the microbial transference of soil nutrients into the litter (Berg and McClaugherty 2020). The content of C, K, Ca and Mg was decreased for all studied species within annual litter decomposition while K, Ca and Mg contents were significantly decreased for all studied species in this study (Table 3).

The nutrient loss-gain dynamics of decomposing litter depends on many factors. These include initial litter chemistry which depend on plant species; microbial transference of soil nutrients that enhances nutrient contents; types of the nutrients; the higher environmental moisture and higher nutrient content which are responsible for rapid release of nutrients otherwise tend to

retain (Paudel et al. 2015; Seta et al. 2016; Patil et al. 2020). For example, in this study the higher nitrogen loss was recorded for *M. ferruginea* as it contains high nitrogen in initial litter.

Table 3

First and second rows indicates initial and decomposed litter nutrient contents (mg g⁻¹ dry matter) respectively.

Woody species	C	P	K	Na	Ca	Mg	N
<i>P. falcatus</i>	448.30(± 3.30) ^a	1.20(± .01) ^a	14.30(± .03) ^a	.24(± .01) _a	22.35(± .02) ^a	5.49(± .01) ^a	15.73(± .14) ^a
	433.80(± 10.50) ^a	.5(± .01) ^b	1.30(± .05) ^b	.22(± .01) _a	18.48(± 1.07) ^b	3.14(± .24) ^b	17.13(± .02) ^b
<i>C. arabica</i>	453.63(± 6.65) ^a	1.07(± .01) _a	21.25(± .01) ^a	.22(± .01) _a	17.29(± .02) _a	4.66(± .01) _a	16.99(± .02) _a
	445.60 (± 5.82) ^a	.83(± .07) ^b	2.59(± .68) ^b	.65(± .07) ^b	10.76(± .47) ^b	3.60(± .50) ^b	26.82(± .02) ^b
<i>P. americana</i>	457.13(± 2.27) ^a	.88(± .01) ^a	9.00(± .02) ^a	.13(± .00) _a	19.51(± .02) _a	5.19(± .01) _a	7.97(± .01) ^a
	438.73(± 4.93) ^b	.76(± .04) ^b	.87(± .10) ^b	.20(± .01) _b	15.61(± .59) _b	3.07(± .10) _b	12.21(± .14) _b
<i>C. africana</i>	409.13(± 6.04) ^a	1.64(± .01) ^a	18.49(± .03) ^a	.52(± .01) ^a	23.58(± .01) ^a	5.12(± .01) ^a	15.63(± .08) ^a
	398.97(± 7.70) ^a	1.08(± .12) ^b	2.95(± .11) ^b	.56(± .04) ^a	14.57(± .40) ^b	3.64(± .40) ^b	23.88(± .03) ^b
<i>M. ferruginea</i>	458.03(± 5.75) ^a	1.50(± .01) _a	11.37(± .01) ^a	.14(± .01) _a	18.85(± .01) ^a	5.68(± .02) ^a	39.28(± .06) ^a
	438.63(± 5.53) ^b	.88(± .02) ^b	.71(± .02) ^b	.29(± .01) ^b	16.22(± .31) ^b	2.73(± .09) ^b	27.27(± .14) ^b
<i>E. camaldulensis</i>	461.92(± 4.39) ^a	.88(± .01) ^a	8.14(± .01) ^a	.76(± .02) ^a	14.53(± .01) ^a	3.72(± .01) ^a	18.37(± .09) ^a
	458.83(± 5.48) ^b	1.04(± .05) ^b	2.26(± .11) ^b	.85(± .05) ^b	12.71(± .69) ^b	2.41(± .15) ^b	14.82(± .05) ^b
<i>O. kenyensis</i>	455.60(± 6.32) ^a	.81(± .02) ^a	7.82(± .01) ^a	.13(± .01) ^a	19.50(± .02) ^a	5.09(± .01) ^a	19.17(± .03) ^a
	442.83(± 6.86) ^b	.35(± .06) ^b	1.84(± .07) ^b	.36(± .04) ^b	12.99(± .12) ^b	3.09(± .12) ^b	16.70(± .04) ^b
<i>M. indica</i>	407.66(± 5.75) ^a	.58(± .00) ^a	6.8(± .01) ^a	.11(± .00) ^a	23.37(± .02) ^a	2.91(± .02) ^a	11.77(± .12) ^a
	400.83(± 1.02) ^b	.39(± .12) ^b	.77(± .04) ^b	.29(± .02) ^b	14.99(± .12) ^b	2.52(± .03) ^b	10.45(± .04) ^b

C = Carbon, P = Phosphorus, K = Potassium, Na = Sodium, Ca = Calcium, Mg = Magnesium, N = Nitrogen.

The same letter within column indicate insignificant difference of nutrient content among woody species ($P < 0.05$).

Percent of nutrient loss or gain vary by woody species and type of nutrient. Carbon loss percent ranges from 0.7 for *E. camaldulensis* to 4.2 for *M. ferruginea*. Loss of Potassium was highest as compared to other nutrients ranging from 72.2 for

E.camaldulensis to 93.8 for *M. ferruginea*. Loss of nitrogen was highest for *M. ferruginea* though its pattern of gain-loss varies by woody species. An increase of Sodium percent ranges from 7.1 for *C. africana* to 66.2 for *C. arabica*.

Table 4
Nutrient loss (indicated with minus sign) or gain percent (indicated with plus sign)

Woody species	C	P	K	Na	Ca	Mg	N
<i>P. falcatus</i>	-3.2	-58.3	-90.9	-8.3	-17.3	-42.8	+ 16.3
<i>C. arabica</i>	-1.8	-22.4	-87.8	+ 66.2	-37.8	-22.8	+ 36.7
<i>P.americana</i>	-4.0	-13.6	-90.3	+ 35.0	-20.0	-40.9	+ 34.7
<i>C. africana</i>	-2.5	-34.2	-84.1	+ 7.1	-38.2	-28.9	+ 34.6
<i>M. ferruginea</i>	-4.2	-41.3	-93.8	+ 51.7	-13.9	-51.9	-44.0
<i>E.camaldulensis</i>	-0.7	+ 18.2	-72.2	+ 10.6	-12.5	-35.2	-23.9
<i>O. kenyensis</i>	-2.8	-56.8	-76.5	+ 63.9	-33.4	-39.3	-14.8
<i>M. indica</i>	-1.7	-32.8	-88.7	+ 62.1	-35.9	-13.4	-12.6

Implication of the decomposition rate and nutrient dynamics to the agro-ecosystems

The rate of litter decomposition has considerable implication for predicting global atmospheric carbon budgets, soil fertility and farming activities. Accumulation of organic matter via decomposition enhances nutrient-holding capacity of the soil (Berg and McLaugherty 2020). Beyond the application as natural fertilizer or mulching, plant litter can be used for the preparation of the organic compost. Understanding the rate of litter decomposition, nutrient contents and nutrient dynamics for tropical tree species in agro-ecosystem is useful to select the type of suitable litter for compost preparation either to replace or supplement inorganic fertilizer (Petit-Aldana et al. 2019; Giweta 2020; Liu et al. 2022). Furthermore, rapid litter decomposition implies fast conversion of carbon from litter into soil organic matter or enhancing soil carbon sequestration (Kerdraon et al. 2019; Berg and McLaugherty 2020).

Conclusion

The production and decomposition of litter differs by tree species. Litter mass loss was gradual during the first two months for all studied species related to low moisture as the experiment was started in the dry season; this indicates that moisture plays a key role for litter decomposition. Three of five indigenous woody species showed faster decay rate while all (three) of the studied exotic species showed gentle decomposition rate. Leaf litter nutrient dynamics within one year decomposition vary by woody species and nutrient type. Nutrients such as Sodium, Phosphorus and Nitrogen showed both increasing and decreasing features depending on woody species. Fast decomposing litters are useful for compost preparation to supplement inorganic fertilizers and the rapid litter decomposition converts litter mass into soil organic matter that enhances soil carbon sequestration. Further research is required on nutrient release aspect of diverse tropical plant species particularly on factors responsible for increase or decrease of the same nutrient during decomposition.

Declarations

Funding: I would like to acknowledge and thanks the following bodies for their financial support of this work:

1. This work was supported by the UK Research & Innovation (UKRI) through the Global Challenges Research Fund (GCRF) programme, Grant Ref: ES/P011306/ under the project Social and Environmental Trade-offs in African Agriculture (SENTINEL) led by the International Institute for Environment & Development (IIED) in part implemented by the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).
2. Ethiopian Ministry of education, Bule Hora University and Sidama regional government.

Conflict of interest: authors declare that there is no conflict of interest.

References

1. Abebe T. 2005. Diversity in home-garden agroforestry systems of Southern Ethiopia [Tropical Resource Management Papers]. Wageningen University.
2. Asfaw, Z, Agren, G. 2007. Farmers' local knowledge and topsoil properties of agroforestry practices in Sidama, Southern Ethiopia. :35–48. doi:org/10.1007/s10457-007-9087-0.
3. Asigbaase M, Dawoe E, Sjogersten S, Lomax B H. 2021. Decomposition and nutrient mineralisation of leaf litter in smallholder cocoa agroforests: a comparison of organic and conventional farms in Ghana. *Journal of Soils and Sediments*. 2021(21):1010–1023. doi:10.1007/s11368-020-02844-4.
4. Batish D R, Kohli R K, Jose S, Singh H P. 2008. *Ecological Basis of Agroforestry*. Boca Raton London New York: Taylor & Francis Group.
5. Becker J, Pabst H, Mnyonga J, Kuzyako Y. 2015. Annual litterfall dynamics and nutrient deposition depending on elevation and land use at Mt. Kilimanjaro. *Biogeosciences*. 12:5635–5646.
6. Bekele M. 2011. *Forest Plantations and Woodlots in Ethiopia*.
7. Berg B, McClaugherty C. 2020. *Plant Litter: Decomposition, Humus Formation, Carbon Sequestration*. Fourth. Springer Nature Switzerland. <https://doi.org/10.1007/978-3-030-59631-6>.
8. Bohara M., Yadav, Dong W, Cao J, Hu C. 2019. Nutrient and isotopic dynamics of litter decomposition from different land uses in naturally restoring Taihang Mountain, North China. *Sustainability*. 11(6). doi:<https://doi.org/10.3390/su11061752>.
9. Bradford M A. , Berg B, Maynard D S, Wieder W R, Wood S A. 2016. Understanding the dominant controls on litter decomposition. *Journal of Ecology*.:229–238. doi:10.1111/1365-2745.12507.
10. Buckland S T., Borchers D L, Johnston A, Henrys P A, Marques T A. 2007. Line Transect Methods for Plant Surveys. *Biometrics*. 63:989–998. doi:10.1111/j.1541-0420.2007.00798.x.
11. Carvajal, Feijoo A, Quintero H, Rondón M. 2013. Soil organic carbon storage and dynamics after C 3 -C 4 and C 4 -C 3 vegetation changes in sub-Andean landscapes of Colombia. *CHILEAN JOURNAL OF AGRICULTURAL RESEARCH*. 73(4). doi:<https://doi.org/10.4067/S0718-58392013000400010>.
12. Demessie, Singh B, Lal R, Strand L. 2012. Leaf litter fall and litter decomposition under Eucalyptus and coniferous plantations in Gambo District, southern Ethiopia. *Acta Agriculturae Scandinavica, Soil & Plant Science*. 62(5):467–476.
13. Giweta M. 2020. Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: a review. *Journal of Ecology and Environment*. 44(11). doi:<https://doi.org/10.1186/s41610-020-0151-2>.
14. Hasanuzzaman M, Hossain M. 2014. Leaf Litter Decomposition and Nutrient Dynamics Associated with Common Horticultural Cropland Agroforest Tree Species of Bangladesh. *International Journal of Forestry Research*. 2014:10. doi:10.1155/2014/805940.
15. Huang W, Yu W, Yi B, Raman E, Yang J, Hammel KE, Timokhin VI, Lu C, Howe A, Weintraub-Leff SR, et al. 2023. Contrasting geochemical and fungal controls on decomposition of lignin and soil carbon at continental scale. *Nat Commun*. 14(1):2227. doi:10.1038/s41467-023-37862-6.
16. Jo, Fridley J, Frank D. 2017. Invasive plants accelerate nitrogen cycling: evidence from experimental woody monocultures. *Journal of Ecology*. 105(4):1105–1110. doi:<https://doi.org/10.1111/1365-2745.12732>.
17. Kagezi, Kaib M, Nyeko P, Bakuneeta C, Schädler M, Stadler J, Brand R. 2016. Impacts of land-use intensification on litter decomposition in western Kenya. *Web Ecol*. 2016(16):51–58.
18. Kanshie T K 2002. 2002. *Five Thousand Years of Sustainability?: A Case Study on Gedeo Land Use*. Wageningen.
19. Kassa G, Bekele T, Demissew S, Abebe T. 2022. Leaves litterfall and nutrient inputs from four multipurpose tree/shrub species of homegarden agroforestry systems. *Environmental Systems Research*. 11(29). doi:10.1186/s40068-022-00278-0.

20. Kerdraon D., Drewer J, Castro B, Wallwork A, Hall J, Sayer E. 2019. Litter Traits of Native and Non-Native Tropical Trees Influence Soil Carbon Dynamics in Timber Plantations in Panama. *Forests*. doi:doi:10.3390/f10030209.
21. Kim J. 2007. Litter Decomposition and Nitrogen Release in Three *Quercus* Species at Temperate Broad-leaved Forest. *Forest Science and Technology*. 3(2):123~131.
22. Li Q., Geng Q, Zhang M, Jin C, Zhu J, Ruan H, Xia X. 2020. The roles of initial litter traits in regulating litter decomposition: a “common plot” experiment in a subtropical evergreen broadleaf forest. *Plant Soil*. 452:207–216. doi:https://doi.org/10.1007/s11104-020-04563-8.
23. Lisanework N., Michelsen A. 1994. Litterfall and nutrient release by decomposition in three plantations compared with a natural forest in the Ethiopian highland. *Forest Ecology and Management*. 65(2–3):149–164.
24. Liu, S, Yang, R, Peng, X, Hou, C, Ma, J, Guo, J. 2022. Contributions of Plant Litter Decomposition to Soil Nutrients in Ecological Tea Gardens. *Agriculture*. 2022(12). doi:10.3390/agriculture12070957.
25. Molla, Asfaw. 2014. Woody species diversity under natural patch forest and adjacent enset coffee based agroforestry in the midland of Sidama, Ethiopia. *International Journal of Biodiversity and Conservation*. 6(10):708–723.
26. Motsara R M., Roy R. 2008. Guide to laboratory establishment for plant nutrient analysis.
27. Negash M, Starr M. 2013. Litterfall production and associated carbon and nitrogen fluxes of seven woody species grown in indigenous agroforestry systems in the south-eastern Rift Valley escarpment of Ethiopia. *Nutr Cycl Agroecosyst*. 97:29–41. doi:10.1007/s10705-013-9590-9.
28. Olson J S. 1963. Energy Storage and the Balance of Producers and Decomposers in Ecological Systems. *Ecology*. 44(2):322–331.
29. Orrego M, Ugawa S, Inoue A, Laplace S, Kume T, Koga S, Hishi T, Enoki T. 2022.) Climate, Soil, and Plant Controls on Early-Stage Litter Decomposition in Moso Bamboo Stands at a Regional Scale. *Front For Glob Change*. 2022(5). doi:10.3389/ffgc.2022.921028.
30. Patil M, Kumar A, Kumar p, Cheema N K, Kaur R, Bhatti R, Singh A. 2020. Comparative litter decomposability traits of selected native and exotic woody species from an urban environment of north-western Siwalik region, india. *Scientific RepoRtS*. 10. doi:10.1038/s41598-020-64576-2.
31. Paudel E, Dossa, de Ble´court, Beckscha´fer, Xu, Harrison. 2015. Quantifying the factors affecting leaf litter decomposition across a tropical forest disturbance gradient. *Ecosphere*. 6(12):267. doi:http://dx.doi.org/10.1890/ES15-00112.1.
32. Petit-Aldana J, Rahman M M, Parraguirre-Lezama C., Infante-Cruz A, Romero-Arenas O. 2019. Litter Decomposition Process in Coffee Agroforestry Systems: Review Article. *J For Environ Sci*. 35(2):121–139. doi:10.7747/JFES.2019.35.2.121.
33. Seta T., Demissew S, Woldu Z, Lemenih M. 2016. Carbon and Nutrient Release Patterns during Leaf litter Decomposition in Boter Becho Forest, Southwestern Ethiopia. *J Ecosys Ecograph*. 6. doi:10.4172/2157-7625.1000222.
34. Taylor B R. 1998. Air-Drying Depresses Rates of Leaf Litter Decomposition. *Soil Biol Biochem*. 30(3):403–412.
35. Tesfay F., Kibret K, Gebrekirstos A, Hadgu K. 2020. Litterfall production and associated carbon and nitrogen flux along exclosure chronosequence at Kewet district, central lowland of Ethiopia. *Environ Syst Res*. 9(11). doi:https://doi.org/10.1186/s40068-020-00172-7.
36. Wang, Wang S, Huang Y. 2008. Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China. *Forest Ecology and Management*. 255:1210–1218.
37. Yue K, Yang W, Yan P, Zhang C, Huang C, Xu Z, Tan B, Wu F. 2016. Dynamics of multiple metallic elements during foliar litter decomposition in an alpine forest river. 75:547–557. doi:10.1007/s13595-016-0549-2.

Figures

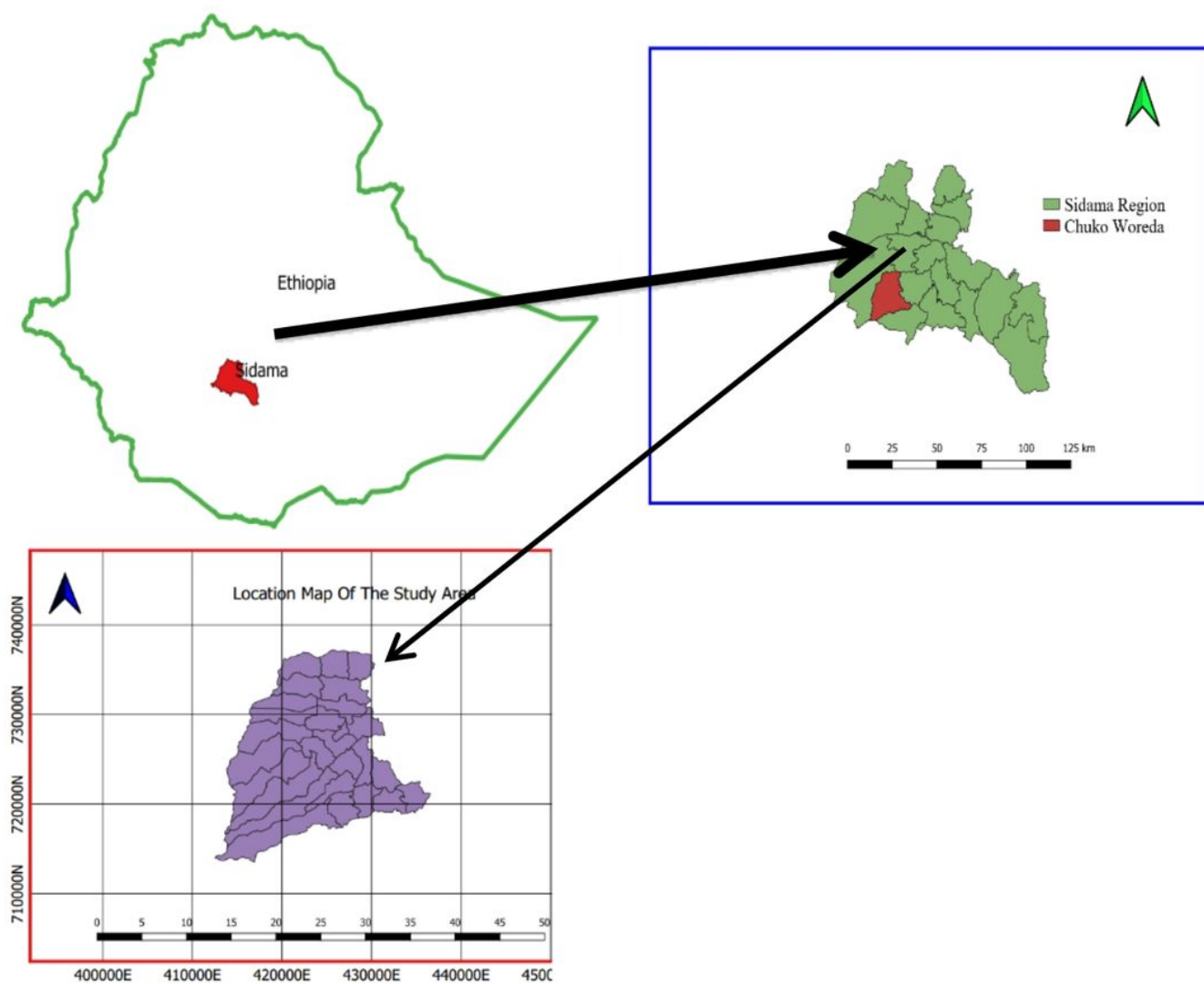


Figure 1

Map of Aleta Chuko district (Source: Ethio-GIS)

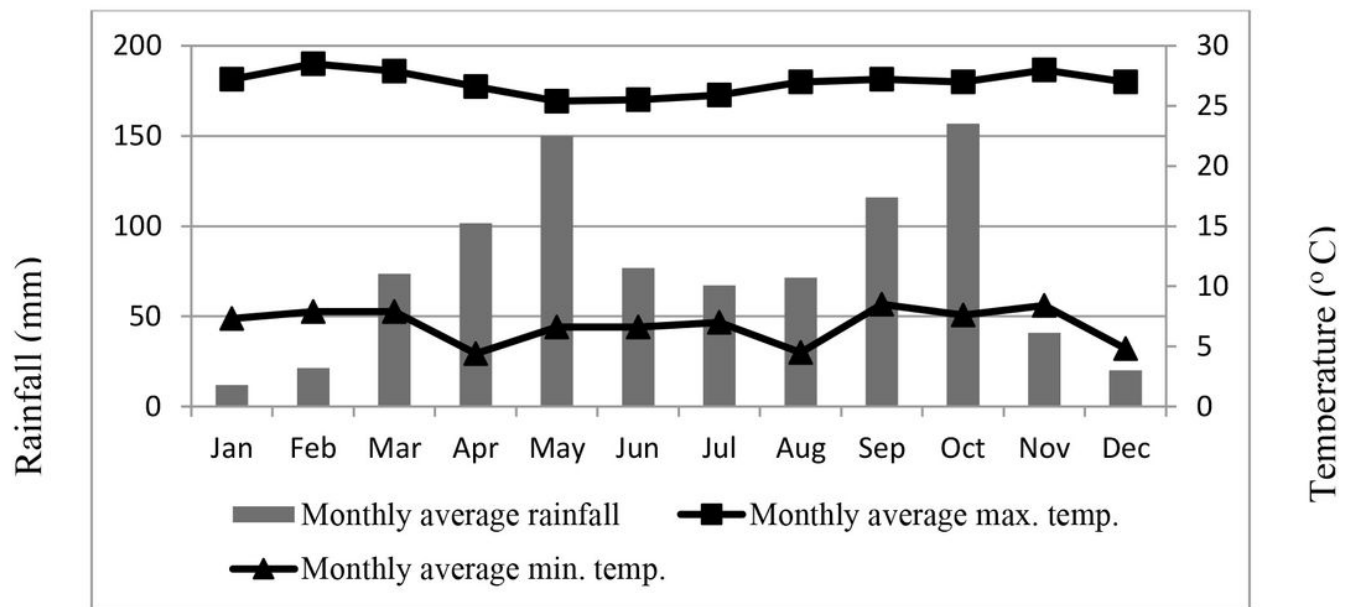


Figure 2

Mean monthly rainfall (mm), mean monthly maximum and minimum temperature (° C) (2009-2018). (Source: National Meteorological Service Agency, 2022)

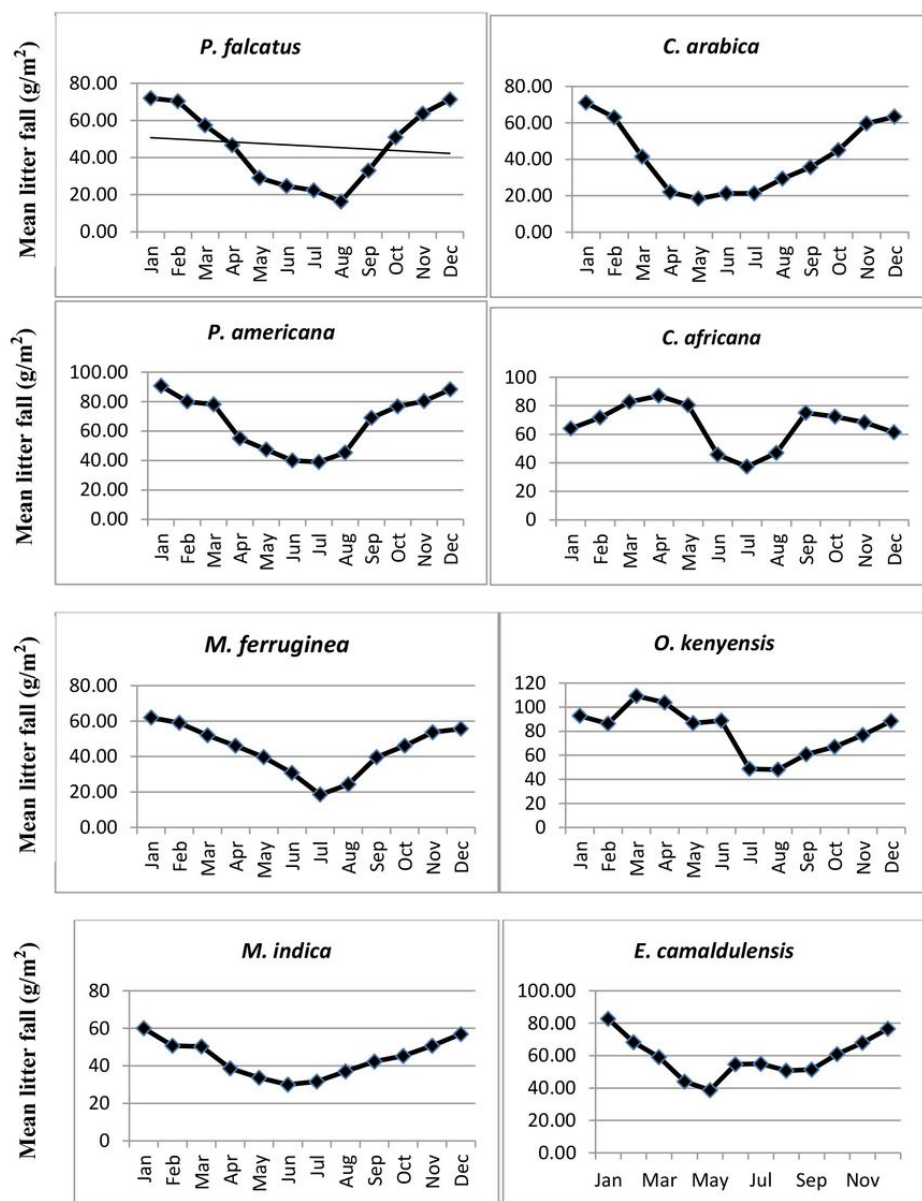


Figure 3

Monthly and seasonal variation of litterfall

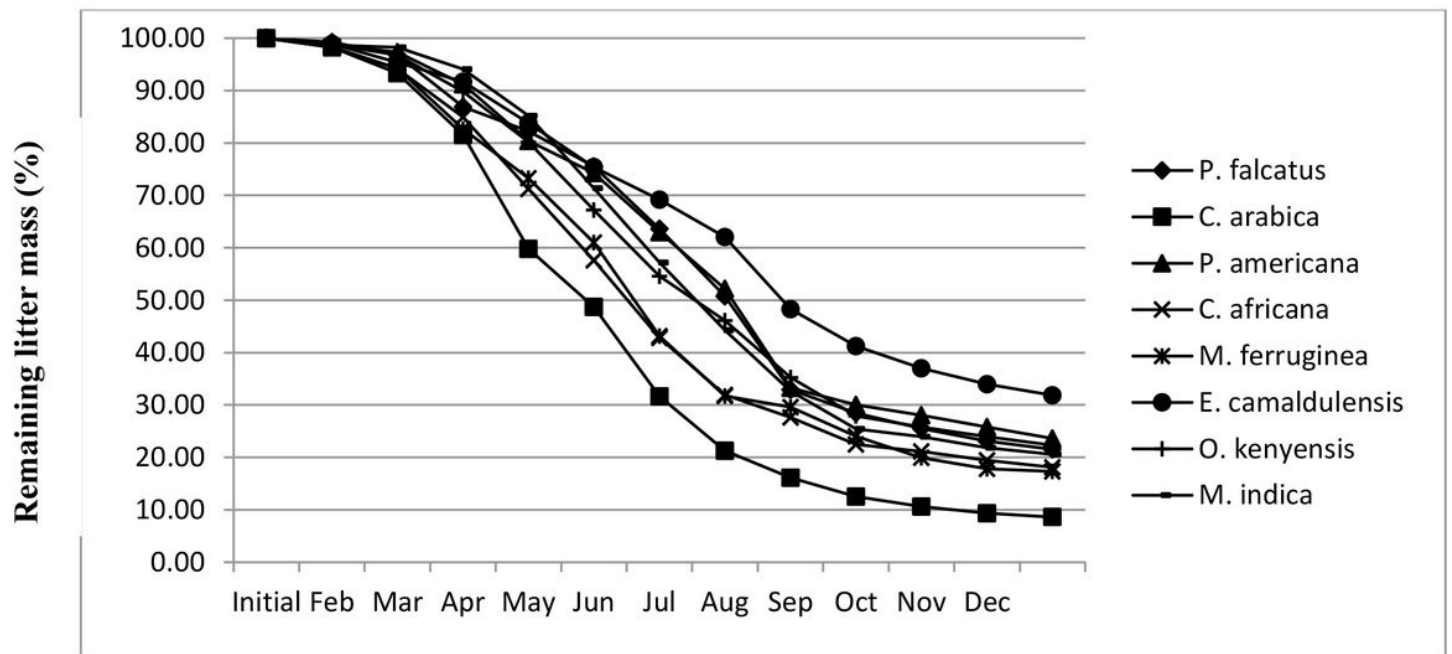


Figure 4

Leaf litter mass loss patterns