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EFFECT OF ORGANIC AND INORGANIC SOIL AMENDMENTS ON SOIL PHYSICAL AND CHEMICAL PROPERTIES IN A WEST AFRICA SAVANNA AGROECOSYSTEM

[EFECTO DE ENMIENDAS ORGANICAS E INORGANICAS SOBRE LAS PROPIEDADES FISICAS Y QUIMICAS DEL SUELO EN AGROECOSISTEMAS DE LA SABANA AFRICANA OCCIDENTAL]

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SUMMARY

Long-term agroecosystem productivity has stirred up the need to develop and implement nutrient management strategies that maintain and protect soil resources. In an attempt to address this, the current study involved the incorporation of residues of *Centrosema pascuorum, Lablab purpureus* and *Parkia biglobosa.* In addition, an inorganic fertilizer amended soil and, a maize/*Lablab purpureus* intercrop, along with the control (no amendment) was included. The treatments were replicated three times and the site had been under continuous cultivation for eight years in a savanna Alfisol. Soil quality (physical and chemical) indicators were examined for treatments effects. Dry macroaggregate turnover increased by 7% under *C. pascuorum* amended soils. This same treatment had more water-stable large microaggregates and a 40% increase in aggregated silt and clay content. Soil bulk density and saturated hydraulic conductivity reduced in nutrient management practices involving residue incorporation. However, soil organic carbon, total soil nitrogen, exchangeable Ca^{2+} and Mg^{2+} concentration were highest with soil receiving *C. pascuorum.* Crop residue management practices involving incorporation of *C. pascuorum* significantly improved soil physical and chemical properties of the study area.

Key words: Aggregate stability; soil organic carbon; crop residue management; fertilizer; Northern Guinea Savanna.

RESUMEN

La productividad a largo plazo de los agroecosistemas ha estimulado el desarrollo e implementación de estrategias de manejo de nutrientes que mantengan y protejan el suelo. Para contribuir a este objetivo, el presente estudio estudio la incorporación de residuos de *Centrosema pascuorum, Lablab purpureus* y *Parkia biglobosa.* Adicionalmente se estudió el empleo de fertilizante inorgánico, cultivo intercalado de maíz/*Lablab purpureus*, y un control. Los tratamientos se aplicaron en un área que había estado en cultivo contínuo por ocho años (Alfisol de savana). Se evaluaron las características físicas y químicas del suelo. El recambio de macroagregados secos se incrementó 7% en los suelos con adición *C. pascuorum.* Este mismo tratamiento tuvó mayor cantidad de microagregados hidro-estables y un incremento de 40% en los agregados de arcilla y limo. La densidad del suelo y la conductividad hidraúlica saturada se redujó en las prácticas que involucraban incorporación de residuos. Sin embargo, el carbono orgánico del suelo, nitrógeno total, Ca^{2+} intercambiable y la concentración de Mg^{2+} fueron más altos en el suelo que recibió *C. pascuorum*. La prácticas de manejo de residuos involucrando la incorporación de *C. pascuorum* mejoraron significativamente las propiedades físicas y químicas del suelo del área de estudio.

Palabras clave: Estabilidad de agregados; carbono organico; manejo de residuos de cosecha; fertilizantes; Savana Norte de Guinea.

INTRODUCTION

The intensification of land use systems in the West African savanna agroecosystem has adversely affected soil quality. Declining fertilizer use as well as unsuitable crop rotation has resulted in negative nutrient balance in most of these soils of the region. The high degree of weathering and the continuous mining of soil nutrients in the absence of sufficiently amount of external inputs have further degraded the soil quality (Vanlauwe *et al.,* 2002).

The traditional method of soil fertility maintenance in the west African savanna agroecosystem is bush fallow, which is an efficient soil fertility restoration practice, since it mimics the natural ecosystem from which the agricultural systems developed (Lefroy *et al*., 1995). However, increasing population in most west African countries and, economic changes have caused a widespread disappearance of the restoration practice and cultivation has expanded into marginal soils. The result of all these is systematic degradation of many land holdings and declining crop yields.

Maintenance and improvement of soil quality is vital if agricultural productivity and environmental quality are to be sustained for future generations (Reeves, 1997). Soil aggregation and soil organic matter are important indicators of soil quality. Soil aggregation is important in maintaining soil structural stability. Soil water movement and retention, crusting and aeration are all influenced by aggregation. Soil organic matter is the primary source of energy and nutrients for many soil organisms and influences soil structure, water holding capacity, cation exchange capacity and the formation of stable aggregates (Craswell and Lefroy, 2001).

Long term studies in the Nigerian Guinea savanna have shown consistently the benefits of manure and mineral fertilizers in maintaining and improving organic matter and aggregation in soils (Ogunwole, 2005; Ogunwole and Ogunleye, 2004). Organic matter inputs such as green and farmyard manures, crop residues provide short term of nutrient supply. Hence, the recycling of these organic inputs through their disposal on cultivated land for crop production is a good soil fertility management strategy from the standpoint of improving soil's productive capacity and reducing dependence on mineral fertilizers. There is presently a widespread interest in exploring the possibility of integrating organic input and inorganic fertilizer in the west African farming systems, as this practice may advance both economic and environmental aspect in the long-run. The objectives of this study were to evaluate the impact of eight years of organic/inorganic input practices under continuous cultivation on soil quality and to establish relationship between soil aggregate stability and the soil quality indicators.

MATERIAL AND METHODS

Site description

The experiment was located at the experimental research farm of the Institute for Agricultural Research (IAR) Samaru (11º 11'N; 07º38'E; 686m asl) in the Northern Guinea Savanna of Nigeria and, established on a leached tropical ferruginous soil, classified as Typic Haplustalfs (silt loam, isoyperthermic according to the USDA Soil Taxonomy of 1975). These soils have a clay fraction made up of predominantly Kaolinitic mineral with some portion of fine quartz. The experimental plot was planted to maize between 1997 and 2005, either as a sole crop or intercropped with legumes. The high soil available phosphorus (P) level (11mgkg^{-1}) in the surface soil at the commencement of the experiment was principally due to depositions of high phosphorus silt from harmattan dust (Table 1). Long term mean annual rainfall at Samaru is 1050 mm with a unimodal rainfall pattern concentrated between May and October of the year.

Table 1. Selected soil properties at the commencement of study in 1997

Properties	Amount in soil
Sand (g kg^{-1})	470
Silt (g kg^{-1})	430
Clay (g kg^{-1})	100
Texture	Silt loam
pH 1:2.5 (water)	5.2
Organic carbon (g kg^{-1})	5.4
Total nitrogen (g kg^{-1})	0.5
Available phosphorus (mg kg^{-1})	11
Exchangeable calcium (cmol kg^{-1})	2.3
Exchangeable magnesium (cmol kg^{-1})	0.4
Exchangeable potassium (cmol kg^{-1})	0.2

Experimental details

The trial is an organic/inorganic input experiment, whose treatments involved three maize/legume intercropping systems (i.e. maize/ *Lablab purpureus*; maize/*Centrosema pascorum* and maize/*Vigna unguiculata*), with the legume residues either incorporated into the Ap horizon or removed totally from the field, with different combination of inorganic fertilizer added to the various plot since 1997. Another set of treatment involving maize monoculture with cowdung, poultry litter or locust bean (*Parkia biglobosa*) as soil amendment at different levels of inorganic fertilizer commenced 1998. A total of 33 treatments were laid out in a randomized complete block design with three replications and each plot size was 36m^{2}.

Land preparation was done manually using the traditional hoe. For the plots amended with *C. pascorum* and *L. purpureum*, the legumes were sown on these plots and the quantity of inorganic matter incorporated was the quantity grown on the plot, which varied on yearly basis. For the *P. biglobosa* amendment plots, the quantity of leaves equivalent of 45KgN/ha were harvested from Parkia trees near the research farm, chopped and incorporated at 10cm below the soil surface. The plots were ridged with inter-row spacing of 0.75m and maize were sown at a population of 53,000 plants/ha. All treatments (except the control) received Urea fertilizer (2 split dose) at 45 Kg N/ha, 10 Kg P/ha and 30 Kg K/ha as Triple Superphosphate and Potassium chloride respectively.

Soil Sampling and Analysis

The Ap horizon (0 – 15 cm depth) from five plots was sampled for this study. In addition, a control plot (unfertilized), under continuous cropping for 8 years (1997-2005) was sampled. Table 2 gives a detailed description of the selected plots. Both disturbed and undisturbed (core) soils were sampled from these six treatment plots.

The disturbed soils samples were passed through a 4-mm sieve before air-drying. The air-dried bulk soil samples were each divided into two portions, one portion was ground and sieved through a 2-mm sieve, and the fine samples (< 2-mm) were used to determine particle size by the hydrometer method (Gee and Bauder, 1986), with calgon and water each as dispersant. Soil reaction was determined in 1: 2.5 soil/water suspension. The Kjeldahl digestion procedure was used to determine total nitrogen while organic carbon was determined by the Walkley and Black wet oxidation method. Available P was extracted by Bray P_1 acid-fluoride method, with P concentration in the extract determined colorimetrically with the Bausch and Lomb spectronic 70 Spectrophotometer. Exchangeable bases were determined by ammonium acetate extraction, with Ca and Mg estimated by Atomic Absorption Spectrophotometer (AAS), and K and Na by the flame photometer.

Table 2. The selected nutrient cycling treatments of the Samaru soil under continuous cultivation for 8 years (1997-2005)

Plot No.	Name	Treatment description	Inorganic fertilizer rates (kg/ha)	Remark
1	Control	Maize monocrop	Nil	Control plot
4	*Lablab purpureus* amended soil	Maize/*Lablab purpureus*	N = 45 P = 10 K = 30	Lablab residue incorporated into the Ap horizon, i.e. organic/ inorganic treatment
5	Maize/*Lablab purpureus* intercrop	Maize/*Lablab purpureus*	N = 45 P = 10 K = 30	Lablab residue is removed from the plot, i.e. inorganic treatment
8	*Centrosema pascuorum* amended soil	Maize/*Centrosema pascuorum*	N = 45 P = 10 K = 30	*C. Pascuorum* residue incorporated into the Ap horizon, i.e. organic/ inorganic treatment
18	Inorganic fertilizer amended Soil	Maize monocrop	N = 45 P = 10 K = 30	An inorganic treatment
27	*Parkia biglobosa* amended soils	Maize monocrop, soil incorporated with *Parkia Biglobosa*	N = 45 P = 10 K = 30	Locust bean leaf incorporated into the Ap horizon @ 45 kgN/ha from 1998. An organic/inorganic treatment.

Electrical conductivity (EC) in saturated soil paste was also determined. Total porosity was calculated from values of bulk and particle density, i.e.

$$TP = 100\left(1 - \frac{\ell_b}{\ell p}\right)$$

While capillary porosity (CPS) was calculated as;

$$CPS = TP - (\theta - 33 \times 100)$$

Where:
$\theta - 33$ = Moisture content at -33kPa matric potential.

The pressure plate apparatus was used to estimate soil water content at -33 KPa (field capacity) and -1500 KPa (wilting point) matric potential. The water displacement technique was used to determine particle density and, the constant head permeameter method along with the undisturbed core samples estimated saturated hydraulic conductivity, after which the saturated undisturbed core samples were oven-dried at 105ºC for 24 hours to determine soil bulk density.

The second portion of the disturbed soil was used to determine dry aggregate size distribution. 500 g of air-dried soil was dry sieved with a mechanical shaker for 3 minutes. The shaker separated the samples into four different dry aggregate fractions namely, <53 µm, 53 to 106µm, 106 to 250 µm and 250 – 2000 µm. Prior to wet sieving, samples were tension wetted on the sieve by placing a moist filter paper disk between the top sieve (2 mm) and the tension plate (Beare *et al*., 1994) and, wetted for 5 minutes. Sieves of similar size fraction with those of the dry aggregates fraction were oscillated in water column by hand (40 ± 4 strokes in 3 minutes). Following wet sieving, the water columns were drained and particles collected on sieves were dried first on sieve (15ºC, 12 hrs), then transferred into cans, oven dried (105ºC) and weighed. The dry masses of particles and sand content for each aggregate fraction were determined after dispersion in sodium-hexametaphosphate (calgon). The water stable aggregates in each size fraction were corrected for the coarse fraction.

Calculations and Statistical Analysis

The mean weight diameter (MWD) of both wet (MWD_w) and dry (MWD_d) was calculated as:

$$MWD = \sum_{i=1}^{n} \bar{x}_i w_i$$

Where:
$\bar{x}_i$ = mean diameter of each size fraction
w_i = proportion of the total sample weight occurring in the size fraction *i*.

Aggregate silt and clay (ASC) along with the clay dispersion index (CDI) were determined using the technique of Middleton (1930) and Dong *et al.* (1983) respectively, as quoted by Mbagwu and Bazzoffi (1998).

$$ASC = \begin{pmatrix}\text{Silt and clay in}\\ \text{calgon-dispersed}\\ \text{sample}\end{pmatrix} - \begin{pmatrix}\text{Silt and clay in}\\ \text{water-dispersed}\\ \text{samples}\end{pmatrix}$$

While,

$$CDI = \frac{\text{Clay in water - dispersed samples}}{\text{Clay in calgon - dispersed samples}}$$

Arc-sine transformation was performed on values of MWDW, SOC, and Water-stable aggregates before data analysis. Analysis of variance procedures were conducted using the General Linear Model statistical procedures of SAS (SAS Institute Inc., 1985) of all values (both transformed and non-transformed). The Duncan Multiple Range Test (DMRT) at P<0.05 was used for mean comparisons.

RESULTS

Effect on soil physical properties

Organic/inorganic input management effects on mean weight diameter (MWD) of dry aggregates and other soil properties are indicated in Table 3. There was no significant treatment difference in the mean weight diameter (MWD) of dry aggregates. However, the control treatments followed by the *C. pascorum* amended soil recorded higher MWD of dry aggregates than all the other treatments. A significant change was recorded in the proportion of dry aggregates >250 µm. This was followed by the inorganic fertilizer amended treatment which is similar with all other treatment. However, the *P. biglobosa* amended soils recorded the lowest fraction of macroaggregates. Distribution of dry aggregates <250µm was not influenced by input management practices in these soils.

The surface soil bulk density was significantly (P<0.0001) affected by the various input management practices. Soils amended with crop residues recorded lower soil bulk densities values than those of other practices. Soils amended with *C. pascorum* experienced 9.6% decrease in bulk density values, *P. biglobosa* amended soil recorded decreased bulk density of 8.2% and soil amended with *L. purpereus*, 6.2% - relative to the control

Differences in total and capillary porosity due to input management were statistically significant ($P<0.01$) in most cases. The *L. purpereus* amended soils recorded the highest soil porosity value which was 16% higher than values of the control. Porosity value for *L. purpureus* amended soils was similar to values obtained under inorganic fertilizer (13.4%) and *C. pascorum* (8.4%) amended soils. Lowest porosity value was recorded under the maize/Lablab intercrop. In the case of capillary porosity, the *L. purpureus* amended soils resulted in a higher proportion of capillary pores than all other treatments.

Results of soil moisture content at -33kPa and -1500kPa, showed no significant difference among treatments. However, *Parkia biglobosa* amended soil held less water at -33kPa while, soil amended with *Lablab purpureus* recorded higher water content compared to other treatments at -1500kPa.

The distributions of water-stable aggregates obtained by wet sieving were not significant at any of the size range (Table 4). However, there was a significant influence of input management on MWD of water-stable aggregates. The control, maize/*Lablab purpureus* intercrop and inorganic fertilizer amended soils recorded the highest values which were similar to MWD values of *Centrosema pascuorum* and *Lablab purpureus* amended soils. The soils amended with *Parkia biglobosa* recorded significantly lower MWD values with other crop residues. There was a notable significant differences ($P<0.05$) in the values of Aggregated silt and clay (ASC) with input management practices. *Centrosema pascuorum* amended soil recorded the highest value of ASC. This was followed by the inorganic fertilizer and *Lablab purpureus* amended soils in that order. The soils amended with *Parkia biglobosa* produced significantly ($P<0.05$) lower ASC values. The clay dispersion index (CDI) for the soils of the various input management practices was found to be quite high (Table 4). However, clay dispersion was not affected by the different input management practices.

Table 3: Effect of Organic/Inorganic Input Management on dry aggregate size distribution and other physical soil quality indicators.

Soil Management Practices	MWD*	Dry aggregate Fraction		Soil bulk density	Total porosity	Capillary porosity	Moisture content @	
							-33 kPa	-1500 kPa
	-mm-	>250μm	<250μm	Mgm^{-3}	←	% →	← g/g	→
Lablab purpureus-amended soil	0.84	0.62^{ab}	0.38	1.37^{b}	54.9^{a}	51.8^{a}	0.11	0.07
Maize/ *Lablab purpureus* intercrop	0.79	0.62^{ab}	0.38	1.45^{a}	44.2^{c}	33.5^{c}	0.11	0.05
Pascuorum amended soil	0.85	0.65^{b}	0.35	1.32^{c}	51.3^{abc}	39.9^{bc}	0.11	0.06
Inorganic fertilizer-amended soil	0.84	0.63^{ab}	0.37	1.44^{a}	53.8^{ab}	42.6^{b}	0.10	0.06
Parkia-amended soil	0.76	0.58^{b}	0.40	1.34^{bc}	47.5^{bc}	38.3^{bc}	0.09	0.06
Control	0.87	0.61^{b}	0.39	1.46^{a}	47.3^{bc}	36.8^{bc}	0.11	0.05
S.E.	0.034	0.0017	0.023	0.014	2.11	2.23	0.008	0.005
CV (%)	7.1	4.8	10.3	1.7	7.3	9.5	12.8	13.8

Means followed by different letter(s) within the same column are significant at 5% level of probability

* Mean weight diameter, CV= Coefficient of Variability

Table 4. Effect of organic/inorganic input management on water soluble aggregate distribution on microaggregate stability.

Soil Management Practices	^{a}MWDw	Water-stable aggregate fraction >250μm	>106μm	>53μm	<53μm	^{b}ASC	^{c}CDI
Lablab purpureus amended soil	0.046^{ab}	0.039^{ab}	0.45	0.40	0.11	0.12^{abc}	0.42
Maize/*Lablab purpureus* intercrop	0.050^{a}	0.044	0.070	0.33	0.09	0.11^{bcd}	0.40
Centrosema pascuorum amended soils	0.047^{ab}	0.041	0.062	0.29	0.06	0.14^{a}	0.44
Inorganic fertilizer-amended soil	0.051^{a}	0.047	0.055	0.39	0.10	0.13^{ab}	0.44
Parkia biglobosa -amended soil	0.031^{b}	0.059	0.070	0.31	0.10	0.09^{d}	0.40
Control	0.059^{a}	0.039	0.052	0.42	0.31	0.10^{cd}	0.40
SE	0.05	0.175	0.0243	0.151	0.258	0.009	0.025
Coefficient of variability (%)	18.9	13.8	17.1	6.1	15.1	13.2	10.4

[a] Mean weight diameter of water stable aggregates; [b] aggregated Silt and clay; [c] Clay dispersion Index

Means followed by different letter(s) within the same column are significant at 5% level of probability

Table 5. Soil chemical quality indicators as affected by inorganic/inorganic inputs management practices

Soil Management practices	Soil pH	Organic carbon	Total nitrogen	Available phosphorus	Calcium	Magnessium
		← gKg^{-1} →		mgKg^{-1}	← cmol kg^{-1} →	
*Lablab purpureus a*mended soil	5.3^{d}	3.58^{ab}	0.53^{b}	16.9^{a}	2.73^{ab}	1.33^{b}
Maize/lablab purpureus intercrop	6.0^{a}	2.90^{b}	0.41^{b}	14.5^{ab}	2.40^{bc}	1.10^{bc}
Centrosema pascuorum amended soils	5.5^{cd}	4.68^{a}	0.59^{a}	12.3^{bc}	3.00^{a}	1.63^{a}
Inorganic fertilizer-amended soil	5.7^{abc}	3.18^{b}	0.41^{b}	11.6^{c}	2.47^{abc}	1.17^{bc}
Parkia-amended soil *biglobosa*	5.9^{ab}	3.67^{ab}	0.59^{a}	16.1^{a}	2.00^{c}	0.90^{c}
Control	5.6^{bc}	2.92^{b}	0.41^{b}	8.4^{d}	2.13^{c}	1.17^{bc}
Standard Error (SE)	0.09	0.89	0.024	0.83	0.18	0.088
Coefficients of variability (%)	2.6	7.9	8.6	10.8	12.2	12.6

Means followed by different letter(s) within the same column are significant at 5% level of probability

DISCUSSION

Distribution of dry sieved aggregates >250 μm (referred to as macroaggregates) was influenced by input management practices. Incorporation of *C. pascuorum* increased macroaggregate by 7% compared to 3- and 2-% for inorganic fertilizer- and *L. purpureus-* amended soils respectively. Dry macroaggregate distribution is generally associated with wind erosion (Unger, 1997). Increasing the proportion of macroaggregates in surface soils will help control the wind erosion. Hence, organic/inorganic input practices involving incorporation of *C. pascuorum* will increase soil aggregate stability and reduce wind erosion. The fact that dry microaggregates (<250 μm) were not affected by input management practices is an indication that these fractions may be less dependent on agricultural management practices. The macroaggregate fraction in the water-stable aggregates was not responsive to organic/inorganic input management practices. The loss of soil organic matter (SOM) due to intensive cultivation may be responsible for this scenario. Six *et al.* (2000) hypothesized that increasing cultivation intensity will lead to a loss of carbon-rich macroaggregates resulting in a lack of consistent significant differences in the proportion of macroaggregates. In addition, Elliott (1986) showed that macroaggregates contain more labile and less highly processed SOM which can be lost upon cultivation. The more water-stable microaggregate fractions which were not influenced by input management practices is an indication that agricultural management practices does not dictate microaggregate distribution in soils.

Management practices involving Maize/*L. purpereus* intercrop, incorporation of residues of *C. pascuorum* and *P. biglobosa* in soils resulted in formation of more water-stable, large microaggregate (106 μm – 250 μm) fraction than the rest of the treatments. One plausible explanation here is their increasing organic carbon concentration of residue amended soils and the abundant root mass of the intercrop which supported the stability of their microaggregates. Oades (1984) suggested the possibility of SOM increasing the stability of aggregates that are < 250 μm in diameter in soils under grass, through the binding action of soil particles by polysaccharides. There was a 40-, 30-, and 20% increase in aggregated silt and clay (ASC) with input management practices involving *C. pascuorum,* inorganic fertilizer and *L. purpureum* amended soils respectively (Table 4). The ASC and Clay Dispersion Index (CDI) are microaggregate stability indices (Mbagwu and Bazzoffi, 1998). The higher the ASC or the lower the CDI, the more stable the microaggregate fraction of the soil. The contribution of SOM to soil aggregation cannot be overemphasized. Soil organic matter has been reported to act as an aggregating or disaggregating material in soil (Mbagwu and Bazzoffi, 1998). However, our findings substantiate the assertion that SOM is an important bonding agent in soils with low clay content. The clay content of this soil is as low as 10% (Table 1) and there was a very strong correlation of ASC and CDI with SOC concentrations (result not shown here). The lack of significant effect of input management practices on CDI is an indication of the relative contribution of other aggregate-stabilizing substances.

The bulk density of soils is a reflection of the level of compaction, cohesiveness and structural development of soils (Heard *et al*., 1988). The reduction in surface soil bulk density due to incorporation of *C. pascorum*, *P. biglobosa* and *L. purpureus* is an indication of the contribution of crop residue management practices to improving soil physical conditions as observed in this study. Low soil bulk density facilitates root growth and penetration. Ikpe and Powell (2002), observed that low soil bulk density enhanced access to soil moisture and increased nutrient uptake resulting in higher crop yield. Runoff and erosion losses of soil and nutrient can result, due to high bulk density causing surface water to be restricted from moving through the soil. For a silty loam soil, Evanylo and McGuinn (2000) suggested soil bulk density ≤ 1.40 Mg m^{-3} as ideal for optimum root growth. Generally, from this study, practices that involved crop residue incorporation recorded soil bulk density values <1.40Mgm-3. Soil bulk density values of the other treatments however, have also not attained critical values. Evanylo and McGuinn (2000) observed that bulk density values of 1.55 to <1.65 Mg m^{-3} can critically affect or restrict root growth and development in silt loams.

Incorporation of *L. purpereus* and *C. pascuorum* appeared to have a slight soil pH depression effect in the surface soils of these treatments. Organic acids released from the biomass of these residues may be a probable reason for the pH depression in these soils.

The increase in exchangeable Ca^{2+} and Mg^{2+} in soils due to input management practices are attributed to the effect of incorporating the residues into the soil. Lal (1997), reported increased concentration of exchangeable Ca^{2+} and Mg^{2+} with residue incorporation compared to residues left on the surface as mulch.

Incorporation of crop residues was beneficial to the soil in terms of increased soil organic concentrations (SOC). An accumulation of SOC is not only beneficial to soil in relation to agriculture but also represents a sequestration of carbon from atmospheric carbon dioxide. When residues of *C. pascuorum* and *P. biglobosa* were incorporated into soil, they increased total soil nitrogen content by 44%. This increase may be attributed to the quality (i.e. nutrient composition) of the incorporated residue. The residues of these two crops have been analysed within this ecosystem by Odunze (2003) and Uyovbisere and Elemo (2002). Both authors have respectively reported total nitrogen content of 26.9 g kg^{-1} (*C. pascorum*) and 26 g kg^{-1} (*P. biglobosa*). Higher total soil nitrogen in most cases means a small C: N ratio, which is one indication of the rate of decomposition in the soil. Increased SOC and total soil nitrogen content are indication of soil quality improvement. Available phosphorus content showed a moderate concentration (>10mgKg^{-1}in all treatments except the control.

CONCLUSION

Organic/inorganic input management practices involving the incorporation of crop residues into soils enhanced macro-aggregate stability and fairly increased stability of mean weight diameter relative to other practices. Soil physical properties like soil bulk were reduced under crop residue incorporation and soil porosity was improved. This practice also favours increased SOC sequestration in soil while increasing the fertility status of the soil. Among, the three crop residues used in this study, *C. Pascorum* and *L. Purpureus* in that order, had the potentials of improving soil properties.

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