DECOMPOSITION AND MINERALIZATION OF SELECTED LEGUMINOUS TREE SPECIES LEAF LITTERS AND THEIR IMPACT ON SOIL NUTRIENTS

[1]DAHUNSI O. M., [2]OLUJOBI O. J., [3]ERHABOR T. A. and [4]BABA G. O.
[1&3]Department of Forestry and Environmental Technology, Federal College of Forestry Jos.
[2]Department of Forestry Resources Management, Ekiti State University, Ado Ekiti.
[4]Savana Forestry Research Station Samaru, Zaria

Abstract
The condition of a site is a function of processes acting upon it. This affect both the physical, chemical and biological attributes. Four leguminous tree species P. biglobosa, L. leucocephala, T. indica, and A. lebbeck leguminous were used. Degraded soil samples were collected. Both the soil and leaf litter were air-dried. Routine soil analysis was carried out. For the decomposition experiment, 120g of leaf litter from the four (4) selected species were put inside the litter bags and buried in the soil inside the cement bags. Results on decomposition and chemical properties showed that T. indica has the highest value. L. leucocephala significantly ($p<0.05$) improved the clay and silt contents of the soil. The study revealed that T. indica and L. leucocephala litter were high-quality litters that decomposed very rapidly to release a considerable amount of nutrients within a short period of time. Hence, they are recommended for quick nutrient restoration.

Key word: Decomposition, Mineralization and Soil Nutrient Restoration

Introduction

Natural resource extraction can irrevocably change a landscape and its inherent functions. Mitigating the loss of such an area requires actions that may have complex effects on the site and its surrounding. A site's condition is a function of processes acting upon its physical, chemical, biological and social attributes. A site can originate and facilitate the continuance of processes, such as hydrology or species composition. Hence, every action taken on a site can affect both plant and animal components and their level of interaction on a large scale, which may eventually lead to land degradation (Aide *et al.,* 2000). Agricultural productivity and human welfare in tropical Africa increasingly view land degradation and declining soil fertility as critical problems. It is estimated that an average of 660 kg of nitrogen (N) ha^{-1}, 75 kg of phosphorus (P) ha^{-1} and 450 kg of potassium (K) ha^{-1} have been lost during the last 30 years from around 200 million ha of cultivated land in 37 countries in sub-Saharan Africa due to continuous cropping and geometric increase in population (Chamberlin *et al.*, 2001). Fertilizer application is one of the methods commonly used to correct nutrient depletion and increase crop yield in sub-Saharan Africa (Dudal, 2002). However, most farmers cannot afford the cost or have limited access to it. In addition, fertilizer application alone cannot guarantee sustainable long-term productivity on many soils. In the long term, population pressure dictates that efficient, high-input systems must be developed (Rowe *et al*., 2009). Hence, organic material inputs are needed to maintain soil organic matter levels (Usman & Kundiri, 2016). In this respect, the role of agroforestry-based alternatives in improving soil quality and at the same time providing other multipurpose benefits (*e.g*. timber, fuelwood, fodder, fruits, and carbon sequestration) has long been recognized (Nebiyou & Menamo, 2016). The main objective of this study is to investigate the rate of decomposition and mineralization of selected leguminous tree species leaf litter and to evaluate the effect of selected leguminous tree species leaf litter on the physical and chemical properties of the sampled soil. It is accepted that degraded land requires the return to a viable use. It is not sufficient to simply physically reclaim degraded lands as the ecological, physico-chemical, microbiological and micro-climatic impacts of the land must also be assessed and managed. The reclaimed land can be used for farming to combat the food insecurity challenge due to limited arable land. It can also restore degraded ecosystems, such as converting former mining or waste disposal sites into usable land. The present study, therefore, seeks to evaluate the effectiveness of selected multipurpose legume tree fallows on soil nutrient restoration for sustainable agricultural production and some other industrial uses in the near future.

Materials and Methods

The study area

The study was carried out in the Teaching and Research Nursery of the Department of Forestry and Environmental Technology, Federal College of Forestry, Jos, Plateau State. Jos lies between latitude 9^o 54'N and 10^o 10'N and longitude 8^o 48'E and 9^o 30'E in the southern limit of the Guinea Savannah ecological zone. The soil is sandy, ranging from light to dark in colour. It's well-drained and well aerated. Annual rainfall is about 1460 – 4800 mm. The temperature ranges from 10°C to 32°C with an altitude of 1220 m above sea level (University of Jos Metrological Station Directory, 2009).

Research Method

Soil analysis

Routine analysis was carried out on the collected soil sample on the following soil properties (Soil particle size distributions, pH, Organic carbon, Nitrogen, Phosphorus, Potassium, Exchangeable acidity, Cation Exchange Capacity and Base saturation). The physical properties of the experimental soil were also determined. This was done in the soil laboratory at the Institute of Agricultural Research of Ahmadu Bello University, Zaria.

Degraded soil samples were collected from an old mining site in Jos metropolis. Leaf litter of *Parkia biglobosa*, *Leucaena leucocephala, Tamarindus indica,* and *Albizia lebbeck* leguminous trees was collected from the farmer's farm. Both the soil and leaf litter were air-dried at the screen house of the Federal College of Forestry, Jos.

Decomposition and nutrient release of leaf litter

20kg of the soil sample from degraded land were put inside used cement bags. One hundred and twenty grams (120 g) of leaf litter from the selected multipurpose trees was put inside the litter bag and inserted into the soil inside the cement bags. The treatments were replicated five times to allow for periodic sampling. The treatments were well watered in the morning at two-day intervals and left for decomposition. Using this formula, the percentage of litter mass remaining for each species was determined at 30, 45, 60, 75, and 105 days.

Mass remaining (%) = DM_t / DM_0 x 100 .... (Hossain *et al.*, 2011)

Where DM_t is the mass of litter after incubation and DM_0 is the initial mass of litter before incubation. Soil samples were collected for analysis to determine nutrient gains at 30, 45, 60, 75, and 105 days, respectively.

Data Analysis

Data obtained from the experiments were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS, version 9.0). Separation of means among treatments was done using the Duncan multiple range test (DMRT) at 5% level of probability.

Results

Soil

Table 1 presents the results of the chemical and physical properties of the degraded soil in the study site. The result shows that the soil is slightly alkaline (7.40) with low nitrogen and potassium contents (0.32% and 0.61 cmol.kg^{-1}) respectively. The soil textural class is sandy loam.

Table 1: Chemical and physical properties of the degraded soil in the study site

Soil pH	(%)			Bray-1 avail p (mg.kg^{-1})	Exchangeable macro nutrient (cmol.kg^{-1})				Exch Acidity	Particle size distribution			texture (USDA)
	O.C	O.M	N		K	Na	Ca	Mg		(%) Clay	(%) Slit	(%) Sand	
7.40	1.59	2.74	0.32	22.64	0.61	0.36	6.80	1.84	0.40	3	20	71	Sandy loam

Litter decomposition of the tested species during the experimental period

Table 2 indicated that *Tamarindus indica* decomposed faster than other species throughout the experimental period, with all 120g of the biomass decomposing after 105 days. During the first 30 days of the experiment, *Albizia lebbeck* showed no decomposition. The results showed that the mass of litter remaining ranged from 100g in *Tamarindus indica* to 120g in *Albizia lebbeck* during the first 30 days. After 105 days, the amount of *Tamarindus indica* litter mass remaining was 0 g compared to *Albizia lebeck,* which had 81 g of undecomposed litter (Figure 1). The results showed that 100% of *Tamarindus indica* litter decomposed at the end of 105 days, followed by *Leucaena leucocephala* (85.83%) and *Parkia biglobosa* (52.50%), and the least was *Albizia lebbeck* (32.5%) (Figure 2).

Table 2: Mass of litter decomposed (g)

Tree species	30days	45days	60days	75days	90days	105days
Albizia lebbeck	0.00^{d}	20.0^{d}	34.0^{d}	29.0^{d}	36.0^{d}	39.0^{d}
Leucaena leucocephala	10.0^{b}	38.0^{b}	53.0^{b}	60.0^{b}	102.0^{b}	103.0^{b}
Parkia biglobosa	5.0^{c}	30.0^{c}	23.0^{c}	34.0^{c}	62.0^{c}	63.0^{c}
Tamarindus indica	20.0^{a}	80.0^{a}	95.0^{a}	117.5^{a}	118.2^{a}	120.0^{a}
SE+	0.055	0.226	0.280	0.297	0.413	0.420

Means followed by the same letter(s) within the same column are not significantly different at a $p \leq 0.05$ level of probability using DMRT.

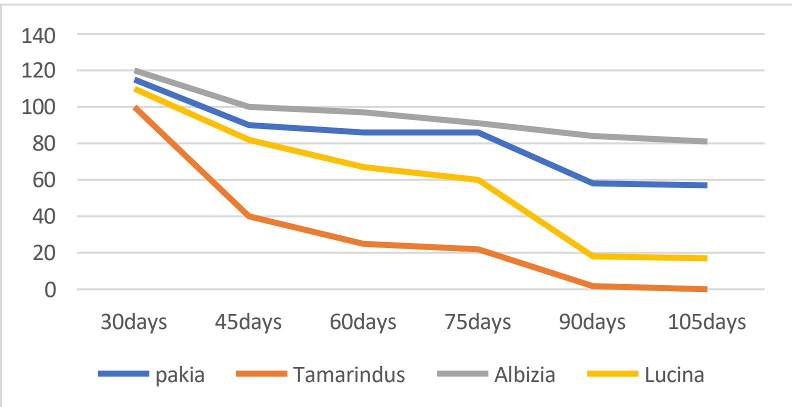

Figure 1: Mass of litter remaining in the litter bag during the decomposition period

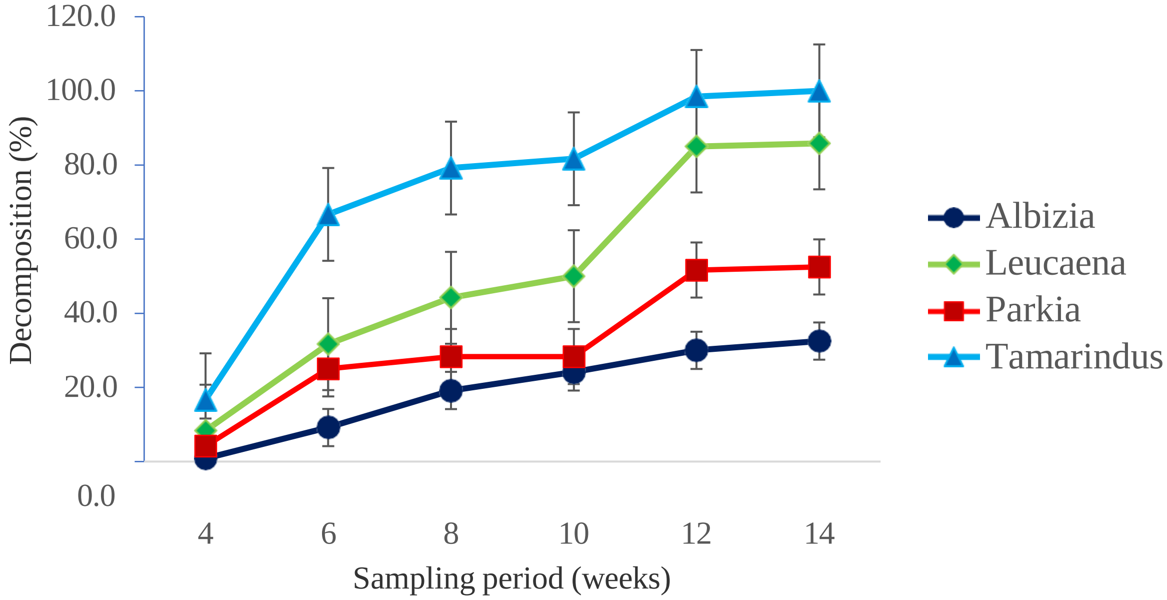

Figure 2: Litter decomposed during the experiment (%)

Effect of leaf litter of leguminous tree species on soil chemical properties

The effect of leaf litter of leguminous tree species on soil chemical properties presented in Table 3 showed that there was a significant difference ($p<0.05$) in the effect of leaf litter of each of the leguminous tree species (*Albizia lebbeck*, *Leucaenia leucocephala, Parkia biglobosa* and *Tamarindus indica*) on soil organic matter over the experimental period (14 weeks). Soil with *Tamarindus indica* litter application has the highest value of organic matter (3.10%) at 14 weeks, followed by Pakia (7.74%), Leucaena (2.62%) and Albizia (1.48%), respectively. Results on soil organic carbon showed that Tamarindus-treated soil had the highest values throughout the experimental period, with the following values: 1.92%, 1.71%, 1.67%, 1.90%, 1.88% and 1.80% at 4, 6, 8, 10, 12 and 14 weeks respectively.

The results revealed that Tamarindus litter released a significantly ($p<0.05$) higher amount of nitrogen to the soil throughout the experimental period. The results also showed that phosphorus values in the soil samples containing *T. indica* leaf litter at the early stage of the experiment (4 and 6 weeks) were significantly ($p<0.05$) higher (52.5 mg kg^{-1} and 59.7 mg kg^{-1}) than in the soil containing leaf litter of other species. The result also revealed that at the 12^{th} and 14^{th} weeks of the experiment, the soil sample containing *T. indica* had the highest phosphorus values (48.5 mg kg^{-1} and 45.6 mg kg^{-1}, respectively.

It was also revealed that the litter of the tested species significantly ($p \leq 0.05$) reduced the pH value of the soil compared to the control throughout the experimental period. The result also showed that the exchangeable acidity of the soil increases with the addition of leguminous leaf litter compared to the control throughout the experimental period. The results showed significant differences ($p<0.05$) in exchangeable cations obtained from the application of leguminous tree species litter compared to the control during the experimental period, with the highest values of Ca (12.60 cmol kg^{-1}) and Mg (3.40 cmol kg^{-1}) being obtained in Leucaena treatment at 4 weeks after application. The results also showed a decreasing trend in the values of Ca and Mg with 7.20 cmol kg^{-1} and 1.94 cmol kg^{-1}, respectively, for Albizia treatment at 14 weeks after application. It was also revealed that higher values for Na and K in soil with leguminous leaf litter compared to the control during the experimental period, with Tamarindus treatment soil having the highest Na and K values of 0.47 cmol kg^{-1} and 0,67 cmol kg^{-1}, respectively, at 14 weeks after application.

Table 3: Effect of multipurpose tree legumes on chemical properties of degraded soil under fallow at 14 weeks

Treatment	Organic matter (O.M)	Organic carbon (O.C)	Nitrogen (N)	Available phosphorus (P)	Soil PH	Exchangeable acidity	Calcium (Ca)	Sodium (Na)	Potassium (k)	Silt
Albizia lebbeck	1.48^{d}	1.48^{d}	0.13^{c}	41.00^{b}	6.30^{b}	0.60^{a}	7.20^{d}	0.35^{b}	0.62^{d}	12.00^{a}
Leucaena leucociphala	2.62^{c}	1.32^{c}	0.30^{c}	39.80^{c}	6.60^{b}	0.60^{a}	8.40^{c}	0.42^{b}	0.65^{a}	10.00^{b}
Parkia biglobosa	7.74^{b}	1.59^{b}	0.33^{b}	32.00^{d}	6.50^{b}	0.60^{a}	9.40^{a}	0.45^{a}	0.69^{a}	10.00^{b}
Tarmarindu s indica	3.10^{a}	1.80^{a}	0.34^{a}	45.60^{a}	6.60^{a}	0.60^{a}	8.60^{b}	0.47^{a}	0.67^{b}	$10,00^{b}$
Control	1.74^{e}	1.09^{e}	0.24^{d}	22.60^{c}	7.40^{c}	0.40^{b}	6.80^{c}	0.36^{c}	$0,61^{c}$	9.0^{c}

Means followed with the same alphabet(s) within the same column are not different statistically at *P=0.05* level of probability using DMRT.

Discussion

This study revealed significant variation in the decomposition rates in the litters of the tested tree species. The observed variation in the rate of decomposition of the sampled litters could be attributed to litter quality rather than climatic and environmental factors since all the treatments were subjected to the same conditions. This assertion aligns with Bradford *et al.* (2016), who affirmed that litter quality plays a more direct role in determining decomposition rates. Since both the morphological characteristics of *Albizia lebeck* foliage and *Parkia biglobosa* were tougher and larger, they were unable to decompose fast due to their large surface area and probably high lignin contents, unlike *Tamarindus indica and* Leucaena *leucocephala* with smaller and succulent foliage. Wassie *et al.* (2013) have previously reported a similar observation. The high organic matter and organic carbon in *Leucaena leucocephala* and *Parkia biglobosa* indicate their superior ability to contribute to soil organic content, which is important for soil fertility, structure, and the general function of the ecosystem. Soil organic matter controls many soil properties, including infiltration rate, bulk density, aggregate stability, cation exchange capacity, nitrogen availability, and a number of soil quality parameters (Patiram, 2003).

The total nitrogen recorded from the sampled soil during the experimental periods varies. *Leucaena leucocephala* had the highest nitrogen content, followed by *Tamarindus indica*. *Albizia lebbeck* had a moderate nitrogen value, while *Parkia biglobosa* had the lowest nitrogen content. Since nitrogen is essential for plant growth, *Leucaena leucocephala* and *Tamarind indica* are the most beneficial for improving soil fertility. This finding was in agreement with Paudel *et al.* (2015), which states that the decomposition of organic matter and N mineralization will decline as the concentration of lignin increases or the N content decreases. Nutrients accumulated in leaves return to the ecosystem through litterfall, and this process is the most important component of the forest ecosystem; it is a major pathway of nutrient and energy transfer, as stated by Shukla (2009).

The leaf litter has an impact on both soil pH and the exchangeable acidity. These results suggest that the properties of litter in a given forest could fundamentally influence the soil pH and, consequently, the nutrient mobility. This was in agreement with the report of Kabata-Pendias, (2011). It explains that lower pH (acidic soil) generally increases the solubility and mobility of many trace elements, which determine their translocation in plants. It has also been established that with increasing soil pH, the solubility of most trace elements will decrease, leading to low concentrations in soil solution. The amount of Ca and Mg obtained during sampling periods varies in those same periods. The variations were primarily due to leaf quality and thus decomposition processes. This explanation was supported by observations in an alpine forest where the nutrient loss from deciduous leaves was twice that from evergreen leaves after 360 days of decomposition (Liu *et al*., 2016). There were significant effects of leaf litter from leguminous tree species on the particle size distribution of the experimental soil. The soil aggregates are paramount in the restoration of the soil structure from destructive forces. Structural stability increases with increasing organic matter content, which in turn is correlated with increased biotic activity.

Conclusion and Recommendation

The study revealed that *Leucaena leucocephala* litter had the significantly highest value ($p \leq 0.05$) for all variables in terms of chemical composition, organic carbon (18.35%), organic matter (31.64%) and nitrogen content (0.53%). Indicating its superior ability to improve soil fertility. Albizia had a moderate nitrogen value

(0.34%), while Parkia had the lowest nitrogen content (0.21%). Since nitrogen is essential for plant growth, Leucaena and Tamarindus are the most beneficial for improving soil fertility. The soil pH values recorded during the periods range between 6.40 and 7.40, while the exchangeable acidity ranges between 0.40 and 0.60 cmol/kg. These results suggest that the properties of litter in a given forest could fundamentally influence the soil pH and, consequently, the nutrient mobility. Leucaena showed the highest clay content across the weeks, while the silt was highest in Tamarindus (22–23%). Combating land degradation and restoring degraded land are urgent priorities to protect the biodiversity and ecosystem services vital to all life on Earth and to ensure human well-being; sustainable institutional policy and governance responses to address the ultimate causes of land degradation need to be enforced. This approach is essential for effective management of land resources in ensuring sustainable food and agricultural practices.

References

Aide, T. M., Zimmerman, J. K., Pascarella, J. B., Rivera, L. & Marcano-Vega, H. (2000). Forest regeneration in a chronosequence of tropical abandoned pastures: Implications for restoration ecology. *Restoration Ecology*, *8*, 328-338, 1-11.

Bradford, M. A., Berq, B., Magnard, D. S., Wielder, W. R., & Wood, S. A. (2016). Understanding the dominant controls on litter decomposition. *Journal of Ecology*, *104*(1), 1-4.

Chamberlin, J., Jayne, T. S., & Snapp, S. (2021). The role of active soil carbon in influencing the profitability of fertilizer use: Empirical evidence from smallholder maize plots in Tanzania.

Dudal, R. (2002). Forty Years of Soil Fertility Work in Sub-Saharan Africa. In: B. Vanlauwe, J. Diels, N., Sanginga & R. Merckx (Eds.). *Integrated Plant Nutrient Management in Sub-Saharan Africa: From Concept to Practice*, CAB International, Wallingford, UK, 7-21.

Kabata-Pendias, A. (2011). Trace elements in soils and plants (4th ed) CRC Press, Taylor and Francis Group.

Liu, C., Liu, Y., Guo, K. E., Zhao, H., Qiao, X., Wang, S., & Cai, X. (2016). Mixing litter from deciduous and evergreen trees enhances decomposition in a subtropical karst forest in southwestern China. *Soil Biology and Biochemistry*, *101*, 44–54.

Nebiyou, M., & Muluneh, M., (2016). The role of agroforestry for rehabilitation of degraded soil. *Journal of Biology, Agriculture and Healthcare*, *6*(5), 128 - 135.

Patiram, (2003). Environmentally sustainable hill agriculture for soil and water conservation in north-eastern hills region. *Indian J. Hill Agric., 15*, 1-9.

Paudel, E., Dossa, G. O., Philip, B., Jianchu, X. U., & Rhett D. H. (2015). Quantifying factors affecting leaf litter decomposition across a tropical forest disturbance gradient. *Journal of Ecosphere*, *6*(12), 267.

Rowe, R. L., Street, N. R., & Taylor, G. (2009). Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. *Renewable and Sustainable Energy Reviews*, *13*, 271–290.

Shukla, P. K. (2009). Nutrient dynamics of teak plantations and their impact on soil productivity Nitrogen and phosphorus release in a forest ecosystem. *Open J. Soil Sci*. 01

Usman, S., & Burt, P. J. (2013). Preliminary experimental assessment of 12 different organic materials for soil quality and soil fertility management exercises. *Int. J. Cur. Res. Rev. 5*(6), 7-15.

Wassie, A., Haile, M., & Abay, F. (2013). Potential of local plant species for ecological restoration and soil fertility improvement in northern Ethiopia. *Journal of Dry Land*, *6*(2), 95-105.