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COMPARATIVE STUDY OF SOME PHYSICO-CHEMICAL PROPERTIES AND CARBON STORAGE OF SOILS UNDER FIVE DIFFERENT MULTIPURPOSE TREES AND SHRUBS IN THE SEMI DECIDUOUS ZONE OF GHANA

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ABSTRACT: *Leaf biomass from Multipurpose Trees and shrubs (MPTs) like Senna siamea, Senna spectabilis, Leucaena leucocephala, Gliricidia sepium and Albizia lebbeck, are known to provide enormous amount of nutrient for crops when used in rotations and/ or fallow to address the decline in soil fertility and yields and store Carbon and biomass and the soil. A study was conducted on soil of Kumasi-Ofin–Nta compound association of the Agroforestry plot belonging to the Natural Resources Faculty of Kwame Nkrumah University of Science and Technology (KNUST) at Gyinase in the Ashanti Region of Ghana to investigate the effect of five selected fallow species on some selected physical and chemical properties of the soils thirteen years after fallow. The field was a Randomized Complete Block Design made up of five MPTs species in three blocks with replications. The sampling depths were 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. Soil samples were taken through physical and chemical laboratory analysis. Data collected were subjected to analysis of variance (ANOVA). The five MPTs species showed no significant influence on chemical properties of the soil (pH, nitrogen, phosphorus, potassium, Calcium, Magnesium and Carbon). However, there was significant influence of the MPTs on some soil physical properties (bulk density and porosity).*

KEYWORDS: Multipurpose Tree, Shrubs, Physical Properties, Chemical Properties, Soil Degradation

INTRODUCTION

Soil degradation and food shortage are some of the major challenges facing the smallholder farm families in Sub Saharan Africa. Its extent and impacts on human welfare and global environment have assumed greater proportions now than ever before (Berry *et. al*., 2003). The rates of soil degradation continue to rise, affecting over 485million Africans (Bationo, 2004) while average crop yields and energy supply is rapidly declining making agriculture a risky enterprise especially in communities where climate change vulnerability is high. There is the need to put up measures to curtail further soil degradation, improve food and fuelwood supply sustainably to support farm families (approx. 100m people are facing 'fuelwood famine', FAO1995). Fuelwood supply has gender implications; fuelwood collection is the responsibility of our women and children. The growing scarcity of fuelwood and charcoal in urban Africa affects women and children and could be addressed with a little more interest in Agroforestry.

Erratic rainfall and the inherently low fertility status of the soils place a serious constraint to crop production in many parts of the tropics (Tripathi*et. al*., 1992). The problem is exacerbated with agricultural intensification cultivation with little or no inputs by large number of 'resource- poor farmers' who cannot afford recommended amount of fertilizers and other

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purchased inputs (Young, 1997). Though some subsidies have been provided by successive governments, prices are still considered high beyond the reach of most subsistent farmers (Gerner*et. al*., 1995). This makes it difficult for them to apply recommended quantities, there is therefore the need to use agroforestry technologies have been evaluated and known to contribute towards addressing the declining crop yields and land degradation. These technologies could easily be integrated into our farming systems for the benefit of our poor farm families with an attendant increases in C stocks (World Agroforestry Centre, 2007).

Multipurpose trees and shrubs (MPTs) like *Leucaenaleucocephala*, *Albizialebbeck, Sennaseamea*, *Sennaspectabilis*, *Gliricidiasepium*, *Faidherbiaalbida* among others lend themselves to farmers by contributing nutrient-rich biomass on soil surface to reduce surface runoff and provide nutrient elements in decomposing organic matter (Young, 1997). MPTs are able to co-exist with crops in different arrangements to replenish soil nutrient lost through crop removal and improve yields sustainably.MPTs are intrinsically better than herbaceous legumes because the latter have limitation to its use; some are not compatible with many tropical climates, especially their susceptibility to the long drought that precedes the main crop season (Wilson *et. al*., 1986) where there would be no green matter to be turned over at critical period when they are most needed.

The purpose of this study was to compare the physical and chemical properties of soils under five different MPTs; *Leucaena leucocephala*, *Albizia lebbeck*, *Senna siamea*, *Senna spectabilis, Gliricidia sepium* and the ability to store C after 13 years of fallow.

Description of the Study area

The study area is an Agroforestry plot belonging to the Natural Resources Faculty of Kwame Nkrumah University of Science and Technology (KNUST) at Gyinase in the Ashanti Region of Ghana. The geographical location of the study area lies in Latitude 6.42°N and Longitude 1.34°W with an altitude of 284m above mean sea level (Figure 1).

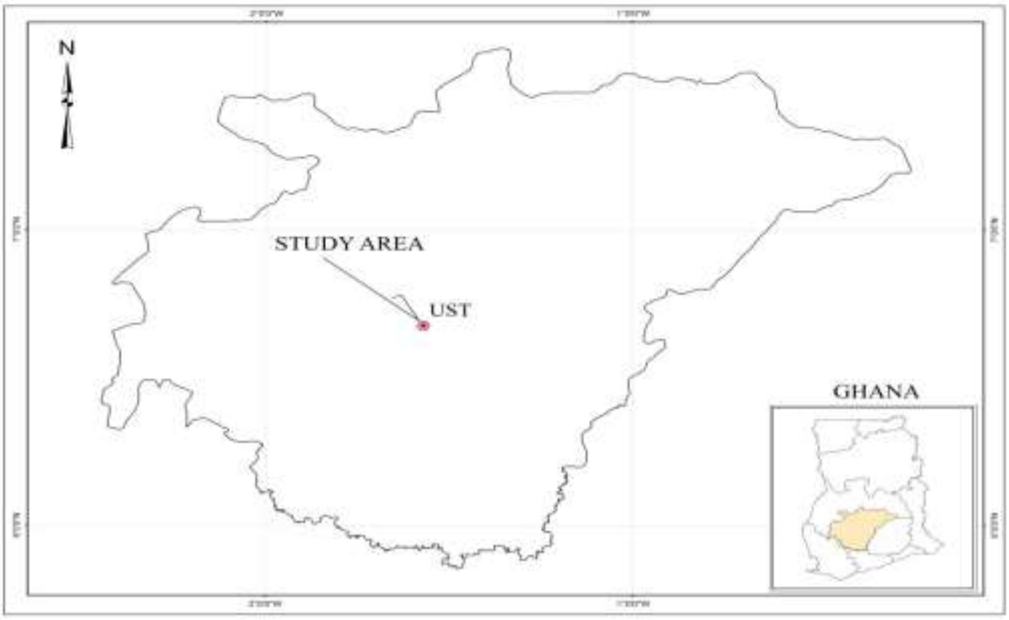

Figure 1: Location of the Study Area

The study area is in the tropical climatic zone with a bi-modal rainfall peaks (i.e. major and minor seasons). (Adjei and Sadick, 2015). The major season normally starts in March; reaches a peak in July and drops sharply in August whilst the minor season starts in September with the lowest occurring in late November. Thereafter, there is a long dry period from December to February during which small amounts of rain normally (below 10mm) are received (Adjei and Sadick, 2015)

Mean monthly temperatures remain high throughout the year only falling around 24^{o} C in August. February and March are the hottest (nearly 28^{o}C) recorded months. Absolute minimum temperatures of around 20^{o}C are usually recorded in December and January with absolute maximum temperature of about 33^{o}C occurring in February and March (Adjei and Sadick, 2015).

MATERIAL AND METHODS

Laboratory methods and Statistical Analysis

Soil was sampled at 0-10, 10-20 and 20-30cm and placed in a labeled polythene bags. The auger, chisel and core sampler were used in the sampling. Samples for Bulk density were done using the 5cm diameter steel cores driven to the desired depth. In-situ hydraulic conductivity measurement was also determined using the 5mm disc infiltrometer. The samples were then transported to Soil Research Institute laboratory in Ghana for analysis. All soil Samples were subsequently air-dried to constant weight to avoid microbial degradation (Kakulu, 1993). They were homogenized, made lump free by gently crushing repeatedly using a pulverizing machine and passed through a 2 mm plastic sieve prior to analysis. Leaf samples were harvested (fresh) from growing shoots of the five MPTs species where soil samples have previously been taken in each replicated alley of the five MPTs. Sub samples were collected for laboratory analysis.

The physio-chemical properties of the soil samples were determined using routine methods as described by Allison and Ibitoye (2006). The physio-chemical parameters used for this study were pH, organic matter (OM), cation exchange capacity, total nitrogen, particle size distribution and bulk density. Leaf samples were air-dried at room temperature to a constant weight, milled and analysed to estimate nutrient quantities that may contribute to their build up in the soil.

Data analysis was done using Analysis of Variance (ANOVA). Treatment means were separated by Fisher's least significant difference (Lsd) test at 5% probability level. SAS analysis package was used.

RESULTS AND DISCUSSION

Soil physical properties are presented in Tables 1. The soils texture was generally sandy loam and loamy sand. The soil consists of large proportions of sand ranging between 61.07-74.28% with low amounts of clay between 2.05 and 4.76%.

Bulk density of the top soils ranged from 1.11 to 1.42. The degree of soil compaction increased to levels between 1.31 and 1.54 in the 10-20cm and remained similar (1.35 and 1.54) in the lower horizon.

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Porosity of the soils ranged from 46.56 to 58.02% in the 0-10cm depth, 41.86-50.71% in the 10-20cm and 41.25-49.25% in the lower depth.

Hydraulic conductivity of the soils ranged between 0.85 and 0.116cm/hr considered moderately slow. Moisture availability of the soils computed by the difference of field capacity and wilting point were low throughout the profile.

Chemical properties of soils under five different multipurpose trees and shrubs

Some of the soil chemical properties studied under the five different multipurpose trees are presented in Tables 2- 1 – 2 .3. Soil pH for the top soil (0 and 10cm) ranged from 4.20 to 4.84. Subsoil pH is strongly acidic ranging from 4.00 to 4.58 for 10-20cm depth and 4.03 - 4.93 for the 20-30cm. The lowest soil pH occurred on soils under *Albizialebbeck* and the highest soil pH value occurring on soils under *Leucaenaleucocephala*.

Organic matter content of the soils ranged between 2.24 and 3.09 percent which is considered moderate to high for top soils. The lower depths gave low values ranging from 1.20 to 1.62% and moderate value of 2.45 and 2.85% respectively. The lowest value was observed on soils under *Albiziaspp*with the highest occurring on soils under *Gliricidia spp*. Carbon levels in the soils were between 0.70 and 2.05%, with the lowest in the 10-20 cm. the highest value occurred in the 20-30 cm soil depth.

Total Nitrogen of the soils was generally low to moderate ranging from 0.10 to 0.16% in the top soil, the highest occurring on soils under *Albizia spp.* N levels decline in the 10-20cm to a low range of 0.04 - 0.08%. The lowest value was observed under *Gliricidia spp.* N levels increased to 0.12 to 0.15% in the 20-30cm depth, with the lowest occurring under *Albizia spp.* In general ECEC were relatively low, between 4.54 to 6.88cmol $^{(+)}$ /kg soil in the 0-10cm depth. The lowest observed under *Gliricidiaspp,* levels declined to 3.27 and 4.89 cmol$^{(+)}$/kg soil in the 10-20cm and remained almost similar (2.55-5.54 cmol (+)/kg soil) in the 20-30cm.Exchangeable calcium (Ca^{++}) was generally low with values between 2.36-4.18 cmol (+) /kg soil, declining to 1.73-2.94 cmol (+) /kg soil and 1.38-2.76 cmol (+) /kg soil in the 10-20cm and 20-30cm depth respectively. Values were consistently low under all species throughout the soil depths. Exchangeable magnesium was generally low ranging from 1.65-2.58 cmol (+) /kg soil in the topsoil, the levels however declined slightly to 0.71-1.69 cmol (+) /kg soil in the 10-20cm depth and further declined to 0.27-0.80 cmol (+) /kg soil in the 20-30cm. Exchangeable potassium (K+) levels were low to moderate with values between 0.18 -0.27 cmol (+) /kg soil in the 0-10cm depths, levels declined to 0.01-0.14 and 0.06-0.12 in the 10-20cm and 20-30cm depths respectively. The highest value occurred under soils under *Leucaena spp.* Available potassium in the 0-10cm was observed to be moderate 82.40 - 92.33 mgK^{-1}, the value declined to 45.05 - 58.81ppmK in the 10-20cm. There is however an accumulation of K in the lower depth of 20-30cm, where values increased to between 66.96 - 83.55 mgK^{-1}.Available P in the 0-10cm depths was 6.01 - 8.37ppmP, decreasing to very low value of 1.14 - 1.19 and 1.47 - 2.35ppmP in the lower depths (10-20cm and 20-30cm).

The results showed significant differences in the level of nutrients in the leaves, the nutrients were N, P, K, Ca, Mg and C (Table 3). Carbon in the leaves of the five MPTs were significantly different ($P \leq 0.05$) from each other, levels were in the range 40.5 and43.0%. The order was *Sennaspectabilis,* 43.0>*Sennasiamea,* 42.5>*Albizialebbeck,* 41.5>*Gliricidiasepium,* 40.5=*Leucaenaleucocephala,* 40.5(Table 3).

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Soil reaction under all the five MPTs species soil pH were generally strongly acidic, ranging from 4.2-4.8 in the topsoil and 4.0-4.6 in the subsoil. This condition is less suitable for most of the common staple crops that are cultivated by our farmers. This would require some improvement with lime to raise the soil pH to acceptable levels. The strongly acidic nature of the soil may partly be explained by the low level of exchangeable cation capacity of the soils with relatively moderate amount of exchangeable bases. Acidic compounds released during decomposition could have influenced the soil pH. This happens when amino acids are converted into acetic acids, hydrogen gas and carbon dioxides. Soil erosion, leaching and crop harvest may also contribute to the removal of exchangeable cations in soil to reduce pH. Most crops grow well in the range 5.8-6.5. Legumes generally grow better in soils with pH range of 6.2 to 6.8(Jones, 1998).Exchangeable cations; Potassium, calcium and magnesium generally are not available for plant uptake in acid soils and are also leached from the top soils most of which are present in soil at a range above the pH of 6.0. K values were of the range 82.40 – 92.38 cmolkg^{-1} soil and considered moderate for agricultural soils in crop production. K is often required in large quantities especially in root crops like cassava and yams. Inorganic K application should be split; this can minimize luxury consumption and provide available K throughout the growing season.

Calcium values ranged from 2.36 to 4.18 cmolkg^{-1} soil, which is slightly below the minimum quantities required for sustainable crop production. The amount of calcium in the soil reflects high acidity. ECEC values also ranged between 2.64 – 4.74 cmolkg^{-1} soils and considered low. Calcium and magnesium are required in relatively large amounts for good crop growth. Low calcium levels are characteristics of highly weathered soil of the tropics (Havlin*et. al*., 2005). Soil Mg is low in coarse humid region soils and an indication of low Mg in soil forming rock, which lacks minerals like biotite, hornblende or dolomite (Brady and Weil, 2002). Leaching may also account for the levels recorded in the study. Application of industrial lime is expected to raise level to supplement amounts that could be recycled in leave biomass.

Organic matter (OM) levels were low to moderate; the low values are in line with the typical levels in tropical soils. They are soils of inherently low soil fertility, low textured and highly leached of their basic ions. The prevailing environmental conditions in the study area encourage rapid decomposition of biomass and high turnover rates of organic material. However, under fallow conditions, organic matter decomposition is expected to be controlled by the shading of the tree canopy, which may slow down the decomposition rates. The low level of OM in the soil may also be attributed to losses in runoff during rains or leaching (Radulovich and Sollium, 1991). Leaching is evident in the high amount of organic matter observed in the 20 – 30 cm depth as compared to that of the top soil (0 – 10 cm). Total N levels of the fallow plots ranged from 0.04 - 0.16%, considered to be low to moderate in terms of its rating. Total N in the soil was as results of N inputs from N-fixation in trees and/or mineralization and nutrient release of organic matter from leaf and N-yields from root biomass in the soil. There were no differences of the N content of soils from the MPTs plots which showed that there were no comparative advantages of the leguminous trees over the non-leguminous ones. This could be because non-leguminous trees produced enough biomass as well as developing deep root systems to capture and recycle nutrients in order to compensate for their inability to nodulate like leguminous trees.

Phosphorus levels ranged between 6.01 – 8.37 ppm (no significant different at $P \leq 0.05$) at the top soil (0 - 10cm depth). The highest P value in the soil profile is recorded at the top soil, declining to a low range of 1.0-2.33. The trend may be due to the accumulation of P in organic

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matter and declining down the profile. The low P obtained in the study may be attributed to the low pH levels of the soils. Low pH allows the P to be fixed rather than being available. There is also an apparent lack of P in parent rock. In the cultivation of such soils, there is the need to apply mineral fertilizer in the form of super phosphates (TSP and SSP) to raise soil P for increase yield. Low applications of P placed by newly planted crop helps to invigorate the plant. Continuous cropping without adequate P additions may also deplete P in the soils that have accumulated over a long period. A sustainable addition of rock phosphate combined with improved fallow will go a long way to augment P levels in the soil. It is worth noting that tree is unable to recycle P if it does not exist in the soil (parent material).

Leaf materials from the five different MPTs have the potential to provide nutrients required in the soil for plant growth. N in the leaf materials the MPTs were significantly different (P≤0.05). The levels were between 3.08 and 4.76% and ranged in the order Albizia*lebbeck*(4.76)>*Leucaenaleucocephala*(4.48)>*Sennaspectabilis*(3.88)>*Gliricidiasepium* (3.55)>*Sennasiamea*(3.08) (Table 3). The levels were above the reported critical value of 2.00 – 2.50% (Palm *et al*, 2000, Uchida, 2000) that would enhance net N-mineralization. The N levels in the MPTs especially that of leguminous species showed good attributes of N-fixating trees. The carbon, nitrogen ratios were below 25 (8.72-13.8),

Agriculture in the tropics, especially in areas where shifting cultivation is practiced, a lot of plant biomass accumulated during land preparation is burnt, a process that reduces the potential of leaf to supply nutrient and accumulate Carbon in the biomass and soil. Analysis showed substantial levels of N (3.08-4.76%), high enough to supply N to growing crops. Apart from high nitrogen levels, Palm *et. a.l*, (2001) reports of low levels of soluble polyphenols in leaves, between 1.6 – 1.7%, less than the critical value (2%) above which decomposition is delayed. MPTs leaves could be applied directly to the soil to supply N especially with *Leucaena, Gliricidia*and *S. spectabilis*. *Kang et. al*., (1984) asserts that when biomass from *Leucaena* and*Gliricidia* are applied to growing crop they do well. Phosphorus levels of the leaf from the MPTs were low to moderate (0.16 – 0.23%). Palm *et. al.*, (2001) are of the view that legumes have comparatively lower P and thus net immobilization is expected when biomass is applied to the soil. This may also support results of low P in soils under some of the five MPTs. Potassium levels were in the range of 0.43 - 0.68% and are considered low to moderate. Carbons stored in leave biomass were between 40.5 and 43.0% are substantially enough to add up to amounts recorded in the soil for C storage. Ghanaian farmers could be encouraged to practice agroforestry and fallow of their lands to benefit from Carbon trade certification as done by SCC &Vi Agroforestry in East Africa (SCC & Vi Agroforestry 2008) for farmers to be paid an insurance in years that annual crops fail.

Physical properties of soils under five different multipurpose trees and shrubs

Soils sampled were coarse textured, dominated by sand (61.07 – 74.28%) with small amounts of clay (2.05 – 5.45%) referred to as low activity clay soils (LAC soils). They have less ability to hold nutrient and water within the profile and may be prone to erosion if cover is removed especially on continuously cultivated land (Juo and Adams, 1986). Bulk density of the top soil was relatively low (1.11 gcm^{-3} to 1.54 gcm^{-3}) through the soil profile and a moderately compacted sub-soil which could be good for working the soil during cultivation and the use of indigenous farm tools. There is also the ease seeding, root ramification and water permeability. The high porosity range also confirms the good aeration and water movement in the profile as indicated by the bulk densities and hydraulic conductivity which could be good for varied crop production.

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Table 1 A. Comparison of selected soil physical properties within 0-30 cm depth under five MPTs

Soils under Species	Sand (cm)			Silt (cm)			Clay (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Sennasiamea	67.75	72.77	61.07	30.14	30.14	33.51	2.08	3.07	5.45
Sennaspectabilis	74.28	71.11	66.99	23.66	28.61	28.85	2.06	3.11	3.50
Leucaena leucocephala	69.33	70.69	69.32	28.61	25.89	25.97	2.05	3.05	4.71
Gliricidiasepium	69.19	68.33	67.01	28.02	25.78	28.20	2.79	3.41	4.79
Albizialebbeck	73.93	66.78	65.04	23.96	23.96	30.22	2.07	3.08	4.74
Lsd (0.05)	7.66	8.46	7.03	7.42	8.22	5.21	0.96	0.52	2.03

Means significantly difference at (P≤0.05)

Table 1 B. Comparison of selected soil physical properties within 0-30 cm depth under five MPTs

Soils under Species	Bulk density			Porosity		
	0-10	10-20	20-30	0-10	10-20	20-30
Sennasiamea	1.36	1.54	1.54	48.65	42.01	41.85
Sennaspectabilis	1.10	1.51	1.51	58.02	42.80	42.97
Leucaena leucocephala	1.29	1.31	1.44	51.37	50.71	45.51
Gliricidiasepium	1.42	1.45	1.48	46.56	45.19	44.33
Albizialebbeck	1.32	1.54	1.35	50.31	41.86	49.25
Lsd (0.05)	0.10	0.12	0.21	6.81	4.61	7.97

Means significantly difference at (P≤0.05)

Table 2: Comparison of selected soil chemical properties within 0-10 cm depth under five MPTS

Soils under Species	pH	OM	C	TN	Ca	Mg	K	Exc. Acidity	ECEC	BS	P	K
		%			cmol(+)/kg					%	ppm	
S. *spectabilis*	4.4	2.66	1.54	0.14	3.56	2.31	0.24	0.25	6.17	94.79	6.91	92.38

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S. siamea	4.8	2.41	1.40	0.12	3.69	2.27	0.24	0.17	6.25	96.87	6.72	87.33
L. leucocephala	4.9	3.09	1.79	0.16	4.18	2.14	0.27	0.23	6.64	96.18	8.37	89.75
G. sepium	4.5	2.87	1.66	0.13	3.20	2.58	0.26	0.12	6.08	97.88	7.87	87.44
A. *Lebbeck*	4.2	2.24	1.30	0.10	2.36	1.65	0.18	0.32	4.22	92.16	6.01	82.40
LSD (0.05)	0.10	0.93	0.35	0.057	0.47	1.91	0.15	0.24	4.33	6.84	2.58	23.60

Means significantly difference at (P≤0.05)

Table 3:Comparison of selected soil chemical properties within 10-20 cm depth under five MPTS

Soils under Species	pH	OM	C	TN	Ca	Mg	K	Exc. Acidity	ECEC	BS	P	K
		%			cmol(+)/kg					%	ppm	
S. spectabilis	4.4	1.62	0.94	0.08	2.49	1.51	0.10	0.27	4.14	93.17	1.29	50.45
S. siamea	4.4	1.62	0.94	0.07	2.85	1.69	0.14	0.15	4.74	96.91	1.00	58.81
L. leucocephala	4.6	1.53	0.89	0.08	2.94	0.80	0.14	0.53	3.93	85.58	1.95	45.20
G. sepium	4.2	1.20	0.70	0.04	1.96	0.89	0.12	0.52	3.02	84.19	1.77	50.69
A. *Lebbeck*	4.0	1.20	0.70	0.07	1.73	0.71	0.11	0.65	2.64	79.45	1.14	48.05
LSD (0.05)	0.92	0.34	0.31	0.03	1.47	1.05	0.07	0.47	2.31	15.84	1.34	22.83

Means significantly difference at (P≤0.05)

Table 4: Comparison of selected soil chemical properties within 20-30 cm depth under five MPTS

Soils under Species	pH	OM	C	TN	Ca	Mg	K	Exc. Acidity	ECEC	BS	P	K
		%			cmol(+)/kg					%	ppm	
S. spectabilis	4.9	2.73	1.58	0.13	2.76	0.71	0.12	0.43	3.65	87.70	1.88	81.46
S. siamea	4.8	2.89	1.68	0.15	2.23	0.80	0.11	0.40	3.18	87.76	2.33	82.58
L. leucocephala	4.7	3.54	2.05	0.18	1.78	0.31	0.09	0.47	2.20	81.83	2.31	78.12
G. sepium	4.4	2.63	1.53	0.12	1.69	0.27	0.09	0.47	2.08	80.61	1.47	74.68
A. *Lebbeck*	4.1	2.45	1.42	0.12	1.38	0.31	0.06	0.73	1.82	71.50	2.35	66.96
LSD (0.05)	0.17	2.87	0.48	0.15	1.67	0.49	0.081	0.27	1.95	26.44	1.64	18.90

Means significantly difference at (P≤0.05)

Table 5: Comparison of the nutrient levels of leaf material from five MPTs species

Soils under Species	N	P	K	Ca	Mg	Org. Carbon
S. spectabilis	3.88	0.16	0.57	0.35	0.41	43.0
S. siamea	3.08	0.18	0.47	0.54	0.39	42.5
L. leucocephala	4.48	0.18	0.68	0.90	0.59	40.5
G. sepium	3.55	0.23	0.66	1.12	0.57	40.5
A. *Lebbeck*	4.76	0.18	0.43	0.42	0.63	41.5
LSD (0.05)	0.02	0.02	0.01	0.03	0.021	0.33

Means significantly difference at (P≤0.05)

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CONCLUSION

The essence of fallow is to restore the productive potential of the soil; building up the chemical and physical soil for subsequent crop use. Generally, all five MPTs species have equal potential in improving soil physical and chemical properties despite the differences seen in levels of nutrient in the biomass. The analytical data compiled for the chemical and physical properties of the soils under the five different multipurpose trees agrees with the general agroforestry hypothesis; that all MPTs species have equal potential of improving soil physical and chemical properties. There were no significant differences between soil properties under the different MPTs.

The hypothesis that soil chemical properties after fallow will not differ in a particular agro-ecological zone under the five MPTs; the hypothesis is true; results from the analysis of the soil of the study area showed that nutrient levels from soils under the different MPTs were not significantly different from each other. Though there are differences in the levels of nutrient inputs from biomass, these differences did not reflect in the soil studies.

The objective for determining soil physical and chemical properties, especially nutrient levels, is to ascertain their levels in the soil that could support the cultivation of preferred crops on farmers' fields. The amounts of nutrients reported were between low and moderate N; 0.1-0.16%, P; 6.01-8.37ppm P, K; 82.4-92.38ppmK and Ca; 2.36-4.18cmol (+)/kg. These amounts could be harnessed with the support and benefits derived from leaf biomass decomposition which would provide an extended nutrient release from the various fractions of OM and humus to improve the soil chemical and physical properties. The added advantage for the global environment is when through agroforestry carbon sequestration is increased.

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