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Original Research Article

Comparative Assessment of the Effects of two Vegetation Zone Forests on Plant Litter Quantity and Quality in Taraba State, Nigeria

Soba T.M.[2*], Abdulazeez B.S[1], Ndagi H.I[2]

[1]Department of Forestry and Wildlife Management, Federal University of Lafia, Nasarawa State, Nigeria
[2]Department of Forestry and Wildlife Management, Nasarawa State University Keffi, Nasarawa State, Nigeria

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Abstract: The study was carried out to assess plant litter quantity and quality between montane and high forest zones of Taraba State, Nigeria. Two forest reserves were randomly selected out of the forest zones in Taraba State for this study; the forests were River Amboi and Ngel Yaki forest reserves for high forests and montane forest zones respectively. Two 10 kilometers line transects were established in each of the forest reserves along which 20 m x 20 m plots were laid at 2 kilometers intervals. Plants litter samples were systematically collected from each plot for onward transfer to the laboratory for analysis using standard laboratory procedures. Plant litter was analysed for litter quantity and quality parameters. Student's t-test and Pearsons correlation coefficient were used to compare and determine the relationship between the plant litter parameters assesed respectively between the two forest zones. There was significant difference in plant litter quantity ($P<0.05$) between Montane forest (0.6630) and High forest (0.5040). The distribution of litter quality, Mg (0.000) and Na (0.000) showed that montane forest significantly higher than the high forest ($p < 0.05$). Organic carbon (0.357), Total nitrogen (0.598), available Phosphorus (0.662), K (0.428), Ca (0.531), and S (0.564) show no significant differences ($p > 0.05$) between the montane and high forest zones. The result showed that in montane forest correlation between Na and Ca were significant (0.684) at ($p < 0.05$). However, litter quantity and available phosphorus was significantly and negatively correlated (- 0.655) at ($p < 0.05$). At high forest K and organic carbon was significantly and negatively correlated (- 0.644) at ($p < 0.05$) litter quantity and TN also showed significantly and negatively correlation (- 0.751) at ($p < 0.05$). Inclusion montane forest had higher litter quantity and quality than high forest.

Keywords: Vegetation Zone, Plant litter, Quantity, Quality.

INTRODUCTION

It is obvious that maintaining soil quality is of paramount importance to ensuring sustainable land utilizations. Forest ecosystems play a vital roles in maintaining the soil quality which can be achieved by the influence of forests on the environment through processes such as addition of plant litter and nutrient cycling (Usman *et al.*, 2020). Plant litter is senescent or dead plant materials that gradually decompose in to soil (Nagler *et al.*, 2000). It can be considered to be both senesced tree leaves and the portion of annual crops left in the field after harvest (Daughtry, *et al.*, 2010). Thus, the presence of plant litter on the soil surface influences the flow of nutrients, carbon, water and energy in terrestrial ecosystems (Nagler *et al.*, 2000). The timing and magnitude of litter inputs is closely linked to seasonal variability in rainfall, with peak litter fall most often occurring toward the end of the dry season (Wood *et al.*, 2009). In tropical and subtropical forests, however, the time between the litter production and subsequent release of these nutrients from the festering litter is too long which makes it complex to differentiate the effect of litter fall from those of other factors that influence forest productivity such as forest age, soil fertility and seasonal changes in climate (Wood *et al.*, 2006).

Plant litter plays a fundamental role in nutrient turnover and in the transfer of energy between plants and soil, the main source of organic material and nutrients being accumulated in the uppermost layer of

***Corresponding Author:** Soba, T.M
Department of Forestry and Wildlife Management, Nasarawa State University Keffi, Nasarawa State, Nigeria

the soil (Gonza´lez-Rodrı guez *et al.,* 2011). Nutrient release from decomposing litter is an important internal pathway for nutrient flux in forest ecosystems (Regina *et al*., 1997). The quality of these plant litter or organic residues can be assessed by the amount of Nitrogen, Phosphorus, Potassium, Calcium, Magnesium Novaket *et al.,* (2014), Sulfur (S) and Sodium (Na) present in the plant litter Becker *et al.,* (2015).

Studies on measurements of plant litter quantity and quality from different forest zones or plant communities are rare, particularly for tropical forests, but are strongly needed for a closer evaluation of plant nutrient use strategies, and plant-soil feedbacks on nutrient cycling. However, plant litter quantity and quality has been reported on litter type Moroni and Smethurst (2003), plant species Hattenschwiler *et al.,* (2008), soil fertility, forest type Wood *et al.,* (2009). Leaf senescence is a physiological process involving nutrient reabsorption (Killingbeck, 1996; Aerts, 1996) that can vary among species and forest zones. Despite the assume significance role plant litter play in nutrient recycling there is little or no local knowledge about it in the study area. In this study we assess plant litter quantity and quality from different forest zones in tropical forest of Taraba State, with a focus on C, N, P, K, S, Na, Mg, and Ca concentrations. The questions of how difference forest zones affect plant litter quantity and quality in tropical forest has been answer despite its complexity.

MATERIALS AND METHODS

Study Location

The experiment was conducted in two government forest reserves (Ngel Nyaki Forest Reserve, and River Amboi Forest Reserve) in Taraba State, Nigeria. Ngel Nyaki Forest Reserve is located towards the Western escarpment of Mambilla Plateau, lying between 14501600 m asl, (7º 14" N, 11º 04" E) (Akinsoji, 2013). The mean annual rainfall is approximately 1800 mm, most of which is confined between April and October followed by a dry season from November to March (Chapman and Chapman, 2001). The climate in this part of the country is relatively cool with an average temperature of 19.3 ºC (Climate-Data. Org, 2013). The reserve comprises approximately 46 km2 in area, 7.2 km2 of which comprises one of the most floristically diverse submontane – montane forests, being rich in endemic or near endemic plant species ralely seen elsewhere.

The reserve soil is volcanic and it can be reached on foot from Yelwa village after crossing the mayo Jigawal (Chapman and Chapman, 2001). River Amboi Forest Reserve (7º 14" N, 10º 38 E), is situated a few kilometers East of Baissa, Taraba State. It comprises approximately 20 km2 in area of high forest, lying at 230 m above the sea level (Chapman and Chapman, 2001). The mean annual rainfall is approximately 1601 mm, most of the rainfall is confined in summer followed by winter. The average temperature is 26.8 Cº (Climate-Data. Org, 2013).

Sampling Method

Site Selection

The two forest reserves were randomly selected from the list of forest reserves in Taraba state representing the two distinct forest types. Ngel Nyaki Forest Reserve was selected in the Montane Forest Zone, while River Amboi Forest Reserve was selected in the High Forest Zone of the State. Two 10 km line transects were established across each of the selected forest reserves. 20m x 20m plots were established at interval of 2 km making a total of 5 sampling plots per transect.

Plant Litter Sample Collection

Plant litter samples were collected from the two forest reserves. Freshly fallen plant litter was collected with the used of 1 by 0.7 m^2 litter traps during the season of maximum leaf senescence in 2018. The top of the traps was the collecting area of 0.7M^2 which stands at height of 0.3 M above the forest floor. Five (5) leaf litter traps were set per plot one at the center and four at the vertex of the plot which was mixed to form a single sample, which was replicated five times across each of the line transect.

Determination of Plant Litter Quantity and Quality

Litter samples collected were sun dried and weighed repeatedly until it's attained a constant weight using weight balance in the Department of Soil Science Laboratory, Taraba State College of Agriculture, Jalingo in 2018.

Plant Litter Quality

Carbon concentration in litter samples (%C) was measured using the $K_2Cr_2O_7$-H_2SO_4 calefaction method as used by Wang *et al.,* (2015). Litter nitrogen concentration (%N) was analyzed following the Kjeldahl digestion procedure as used by Wang *et al.,* (2015). After a preparative pressure digestion, inductively coupled plasma optical emission spectrometry (ICP-OES, Spectro Analytical Instruments) was used to determine contents of Ca, K, Mg, P, S, and Na as used by Becker *et al.,* (2015).

Statistical Analyses

Student's t –test was used to compare the difference between the two forest zones of Taraba State. Pearson correlation coefficient was used to establish the relationship between litter quantity and quality parameters. All statistical analysis was carried out using statistic 9.0 software.

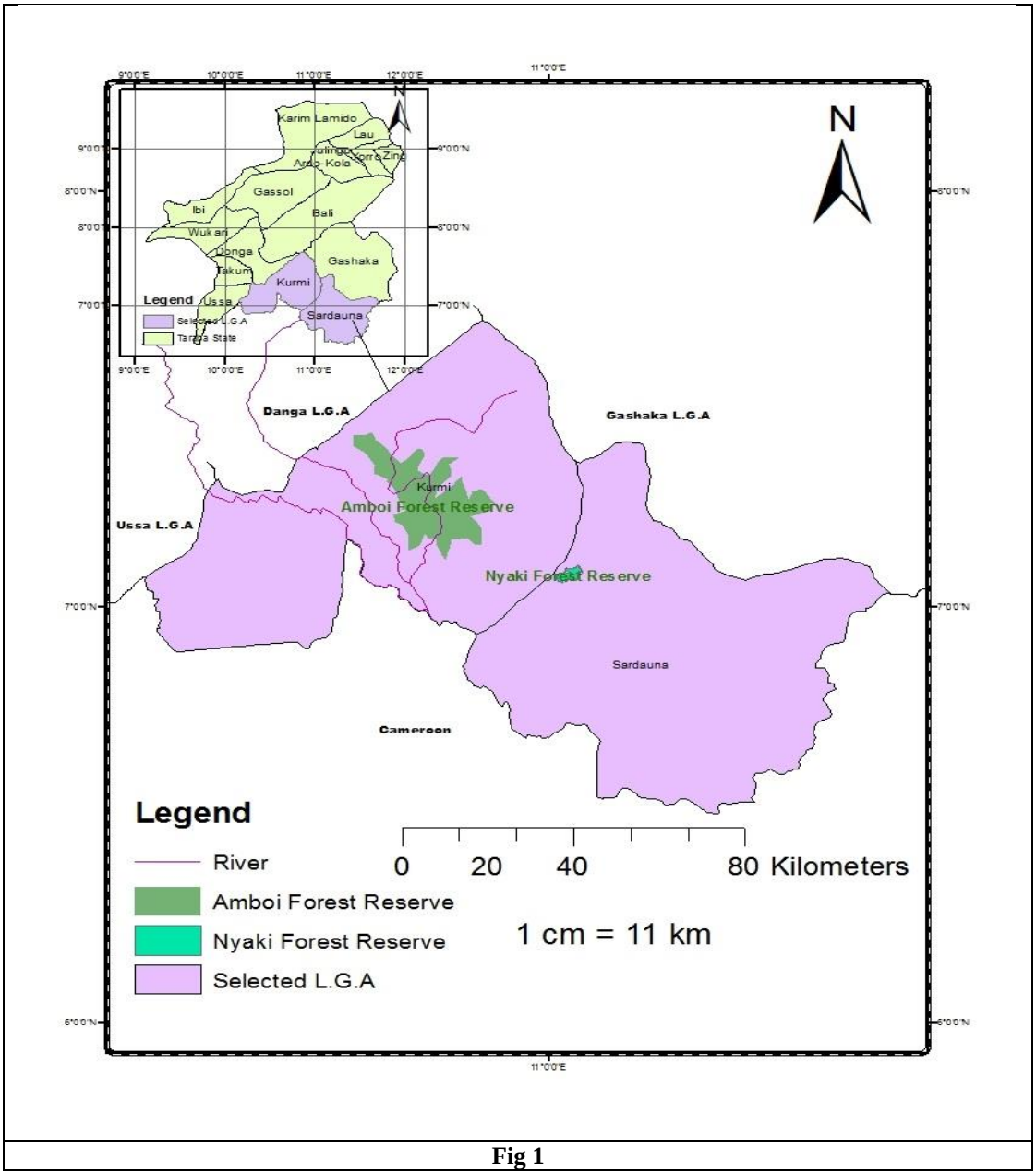

Fig 1

RESULTS AND DISCUSSIONS

Plant Litter Quantity

The results for the plants litter quantity are presented in Tables 1 and 2. The results indicated that there were significant differences ($P < 0.05$) in the quantity of plant litter between the two forest zones. Higher amount of plant litter (0.6630) was however, recorded in the montane forest which was significantly different ($P < 0.05$) from the high forest zone (0.5040). From the T- test its shows that the significant value of plant litter quantity is (0.014), indicating that there was a significant difference of plant litter quantity between the forest zones. The presence of high amount of plant litter at montane forest could be attributed to the presence of numerous trees species at Ngel Nyaki with about 68 tree species, of which many of these are tree endemic to the Afromontane Region, forest structure, and canopy cover of the area.

It could also be due abiotic factors such soil nutrients, higher amount of rainfall observed, very low temperature of the area as well as the good management and conservational status that was observed in the Montane forest. River Amboi which is a high forest has a number of oil palm trees in different parts of the forest indicating how widespread farming activity had been taken place there. Poor management of the reserve could be responsible for the reduced plant litter quantity. The result of this study disagrees with the findings of Roderstein *et al.*, (2005), Becker *et al.*, (2015) who reported that the amount of plant litter in natural forests decreases with increase in elevation. Lower elevation had a significantly higher total plant litter fall than higher elevation forest. This was

observed by Roderstein *et al.,* (2005) in a study above and below litter production in three tropical montane forests in Southern Ecuador.

Table 1: T- test Group Mean for Litter Quantity and Quality in the Montane and High Forests

Parameters	Vegetation Type	Mean	Standard Deviation	Standard Error Mean
Quantity (kg)	Montane forest	0.6630	0.17595	0.05564
	High Forest	0.5040	0.05892	0.01863
Org C (%)	Montane Forest	0.9590	0.28140	0.08899
	High Forest	1.0490	0.10671	0.03375
TN (%)	Montane Forest	0.1050	0.01354	0.00428
	High Forest	0.1080	0.01135	0.00359
AVP (mg/kg)	Montane Forest	7.9150	1.55434	0.49153
	High Forest	8.2790	2.07644	0.65663
K (cmol/kg)	Montane Forest	0.8770	0.52149	0.16491
	High Forest	0.7370	0.16228	0.05132
Ca (cmol/kg)	Montane Forest	5.1470	2.41819	0.76470
	High Forest	4.6030	1.18282	0.37404
Mg (cmol/kg)	Montane Forest	1.3040	0.19426	0.06143
	High Forest	2.6280	0.50745	0.16047
Na (cmol/kg)	Montane Forest	.2470	0.12676	0.04008
	High Forest	.6270	0.18803	0.05946
S (mg/kg)	Montane Forest	9.6460	1.68930	0.53420
	High Forest	9.1630	1.97609	0.62489

Org C = Organic Carbon, TN = Total Nitrogen, AVP = Available Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium and S = Sulfur

Table 2: T-test Comparing the Means of Litter Quantity and Quality in the Montane and High Forests

Parameters	t-test	Degree of freedom	Significant (2-tailed)
Quantity (kg)	2.710	18	0.014
Org C (%)	-0.946	18	0.357
TN (%)	-0.537	18	0.598
AVP (mg/kg)	-0.444	18	0.662
K (cmol/kg)	0.811	18	0.428
Ca (cmol/kg)	0.639	18	0.531
Mg (cmol/kg)	-7.705	18	0.000
Na(cmol/kg)	-5.299	18	0.000
S (mg/kg)	0.588	18	0.564

* Significant ($p < 0.05$)

Quantity = Plant Litter Quantity, Org C = Organic Carbon, TN = Total Nitrogen, AVP = Available Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium and S = Sulfur

Plant Litter Quality

The results of the plant litter quality (Tables 1 and 2) indicated that there were no significant differences between the vegetation zones ($P > 0.05$) in the OC, TN, and AVP contents between the two forest zones. The amount of these nutrients were lower at the montane forest which recorded 0.9590, 0.1050 and 7.9150 while the high forest recorded higher amount of these nutrients of 1.0490, 0.1080 and 8.2790 respectively. The results of Magnesium (Mg) and Sodium (Na) showed significant differences between the two forest reserves, high forest had significantly high amount of Mg and Na than the montane forest.

The concentration of nutrients in plant material is used as a guide for the supply of that particular nutrient and as such is directly related to the quantity in the soil (IITA, 1979). The organic carbon values indicated the highest mean values are at the high forest, the same was reported for TN, AVP, Mg and Na. This implies that tree species from high forest have less ability to reabsorb their nutrients element during translocation and abscission before shading their leaves. The observed result could also be attributed to the accumulation of complex organic materials caused by wind in the site.

This observation could further be explain by the effect of precipitation since montane forest had higher amount of precipitation and it has the potential to affect nutrient cycling in tropical forest either direct or indirect processes. The direct effects of precipitation on nutrient cycling include removal of highly mobile nutrients in the soil solution through leaching (Radulovich and Sollins 1991, Schuur and Matson 2001), reduced mineralization of nitrogen (N) and

phosphorus (P) in poorly drained soils or anaerobic micro sites (Schuur and Matson 2001), and more intense weathering to produce secondary minerals with higher surface area and thus higher capacity to adsorb organic matter (Torn *et al.,* 1997).

The amount of N decreases with increasing precipitation (Schuur and Matson 2001; Schuur *et al*., 2001). The Indirect effects of precipitation on nutrient cycling in tropical forest include variation in vegetation that can influence nutrient cycling through effects on litter quality and decomposition. Plant leaves from wetter sites (>2500 mm $y^{-}1$) decomposed more slowly than plant leaves from the same tree species from drier sites when decomposed at a common site (Austin and Vitousek 2000; Schuur 2001), illustrating how precipitation may affect mass loss and nutrient release from litter through leaf traits and litter quality. From this it can be deduced that montane forest had less ability to decompose it leaf litter and releases the available nutrient in it's for plants nutrition. Montane forest has the higher amount of leave litter accumulated which may also be responsible for low decomposition process to release this nutrient for recycling.

This result agrees with that of Tsui *et al*., (2004) who reported higher contents of total nitrogen, organic carbon and organic matter at the lower altitude. They explain this in relation to quality of litter. Howerve, Potassium (K), Calcium (Ca) and Sulfur (S) all showed no significant differences ($p > 0.05$) with higher values at montane forest. The relatively higher amount of these plant nutrients in the montane forests compared to the high forest is most likely due to the effect of high number of tree species resulted to high amount of litter quantity influencing the accumulation and availability of K, Ca, and S. This could also be explained by less ability of tree species in the montane forest to reabsorb this nutrient before shading of their leaf.

Relationship between Litter Quantity and Quality Parameters

Relationship between Litter Quantity and Quality Parameters in Montane Forest

The results for the litter quantity and quality parameters relationship for montane forest are presented in Table 3. The results showed that correlation between Sodium (Na) and Calcium (Ca) were significant (0.684) at ($p < 0.05$) indicating a positive correlation between the elements. This implies that as Sodium increases the available Calcium increases. Thought, it's expected that, they should be negative correlation between Na and Ca. This is because excess Na in the soil competes with Ca, and other cations to reduce their availability to crops. However, Chapman and Chapman (2001) reported that the soil in Ngel Nyaki forest reserve (Montane forest) is volcanic. But, According to Brew (2018), soils known as volcanic are usually basalt based. And soils based on basalts are higher in nutrients than any other soil types, but fertility varies depending on extend of weathering, slope, aspect, drainage and history of clearing and land use.

This basalt is in rich in readily weathered minerals especially iron, calcium, magnesium and phosphorus. Under strongly leaching condition of rainfall, the forest canopies act as major stores of buffering losses through soil erosion and leaching. This report supported the above finding of this study. The correlation between litter quantity and available phosphorus (-0.655) was significant ($p < 0.05$) indicating negative correlation between the parameters. This signifies that as litter quantity increase available phosphorus decrease. But it is expected that they should be a positive correlation between litter quantity and available phosphorus which may be due to chelating of polyvalent cations by organic acid and other decay products (Malhotra, 2015).

Moreso, in unfertilized undisturbed soil even if vegetated by say forest or grassland there will be obviously be a relationship. High organic matter will mean higher available phosphorus but Agricultural soils under high phosphorus fertilized intensive agriculture, organic matter may be low but available phosphorus can be high (Desiraju, 2015). But according to Azim (2015) indirect action of microorganisms such as *Pseudomonas* and other phosphorus suloblizing microbes could reduce the availability of phosphorus for plants uptake which could be in line with the presence results.

Table 3: Correlation Matrix of Litter Quantity and Quality Parameters in Montane Forest

	Org C (%)	**TN (%)**	**AvP (mg/kg)**	**K (cmol/kg)**	**Ca (cmol/kg)**	**Mg (cmol/kg)**	**Na (cmol/kg)**	**S (mg/kg)**	**Quantity (kg)**
Org C	1								
TN	0.357	1							
AvP	-0.118	0.140	1						
K	0.034	0.180	-0.353	1					
Ca	0.193	0.041	-0.387	0.295	1				
Mg	0.450	0.106	-0.033	-0.047	0.347	1			
Na	0.155	-0.405	-0.201	-0.402	0.684*	0.366	1		
S	0.531	0.374	-0.050	-0.253	-0.459	0.185	-0.305	1	
Quantity	-0.195	0.021	-0.655*	-0.087	0.400	-0.024	0.373	-0.083	1

* Significant ($p < 0.05$), *

Significant ($p < 0.01$), Quantity = Plant Litter Quantity, Org C = Organic Carbon, TN = Total Nitrogen, AVP = Available Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium and S = Sulfur

Relationship between Litter Quantity and Quality Parameters in High Forest

The relationship between litter quantity and quality parameters at high forest are presented in Table 4. The correlation of potassium and organic carbon (-0.644) was negative and significantly correlated ($p < 0.05$). This means increase in K decreases organic carbon.

The high level of potassium in forest soils normally due to decomposition of leaves which increased the soil organic matter content and supplies more cations such as K, Ca, and Mg to improve soil cations exchange capacity (Ibukunoluwa, 2017). Nutrients limitation in plant communities is often operationally defined as the requirement of a single nutrient necessary to stimulate an increase in production of biomass, usual phenomenon in forest ecosystem. There can be substantial variation in the nutrients demands and relative proportions of essentials nutrients at the species level. Multiple elements, including K, may also co-limit tree growth in forests systems.

Therefore, plant species may actually vary in their resources demands for N, P, and more especially K based on their stoichiometric requirement, and the relative and absolute abundance of N, P, and K in soils may influence plants community composition in addition to growth (Srivastava, 2017). Besides, the organic matter under forest does not undergo breakdown easily because of forest layer unlike soils that are exposed to sunlight (Ibukunoluwa, 2017). Therefore, the negative correlation between organic carbon and potassium in this present study supported the above findings. Potassium on the other hand did not significantly correlate with total nitrogen (0.027) and available phosphorus (0.427).

Litter quantity and total nitrogen (-0.751) was negatively and significantly correlated ($p < 0.05$). The negative correlation between litter quantity and Nitrogen indicate significant correlation ($p < 0.05$) which means as litter quantity increased N decreased or viz viser. Although, a valuable reservoir of N is humus (plant litters). Humus is formed from raw organic matter by soil organisms and supports a healthy population of microbes and as sponge, holding more moisture than would otherwise be the case. As nitrate is negatively charge (anions), it is not attracted to clay particles and so is subjected to leaching.

Litters have an anion exchange capacity and therefore can hold some nitrate which may lead to reduction in nitrate available for plants uptake by the roots. Further, as the reservoir (litters) decomposed or mineralized the nitrogen is released and become available to the trees. Obviously, soil containing much litter can released considerate amount of nitrogen. But normal growing practice over-aerates the soil and stimulates soil organisms. These feed on the carbon in litters and released nitrogen in the processes. Although rivers is the case in this study (Caxton, 2014).

Table 4: Correlation Matrix of Litter Quantity and Quality Parameters in High Forest

	Org. C (%)	TN (%)	AVP (mg/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	S (mg/kg)	Quantity (kg)
Org C	1								
TN	0.246	1							
AvP	0.022	0.099	1						
K	-0.644*	0.027	0.427	1					
Ca	0.068	0.255	-0.116	-0.108	1				
Mg	-0.235	0.267	0.021	0.212	0.483	1			
Na	0.150	-0.237	0.052	0.234	0.297	0.221	1		
S	0.056	0.159	-0.329	-0.364	-0.373	0.021	-0.219	1	
Quantity	-0.121	-0.751*	0.062	-0.107	-0.580	-0.588	-0.052	0.136	1

*Significant ($p < 0.05$)

* *Significant ($p < 0.01$), Quantity = Plant Litter Quantity, Org. C = Organic Carbon, TN = Total Nitrogen, AVP = Available Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium and S = Sulfur

CONCLUSION

The outcome of this study showed that plant litter quantity between montane and high forests zones significantly differed ($p < 0.05$) montane forest had the highest amount of plant litter. The results of plant litter quality show that Mg and Na are significantly differed between the two ecological zones ($p<0.05$), organic carbon, TN, AVP, K Ca and Na were not significantly differed. Correlation between plant litter quantity and available phosphorus is negatively and significantly correlated in montane forest. The correlation between plant litter quantity and total nitrogen were negatively and significantly correlated ($p< 0.05$) in the high forest.

Na and Ca was significantly correlated ($p< 0.05$) in montane forest while K and organic carbon were negatively and significantly correlated ($p<0.05$) in high forest. In conclusion High forest had the best litter quality for agroforestry practice because of the present of high nutrient content in leaf litter that are suitable for the growth and yield of agricultural and forest products.

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