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Qualitative and Quantitative Evaluation of Four Organic Materials as Nutrient Resources for Maize in the Nigerian Savanna

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Abstract: This study reports on the evaluation of four organic materials as key ecosystem resources for maize intensification in the Nigerian savanna. Two aspects are examined, first the qualitative value of the organic materials as sources of nutrients and secondly the quantitative significance of the organic materials within the context of the Nigerian savanna. The results showed that cow dung, *M. pruriens* vines and *L. leucocephala* pruning contained sufficient nutrients to meet the N and K requirements of a maize crop at an application rate of 5 t ha^{-1}. Phosphorus contents of maize stover and *L. leucocephala* pruning were not in sufficient quantities to meet crop demand. The calcium and magnesium requirements can be adequately met by this rate for all the organic amendments used. When the organic materials were evaluated based on the contents of nutrients and deduced ratios, cow dung, *M. pruriens* vines and *L. leucocephala* pruning were characterized as high quality materials, while maize stover was considered to be a low quality material. Based on their nutrient concentrations and deduced ratios, cow dung, *M pruriens* vines and *L. leucocephala* pruning were characterized as high quality materials. Maize stover may be considered as a low quality material. This grouping of the organic materials was confirmed using principal component and correlation analysis. The study also indicated that there are insufficient amounts of organic materials available to support crop production at a scale wider than small on-farm levels.

Key words: Organic materials, soil fertility, maize, savanna, nutrient quality

INTRODUCTION

The Nigerian savanna covers an area of about 65 million ha (773,789 km^2) accounting for about 78.7% of the country's land area stretching from the humid to dry savannas. Soil fertility depletion below critical levels is a major constraint to crop production in the Nigerian savanna. Nutrient depletion and soil degradation have increased gradually in this ecological region and have become serious threats to agricultural productivity in Nigeria. Earlier approaches at restoring and maintaining soil are no longer viable and sustainable due to rapid population growth and other socio-economic problems. High fertiliser costs have also limited farmers from applying the recommended quantities in balanced proportions (Ange, 1995; Dudal, 2002). This has resulted in net negative nutrient balance in most fields. Organic materials have been found to play critical roles in both short and long-term nutrient availability and maintenance of soil organic matter in small holder systems in the tropics and represent key materials in reversing nutrient depletion.

Organic amendments (which include multipurpose shrub and tree pruning, green manures, crop residues and animal wastes) are materials of plant or animal origin used for improving the fertility of soils. Traditional organic materials generated in the Nigerian savanna are crop residues and animal wastes, with maize stover and cow dung being the most important in terms of availability. Green manuring including legume cover crops are practices that have not been extensively used.

The significance and agronomic value of organic materials is measured by their quality, which is a reflection of their ability to supply plant nutrients. Considerable information is available on the quality of organic manure, which has been found to vary widely (Uyovbisere and Elemo, 2000; Vanlauwe *et al*., 2001). An organic material database, reflecting quality parameters for a wide range of organic materials has been compiled (Palm *et al*., 2001). This information is lacking for organic materials generated

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in the Nigerian Savanna, which should have been used for the development of soil management strategies for efficient utilization of organic manures (Agbim and Adeoye, 1991; Swift and Palm, 1995; Xie and Mackenzie, 1986).

Research over the last decade has led to the identification of several quality parameters for predicting nutrient release and decomposition from organic materials. Nitrogen content and C:N ratios are the primary indicators of decomposition and nutrient release across a wide range of organic materials (Delve *et al*., 2004). However, several other factors such as concentration of P, carbon, hemi-cellulose and lignin and ratios of chemical components such as lignin:N, N:P and C:P have also been identified as parameters for evaluating quality of the materials (Gordillo and Cabrera, 1997; Lupwayi and Hague, 1998; Palm *et al*., 1999). They are needed to explain variations observed in decomposition and nutrient release studies. The relative importance of the different parameters in different organic materials and their interaction is still a matter of considerable debate and research effort (Heal *et al*., 1997; Palm and Sanchez, 1990; Vanlauwe and Sanginga, 2004). The incorporation of organic amendments with C: N ratios higher than 30:1 results in N immobilization, N deficiency and slow rate of decomposition. Residues with a lignin content of 20-25% decompose too slowly to be effective nutrient sources for growing crops (Brady and Weil, 1999). The addition of plant materials with P concentration less than 2.4 g kg^{-1} results in net immobilization by soil microbes and a decrease in plant available P in the soil P (Blair and Boland, 1978).

The study was therefore, conducted to assess and classify four organic materials in the Nigerian savanna with respect to their nutrient contents and quality characteristics as soil amendments.

MATERIALS AND METHODS

Four organic materials, (cow dung, maize stover, *M. pruriens* vines and *L. leucocephala* pruning), commonly used in the Nigerian savanna, were collected and characterized over a three year period (1998-2000), at Samaru, Nigeria. Samaru is located on 11°11"N and 7°38"E at an altitude of 686 m above sea level. The cow dung was obtained from diary cattle at the National Animal Production Research Institute, Shika, Nigeria. The maize stover, *M. pruriens* vines and *L. leucocephala* pruning were obtained from research fields of the Institute for Agricultural Research, Zaria, Nigeria. For the green manures, the above ground portion of *Mucuna pruriens* was harvested after eight weeks of growth with supplementary irrigation and leaf prunnings (including leaves and twigs) of *leucaena leucocephala* were obtained from the IAR Farm Samaru. The crop maize residue consisted of maize stover left on the field after harvest of the previous season crop. The various organic materials were collected, air dried and chopped into small bits (about 2-5 cm) as large fragments can cause marked immobilization during incubation.

Samples of the organic materials for chemical analysis were taken at time of collection. The ground sub samples of the organic materials were chemically characterized. Total N was determined by the Microkjeldhal wet digestion method. Total carbon was determined according to Walkley and Black method as described by Page *et al.* (1982). The organic materials were wet digested according to Juo (1979) and P in the digest determined calorimetrically, while K, Fe and Zn were determined by using atomic absorption spectrophotometer. Cellulose and lignin were determined by the modified Van Soest system of analysis as described by Fonnesbeck and Harris (1970). This method is an improvement over Van Soest system of analysis, as it more accurately partitions the cell wall constituents (Krisha and Ranjhan, 1980). Statistical analysis of all the parameters was undertaken using SAS and S-Plus programmes (Statistical Analysis System, 1985; S-Plus, 2000). Correlations and principal component analysis were used for grouping the organic materials into clusters based on their chemical characteristics. Principal component analysis finds a set of standardized linear combinations called the principal components, which are orthogonal and taken together explain all the variance of the original data (Mardia *et al*., 1979). The first principal component has the largest variance among all standardized linear combinations of a vector. Similarly, the second principal component has the largest variance among all standardized linear combinations uncorrelated with the first principal component and so on. In general, there are as many principal components all standardized linear combinations as variables. The principal component loadings are the covariance's of the principal components with the original variables. However, it is recommended that only a few of the principal components, which together explain most of the original variation, be considered (S-Plus, 2000).

RESULTS AND DISCUSSION

The compositions (Table 1) reflected differences in the sources, as organic materials very widely depending upon their sources (Mengel and Kikby, 1979; Titiloye *et al*., 1985). Although all the nutrients in the organic materials may not be available to the crop, the

Table 1: Selected chemical characteristics of organic materials used in the study for the various years

	Cow dung			Maize stover			*Mucuna pruriens*			*Leucaenae leucocephala*		
Parameter	1998	1999	2000	1998	1999	2000	1998	1999	2000	1998	1999	2000
N (%)	2.18	2.55	2.36	1.06	1.46	1.26	2.29	2.77	3.08	2.49	2.88	2.77
P (%)	0.55	0.58	0.49	0.17	0.23	0.19	0.35	0.37	0.40	0.25	0.29	0.28
K (%)	1.36	1.09	1.95	0.95	0.91	0.73	1.38	1.35	1.37	1.73	1.45	1.18
Ca (%)	1.24	1.29	1.36	0.60	0.70	0.60	1.47	1.43	1.45	1.64	1.52	1.56
Mg (%)	0.39	0.41	0.36	0.39	0.41	0.32	0.40	0.40	0.42	0.43	0.36	0.39
C (%)	52.79	50.95	53.23	55.94	58.65	56.64	44.21	42.79	41.81	32.45	31.28	32.26
Lignin (%)	15.96	17.44	11.83	12.22	11.30	14.21	17.21	14.27	16.95	24.92	23.06	24.81
Cellulose (%)	41.95	41.76	61.07	39.85	40.39	38.94	62.20	55.63	57.69	34.75	56.38	51.22
Fe (ppm)	1500	1600	1650	500	580	450	750	500	800	900	880	720
Cu (ppm)	30	30	35	10	10	25	20	30	10	25	20	20
Zn (ppm)	82	82	70	42	42	30	36	42	60	50	70	72
C:N	24	20	23	58	60	53	19	15	14	12	11	13
N:P	4	4	5	6	4	6	7	7	8	10	10	10
C:P	96	88	109	329	255	298	126	116	105	130	108	115
C:N:P	44	34	47	344	260	281	54	40	35	52	38	42
N:C	0.04	0.05	0.04	0.02	0.02	0.02	0.06	0.07	0.08	0.09	0.09	0.06
Lignin:N	7	7	5	12	12	11	8	5	6	9	8	10
Lignin:cellulose	0.38	0.42	0.19	0.31	0.28	0.36	0.28	0.26	0.29	0.72	0.41	0.48
Cellulose:N	19.38	16.38	25.88	41.61	41.21	36.74	27	20	19	14	20	18
N-P_2O_5-K_2O (2:1:1)	2:1:1	2:1:1	2:1:2	3:1:3	3:1:2	3:1:2	3:1:2	3:1:2	3:1:2	4:1:4	4:1:3	4:1:2

information can provide a qualitative estimation of the organic materials (Palm *et al*., 1997). The findings on compositions of the organic materials were in general agreement with previous reports on the subject (Vanlauwe *et al*., 2001; Palm *et al*., 1997, 1999; Mafongoya *et al*., 1997).

Cow dung: The N values of cow dung in the study for the three years ranged from 2.18 to 2.55% with a mean of 2.36%. The P content also varied as for N and ranged from 0.49-0.58% with a mean of 0.54% (Table 1). The lignin contents were generally above the critical values of 150 g kg^{-1} and ranged from 118.3-174.4 g kg^{-1} with a mean of 150.8 g kg^{-1}. Animal manure has been shown to vary with age, species, feed composition and husbandry systems (Van and Van, 1987; Ofori and Sant' Anna, 1990). It was found in a long term study, that even when the manures were obtained from the same source in each study, there were wide yearly differences in dry matter C and N contents (Rasmussen and Collins, 1991). The C:N ratio however varied less ranging from 20-24 with a mean of 22.

Nitrogen content was highest of the macronutrients, followed by K and Ca with the Mg and P contents being the lowest. The results compare favourably with previous studies by other researchers (Vanlauwe *et al*., 2001; Williams *et al*., 1995). The average contents for Fe, Zn and Cu were in agreement with reports found in literature (Lupwayi *et al*., 2000). Cow dung had N and P values above the critical levels of 2.0 and 0.2% and would be expected to result in net release of these nutrients on application to the soil (Blair and Boland, 1978; Palm *et al*., 1997). Also cow dung had C:N, C:P and N:P ratios below the critical ranges of between 100-300, 25-30 and 10, respectively (Iyamuremye and Dick, 1996) and is expected to mineralise N and P more readily and quickly on application to the soil.

Lignin is an important modifier of N release from organic materials. The mean value of 15.08% is at about the critical lignin levels for cow dung and indicates that cow dung may show a time lag in nutrient availability (Table 1). This would suggest that cow dung can be considered as an intermediate quality material. A chemical characterization study of a wide range of organic materials was observed to similarly group cow dung into the intermediate quality class (Gachengo *et al*., 2004). However, the high nutrient value obtained for cow dung in this study, would suggest a high quality class for the material, despite its marginal lignin content. Organic materials should normally be considered complete fertilisers (N-P_2O_5-K_2O) (Palm *et al*., 1997). The cow dung was observed to have an NPK nutrient ratio (2:1:1) that is similar to that required by the maize crop (Table1).

Maize stover: Nitrogen content of the maize stover was lowest of the four organic materials considered, with values that ranged from 1.06-1.46%, with a mean of 1.26%. The P values ranged from 0.17-0.23% with a mean of 0.2% (Table 1). Climate, soil type, plant species and management practices are major factors that influence the nutrient content of plant residues. Both N and P values of the maize stover were below critical values, with implication of possible immobilization on application to the soil.

The lignin content was less than the critical value and ranged from 11.30-12.22%. Lignin concentrations of crop

Table 2: Simple linear correlation coefficients for some quality parameters

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	C (%)	Lignin (%)	Cellulose (%)	Fe (ppm)	Cu (ppm)	Zn (ppm)
N (%)	1										
P (%)	0.4942	1									
K (%)	0.6060	0.4167	1								
Ca (%)	0.9263*	0.4276	0.7508	1							
Mg (%)	0.3493	0.1897	0.2124	0.3872	1						
C (%)	-0.7571	0.0943	-0.4559	-0.8217	-0.2626	1					
Lignin (%)	0.5923	-0.0819	0.2844	0.6975	0.2174	-0.9057	1				
Cellulose (%)	0.5734	0.2890	0.4807	0.5149	-0.0934	-0.3037	-0.0073	1			
Fe (ppm)	0.3210	0.8648*	0.5302	0.3526	0.0594	0.1009	0.0143	0.09879**	1		
Cu (ppm)	0.2636	0.6069	0.4599	0.3509	-0.2761	-0.0071	0.0427	0.09257*	0.6283	1	
Zn (ppm)	0.5375	0.7260	0.3742	0.4716	0.1234	-0.2298	0.3337	0.1073	0.8047	0.3761	1
C:N	-0.9496*	-0.4942	-0.6941	-0.9794**	-0.3014	0.7993	-0.682	-0.5147	-0.3801	-0.4104	-0.5205
N:P	0.5096	-0.4320	0.2993	0.5817	0.0892	-0.9189*	0.8178	0.2254	-0.3804	-0.1964	-0.0518
C:P	-0.9153*	-0.7390	-0.6851	-0.9109*	-0.3407	0.5732	-0.4881	-0.5094	-0.6084	-0.4953	-0.6786
C:N:P	-0.9342**	-0.6742	-0.7036	-0.9446*	-0.3166	0.6389	-0.5396	-0.5310	-0.5408	-0.4985	-0.6124
N:C	0.8891	0.1108	0.4973	0.8810*	0.2867	-0.9655**	0.8445	0.4079	0.0457	0.0698	0.39383
Lignin:N	-0.7394	-0.7744	-0.6891	-0.6668	-0.1314	0.2367	-0.0180	-0.6233	-0.5617	-0.6029	-0.4475
Lignin:cellulose	0.1862	-0.1928	0.1132	0.3492	0.2965	-0.5770	0.8052	-0.5554	0.0125	0.07048	0.1675
Cellulose:N	-0.8922*	-0.5667	-0.5950	-0.9055*	-0.3667	0.7205	-0.7016	-0.2396	-0.474	-0.4771	-0.6261

residues have been reported to be generally less than 15% (Palm *et al*., 2001). This value is considered too low to affect decomposition and nutrient release processes of the organic material. The C:N and C:P ratios of maize stover were above the critical ranges of 25-30 and 100-300, respectively indicates possible immobilization of nutrients on application. The relative average content of macro and micro-nutrients in maize stover was similar to that observed in cow dung (Table 1). Maize stover was observed to have a nutrient ratio that is considerably lower in P_2O_5 than in N and K_2O.

***Mucuna pruriens* vines:** The N content of *M. pruriens* vines was superior to the values for cow dung and maize stover. The N values ranged from 2.29 to 3.08%. The P levels on the other hand, were higher with respect to maize stover, but lower in relation to cow dung. The p-values ranged from 0.35-0.40% (Table 1). The values for both nutrients were above the critical range, below which decomposition may be hindered. Decomposition and mineralization of nutrients are expected to proceed readily on application of *M. pruriens* vines to the soil

The lignin contents ranged from 14.27-17.21% for the three years. Although, these levels were above the critical range, lignin content is not considered very important in legumes with high N levels. Legume materials with high lignin and polyphenol contents, but with N contents greater than 2.5% may be classified as high quality materials (Palm, 1995). Reasons adduced for this were that even with high lignin and polyphenol contents, legume materials on the average release more N than non-legumes (Mafongoya *et al*., 1997; Constantinides and Fownes, 1994). *M. pruriens* vines can therefore be classified as a high quality organic material and is therefore expected to decompose and release nutrients quickly. It can therefore be applied directly to the soil for quick contribution to the needs of the crop. The C:N, C:P and N:P ratios were in the adequate to influence release of nutrients. The relative order of macronutrient element content on the average was N>Ca>K, while the order of micronutrient contents was Fe>Zn>Cu. Similar to maize stover, *M. pruriens* vines had a nutrient ratio that is considerably lower in P_2O_5 than in N and K_2O (Table 1).

***Lueceana leucocephala* prunning:** The N content of *L. leucocephala* pruning was relatively high and ranged from 2.49 to 2.88%. The P levels ranged from 0.25-0.29%, while the lignin contents ranged from 31.28-32.45% (Table 1). For plant residues such as *L. leucocephala* pruning, variability may be due to relative proportion of leaves and twigs in the samples (Szott and Kass, 1993). Similar to M pruriens, the N and P values of *L. leucocephala* pruning are above the critical range required for decomposition to occur. Application of *L. leucocephala* pruning to the soil would therefore be expected to lead to mineralization of these nutrients. The C:N, C:P and N:P ratios were also in the adequacy range and would allow for release of nutrients. *L. leucocephala* pruning may therefore be classified as a high quality organic material. The nutrient ratio was considerably lower in P_2O_5 than in N and K_2O when compared to maize stover and *M. pruriens.*

Relationship between chemical characteristics of the organic materials: A strong relationship between any two or more properties implies that they would vary in similar magnitudes (Table 2). The correlation analysis showed that N was linearly correlated with Ca ($r = 0.9623^{**}$) and inversely related with C:N ($r = -0.9496^{*}$), C:P ($r = -0.9153^{**}$), C:N:P ($r = -0.9342^{*}$) and cellulose:N

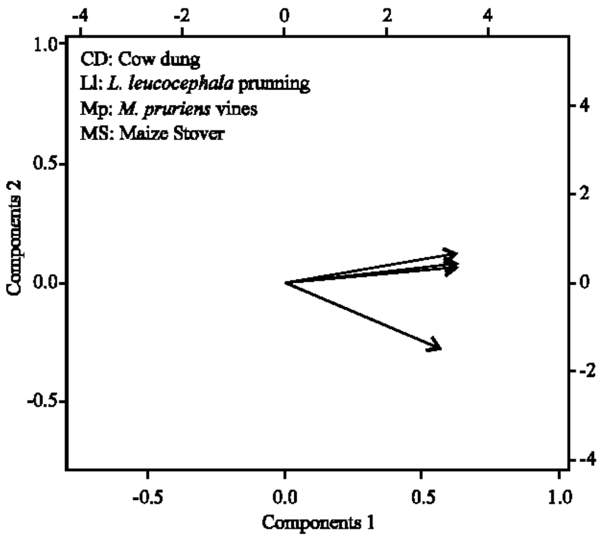

Fig. 1: Principal component analysis of the organic materials

(r = -0.8922*). This is consistent with current research findings, which indicated that high values of C:N, C:P, C:N:P and cellulose: N ratios reduce the quality of organic materials. Hence, *M. pruriens* vines and *L. leucocphala* that had relatively higher N values, also had high contents of Ca and low nutrient ratio values. Maize stover, which was classified as a low quality material, was generally low in nutrients and high in nutrient ratio values. The ratios essentially express interactions within variables (Kachaka *et al.*, 1993). The application of ratios helps to clearly distinguish between different organic materials. This is particularly observed with C:N ratio where the difference between the lowest value (*L. leucocephala*) and the highest value (maize stover) represents a five-fold increase (Table 2). The correlation analysis also showed that P contents of organic materials appear to be independent of other chemical parameters, but becomes of importance when the P content is considered in relative proportions to carbon such as C:P and C:N:P.

Principal component analysis: The first principal component explained about 93.48% of the variation. The first two principal components together, explain about 99.95% of the variance (Table 3). Only a few of the principal components, which together explain most of the original variation, be considered (S-Plus, 2000). Figure 1 revealed how the organic materials differed in nutrient contents. A reasonable interpretation is that this represents an average quality value for the organic materials, taking all the parameters shown in Table 1 into consideration. Maize stover had relatively lower average quality value in comparison with the other

Table 3: Relative importance of the components

	Components 1	Components 2	Components 3	Components 4
SD	1.9337931	0.50646278	0.0581986110	0.0235103786
Proportion of variance	0.93489	0.06412614	0.0008467696	0.0001381845
Cumulative proportion	0.93489	0.99901505	0.9998618155	1.0000000000

Table 4: Nutrient contents of the organic materials compared to nutrients required by a maize crop (5 kg ton^{-1} DM) averaged over three years (Adapted (Sanchez, 1976))

Organic materials	N (5 kg ton^{-1} DM)	P (5 kg ton^{-1} DM)	K (5 kg ton^{-1} DM)	Ca (5 kg ton^{-1} DM)	Mg (5 kg ton^{-1} DM)
Cow dung	118	27	73.5	65	19.5
Maize Stover	63	10.7	43	31.5	18.5
M. pruriens vines	135.5	18.5	68.5	72.5	20.5
L. leucocephala pruning	135.5	13.5	72.5	78.5	19.5
Nutrients required by 2 tounes maize grain +3 tounes stover (kg ha^{-1})	82	18	66	15	10

organic materials. Cow dung, *M. pruriens* vines and *L. leucocephala* pruning have similar loadings in absolute value for the first component and the lengths of the arrows are therefore similar (Fig. 1). Although not as clearly, the first principal component also separated the leguminous organic materials from cow dung. Cow dung had slightly lower average nutrient content levels. The principal component analysis thus revealed the differences in the nutrient contents of the organic material.

The second component contrasts maize stover with cow dung, *M. pruriens* vines, *L. leucocepala* (Fig. 1). The loading on the second component was negative for maize stover and positive with differing values, for the other organic materials, thus the arrows are seen to be pointing slightly upwards in different degrees, while the arrow for maize points downwards (Fig. 1). An examination of the component loadings revealed that maize stover had relatively higher values of nutrient ratios and lower N and lignin contents. This grouping by principal component analysis confirms the correlation results as the second principal component separated high quality organic materials from low quality materials. This may indicate the potential of principal component analysis for use in qualitative classification of organic matter sources.

Soil fertility and productivity implications: Generally, none of the organic materials were found to contain all the major nutrients in high amounts. However, the organic materials may influence soil nutrient levels and availability patterns through their effect on net soil mineralisation or immobilization patterns, microbial activity, low P adsorption potential as well as the retention of nutrient elements. On-farm trials in the Nigerian savanna, have indicated that the application of 5-10 t ha^{-1} of organic

Table 5: Potential supply of cow dung and maize stover in Nigerian savanna*

	Maize crop residue		Cattle manure**	
	1993-2002	2003	1993-2002	2003
Biomass (000 MT)	16 592	15 450	30 080	30 327
Biomass (kg ha^{-1} cultivated land)	0.63	0.59	1.15	1.16
Biomass potential (percent of cultivated land per annum)***	12.70	11.83	23.02	23.21

*Based on FAO cattle population and maize production statistics, **Assuming eighty percent of the cattle population are used for manuring and that each animal produces an average of 2.5 tonnes recoverable manure per year when corralled overnight, *** Assuming an application rate of 5 tonnes ha^{-1}

materials is needed to replenish nutrients taken up through crop removal (Karikari and Yayock, 1987). The N and K contents in 5 t dm ha^{-1} of the four organic materials, with the exception of the maize stover, were sufficient to meet the N and K requirements for the production of two tonnes of maize grain and three tonnes of maize stover (Table 4). Phosphorus in maize stover and *L. leucocephala* pruning was not in sufficient quantities to meet the need by the maize crop. The calcium and magnesium requirements could be adequately met by the application of 5 tons of organic material /ha. Most of the soils in the tropics are P limited (Sanchez, 1976). The use of maize stover and *L. leucocephala* pruning as soil amendments would require P supplements from other sources. It has been similarly reported that most organic materials contain sufficient nutrients to meet the need for a two tonne crop but may not meet the P requirements, when applied at moderate levels of 5 t dm ha^{-1} (Palm, 1995).

The fertility effect of application of organic materials to a system depends on the source of the nutrients with regards to the boundaries of the system being considered (Lupwayi *et al*., 2000). The effects may be an addition to the system or a mere cycling of nutrients. In savanna areas, cattle graze extensively on non-arable land and arable land (after harvest) during the day and then corralled in cultivated fields after harvest. This would represent nutrient enrichment from surrounding lands. Unused crop residues are usually burnt *in situ*, used as surface mulch or incorporated into the soil during cultivation. The potential of organic materials to sustain crop production is limited by crop and livestock population, spatial location of the organic materials at the time of application ands other competing uses. Little or no studies have been undertaken to assess the sufficiency of organic materials for crop production at various systems in the Nigerian savanna. A combined application of estimated amounts of these two organic materials would be sufficient to meet the maize crop requirement on about 35% of the cultivated land in the Nigerian savanna (Table 5).

CONCLUSIONS

Laboratory and statistical analysis of four organic materials, (cow dung, maize stover, *M. pruriens* vines and *L. leucocephala* pruning), commonly used in the Nigerian savanna, showed that they can be grouped into two categories with respect to their quality characteristics as it relates to nutrient release. Materials high in N with low nutrient ratios and materials low in N with high nutrient ratios. Results indicate that there are insufficient amounts of organic materials available to support crop production at a scale wider than small on farm levels. Also, whatever the quality of organic materials with regard to plant nutrients, farmers in the Nigerian savanna will use them for other competing uses. It is however not known whether the amount of organic materials available in the Nigerian savanna is sufficient to support crop production.

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