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*Tropical and  
Subtropical  
Agroecosystems*

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**ORGANIC RESOURCES QUALITY AND SOIL FAUNA: THEIR ROLE ON  
THE MICROBIAL BIOMASS, DECOMPOSITION AND NUTRIENT  
RELEASE PATTERNS IN KENYAN SOILS**

**[CALIDAD DE LOS RECURSOS ORGÁNICOS Y FAUNA DEL SUELO: SU  
PAPEL EN LA BIOMASA MICROBIAL, DESCOMPOSICIÓN Y PATRÓN DE  
LIBERACIÓN DE NUTRIMENTOS EN SUELOS DE KENYA]**

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**SUMMARY**

Five organic resources commonly used for soil fertility maintenance in large parts of Kenya were selected for litter decay and nutrient mineralization studies that were conducted in three farms (Machakos, Kabete and Njabini) located at an elevational transect ranging from 1500 to 2800 m above sea level. These organic residues included: bean trash, maize stover, tree prunings (*Grevillea robusta*), *Senna spectabilis* foliage, cow and poultry manures. Organic residues were either mulched or incorporated in the soil. Satellite experiments were also carried out in each of the three sites with one additional site at Maseno based in western Kenya. These experiments aimed at assessing the role of soil biota in the decomposition and nutrient release. Soil fauna were excluded from control plots using 1-mm mesh litterbags. The organic residues were different in chemical composition i.e. nitrogen (N), phosphorus (P), potassium (K), carbon (C), lignin (L) and polyphenol (PP) contents, which in turn influenced their rate of decomposition and nutrient release patterns. Bean trash decomposed and released N and P faster than either the maize stover or *Grevillea* prunings. The slowest rate of decomposition observed for *Grevillea* prunings could be attributed to the high lignin content (24%). The N release was influenced by (L+PP):N ratio. Bean trash having a ratio of 10 released N faster than either maize stover or *Grevillea* prunings whose respective ratios of 20 and 13. P release was influenced by both C:P and N:P ratios. Maize stover with C:P and N:P ratios that were higher than the critical levels of 123 and 10 respectively, mineralized and released P more slowly than either bean trash or *Grevillea* prunings. Incorporated materials decomposed and released nutrients faster than surface applied materials. For surface applied organic materials, the delay in litter decay ranged from 4.1 to 4.4 days for every 100 m increase in altitude, while for incorporated materials the delay in litter decay ranged from 1 to 3 days per

100 m increase in elevation. This implies that farmers at higher elevations would benefit more by incorporating residues before planting, while at low elevations post emergence surface application would lead to improved nutrient availability. Njabini and Kabete recorded significantly higher microbial biomass (C, N and P) than Machakos. This could be linked to the higher organic C, higher total N, higher moisture content but lower temperatures reported for Njabini and Kabete than Machakos. Soil fauna enhanced decomposition of organic residues, although their role in influencing nutrient availability to crops from the organic residues may depend on the nature of the material. Fauna had no significant influence on nutrient release patterns of *Senna* possibly due to secondary compounds present in *Senna*, which were lower than the critical levels of 15 for lignin and 4 for polyphenol respectively.

**Key words:** Resource quality, placement, soil fauna, decomposition, nutrient release, microbial biomass

**RESUMEN**

Cinco recursos orgánicos comúnmente empleados para mantener la fertilidad del suelo en Kenya fueron seleccionados para estudios de descomposición y mineralización de nutrientes en tres fincas (Machakos, Kabete y Njabini) localizados en un transecto altitudinal de los 1500 a 2800 m.s.n.m. Estos residuos orgánicos incluyeron rastrojo de frijol y maíz, ramas de árbol (*Grevillea robusta*), follaje de *Senna spectabilis*, excretas de bovinos y aves. Los residuos orgánicos fueron aplicados como cobertura o incorporados al suelo. Se realizaron estudios adicionales en cada uno de los tres sitios y se incluyó un sitio adicional (Maseno) en el Oeste e Kenya. Estos experimentos tuvieron como objetivo evaluar el papel de la biota del suelo en la descomposición y liberación de los nutrientes. La fauna del suelo fue excluida empleando bolsas de degradación de hojarasca con

mallá de 1-mm. Los residuos de las bolsas fueron analizados para compuestos químicos que pudieran influenciar la tasa de descomposición y el patrón de liberación de los nutrientes, ejem. nitrógeno (N), fósforo (P), potasio (K), carbono (C), lignina (L) y polifenoles (PP). El rastrojo de maíz se degradó y liberó N y P más rápido que el rastrojo de maíz o grevillea. La menor tasa de descomposición observada en grevillea pudiera ser atribuida a su contenido de L (24%). La liberación de nitrógeno estuvo influenciada por la proporción (L+PP):N. El rastrojo de maíz con una relación de 10 liberó N más rápido que el rastrojo de maíz o la grevillea que tuvieron proporciones de 20 y 13 ambos por arriba del nivel crítico de 10%. La liberación de P estuvo influenciada por la proporción C:P y N:P. El rastrojo de maíz mineralizó y liberó P más lentamente. Cuando se incorporó los materiales estos tuvieron una mayor descomposición y liberación de nutrientes que aquellos que se aplicaron únicamente como cobertura. Para los materiales

aplicado en superficie el retraso en la descomposición de la hojarasca fue de 4.1 a 4.4 d por cada 100 m de incremento en altitud, mientras que para los materiales incorporados el retraso fue de 1 a 3 d. Njabini and Kabete registraron mayor biomasa microbiana (C, N, y P) que Machakos, probablemente asociado a el mayor contenido de C orgánico, N total, humedad y menor temperatura reportada para Njabini y Kabete. La fauna del suelo mejoró la descomposición de los residuos orgánicos, aunque su papel en la disponibilidad de los nutrientes para los cultivos puede variar dependiendo de la naturalaza del material. La fauna no tuvo un papel importante en la liberación de nutrientes de *Senna* posiblemente debido a la presencia de compuestos secundarios en este material.

**Palabras clave:** Calidad de los recursos, fauna del suelo, descomposición, liberación de nutrientes, biomasa microbiana.

## INTRODUCTION

The majority of the small-scale farmers in sub-Saharan Africa (SSA) are unable to purchase the required levels of inorganic fertilizers due to their high costs. Application of animal manure which could be recommended as alternative means of maintaining soil fertility and crop productivity are available in inadequate amounts to be effective in attaining the objectives (Bationo and Mkwunye, 1991). Farmers are thus left with the option of using a variety of low external input to maximize crop yields. Studies have demonstrated that agroforestry technologies such as green-manuring (biomass transfer) with tree or crop residues increase crop yields (Gachengo, 1996; Niang *et al.*, 1996; Rao *et al.*, 1998). These organic residues play an important role in soil fertility management through their short term effects on nutrient supply and longer term contribution to soil organic matter (SOM).

Although organic resources used alone offer insufficient nutrients to sustain crop yields and build on soil fertility (Palm *et al.*, 1997), they do continue to play a critical role as nutrient sources to small scale farmers who are unable to access adequate quantities of mineral fertilizers. Therefore, in low external input systems, the overall challenge is to develop ways of managing organic matter decomposition to optimize short- and long-term release of nutrients and the maintenance of soil organic matter (SOM). The potential of these organic residues to supply nutrients depend on their quality and quantity, method and time of application and the soil environment (moisture, temperature, microbial activity) (Myers *et al.*, 1994). Thus the decomposition and subsequent mineralization or nutrient release of organic materials incorporated

into soil is rapid from materials with high chemical quality under adequate moisture conditions and the activities of soil fauna (Swift *et al.*, 1979).

Although the influence of altitude and temperature on litter decay and nutrient release is not fully understood, it is generally known that, rates of litter decay, N mineralization and soil respiration increase exponentially with soil temperature over a range of 10-30°C (Foster, 1989). Thus temperature control on litter decomposition is similar to that of soil respiration, which has a maximum of 30°C and declines at soil temperatures above 40°C (Scholes *et al.*, 1994). At different elevations (1500-2500 m a.s.l), delays in decay could be due to differences in mean air temperatures.

The role of soil fauna in the decomposition processes is recognized, particularly for low quality organic residues such as maize stover (Jones, 1990; Tian *et al.*, 1995), whereby meso- and macro-fauna first stimulate the activities of soil microbes before decomposition starts. Understanding the influence of faunal activity over biomass decay is thought to be an important step in managing organic inputs used in low external input systems based on organic fertilization. Experiments designed to test hypotheses related to the effect of soil faunal activities on soil fertility parameters are limited. However, those that exist, for example Elkins *et al.*, (1986) and Wright and Coleman (1988) indicate that faunal exclusion significantly affects decomposition and nutrient release patterns. The consequence of faunal exclusion on tropical soils however remains to be investigated fully (Dangerfield, 1993). Manipulation of faunal communities through chemical or physical exclusion together with measurements of

various soil biological and fertility parameters would therefore be constructive. This study therefore aims at: (1) Evaluating the effect of organic resources quality and method of placement on the decomposition and nutrient release, (2) assessing the contribution of soil fauna in the decomposition and availability of nutrients to crops, (3) assessing the effects of organic amendments on soil microbial biomass.

## MATERIALS AND METHODS

### Site description

The experiments were set up in the four agro-ecological zones: Kabete, Machakos, Njabini and Maseno. The sites are located at an elevational transect ranging from 1500 to 2600 m above sea level with average annual temperatures ranging between 14 and

23°C. Mean annual rainfall ranged from 700 mm to 1800 mm (Table 1).

Soils varied across the sites, with Central Kenya sites (Kabete, Njabini and Machakos being dominated by the Nitisols, while Maseno site being dominated by Ferralsol. Kabete and Njabini have fairly high % C and N than Machakos.

Six organic residues and two manures commonly used by farmers for soil fertility improvement were identified and used for a series of experiments (Table 2). Maize stover, bean trash (maize and bean cropping systems major residues), *Grevillea* prunings, *Senna* foliage, cattle and poultry manure were selected for both litter decay and *in\_situ* mineralization experiments.

Table 1. Site and soil characterization.

Parameters	Kabete	Machakos	Njabini	Maseno
Altitude (m) a.s.l.	2012	1555	2561	1560
Latitude & Longitude	1°15'S, 36°44'E	1°36'S, 37°15'E	0°43.7'S, 36°37.6'E	0°, 34°35'E
Mean Annual temp (0°C)	15	19.4	14	22.7
Mean annual rainfall (mm)	1006	718	1064	1800
Soil type	Humic Nitisol	Dystric Nitisol	Eutric Nitisol	Ferralsol
Soil pH <sub>0.02M CaCl2</sub>	5.2	4.6	4.7	5.5
% N	0.29	0.11	0.3	-
% Organic C	3.0	0.9	3.0	3.9
CEC cmol <sub>c</sub> kg <sup>-1</sup> soil	22.4	14.8	9.4	-
Ca cmol <sub>c</sub> kg <sup>-1</sup> soil	12.5	9.0	3.6	15.5
Mg cmol <sub>c</sub> kg <sup>-1</sup> soil	3.33	1.28	0.8	1.6
K cmol <sub>c</sub> kg <sup>-1</sup> soil	1.90	1.66	0.5	0.14
Na cmol <sub>c</sub> kg <sup>-1</sup> soil	0.13	0.31	0.5	-

Table 2. Nutrient contents and ratios of selected organic residues used in litter decay and mineralization studies.

Organic residues	Organic C	N	P	K	L	PP	C:N	N:P	C:P	PP:N	L:N	(L+PP):N
Bean trash	54.1	1.14	0.54	14.0	0.29	11.29	48	2	100	9	0.3	10
Grevillea prunings	55.6	2.20	0.79	7.25	23.72	5.63	25	3	72	3	11	13
Maize stover	54.7	0.60	0.05	9.83	10.75	1.08	91	12	1100	2	18	20
Cow manure	41.4	2.10	0.22	16.5	-	-	20	10	188	-	-	-
Poultry litter	43.9	6.30	0.95	9.50	-	-	7	7	46	-	-	-
Senna prunings	39.3	3.61	0.23	15.7	9.0	1.03	11	16	170	0.3	3	3

Source: TSBF Database (1997).

## Sampling and chemical characterization of organic materials

Organic resources (field crop residues, tree prunings, animal manure) were selectively collected from the farms visited in the areas of study. The materials were dried in the oven at 40°C but manures were air-dried, ground and initial chemical characterization was done for each of the organic residues and manure using procedures outlined by Anderson and Ingram, (1993). Total organic carbon was determined by Heanes' improved chromic digestion and spectrophotometry; total nitrogen (N) by microscopic Kjeldahl digestion followed by distillation. Using the same digestion solution for N, phosphorus (P) was determined calorimetrically by spectrophotometer while potassium (K) was measured by flame photometry (Anderson and Ingram, 1993). For the organic residues, extractable polyphenols was determined by Folin-Denis method while lignin was determined by acid detergent fiber method (Anderson and Ingram, 1993).

### Litter decay experiments in the field

#### (a) Central Kenya sites

These experiments were set up in the three agro-ecological zones: Kabete, Machakos, and Njabini to evaluate the effect of organic resource quality and their placement on decomposition and nutrient release and also on soil microbial biomass. The maize stover and bean trash were obtained from the experimental sites where these trials were carried out. Cattle and poultry manure were collected from the Poultry unit, Department of Animal Production, University of Nairobi. *Grevillea robusta* prunings were obtained from a small-scale farmer next to the University field station, Kabete. The materials were air-dried to constant weight and sub-samples taken to the laboratory for characterization. Some of the chemical properties of these organic materials are shown in Table 2. Maize stover, bean trash and *Grevillea* prunings were chopped into smaller pieces using a panga. 30g (fresh weight) of each material were weighed and placed into 5 mm mesh litterbags measuring 30 cm × 30 cm. In the field half of each of the 108 litterbags required for each site were placed on the soil surface, with remaining half (54 bags) being buried at 5-10 cm soil depth. Satellite experiments were carried out in each of the three sites with one additional site at Maseno. These experiments aimed at assessing the role of soil biota in the decomposition and nutrient release. At Kabete, Njabini and Machakos, maize stover was used as test material. 5g of maize stover were weighed and inserted into 1-mm mesh bags measuring 20 cm × 20 cm to exclude soil biota.

#### (b) Western Kenya site (Maseno)

At Maseno, *Senna spectabilis* foliage (5 t ha<sup>-1</sup> rate) was used as the test material and employing the standard TSBF litterbag technique (Anderson and Ingram, 1993). *Senna* foliar biomass was collected from nearby hedges or farms prior to field incorporation. 30g of foliar biomass was weighed (based on predetermined fresh weight to dry weight ratio of 16:1) and placed into 5-mm mesh litterbags measuring 20 cm × 20 cm, and the tagged bags buried at a depth of 5-cm below the soil surface. Two sets plots of 3 m × 3 m plots were established in a completely randomized design (CRD). One set had its soil fauna left undisturbed while in another set, soil fauna were excluded by inserting 5g of *Senna* into 1-mm mesh bags. Ten litterbags containing fresh litter of *Senna spectabilis* (at 5 t ha<sup>-1</sup> rates) were buried at 5 cm depth in each plot allowing two litterbags to be retrieved at each sampling date.

For all the sites (Central and Western Kenya), litterbags were retrieved from each plot at 1, 2, 4, 8, and 16 weeks after incorporating the foliage. At each sampling date, litterbags were carefully dug out from each of the plots. The soil attached to the litter was carefully removed and fresh weight of the litter left undecomposed determined. The sample material was transferred into paper bags and oven-dried at 70°C for 48 hours for dry weight determination (Anderson and Ingram, 1993). The dry weights were expressed as percentage of sample weight remaining undecomposed.

The oven-dry samples were ground in a Wiley mill and passed through a 1.0 mm sieve. Sub-samples were analyzed for nitrogen and phosphorus contents using TSBF procedures (Anderson and Ingram, 1993). One gram of the sample was ashed in a 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 % ash content determined:

$$\% \text{ Ash} = \frac{[(\text{crucible} + \text{ashed sample}) - (\text{crucible}) \times 100]}{[(\text{crucible} + \text{unashed sample}) - (\text{crucible weight})]}$$

The % N and P values were corrected on the basis of ash-free weight:

$$\text{Ash free weight per g of material} = 1 - 0.01 \times \% \text{ ash.}$$

$$\% \text{ Corrected value for NP} = 0.01 \times \% \text{ nutrient (NP).}$$

Decomposition and nutrient release (N and P) over time were calculated following the formula by Giashuddin *et al.*, (1993):

$$\% \text{ dry weight remaining} = (DW_t)/(D_{wi}) \times 100$$

Where:

DW<sub>t</sub> = mean oven dry weight at time t and

D<sub>wi</sub> = initial oven dry weight.

The percentages of nutrients (N and P) at different times were calculated thus:

$$X\% \text{ t (of initial X)} = (X \text{ (mass) t} / X \text{ (mass) initial} X\% \text{ t} \times \text{litter mass t} / X\% \text{ initial} \times \text{litter mass initial})$$

$$X\% \text{ released} = 100 - (\% \text{ of initial})$$

Where X is the nutrient in question.

### In situ mineralization experiment

The potential for short-term immobilization of nutrients by maize stover, bean trash, *Grevillea* prunings, poultry and cattle manure were assessed in the three sites of Kabete, Machakos and Njabini. The main aim of this study was to observe the effects of these varied organic amendments.

Soils at the sites were amended at the rate of 2400 kg C/ha in 1 m x 1 m plots and compared to the untreated soil in a randomized complete block design and the plots watered to field capacity. The plots were covered with plastic sheets to minimize evaporation, runoff and leaching losses. Soil microbial C, N and P were measured at the beginning and after 4 weeks thereafter using the chloroform fumigation-incubation technique as described by Anderson and Ingram (1993).

### Data analyses

The data were subjected to analyses of variance (ANOVA) using the GENSTAT 5 Committee (1993) statistical package. Data were analyzed in a split-plot design where the applied treatments were the main plot factor while sampling period was the sub-plot. Treatment differences were evaluated using the least significance difference (LSD) according to Zar (1984).

## RESULTS

### Effect of residue quality and placement on decomposition and nutrient release.

Large differences in the chemical composition of the organic materials were observed (Table 2). The N content ranged from 0.6% in maize stover to 6.3% in poultry manure. Crop residues have lower N content than either leaves of woody species (*Grevillea* and *Senna*) or animal manures (poultry and cow manure). Similar trend was also observed for P where poultry

manure recorded the highest P (0.95%) while maize stover had the lowest P content. K content was variable ranging from 2% in bean trash to 15.7% in *Senna* prunings. Variability was equally great for organic C among the materials, ranging between 39.3% (*Senna*) and 55.6% (*Grevillea*). Soluble polyphenols was lowest in maize stover but highest in bean trash, while lignin was highest in *Grevillea* but lowest in bean trash.

Two distinctive trends were observed in the decomposition pattern of the organic residues in all the sites. First, there was a period of rapid decomposition in the first four weeks after incorporating the materials in the soil, which was followed by a period of slow decomposition in the subsequent weeks (Figs. 1 a-c). Decomposition proceeded faster in the order bean trash > maize stover > *Grevillea* prunings for both Njabini and Machakos sites. Although no significant difference was observed between *Grevillea* and bean trash, they decomposed faster than maize stover at Kabete. Generally decomposition was fastest at Machakos and Kabete than Njabini. After four weeks, between 40 and 70% of the materials had decomposed at Kabete and Machakos with less than 20% of the materials being recovered after 16 weeks. In contrast, more than 20% of the materials were still recovered at 16 weeks after incorporation at Njabini (Figs. 1a-c).

Placement of the organic materials had significant effect on the decomposition patterns. In all the sites, and for all treatments, incorporated materials decomposed faster than surface applied materials (Figs. 1a-c). Greater than five fold delays were observed in the decomposition of surface mulches when Machakos and Njabini were compared (Fig. 2).

It was found that for surface applied materials, the delay in litter decay was constant across elevation and ranges from 4.1 to 4.4 days for every 100 m increase in altitude. For the materials that were incorporated, the delay in litter decay was lower than surface applied materials and ranged from 1-3 days per 100 m increase in elevation (Fig. 3).

Similar pattern was observed for all the sites in which nitrogen (N) release was very rapid in the first four weeks, but this slowed down in the subsequent weeks (Figs. 4a-c). At Njabini, N release was significantly high in bean trash at four weeks followed by maize stover then *Grevillea* prunings was the lowest. At Kabete, the trend was bean trash > *Grevillea* prunings > maize stover for incorporated materials. However, for surface applied materials, N release was lowest in *Grevillea* prunings but highest in bean trash (Figs. 4a-b). For both sites, N release was significantly higher in buried than surface applied materials.

At Machakos, no significant differences between the three organic materials were observed when incorporated, but a significantly higher N release was obtained from the surface applied materials (Fig. 4c). After 16 weeks no significant differences were observed in N release for all the materials at Kabete and Machakos sites (Figs. 4b-c).

Rapid Phosphorus (P) release was observed from all the materials during the first four weeks for all the sites. This however slowed down in the subsequent weeks (Figs. 5a-c).

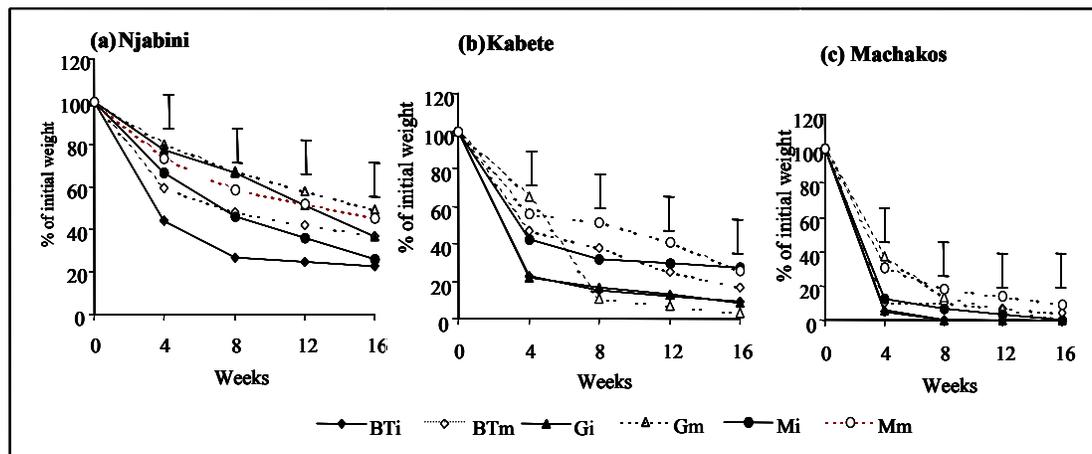


Figure 1. Decomposition patterns of bean trash, *Grevillea robusta* prunings and Maize stover. (BTi=incorporated bean trash; BTm=mulched bean trash; Gi=incorporated *Grevillea* prunings; Gm=mulched *Grevillea* prunings; Mi=incorporated maize stover; Mm=mulched maize stover). Bars represent lsd<sub>0.05</sub>

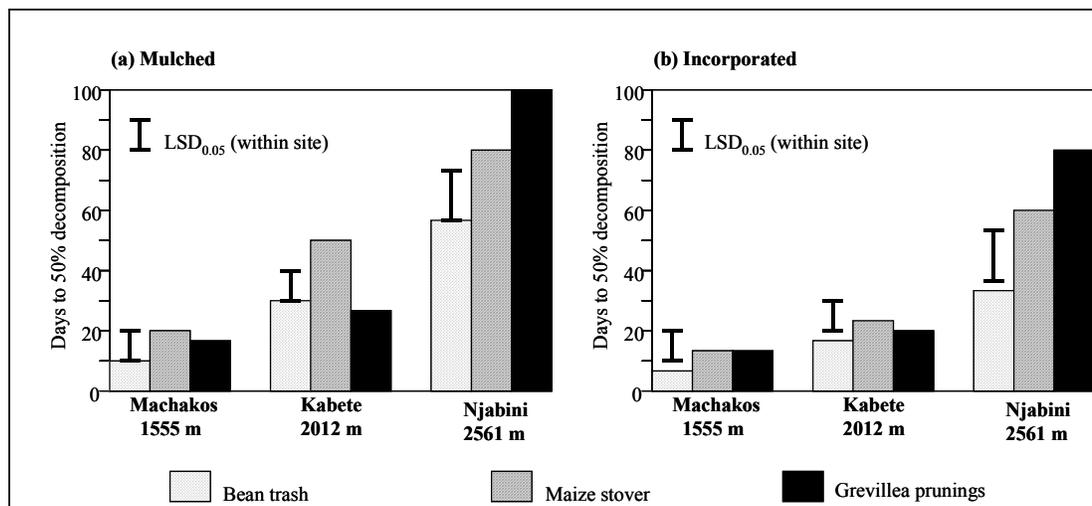


Figure 2. The effect of elevation on decomposition of plant material of different origin.

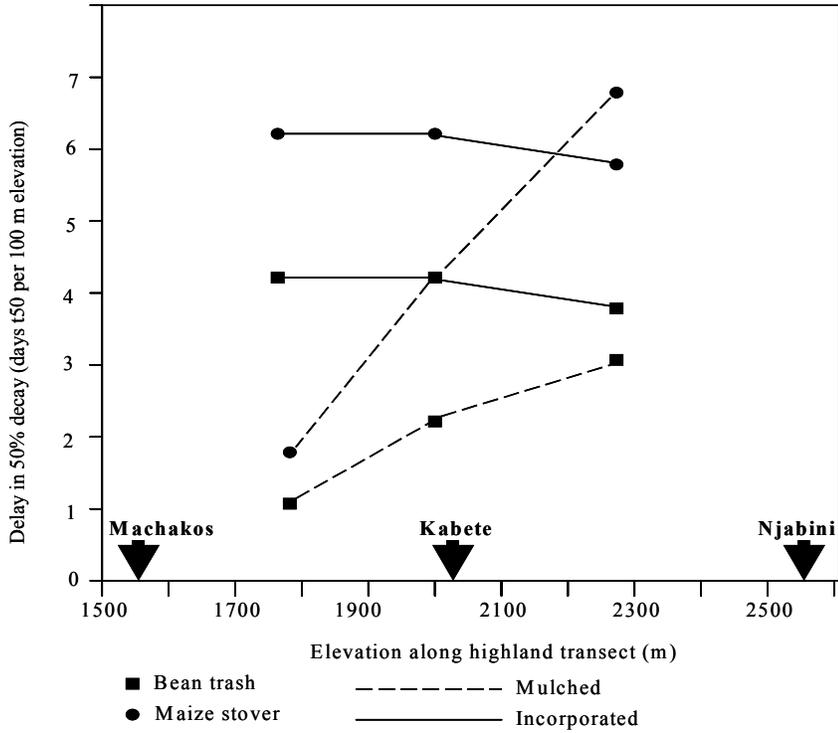


Figure 3. Delay in litter decay due to increase in elevation. Arrows show elevational allocation of the various experimental sites.

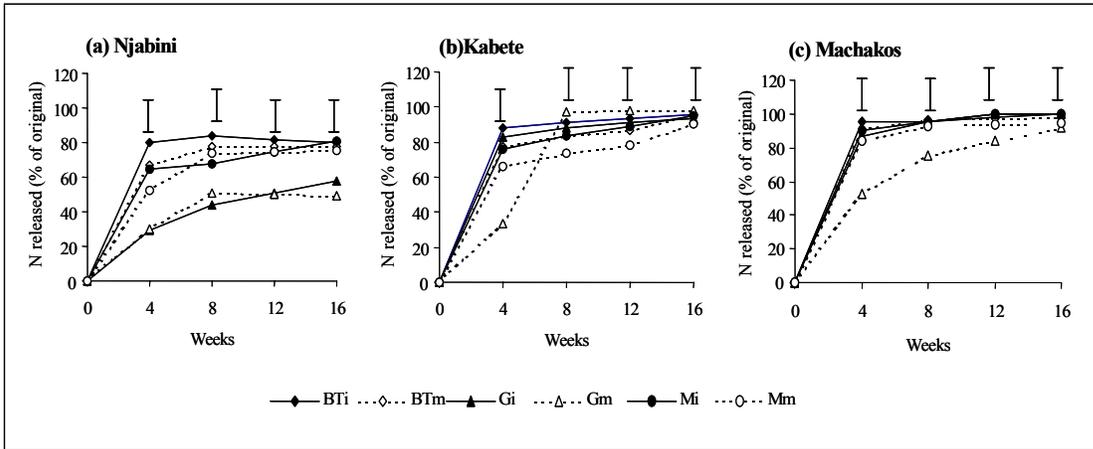


Figure 4. Nitrogen release patterns of bean trash, *Grevillea robusta* prunings and Maize stover. (BTi=incorporated bean trash; BTm=mulched bean trash; Gi=incorporated *Grevillea* prunings; Gm=mulched *Grevillea* prunings; Mi=incorporated maize stover; Mm=mulched maize stover). Bars represent lsd<sub>0.05</sub>

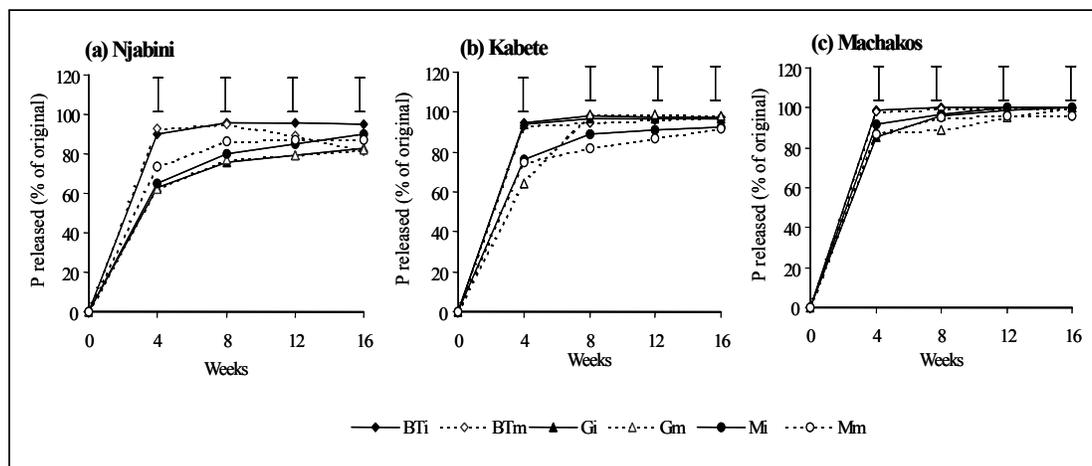


Figure 5. Phosphorus patterns of bean trash, *Grevillea robusta* prunings and Maize stover. (BTi=incorporated bean trash; BTm=mulched bean trash; Gi=incorporated *Grevillea* prunings; Gm=mulched *Grevillea* prunings; Mi=incorporated maize stover; Mm=mulched maize stover). Bars represent  $l_{sd\ 0.05}$

At Njabini, P release proceeded at a significantly higher rate in incorporated bean trash than in either incorporated maize stover or *Grevillea* prunings. P release in surface applied materials was slowest in *Grevillea* prunings followed by maize stover and fastest in bean trash. At Kabete, incorporated bean trash released more P than either *Grevillea* prunings or maize stover. Surface applied bean trash likewise released more P than either surface applied maize stover and *Grevillea* prunings (Fig. 5b). In Machakos, P release was highest for bean trash followed by maize stover, but lowest in *Grevillea* prunings for incorporated materials. P release for surface materials was higher in bean trash than for both *Grevillea* prunings and maize stover (Fig. 5c). No significant differences were observed between surface applied and incorporated for both bean trash and *Grevillea* prunings. However, surface applied maize stover significantly released less P than incorporated maize stover. After 16 weeks, organic materials were not significantly different from each other in the amount of P released into the soil for all the sites (Figs. 5a-c).

#### Effect of soil fauna on decomposition and nutrient release from maize stover and *Senna spectabilis* biomass.

Decomposition was faster in the first four weeks and slowed down in the subsequent weeks (Figs. 6a-d). Faunal contribution to the decomposition processes were significantly higher for incorporated maize stover compared with that applied on the surface such that even the materials in the inserts, decomposed faster than surface applied maize stover.

This observation was true at Njabini, Kabete and Machakos sites. Incorporated maize stover decomposed faster than that applied on the surface

(Figs. 6a-c). Decomposition of *Senna* foliage was higher in the presence of soil fauna (Fig. 6d). After 16 weeks, hardly any materials were recovered in the presence of fauna in contrast to 10% of the materials recovered in the absence of fauna. Nitrogen and phosphorus release were higher upto 4 weeks after which slow trends were observed (Figs. 7a-d and Fig. 8a-d).

At Njabini, Kabete and Machakos, faunal activity had a significant role on the patterns and quantity of nutrient release. Maize inserts recorded significantly lower N and P as compared to the materials held in conventional litterbags (Figs. 7a-c and 8a-c). However, soil fauna showed no significant influence on N and P released for *Senna* foliage (Figs. 7d and 8d).

Microbial biomass C was the highest of the three biomass components ranging from 37 to 190  $\mu\text{m C g}^{-1}$  soil followed by microbial N which ranged from 13 to 74  $\mu\text{m N g}^{-1}$  soil and the lowest was microbial biomass P ranging between 0.2  $\mu\text{m P g}^{-1}$  soil (Fig. 9). No significant differences were observed among the treatments. Soil microbial C and N were significantly lower at Machakos than either Njabini or Machakos in all the treatments (Figure 9a and 9b). Although Njabini recorded higher microbial C and lower microbial N than Kabete, they were nevertheless not significant.

Microbial P was highly variable for all the treatments in all sites. Although Njabini and Kabete recorded significantly higher microbial P in beans, *Grevillea* and maize than Machakos, no significant differences were observed in cattle, poultry and control treatments. Higher microbial P was observed in beans, *Grevillea* but lower microbial P in control, maize and poultry at Njabini than Kabete even though they were not significantly different (Figure 9c).

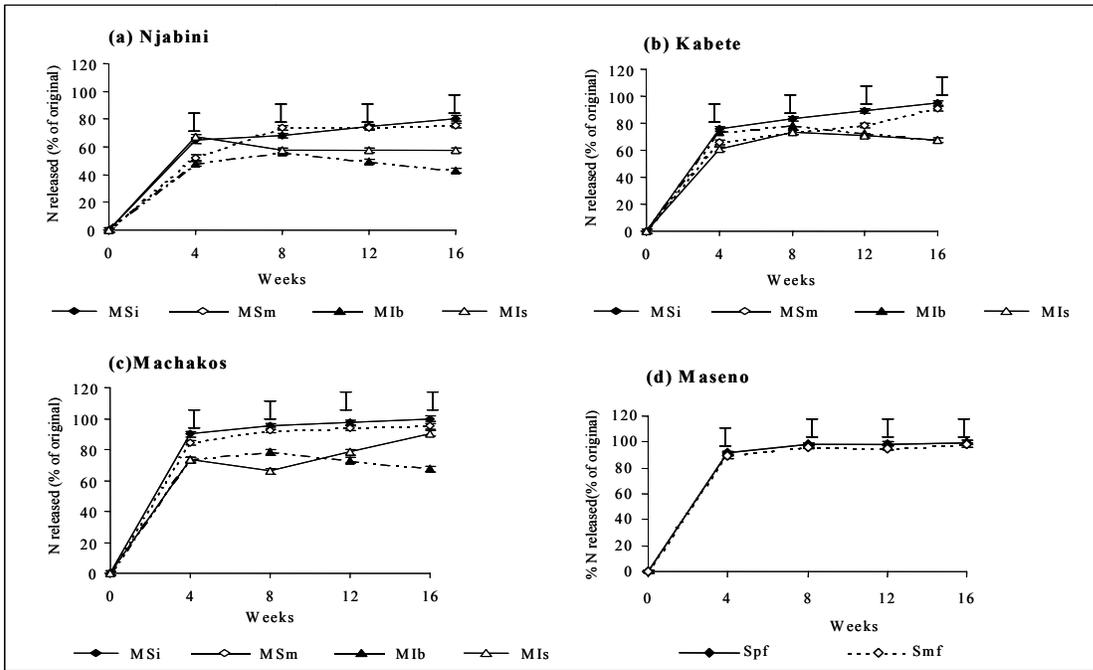


Figure 6. Decomposition patterns of maize stover and *Senna spectabilis* foliage in the presence and absence of soil fauna. (MSi =incorporated maize stover; MSm =mulched maize stover; MIb =buried maize inserts; MIs =surface maize inserts; Spf=*Senna* foliage plus fauna; Smf=*Senna* foliage minus fauna). Bars represent  $Lsd_{0.05}$

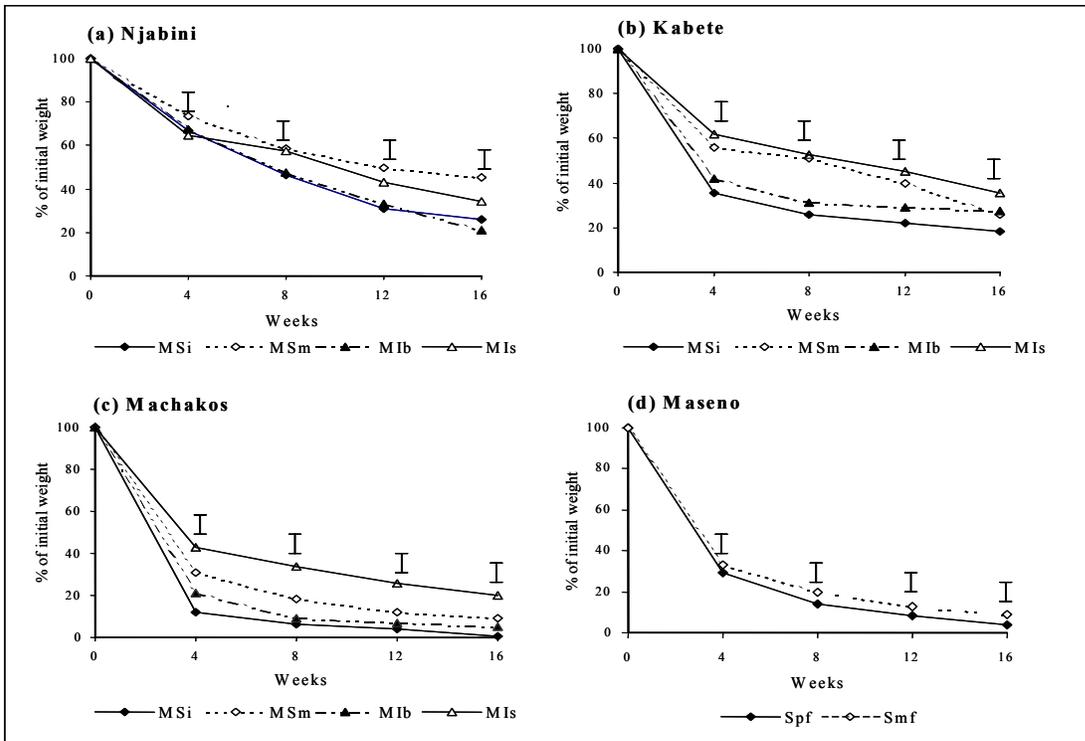


Figure 7. Nitrogen release patterns of maize stover and *Senna spectabilis* foliage in the presence and absence of soil fauna. (MSi =incorporated maize stover; MSm =mulched maize stover; MIb =buried maize inserts; MIs =surface maize inserts; Spf=*Senna* F oliage plus fauna; Smf=*Senna* foliage minus fauna). Bars represent  $Lsd_{0.05}$

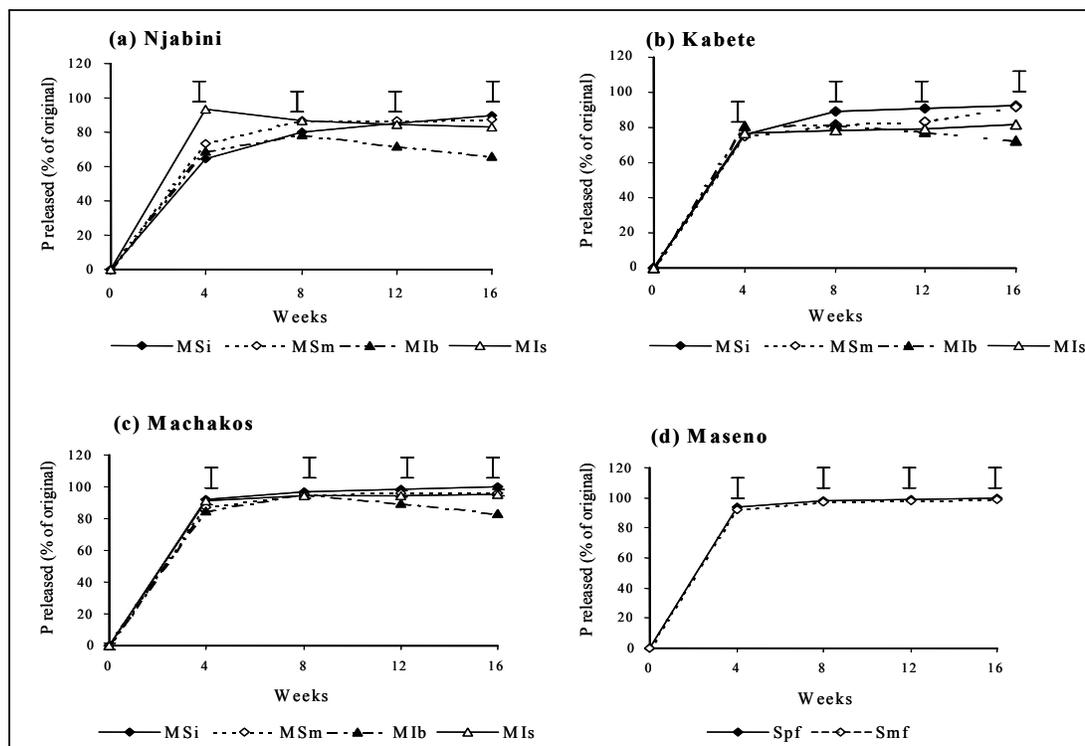


Figure 8. Phosphorus release patterns of maize stover and *Senna spectabilis* foliage in the presence and absence of soil fauna. (MSi =incorporated maize stover; MSm =mulched maize stover; MIb =buried maize inserts; MIs =surface maize inserts; Spf =Senna foliage plus fauna; Smf =Senna foliage minus fauna). Bars represent Lsd<sub>0.05</sub>

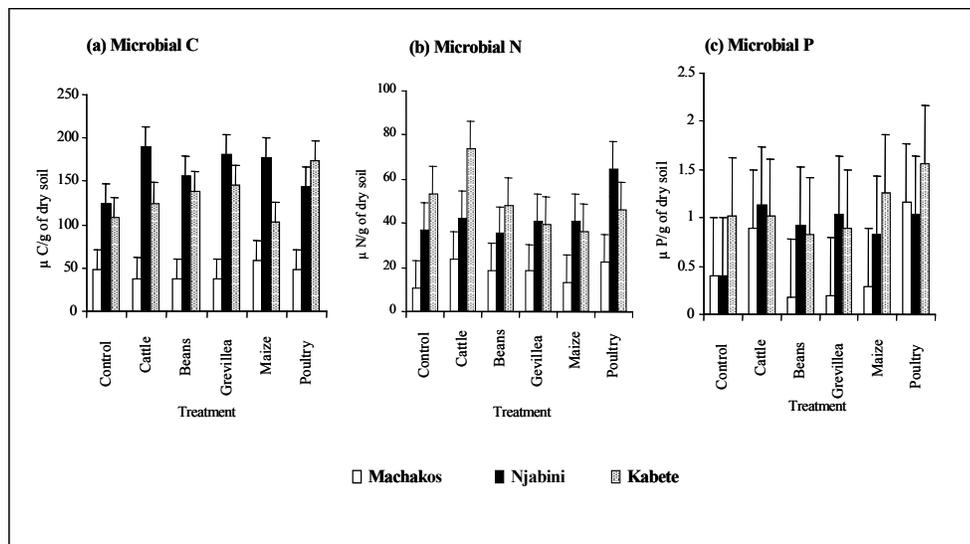


Figure 9. Effect of organic manures on soil microbial biomass. Bar represents standard error of difference of means (SED).

### DISCUSSION

#### Effect of residue quality and placement on decomposition and nutrient release.

Organic resource quality is defined by its organic composition and contents (Mafongoya *et al.*, 1998). The most important chemical factors influencing

decomposition, nutrient release and soil organic matter dynamics are carbon and nitrogen (especially the C: N ratio), lignin and polyphenols (Handayanto *et al.*, 1994; Palm, 1995; Mafongoya *et al.*, 1998). Other factors include the environmental conditions and the decomposer organisms (Trofyman *et al.*, 1995; Swift, 1995). Many researchers have developed predictors or indices of mass loss and nutrient release (White and Ayoub, 1983; Vogt *et al.*, 1986 cited by Myers *et al.*,

1994; Fox *et al.*, 1990; Palm and Sanchez, 1991; Tian *et al.*, 1992a,b; Hadayanto *et al.*, 1994; Tial *et al.*, 1995; Mafongoya *et al.*, 1998). Among the plant indices that were shown to be effective in determining the rate of decomposition and nutrient release include C:P, N:P, C:N, PP:N, L:N and (L+PP):N. However, their application depends on the time frame under consideration and the type of material (Palm, 1995; Mafongoya *et al.*, 1998).

In our study, lignin content, C:N, C:P, N:P and (L+PP):N indices seem to be the best predictors of the rate of decomposition and nutrient release from the organic materials. Lignin negatively influenced the rate of decomposition. The role of lignin as a regulator in the decomposition can be attributed to the fact it is a recalcitrant compound that is highly resistant to microbial decomposition (Melillo *et al.*, 1982). It may also slow down N mineralization due to lignin-bound proteins. The 24% lignin concentration of *Grevillea* prunings was higher than the 15% critical level given by Palm, (1995) and Mafongoya *et al.*, (1998). This may explain partly, why *Grevillea* prunings decomposed and mineralized at a relatively slower pace compared to bean trash and maize stover. The influence of lignin on decomposition is widely reported in literature (Melillo *et al.*, 1982; Fox *et al.*, 1990; Palm and Sanchez, 1991; Oglesby and Fownes, 1992; Tian *et al.*, 1992a). Whereas polyphenol content alone was not a strong predictor of decomposition rate and N release, polyphenol-derived variable: (L+PP):N was an important predictor of N release. In this study (L+PP):N ratio was observed to influence N release. (L+PP):N ratios of *Grevillea* prunings (13%) and maize stover (20%) were higher than the 10% critical level given by Mafongoya *et al.*, (1998), hence they mineralized and released N at a relatively slower pace compared to bean trash. These observations corroborate the work of Fox *et al.*, (1990); Melillo *et al.*, (1982); Mafongoya *et al.*, (1998) in which this ratio was found to be the best index that predicted N release from plant materials. According to Handayanto *et al.*, (1994), it is not necessarily the quantity of polyphenols that is important in decomposition, but the types of polyphenolic compounds. They alluded that some condensed tannins are soluble in polar extracts while others are insoluble hence bind to proteins or cell walls. The soluble condensed tannins and the hydrolysable tannins are likely to react with nitrogen and amino groups in the plant or soil solution to form polymers thus reducing N release (Azhar *et al.*, 1986). It has been reported that P release occurs when C:P ratios of residues are lower than the critical value of 123:1 (White and Ayoub, 1983) or when N:P ratios are lower than 10 (Vogt *et al.*, 1986 cited by Myers *et al.*, 1994). This probably explains why maize stover with C:P and N:P ratios of 1100 and 12 respectively, mineralized and released P at a relatively slower pace than bean trash and *Grevillea* prunings.

It was observed that organic materials incorporated into the soil decomposed and released nutrients faster than surface applied materials. Similar results on placement effect on litter decay were reported by Wilson and Hargrove, (1986); Wilson *et al.*, (1986); Kaufusi and Asghar, (1990) who found that surface organic residues decomposed slowly than incorporated residues. Incorporation of organic materials into the soil enhances accessibility to faunal attack and the microbial organisms, which are responsible for decomposition, and mineralization processes. The reduced rates of decomposition and nutrient release of surface applied materials could be attributed to a combination of factors such as poor contact of the residues with soil and marked temperature and moisture fluctuations at the soil surface (Wilson *et al.*, 1986).

The effects of changes in elevation on litter decay were not identified but distribution and population of soil fauna and the buffering capacity of temperatures with depth may have been some of the mechanisms involved. It is generally known that, rates of litter decay, mineralization and soil respiration increase exponentially with soil temperature over a range of 10-30°C (Foster, 1989). Surface temperatures in the lower midlands (Machakos) could reach to more than 20-30°C in the upper few centimeters when the air temperatures are high, especially during hot/dry months. Litter decomposition is similar to that of soil respiration, which has a maximum of 30°C and declines at soil temperatures above 40°C (Scholes *et al.*, 1994). Thus, the optimum temperature for soil and litter respiration (decay) was most likely related to the mean maximum temperatures experienced in a given site thus the observed delay in decay at different elevations could be due to the differences in mean air temperatures. The delay in litter decay at higher elevations for surface mulch imply that, farmers in the high elevations would benefit more by incorporating organic residues before planting while at low elevations post emergence surface applications would lead to improved nutrient availability.

#### **Effect of soil fauna on decomposition and nutrient release.**

Soil fauna can enhance soil organic matter decomposition and nutrient release, and hence ameliorate soil physical properties (Verhoef and Brussaard, 1990). Results of this study showed that soil fauna significantly contributed to the rate of decomposition and nutrient release in both maize stover and *Senna* foliage. Their contribution accounted for an estimated 15 to 20%. However, this was lower than the level reported by Hunt *et al.*, (1987); and Verhoef and Brussaard, (1990) who estimated it to be between 30% and 40%. The slow rate of decomposition observed in maize stover and *Senna*

could be due to low polyphenols and lignin meaning that the materials are low in quality. Similar results indicating that soil fauna play a significant role in the decomposition of organic residues have been reported by Wright and Coleman, (1988); Jones, (1990); Tian *et al.*, (1995). Several investigators have reported reduced mass loss of litter when soil fauna were sterilized or eliminated using biocides such as aldrin (Wright and Coleman, 1988; Jones, 1990). The role of soil fauna in the decomposition processes is recognized, particularly for low quality organic residues such as maize stover and *Senna* whereby macro-fauna increase the surface area of the organic materials before stimulating the activities of decomposer food web (meso- and microfauna communities).

Fauna had no significant influence on nutrient release patterns of *Senna* possibly due to the secondary compounds present in *Senna*, which were lower than the critical levels given by Palm *et al.*, (1997). Besides, nutrient release being a mineralization process it is mainly controlled by microorganisms hence macrofauna did not play a significant role. Nevertheless, practices that eliminate beneficial soil faunal communities are unlikely to contribute to the sustainable production in the long term, especially in low-input systems where low quality residues such as grass, maize stover, bean trash are the only organic materials that remain on the surface of the plots.

#### **Effect of organic amendments on soil microbial biomass.**

Results indicate that soil microbial biomasses (C, N and P) were positively correlated to site and the microbial biomass was not responsive to addition of animal manures. In Njabini and Kabete, a significantly higher microbial biomass count than Machakos were recorded possibly due to influences other than organic residue input. It is suggested that seasonal changes in moisture, soil temperature and C input from crop roots, rhizosphere products and organic residues do influence soil microbial biomass and the activity of microorganisms (Ross, 1987), which in turn influences supply of nutrients to plants through soil organic matter turnover (Bonde and Roswall, 1987).

Soil microbial biomass, living part of soil organic matter, is an agent of transformation of added and native organic residues and acts as labile reservoir for plant-available N, P and S (Jenkinson and Ladd, 1981). Singh *et al.*, (1989) have reported seasonal changes in the microbial C, N and P in forests and savanna ecosystems. Soil organic carbon levels, too, have been reported to be governed by climatic conditions. The soils at Kabete and Njabini are higher in organic C, total N, but being at higher altitudes the

temperatures are lower than in Machakos. The differences may have contributed to higher microbial biomass obtained in these two sites. However, further studies are needed to understand how these parameters individually influence soil microbial biomass, and how they can be integrated and used for predictive purposes.

#### **CONCLUSION**

The study indicates that: (i) the best predictors of decomposition and nutrient release patterns of the organic materials include: lignin contents, (L+PP):N, C:P and N:P ratios, (ii) farmers in the high elevations would benefit more by incorporating organic residues before planting while at low elevations post emergence surface applications would lead to improved nutrient availability, (iii) soil fauna enhanced disappearance of organic residues, although their role in influencing nutrient release to crops from the organic residues may depend on the nature of the material.

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