APPLICATION OF MULTIVARIATE PRINCIPAL COMPONENT ANALYSIS FOR CHARACTERIZATION OF LEAF LITTERS IN NORTHERN NIGERIA

ABSTRACT

This study was to objectively describe the interrelationship between mass loss and leaf chemical parameters of litter species: *Khaya senegalensis*, *Mangifera indica*, *Gmelina arborea*, and *Eucalyptus camaldulensis* using principal component analysis. Leaf litters were analyzed for chemical compositions. Mass loss and ten litter chemical parameters such as organic carbon, total nitrogen, total phosphorus, potassium, magnesium, calcium, sodium, total soluble polyphenol, total sulphur and carbon to nitrogen ratio were investigated. Principal Component Analysis (PCA) was used to identify the variation of litter chemical properties. The results showed significant relationships between mass loss and litter chemical parameters in PC_1 and PC_2 axes. *Khaya senegalensis* has the highest loadings 84% followed by *Gmelina arborea* 77%, *Eucalyptus camaldulensis* 75.3% and *Mangifera indica* 64.5%. In conclusion, *Khaya senegalensis* showed a propensity to have a faster response in driving biogeochemical cycling during decomposition.

Key words: Leaf litter, Chemical composition, Mass loss, Decomposition

Introduction

Litter mass loss or decay is the sum of carbon dioxide, CO_2, release and discharge of compounds, which contains both carbon compounds and nutrients [4]. According to [25], the breakdown of leaf litter is an important part of the global biogeochemical cycles that affect soil carbon storage, nutrient availability, and plant production. Designing agroforestry systems for soil conservation and improvement requires an evaluation of the quality of the litter and the rate of leaf biomass breakdown [19], [23]. The management of chemical element and compound levels in agroforestry systems is once again emphasized [27], [25]. Many studies concluded that the rate of leaf litter decomposition depended on tree species, the chemical composition of the leaves, and environmental factors such as temperature and soil moisture [2], [26].

A multivariate technique called principal component analysis (PCA) can be used to reduce the dimensionality of such datasets, improving their interpretability while minimizing information loss [22], [11]. It accomplishes this by producing fresh, uncorrelated variables that maximize variance one after the other. As a result, PCA is an adaptive data analysis technique [28]. Finding such new variables, the principal components, reduces to solving an eigenvalue/eigenvector issue, and the new variables are specified by the dataset at hand, not a priori. Many researchers have used the independent factor scores derived from multivariate technique of principal component factor analysis to soil and leaf litter properties [19], [15], [12]. The modelling component of leaf litter decomposition is widely reported in scientific literatures [3], [21]. In Sub-Saharan Africa, there is dearth of information on the interrelationships among mass loss and litter chemistry traits of leaf litters using a multivariate approach. Understanding leaf litter decomposition dynamics is imperative owing to nutrient release rates and synchronization. The overarching aim is to use principal components analysis to account for interrelationship between mass loss and chemical parameters of leaf litters in Northern Nigeria.

MATERIAL AND METHODS

Experimental Site and Climatic Conditions

The study was carried out at Institute for Agricultural Research, Ahmadu Bello University, Zaria, Kaduna State, Northern Guinea Savannah zone of Nigeria field (IAR plot R14). The experimental area in Samaru has a geo reference: 10º10' 0" N and 70º37' 60"E and 688 m a.s.l. [8]. This region is characterized by two distinct seasons: the dry season comprising the cold dry period also known as the harmattan, November-December and the hot dry period between April-June as well as a warm rainy season between July-September with rainfall of about 1060mm annually. October and March constitute traditional months between rainy and cold dry season and between hot dry period and rainy season. Warm conditions and high relative humidity prevail during rainy season. The region is characterized by a lot of leaf falls during the dry season and very high temperatures which affect plant growth and developmental process [9].

Collection and Processing of Leaf Samples

Fall leaves of African mahogany, *Khaya senegalensis*; mango, *Mangifera indica*; Beech wood, *Gmelina arborea*; and river red gum, *Eucalyptus camaldulensis*, were picked from the selected tree species. The collected leaf litter samples were cleaned and all sediments and dirt particles were removed by using a soft brush with running tap water followed by final rinsing in distilled water. Each sample was air-dried under shade at the Department of Soil Science Laboratory.

Chemical Analysis of Leaf Litter

Air dried leaf litter samples were ground in mortar and sieved through a 1mm mesh size sieve. The fine powder was used for the estimation of C, N, P, K, Ca, Mg, lignin and total soluble polyphenols. The standard procedures that were adopted for the chemical analysis are presented below.

Total carbon

The total carbon content was determined by igniting the samples at 550 °C using the Walkey Black method [7].

Total nitrogen

Nitrogen content in fresh leaf litter was determined by digesting 0.1 g of samples in 5 ml of concentrated sulphuric acid using digestion mixture (sodium sulphate: copper sulphate in 10:4 ratio and nitrogen in the digest was determined by Kjeldhal's method as reviewed by [20].

Total phosphorus

Approximately 0.2g of the powdered leaf sample was digested in tri-acid mixture (nitric acid: perchloric acid: sulphuric acid in 1:1:3 ratio) and the digest was made up to 100 ml. A known quantity of aliquot was taken to determine the phosphorus content by following chlorostannus reduced molybdophosphoric blue colour method in sulphuric acid system [5] and the colour intensity was read at 660 nm in UVspectrophotometer.

Total basic cations

Calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were determined using flame photometry and Atomic Absorption Spectrophotometer (AAS) as appropriate after wet digestion [1].

Sulphur

This was determined turbidimetrically using spectrophotometer to read for absorbance at wavelength of 430nm. [24]

Total soluble polyphenols

Total soluble polyphenol was determined in the Pharmacognosy and Drug Development Laboratory of the Department of Pharmacognosy, Ahmadu Bello University, Zaria using the Follin-Ciocalteu's method [17].

Data Analysis

Principal component analysis of morphometric measures and their contribution to mass loss was analyze using the factor procedure of SAS (2014). The correlations coefficient of mass loss and litter chemical parameters was determined. From the correlation matrix, data for the principal component factor analysis was generated. Principal component analysis [6] is a method of transforming the variables in a multivariate data set $X_{1,}$ X_2-------- X_P into variables. $Y_{1,}$ Y_2-------------------Y_P which are uncorrelated with each other and account for the decreasing proportion of the total variant of the original variable.

Results and discussion

Figure 1 shows the relationship between mass loss and chemical composition in litter of *Khaya senegalensis*. Mass loss had high negative and significant p<0.05, association with potassium, organic carbon and phosphorus. Positive and significant association was recorded among sulphur, nitrogen, lignin and total phenol content. PC1 had the highest loadings with eigen value of 9.79 and percent variance of 75.3%. As seen in Figure 2 *Gmelina Arborea*, Organic carbon, sodium, total phenol content, calcium and nitrogen had positive loadings with 84% total variance on the PC1 while magnesium, sulphur, nitrogen: phosphorus ratio, phosphorus, mass loss and potassium had negative loadings. Principal component analysis of mass loss and chemical composition of *Khaya senegalensis* leaf litter is shown in Figure 3. Mass loss had positive relationship with calcium, sodium, magnesium, nitrogen: phosphorus ratio, organic carbon,

carbon to nitrogen ratio. The relationship between lignin and total phosphorus and potassium and total phenol count was negative. PC1 had a percent variance of 64.5% while PC2 recorded 35.5% of the total variations.

Principal component analysis of mass loss and chemical composition of *Mangifera indica* are shown in Figure 4. Sodium had positive relationship with calcium, sodium, nitrogen: phosphorus ratio, organic carbon, carbon to nitrogen ratio, lignin and total nitrogen. The relationship between mass loss, magnesium and total phosphorus was negative.

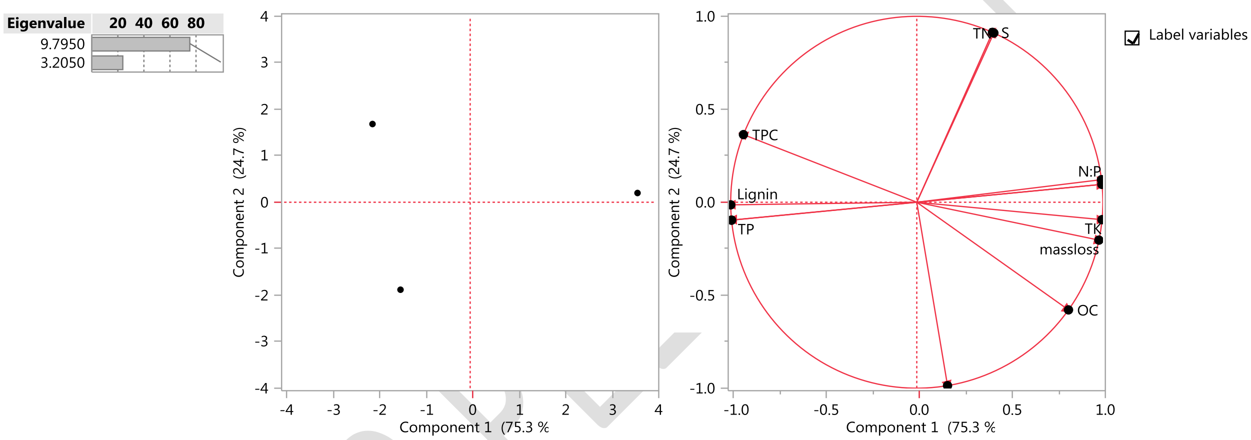

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Figure 1: Principal component matrix of mass loss and chemical parameters in *Eucalyptus Camaldulensis.* TN = total nitrogen, TK = total potassium, OC = organic carbon, TP = total phosphorus, TPC = total phenol content, C: N = carbon to nitrogen ratio, N: P = Nitrogen to phosphorus ratio, Mg = magnesium, Ca = Calcium, Na = sodium, S = Sulphur.

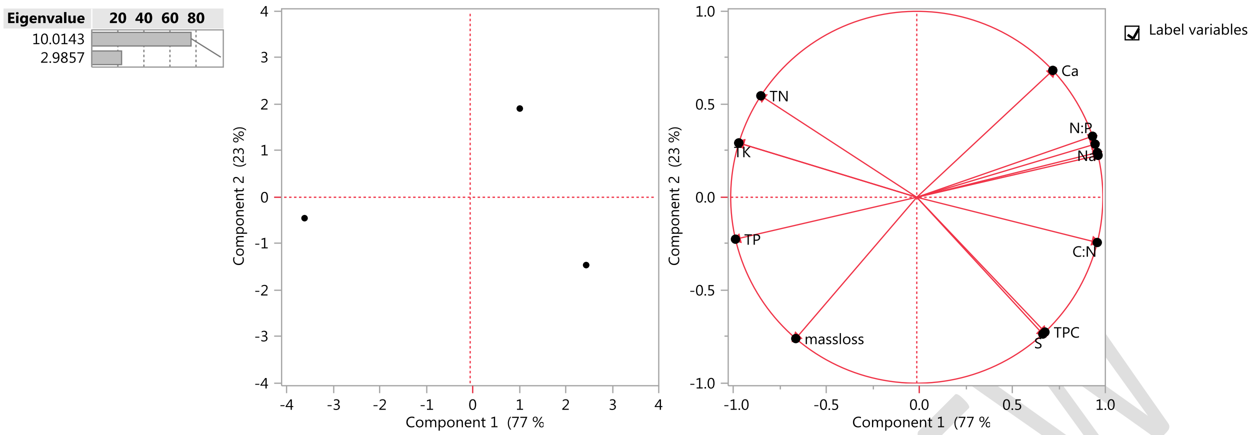

Figure 2: Principal component matrix of mass loss and chemical parameters in *Gmelina arborea*. TN = total nitrogen, TK = total potassium, OC = organic carbon, TP = total phosphorus, TPC = total phenol content, C: N = carbon to nitrogen ratio, N:P = Nitrogen to phosphorus ratio, Mg = magnesium, Ca = Calcium, Na = sodium, S = Sulphur.

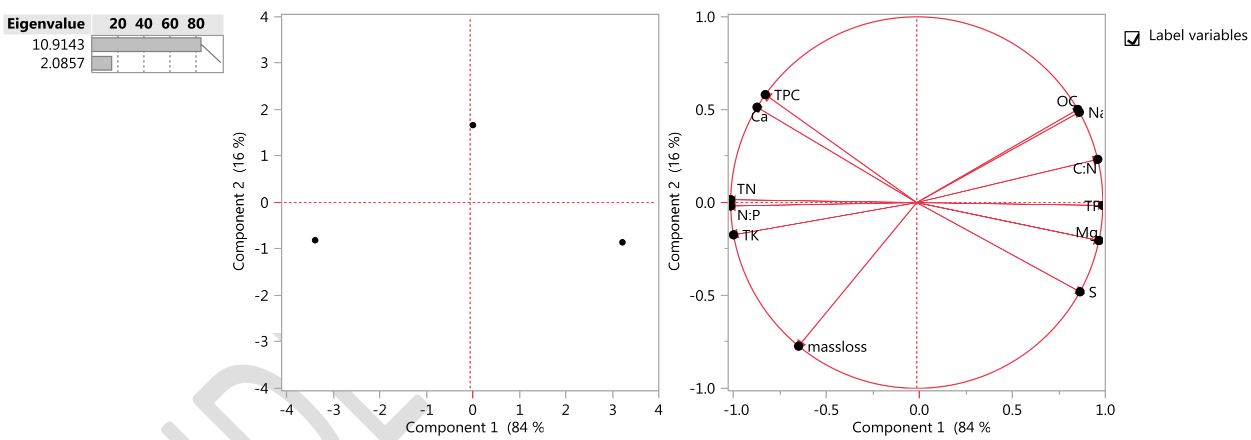

Figure 3: Principal component matrix of mass loss and chemical parameters in *Khaya senegalensis*. TN = total nitrogen, TK = total potassium, OC = organic carbon, TP = total phosphorus, TPC = total phenol content, C: N = carbon to nitrogen ratio, N:P = Nitrogen to phosphorus ratio, Mg = magnesium, Ca = Calcium, Na = sodium, S = Sulphur.

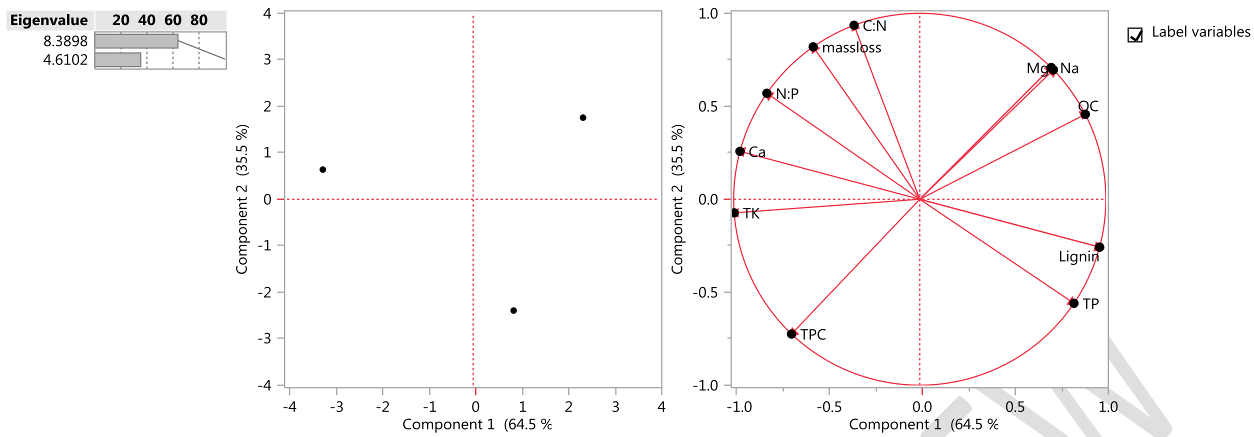

Figure 4: Principal component matrix of mass loss and chemical parameters in *Mangifera indica*. TN = total nitrogen, TK = total potassium, OC = organic carbon, TP = total phosphorus, TPC = total phenol content, C: N = carbon to nitrogen ratio, N: P = Nitrogen to phosphorus ratio, Mg = magnesium, Ca = Calcium, Na = sodium, S = Sulphur.

In *Mangifera indica,* mass loss was strongly and negatively correlated with magnesium and total phosphorus which agrees with the observations of several studies [10], [13]. The positive relationship between carbon: nitrogen ratio and nitrogen: potassium ratio was based on the premise that nitrogen concentration limits the activity of decomposers [16]. In *Gmelina arborea*, increase in mass loss will significantly cause a reduction in organic carbon, calcium, sodium, lignin, total phenol content and C: N this agrees with trend reported by [14]. who observed that mass-loss rates and late-stage litter negatively correlated to carbon, calcium and sodium. In *Eucalyptus camaldulensis*, mass loss was strongly, negatively and highly correlated with potassium, sulphur, total phenol content and C: N ratio. Many studies showed that litter mass loss was strongly correlated with nitrogen, potassium, sulphur and C: N ratio [3], [13]. The concept of the regulatory effect of C: N ratio was based on the fact that nitrogen concentration limits the activity of decomposers [16]. Judging from the positive correlations between mass loss and potassium, magnesium, sulphur, nitrogen and C: N ratio, this implies good predictability of mass loss of litters of *Eucalyptus camaldulensis*.

CONCLUSIONS

Multivariate PCA showed noticeable variations among leaf litters parameters. Since these methods are of high accuracy and have different abilities, they could be used for indicator of soil health through litter decomposition. The main component factor analysis led to an objective simultaneous analysis of organic carbon, total nitrogen, total phosphorus, potassium, magnesium, calcium, sodium, total soluble polyphenol, total sulphur and carbon to nitrogen ratio in different leaf litters rather than on individual basis. This resulted in the reduction of the leaf litters chemical parameters to two PCs in each leaf litter species.

Authors' contribution

This work was carried out in collaboration among all authors. Author FAA conceptualize the study and wrote the first draft of the manuscript. Authors IYA and EYO wrote the protocol and manage the analyses of the study. Author AA performed the statistical analysis. All authors read and approved the final manuscript

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