Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa

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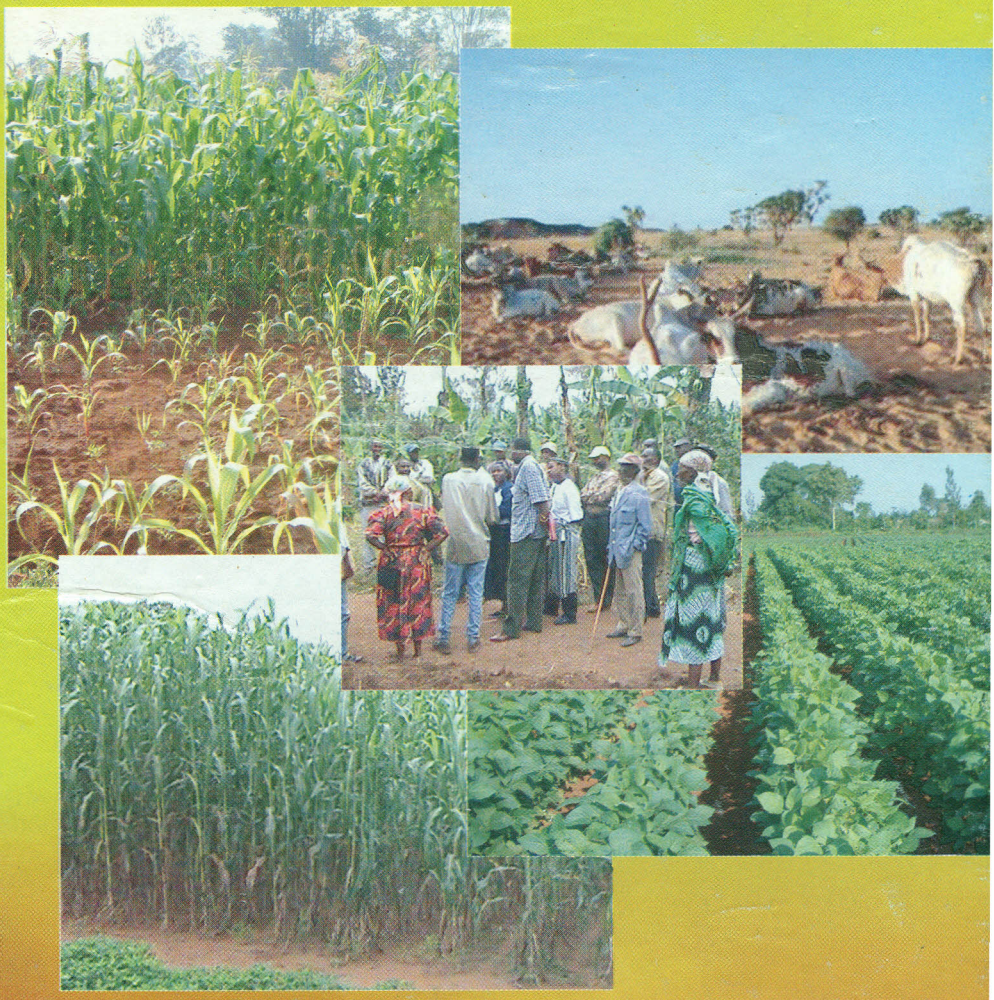

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Soil Invertebrate Macrofauna Composition within Agroforestry and Forested Ecosystems and their Role in Litter Decomposition in Embu, Kenya

Mwangi, M.[1,2*], Mugendi, D.N.[2], Kung'u, J.B[2], Swift, M.J[3], and Albrecht, A.[1]

[1]International Centre for Research in Agroforestry (ICRAF), P.O. Box 30677, Nairobi, Kenya
[2]Kenyatta University, Department of Environmental Foundations, P.O. Box 43844, Nairobi, Kenya
[3] Tropical Soil Biology and Fertility Institute, P.O. Box 30677, Nairobi, Kenya

*Corresponding author (email: mmwangi@lycos.com;t.mwangi@cgiar.org)

Abstract

Adequate food to meet the needs of an ever-increasing population is a major challenge for most developing countries, especially in the tropics. Despite this, few new technical packages capable of increasing net returns without deteriorating the environment have been developed. Crop yields in Embu, Kenya are poor due to declining soil fertility

prompted by continuous cropping and application of fertilizers in non-sufficient quantities by farmers. Studies have shown that soil biota provides the means and regulates the transformation of organically bound nutrients into plant-available forms through mineralization.

An experiment was conducted to investigate soil macrofauna composition within agroforestry and forested ecosystems and their role in litter decomposition. This was anticipated to address poor crop yields in the study region. The study was conducted during the long and the short rains of the year 2000 on-station at Embu in an ongoing hedgerow intercropping experiment. Two types of Standard PVC litterbags with mesh size 7 mm and 1mm, were used. The 7 mm mesh size allowed macrofauna to enter while the 1 mm excluded the macrofauna. Two types of litter: *Calliandra calothyrsus* (low quality) and *Leucaena leucocephala* (high quality), were placed in the litterbags in duplicate in selected treatments of the Embu trials and were sampled at 1, 2, 4, 8, and 16 weeks. Decomposition rate constants (k) were estimated using a non-linear module in the EXCEL spreadsheet upon fitting first order exponential equations.

Results from the study depicted that different management practice and/or land use affect soil macrofauna in varied manner. Soil invertebrate macrofauna enhanced the rate of decomposition of *C. calothyrsus* and *L. leucocephala* litter.

Keywords: Agroforestry, Hedgerow intercropping, Litter decomposition, Macrofauna.

Introduction

Production of adequate food to meet the needs of an ever-increasing population is a major challenge for most developing countries and in particular those of tropical Africa, Borlaug (2000). The focus on food production should therefore, be widened to include the problem of how best to conserve natural resources and biodiversity while achieving optimum sustainable yields.

Soil fauna may affect soil function in a variety of ways, and could be used as indicators of nutrient status of soil in a given site (Doube, 1997; Rao *et al.*, 1998 and Vanlauwe *et al.*, 1996). Soil invertebrates are the major determinants of soil processes in tropical ecosystems, whereas pest management is an integral part of crop production, the potential for manipulating the beneficial soil animals has rarely been considered

in designing management practices (Lavelle *et al.*, 1994b). Practices that eliminate beneficial soil faunal communities are unlikely to contribute to the sustainable production in the long term, especially in low-input systems based on organic residues. Thus focus on food production should be widened to include the problem of how best to conserve natural resources and biodiversity while achieving optimum sustainable yields.

According to ICIPE (1997), the diversity and role of soil fauna have been largely ignored by traditional and conventional agriculturists due to limited knowledge on their impact on crop yields. In recent years, many well-documented articles and reports have established the importance and urgency of improved knowledge and management practice for tropical soils. There is relatively little data and information available regarding tropical soil biology. Moreover, technological developments in temperate zones may not be applicable or appropriate in the tropics. According to Bruyn (1997), soil degradation in the tropics is related to drastic decline in activity and diversity of soil fauna among other aspects. The challenge in the future will therefore be to shift the emphasis of soil fauna research towards understanding their function in soil processes essential to ecosystem functioning. The soil biota, including soil microbial biomass and soil fauna provide the means and regulate the transformation of organically bound nutrients into plant-available forms through mineralization (Vanlauwe *et al.*, 1996; Lavelle *et al.*, 1994 and Tian *et al.*, 1997).

The process of litter decomposition is critical for maintaining the functioning of natural and managed ecosystems. This process occurs with partial involvement of soil invertebrates in the terrestrial ecosystems. Mugendi (1997) pointed out that studies on how litter quality affects decomposition in agroforestry systems are scanty. Studies done elsewhere depicts that the attributes of litter decomposition are determined by litter traits and climatic conditions (Thomas *et al.*, 1993; and Kochy, *et al.*, 1997). According to Upadhyay and Singh (1989), decomposition could be regulated by variables such as decomposer communities among others. Studies have also shown that rates and patterns of litter decomposition can be described as a function of season, climate and the conditions within the soil environment (Kwabiah *et al.*, 1999 and Mafongoya *et al.*, 2000).

This study mainly investigated the role of soil invertebrate macrofauna in litter decomposition within a hedgerow intercropping. Little research has been done on this aspect thus a need to undertake a study on the same. With this sort of experimental evidence, scientists can indicate to the farmer the state of the soil resource. The study specifically investigated the role of soil macrofauna on the rate of litter decomposition and compared the rate of litter decomposition of *C. calothyrsus* and *L. leucocephala.*

Materials and Methods

Experimental site

The study was conducted at the National Agroforestry Research Project (NAFRP) site at the Kenya Agricultural Research Institute (KARI) Regional Research Centre, Embu district in the Eastern province of Kenya. The centre is in the central highlands of Kenya on the southeastern slopes of Mt. Kenya at 0° 30'S, 37o 30'E and an altitude of 1480 m. The average maximum temperature is 25°C; the minimum is 14°C while the long-term monthly temperature is 19.5°C. The area receives a total annual rainfall of between 1200 and 1500 mm in two distinct seasons: long rains (March to June) average of 650mm and the short rains (mid October to December) average of 450 mm. The soils are mainly Humic Nitisols (FAO-UNESCO, 1989), derived from basic volcanic rocks (Jaetzold and Schmidt, 1983). They are deep, well weathered with friable clay texture with moderate to high inherent fertility.

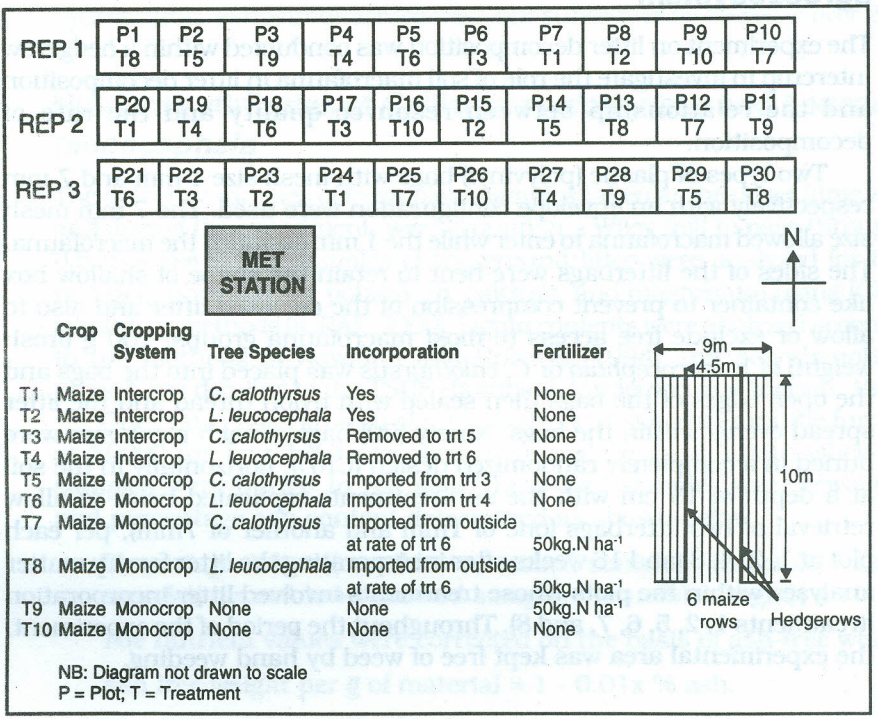
Experimental treatments

Calliandra calothyrsus and *L. leucocephala*, were the two tree species selected for this experiment. The two hedgerow species had been identified as two of the most appropriate species for soil fertility management (Heinemann *et al.*, 1990). The hedgerows were planted in April 1992 while the application of experimental treatments started in the long rain season of March 1993. There were ten (10) treatments replicated three (3) times in randomized complete block design as shown in Figure 32.1.

Management of tree hedges and pruning incorporation

Calliandra calothyrsus and *L. leucocephala* tree hedges were lopped two days before maize was planted. Hedges were lopped at a height of 50 cm using sharp knives. Leafy biomass and succulent stems were separated from hardened stems that were removed for firewood. The leafy biomass were weighed, chopped into smaller pieces (5 to 10 cm) and spread evenly on the ground over the plot area. They were then incorporated in the soil using hand hoes in the plots that were designed to receive pruning (Figure 32.1) as the land was being prepared for maize planting. The rate of leafy biomass of each tree species applied to different treatments was approximately 2 Mg ha^{-1} $season^{-1}$ on dry weight basis.

Figure 32.1: Field and plot layout, and experimental treatments within hedgerows at the National Agroforestry Research Project (NAFRP) site in Embu, Kenya



	Crop	Cropping System	Tree Species	Incorporation	Fertilizer
T1	Maize	Intercrop	*C. calothyrsus*	Yes	None
T2	Maize	Intercrop	*L. leucocephala*	Yes	None
T3	Maize	Intercrop	*C. calothyrsus*	Removed to trt 5	None
T4	Maize	Intercrop	*L. leucocephala*	Removed to trt 6	None
T5	Maize	Monocrop	*C. calothyrsus*	Imported from trt 3	None
T6	Maize	Monocrop	*L. leucocephala*	Imported from trt 4	None
T7	Maize	Monocrop	*C. calothyrsus*	Imported from outside at rate of trt 6	50kg.N ha^{-1}
T8	Maize	Monocrop	*L. leucocephala*	Imported from outside at rate of trt 6	50kg.N ha^{-1}
T9	Maize	Monocrop	None	None	50kg.N ha^{-1}
T10	Maize	Monocrop	None	None	None

NB: Diagram not drawn to scale
P = Plot; T = Treatment

Sampling of soil invertebrate macrofauna

Sampling for macrofauna was done six weeks after the incorporation of the litter biomass. Using a monolith of size 25 cm x 25 cm x 30 cm, samples were taken in two seasons; the long and the short rainy seasons. At each observation, five samples were taken randomly from each plot three times per season. The monolith was placed over a randomly selected spot and using a metallic mallet, it was driven into the soil to the ground level. The soil from the monolith was removed by hand depthwise at 0-10 cm, 10-20 cm and 20-30 cm depths into plastic buckets. The soil from each depth was placed in different plastic trays (20 cm by 30 cm) and gently sorted out to locate the organisms. The organisms were separated into major taxonomic groups and then collected in glass and plastic bottles using a pooter. After sorting, soil was returned to the sampling sites to minimize site degradation. In the laboratory, counting and recording was done. Numbers of different category of organisms were expressed per metre square. After counting, the soil fauna were preserved in 75% alcohol for subsequent identification at the Department of Entomology, National Museums of Kenya, Nairobi.

Decomposition of incorporated litter within hedgerow agroecosystem

The experiment on litter decomposition was conducted within a hedgerow intercrop to investigate the role of soil macrofauna in litter decomposition and the relationship between resource quality and the rate of decomposition.

Two types of plastic (polyvinyl) bags with mesh size 1 mm and 7 mm respectively with an envelope configuration were used. The 7 mm mesh size allowed macrofauna to enter while the 1 mm excluded the macrofauna. The sides of the litterbags were bent to retain the shape of shallow box like container to prevent compression of the enclosed litter and also to allow or exclude free access to most macrofauna groups. 100 g (fresh weight) of *L. leucocephala* or *C. calothyrsus* was placed into the bags and the open edges of the bags then sealed with nylon thread and the litter spread evenly within the bags. Ninety (90) bags of each mesh size were buried in a completely randomized design (CRD), horizontally in the soil at a depth of 15 cm with the subtreatments replicated twice to allow retrieval of two litterbags (one of 1mm and another of 7mm), per each plot at 1, 2, 4, 8, and 16 weeks after incorporating the litter for dry matter analyses within the plots whose treatments involved litter incorporation (treatments 1, 2, 5, 6, 7, and 8). Throughout the period of the experiment, the experimental area was kept free of weed by hand weeding.

Dry matter loss analyses of *Calliandra calothyrsus* and *Leucaena leucocephala*

At each sampling, the soil attached to the litterbag was carefully removed and the litter was put in polythene bags and taken to the laboratory, where soil and organic debris were sorted out by hand from the decomposing plant materials. Samples were then cleaned and oven dried at 65° C to a constant weight for dry weight determination (Anderson and Ingram, 1993). The dry weights were expressed as percentage of the initial sample weight at time zero. Decomposition rate constants (k) were estimated using Wieder and Lang (1982), first order exponential equation:

$$L_R/L_l = e^{-kt}$$

Where: L_R = litter remaining after a given time.
L_l = initial litter weight at time zero.
t = time interval of sampling LR expressed in weeks.
k = rate constant (decomposition rate constant per week).
e = base of natural logarithm.

The k values were estimated using a non-linear module in the EXCEL spreadsheet.

This exponential model was considered to be close to the biological reality where the decomposition rate of fresh litter is rapid when hydrosoluble compounds are leached, but subsequently decrease over time.

Nutrients attributes of *Calliandra calothyrsus* and *Leucaena leucocephala*

The oven-dry samples of fresh plant samples taken at the onset (time zero) and during the experiment, were ground in a Wiley mill to pass through a 0.5 mm sieve. Sub-samples of the ground litter were analyzed for total nitrogen, phosphorus, potassium, calcium, and magnesium using ICRAF laboratory methods (ICRAF, 2000). Lignin contents were analyzed according to the methods of Rowland and Roberts (1994) and polyphenols by procedures detailed in the TSBF Handbook (Anderson and Ingram, 1993).

One gram (1g) of ground plant samples was ashed in a muffle furnace at 500°C for four hours to correct for soil contamination, when the samples were buried in the soil. The ashed samples were reweighed and percentage ash content determined as shown below:

Percentage Ash = [(crucible + unashed sample) - (crucible + ashed sample)] [(crucible + unashed sample) - (crucible weight)] x 100

The nutrient values were corrected on the basis of ash-free weight:

Ash free weight per g of material = 1 - 0.01x % ash.

Percentage Corrected value for nutrient (N, P, K, Ca, and Mg) = 0.01 x % nutrient (N, P, K, Ca, and Mg)

Decomposition over time was calculated following the formula by Giashudin *et al.* (1993):

Percentage of dry weight remaining = (DWt)/(Dwi) 100

Where: DWt = oven dry weight at time t and
Dwi = initial oven dry weight.

Results and Discussions

Soil invertebrate macrofauna abundance within the hedgerow agroecosystem

The macrofauna observed during the period of study were identified into their respective groups/orders. Whenever possible the fauna were identified up to the species level, but for some it was not possible as they were still in their juvenile stage and therefore indicated as not identified (NI). Different macrofauna groups were observed in varying

numbers during the study period as shown in Table 32.1. The hedgerow agroecosystem recorded several distinct groups of macrofauna. This could have been as a result of the region offered a wide range of habitat for diverse faunal groups and therefore, it could be a rich ecosystem.

Table 32.1: Macrofauna groups observed within hedgerow agroecosystem during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya

Group/Order	Family/Subfamily	Genera/Species
1. Myriapoda (Millipedes)	NI*	NI*
2. Coleoptera (Beetles)	1. Scarabidae/aphodina 2. Staphylinidae. 3. Carabidae.	1. *Aphodius ividus* L. (chaffer grub). 2. *Philanthus* sp. (dark tiny beetles). 3. *Hyparpulus ornatus* Per.
3. Hymenoptera (Ants)	Formicidae/Myrmacinae	1. *Bothroponera* sp. (big dark ants) 2. *Euponera* sp. (brownish and small). 3. *Anoma* sp. (red ants).
4. Acarina (Mites)	NI*	NI*
5. Chilopoda (centipedes)	NI*	NI*
6. *Aranae* (Spiders)	Agriopidae	*Araneus drademattus* L.
7. Isoptera (Termites)	Termitinae/ Macrotermitinae	*Microtermes pusillas* Wasmann (tiny termites)
8. Diptera (Flies)	NI*	NI*
9. Lepidoptera (Moths)	NI*	NI*

* Not identified

Relatively higher numbers of fauna were observed within the hedgerows agroecosystem (Table 32.2) compared to the forested site (Table 32.3). This could have been because the macrofauna were able to utilize the benefits accrued from combining trees with crops than with trees alone as observed within the forested site.

Isopterans were the most abundant of the macrofaunal observed followed by Hymenopterans, Lepidopterans, Coleopterans, Chilopoda, Aranae, Myriapoda, Acarinas and Dipterans in that order. It was evident that in the hedgerow agroecosystem, termites formed the major macrofaunal group contributing 76.5% of the total macrofauna observed as depicted in Table 32.2.

Table 32.2: Total macrofaunal counts and percentages observed within hedgerow agroecosystem during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya

Faunal group	Total counts (m^{-2})	Total counts (%)
Isoptera	22406	76.5
Hymenoptera	3344	11.4
Lepidoptera	1466	5.0
Coleoptera	1126	3.8
Chilopoda	403	1.4
Aranae	205	0.7
Myriapoda	166	0.6
Acarina	106	0.4
Diptera	77	0.3

Table 32.3: Total macrofaunal counts and percentages observed within the forest ecosystem during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya.

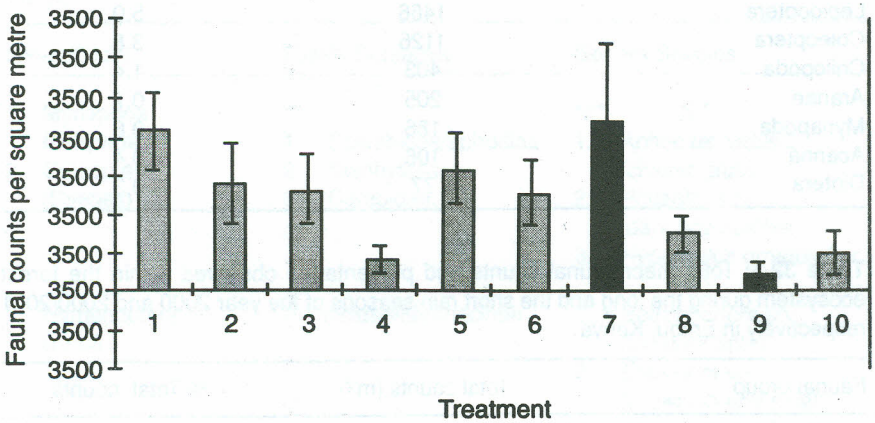
Faunal group	Total counts (m^{-2})	% Total counts
Isoptera	8470	64.87
Hymenoptera	705	5.4
Lepidoptera	1568	12
Coleoptera	934	7.2
Chilopoda	368	2.8
Aranae	213	1.6
Myriapoda	596	4.6
Acarina	106	0.8
Diptera	96	0.7

The presence of high number of termites in the hedgerow agroecosystem could imply that they were better able to withstand disturbed conditions as well as diminishing food resources resulting from such disturbances. It could also have been that the termites being ecosystem engineers, influenced the access of litter to other faunal groups hence their abundance over the rest. Termites may as such be able to survive a wide range of conditions. This corroborates with the work done by Christopher (1994) that showed that the influence of termites is not confined to certain litter qualities and that they control the accessibility of litter to other decomposers to an extent that exceeds their influence by direct consumption.

Total macrofauna abundance varied significantly ($p<0.05$), across treatments with higher numbers of fauna being recorded for treatments with *C. calothyrsus* than with *L. leucocephala* over the sampling period

(Figure 32.2) within the hedgerows. Treatments involving *C. calothyrsus*, biomass incorporation plus fertilizer (Treatment 7), recorded highest numbers of fauna.

Figure 32.2: Macrofauna counts within hedgerows during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya



Key:
1 & 2 = Alley cropping of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated and no fertilizer applied.
3 & 4 = Alley cropping of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with no prunings incorporated and no fertilizer applied.
5 & 6 = Maize only, no alley cropping, prunings of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated from outside and no fertilizer applied.
7 & 8 = Maize only, no alley cropping, prunings of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated from outside and fertilizer applied
9 &10 = Maize only, no alley cropping with and without fertilizer applied respectively fertilizer applied

Litter decomposition as influenced by soil invertebrate macrofauna within hedgerow intercropping in Embu, Kenya

Decomposition and nutrient release of the litter biomass are the key processes by which nutrients locked up in plant parts eventually become available to crops. The processes are regulated by variables such as the quality of the litter, climate, soil properties and decomposer communities (Upadhyay and Singh, 1989). Therefore, understanding the influence of these variables on biomass decomposition and nutrient release is a vital step to better management of organic inputs that are applied in different agroecosystems (Mafongoya *et al.*, 1997).

Nutrient analyses of the litter used in the decomposition study depicted that *C. calothyrsus* and *L. leucocephala* had varied nutrient content as shown in Table 32.4 and therefore, they could be varied in terms of nutritional value hence resource quality. The two species had varied lignin and/or polyphenols to nitrogen ratios (Table 32.5). T-test indicated that nutrient concentrations of the two species were significantly different ($p < 0.05$).

Table 32.4: Average chemical composition of *Calliandra calothyrsus* and *Leucaena leucocephala* within hedgerows in the year 2000/2001in Embu, Kenya.

Material	%N	%P	%K	%Ca	%Mg	% Lignin	%Poly-phenol
Calliandra calothyrsus	2.8	0.1	0.6	1.2	0.4	13.4	11.2
Leucaena leucocephala	2.8	0.1	1.9	1.3	0.3	9.5	8.1
SED	0.02	0.01	0.06	0.04	0.01	0.10	0.11

Table 32.5: Lignin and/or polyphenols to Nitrogen ratios of *Calliandra calothyrsus* and *Leucaena leucocephala* within hedgerows in the year 2000/2001in Embu, Kenya

Plant Material	Lig/N	Pp/N	(Lig +Pp)/N
Calliandra calothyrsus	4.8	4.0	8.9
Leucaena leucocephala	3.4	2.9	6.3
SED	0.02	0.06	0.01

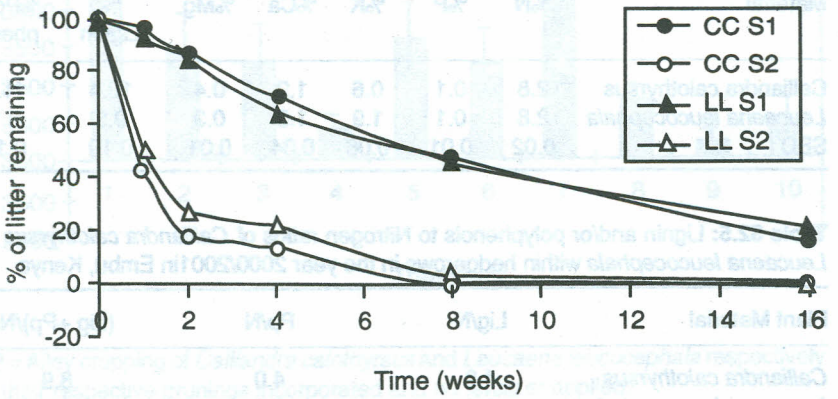
Key:
N = Nitrogen, Lig = Lignin, Pp = Polyphenol

In Figure 32.3, it is evident that *L. leucocephala* decomposed at relatively faster rate than *C. calothyrsus*, save for the second season when *C. calothyrsus* decomposed at faster rate than *L. leucocephala* during the second and the fourth week. The pattern of litter decomposition was gradual in season one and drastic in season two. This could have been due to different abiotic conditions in terms of moisture and temperatures experienced and therefore varied faunal population within treatments involving the two species. These findings agree with the observations made by Mugendi *et al.* (1994) in Machakos district of Kenya, during the short rains and the long rains, which gave an indication that faunal decomposition could be having some relation to climatic conditions and resource quality.

There was some litter remaining for both the species even after the 16th week for the first season, whereas all the litter had decomposed by the 8th week in the second season. The rate of litter decomposition was

relatively slow within the first four weeks of the first season, after which it became fast. During the second season, the rate was slower for the first two weeks after which it proceeded at a faster pace.

Figure 32.3: *Calliandra calothyrsus* and *Leucaena leucocephala* decomposition within hedgerows during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya



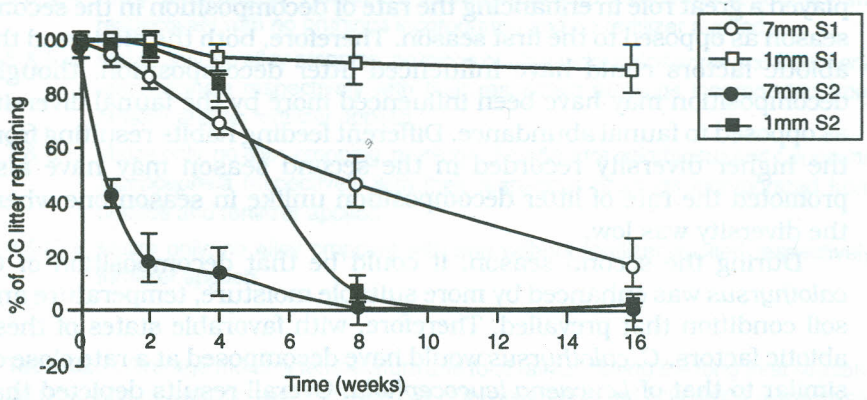
The varied rate of decomposition of *L. leucocephala* and *C. calothyrsus* could have been due to the varied litter substrate quality in which case, the former may be seen to be of higher quality than the latter as it had higher levels of nitrogen and phosphorus, and lower ratios of lignin and/or polyphenols to nitrogen. Lignin is known to be highly resistant to microbial decomposition, according to studies by Melillo *et al.* (1982) and Chesson (1997). This is also in agreement for instance with observation made by Thomas *et al.* (2000) that litter with low levels of lignin decomposes faster. According to Vityakon *et al.* (2000), Polyphenols exhibits a significant influence on nitrogen release from litter biomass hence decomposition. These findings are in agreement with studies conducted by Bubb *et al.* (1998), which indicated that litter-mass loss is strongly correlated with litter quality indicators such as nitrogen, phosphorus, carbon to nitrogen ratio, lignin and polyphenolics.

Overall, the rate of decomposition of *L. leucocephala* and *C. calothyrsus* was faster in the second season than in the first season. This could have been due to the presence of fully established crop that

might have increased the decomposition of the residues of the prunings. This corroborates to findings by Vanlauwe *et al.* (1997) that crop cover may increase decomposition and nitrogen release of the residues.

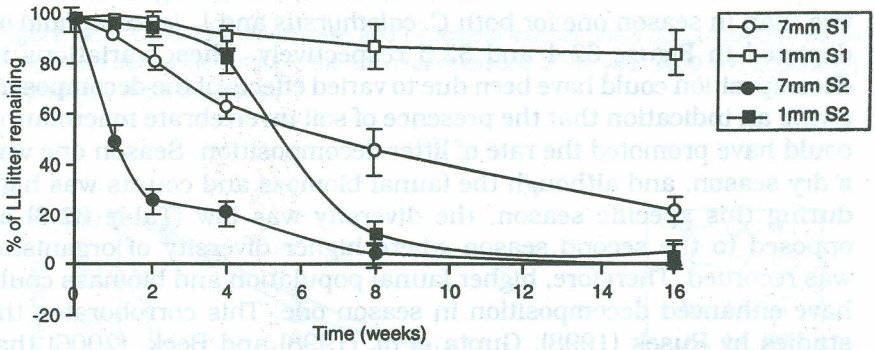
The litter enclosed in 7mm litterbags, decomposed at a faster rate than that in the 1-mm litterbags and the rates were higher in season two than in season one for both *C. calothyrsus* and *L. leucocephala* as depicted in Figure 32.4 and 32.5 respectively. These variations in decomposition could have been due to varied effects of the decomposers giving an indication that the presence of soil invertebrate macrofauna could have promoted the rate of litter decomposition. Season one was a dry season, and although the faunal biomass and counts was high during this specific season, the diversity was low (Table 32.6) as opposed to the second season where higher diversity of organisms was recorded. Therefore, higher faunal population and biomass could have enhanced decomposition in season one. This corroborates the studies by Rusek (1998), Gupta *et al.* (1998) and Beck, (2000) that fauna play an important role in plant litter decomposition processes.

Figure 32.4: The influence of litterbag mesh size on *Calliandra calothyrsus* decomposition within hedgerows during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya



Key: LL = *Leucaena leucocephala;*
S1 = season 1;
S2 = season 2

Figure 32.5: The influence of litterbag mesh size on *Leucaena leucocephala* decomposition within hedgerows during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya



Key: LL = *Leucaena leucocephala;*
S1 = season 1;
S2 = season 2

The moist conditions and favorable temperatures (Table 32.7), coupled with community composition in terms of diversity, may have played a great role in enhancing the rate of decomposition in the second season as opposed to the first season. Therefore, both the biotic and the abiotic factors could have influenced litter decomposition, though, decomposition may have been influenced more by the faunal diversity as opposed to faunal abundance. Different feeding habits resulting from the higher diversity recorded in the second season may have also promoted the rate of litter decomposition unlike in season one where the diversity was low.

During the second season, it could be that decomposition of *C. calothyrsus* was enhanced by more suitable moisture, temperature and soil condition that prevailed. Therefore, with favorable states of these abiotic factors, *C. calothyrsus* would have decomposed at a rate close or similar to that of *Leucaena leucocephala.* Overall results depicted that *L. leucocephala* decomposed and released nutrients faster than *C. calothyrsus.* This could be due to the varied chemical concentration as previously depicted in Table 32.4, hence varied nature of resource quality. *Leucaena leucocephala* had higher levels of nitrogen, phosphorus, potassium and calcium but low levels of magnesium and both polyphenols and lignin as opposed to *C. calothyrsus.* Higher lignin levels in *C. calothyrsus* than in *Leucaena leucocephala* may have slowed its rate of decomposition and may be even the release of nutrients.

Table 32.6: Macrofauna diversity as indicated by Shannon-Wiener index within hedgerows during the long and the short rain seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya.

Treatment	Season 1 Shannon-Wiener Index	Season 2 Shannon-Wiener index
1	-0.043(0.675)	-0.071(0.654)
2	-0.064(0.658)	-0.119(0.616)
3	-0.037(0.679)	-0.061(0.661)
4	-0.000(0.707)	-0.090(0.639)
5	-0.055(0.666)	-0.093(0.636)
6	-0.085(0.642)	-0.095(0.635)
7	-0.034(0.682)	-0.037(0.681)
8	-0.076(0.649)	-0.087(0.641)
9	-0.032(0.683)	-0.087(0.619)
10	-0.013(0.698)	-0.133(0.605)
SED (treatment)	(0.020)	(0.019)

Season 1: F test: P = 0.05;

Season 2: F test: P = 0.047

Values in parentheses are square root {(x + 0.5)} transformed.

1 & 2 = Alley cropping of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated and no fertilizer applied.

3 & 4 = Alley cropping of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with no prunings incorporated and no fertilizer applied.

5 & 6 = Maize only, no alley cropping, prunings of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated from outside and no fertilizer applied.

7 & 8 = Maize only, no alley cropping, prunings of *Calliandra calothyrsus* and *Leucaena leucocephala* respectively with their respective prunings incorporated from outside and fertilizer applied

9 &10 = Maize only, no alley cropping with and without fertilizer applied respectively fertilizer applied

Table 32.7: Average monthly temperature and total rainfall during the long (first season) and the short rain (second season) seasons of the year 2000 and 2000/2001 respectively in Embu, Kenya

Season	Temperature °C	Rainfall mm
1	18.7	262.0
2	17.5	340.9
Total	18.3	602.9

The higher concentrations of polyphenols in *C. calothyrsus* than in *L. leucocephala* could have caused immobilization of nutrients. Lignin and polyphenolics are known to be highly resistant to microbial decomposition according to studies by Melillo *et al.* (1982), Chesson, (1997) and Mafongoya *et al.* (2000). Therefore, based on these varied nutrients concentrations *L. leucocephala* is of higher quality than *C. calothyrsus* and this may explain why the former decomposed and released nutrients at a faster rate than the latter. Mafongoya *et al.* (1998) and Handayanto *et al.* (1997), made similar observations that the potential of the organic inputs from agroforestry species to supply nutrients depends on their quality and different tree species could be having varied chemical constituents. The results are in agreement with Hamada *et al.* (2000) that litter decomposition is affected by lignin content and that the relationship between lignin content and the decomposition rate is inverse. Supply of nutrients by an organic input is largely determined by the rate at which such organic decomposes and therefore, *L. leucocephala* may be of better quality than *C. calothyrsus*.

Generally, the decomposition rates were faster in the second season (which received some rains) as opposed to the first season (where rains failed). This could have been due to increase in moisture and faunal activity, which promoted the release of nutrients hence rate of decomposition. Decomposition and release of nutrients contained in *Leucaena leucocephala* and *Calliandra calothyrsus* is thus determined by their respective quality and/or the environment and the decomposer organisms present.

Conclusions and Recommendations

Results from this study depicted that different management practice and/or land use affect soil macrofauna in varied manner. Soil invertebrate macrofauna populations are high in management practices that entail incorporation of organic material into the soil as opposed to those that do not. Agroforestry system enhances the fauna population unlike forested ecosystems.

Soil invertebrate macrofauna enhanced the rate of decomposition of *C. calothyrsus* and *L. leucocephala* litter. *Leucaena leucocephala* decomposed faster than *C. calothyrsus* and the former had lower lignin and/or polyphenols to nitrogen ratio than the latter. Therefore, the rate of litter decomposition and nutrients release is related to tree species hence resource quality. *Leucaena leucocephala* could be more suitable for use to improve maize yields in alley cropping compared to *C. calothyrsus*.

Farmers should therefore be encouraged to use *L. leucocephala* as a source of nutrients for agricultural crops. *Calliandra calothyrsus* may

be applied at some predetermined time before sowing, to make the nutrients released from the same be utilized by the growing crop. There is also a need to investigate litter decomposition trends in an agroforestry setting in arid and semi-arid lands, which forms the highest percentage of the Kenyan land.

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