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Soil physical properties and carbon/nitrogen relationships in stable aggregates under legume and grass fallow

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ABSTRACT

Short-season fallow with legumes and/or grasses can restore the soil organic C and nitrogen (N) and improve soil structure. In this study, we accessed the effects of 2-season legume and grass fallow on structural properties and C/N relationships in aggregates of a sandy loam soil. Two legumes (*Calopogonium mucunoides* and *Centrosema pubescens*), and two grasses (Guinea grass (*Panicum maximum*) and goose grass (*Eleusine indica*) were used. Results showed that *Calopogonium* and *Centrosema* increased soil total porosity and reduced soil bulk densities, while goose grass increased bulk density and reduced total porosity of the soils at 0–15 and 15–30 cm depths. Guinea grass significantly increased the saturated hydraulic conductivity (50.4 cm h^{-1}) and water holding capacity of the soils. Aggregates, 4.75 to 0.5 mm were greater in Guinea grass and least in goose grass fallowed soils. *Calopogonium* increased macro-aggregates at 0–15 cm soils by 48%, and mean weight diameter (MWD) by 44%. Organic carbon in 0.5–0.25 mm and <0.25 mm aggregate sizes was higher in Guinea grass soils. Generally, grasses had 4-fold increases of C:N contents in dry aggregates. In conclusion, short-season fallow with Guinea grass, *Calopogonium* and *Centrosema*, increased soil C and N and protected them from losses in stable aggregates.

1. Introduction

Plant cover is one of the most measured characteristics of vegetation that affect soil physical, chemical and biological properties [1]. Legumes and grasses, including cereals are the most extensively used types of plant cover that tend to improve the soil properties and carbon and nitrogen storage within aggregate fractions during fallow [2]. They are used during fallow periods to manage soil erosion, runoff, soil organic carbon and nitrogen [3]. During the vegetative fallow period, it is believed that the land is restoring its fertility as the fallow period allows natural processes to rebuild the field's store of nutrients, as well as the soil physical and chemical properties. For example, *Calopogonium mucunoides* is often grown to protect the soil surface and provide nutrient to the soil as green manure in the tropical fallow. It is an important cover crop for plantation crops, especially rubber and oil palm, where it is often grown in a mixture with Centro (*Centrosema pubescens*) and tropical *kudzu* (*Pueraria phaseoloides*) [4, 5].

Soil aggregation and carbon and nitrogen relationships are attributes very sensible to soil management and type of plant cover. Legumes are often grown during the fallow periods due to their capacity to biologically fix high quantities of nitrogen and can contribute to soil carbon addition at rates of 0.88 Mg ha^{-1} per year [6]. These additions are commonly linked to increases in soil aggregation, which, in turn, protect soil carbon against microbial decomposition [7]. Grasses are mainly used in soil conservation systems due to their high above ground biomass yield, with greater C:N ratio [8], and dense root system, which is associated with intense microbial activity. These crop type features can increase soil carbon at a rate of 0.71 Mg ha^{-1} per year [9, 10].

Existing information [11], agreed that legumes may be grown to help improve the soil N, while grasses are grown in the cropping systems to take up nutrients especially N that would have been lost if plants were not present [12]. For example, Souza et al. [13] found that *Centrosema pubescens* added up to 46 kg/ha of N and transferred up to 3.9 kg/ha of N to grasses when it was intercropped. On the other hand, grasses may be very useful for scavenging nutrients especially N-left over from previous crop.

There are wide speculations that aggregate structure and diameter are closely related with soil carbon and nitrogen contents [7]. There is also inconsistency in information regarding the influence of legume and grass fallow on soil physical properties. Their influence on organic C and N occluded in stable aggregates during fallow is not well known, especially, in some West African soils. For example, Udom and Ogunwole [5] found larger amounts of N in smaller aggregates size fractions < 0.25 mm in forested soils, while Blanco-Canqui and Lal [14] found a small effect on micro-aggregate stability and no effect on dry-aggregate size distribution, or wet sieved macro-aggregates in the upper 75 cm in sandy soil after 3-year corn-soybean-winter wheat rotation. Alternatively, Six and Paustian [15] reported an increase in wet aggregate stability of a sandy loam and loam soils after one cycle of annual

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grass as cover crop. Linquist et al. [16] found greater nutrient concentrations in micro-aggregates than in macro-aggregates, while Jastrow et al. [17] observed that greater soil organic carbon (SOC) were stored in micro-aggregates in continuous cultivated soils. However, these facts have not been adequately addressed under legume or grass fallow. The growing demand for land on a scale parallel to the population which made the old traditional shifting cultivation method involving cultivation of a parcel of land once followed by fallowing with land use factors unrealistic suggest use of short fallow periods with legumes or grasses to keep the soil healthy. The objective of this study was to evaluate some soil physical properties and dynamics of C and N in stable aggregate fractions under 2-season legumes and grass fallow. This would provide useful information on certain legumes and/or grasses during fallow periods to increase soil organic C and N and their protection within soil aggregates.

2. Materials and methods

2.1. Site description and sampling

The experiment was carried out at the University of Port-Harcourt Farms (Lat 4°15′ to 4°20′N and Long 7°45′ to 7°48′E) in the rain forest zone of southern Nigeria. Total annual rainfall in the area is in excess of 2400 mm, with two peaks, each in the months of June and September. Mean monthly temperature ranges between 22 °C and 32 °C, with minimum and maximum relative humidity of 35% and 78% respectively during cropping season [18]. The soil is derived from coastal plain sands and classified as *Arenic acrisol* [19]. It is sandy loam; highly weathered, and dominated by low activity clays. Soil samples from the non-fallowed plot, under continuous cropping to maize and cassava for >10 years, (Table 1) showed that organic carbon and nitrogen contents in the surface 0–15 cm were 13.5 g kg^{-1} and 0.79 g kg^{-1}, respectively. Total sand, porosity, and bulk density were 710 g kg^{-1}, 22.9%, and 1.57 g cm^{-3}, respectively The study area consisted of: (1) Twenty-hectare plot under Calapo (*Calopogonium mucunoides*) cover. (2) Twenty-hectare plot under Centro (*Centrosema pubescens*) plant cover. (3) Fifteen-hectare plot under Guinea grass (*Panicum maximum*) and (4) fifteen-hectare plot under goose grass (*Eleusine indica*) cover. The fallow periods were extended to 2-cropping seasons after the removal of maize crop. These were compared with the non-fallowed plots under continuous cropping to maize and cassava for >10 years, where inorganic fertilizers have been used to improve the soil fertility (Table 1). Land area under each plant cover was divided into a 50 m × 50 m subarea in four (4) blocks based on physiographic/landscape positions. Sixteen representative undisturbed core and sixteen bulk soil samples were randomly collected in each block at 0–15 cm and 15–30 cm depths. In total, 128 core and 128 bulk soil samples were collected in the whole for laboratory analysis.

Table 1
Some properties of soils of the site under 10-year continuous cropping with maize and cassava.

Soil properties	0–15 cm	15–30 cm
Sand (g kg^{-1})	710	651
Silt (g kg^{-1})	172	188
Clay (g kg^{-1})	118	161
Textural class	Sandy loam	Sandy loam
Bulk density (g cm^{-3})	1.57	1.59
WHC (g g^{-1})	0.16	0.21
Total porosity (%)	22.9	20.8
Ksat (cm h^{-1})	14.2	12.9
Organic carbon (g kg^{-1})	13.5	10.1
Total N (g kg^{-1})	0.79	0.71
C/N ratio	17	14.2

WHC - water holding capacity.
Ksat - saturated hydraulic conductivity.

2.2. Soil analyses

2.2.1. Determination of organic carbon and nitrogen in whole soil and dry aggregate fractions

The disturbed samples were air-dried and passed through a nest of sieves to obtain dry aggregates, 4.75–2.0, 2.0–1.0, 1.0–0.5, 0.5–0.25 and <0.25 mm size classes. Aggregate sizes collected on each sieve were used for the determinations of total organic carbon and nitrogen. Total organic carbon was determined by the wet oxidation dichromate method with H_2SO_4-K_2Cr_2O [20]. Total nitrogen was determined by the modified macro Kjeldahl digestion method [21]. The NH_3 from the digestion was distilled and titrated with 0.05 N HCl.

2.2.2. Water stable aggregates

Water stable aggregates were measured by wet-sieving procedure as described by Kemper and Rosenau [22], while aggregate stability was evaluated by the mean-weight diameter (MWD) as index. In this method, 50 g of 4.75 mm dry-sieved aggregates were placed in the topmost of a nest of sieves of 4 classes: 2.0, 1.0, 0.5, and 0.25 mm. The aggregates were pre-soaked by capillary at 0 kPa in distilled water for 5 min before oscillated vertically at one oscillation per second in water 20 times, using 4 cm amplitude in a mechanical device. The remaining stable aggregates on each sieve were oven-dried at 50 °C for 24 h and weighed. The mass of aggregates < 0.25 were obtained by the difference between mass of sample and the sum of sample weights collected on the 2.0, 1.0, 0.5, and 0.25 mm nest of sieves. The percentage of the stable aggregates on each sieve representing water stable aggregates was calculated as

$$\%\mathrm{WSA} = \frac{MR}{MT} \times \frac{100}{1} \quad (1)$$

where *MR* is the mass of resistant aggregates (g) and *MT* is the total mass of wet-sieved soil (g). Water-stable aggregates were measured by the mean-weight diameter (MWD) and calculated by the following equation [23].

$$\mathrm{MWD} = \sum_i^n \mathrm{XiWi} \quad (2)$$

where Xi is the mean diameter of any particular size range of aggregates separated by sieving and Wi is the weight of aggregates in that size range as a fraction of the total dry weight of the sample analysed. The proportion of aggregates ≥ 0.25 mm in diameter are defined as macro-aggregates and proportion of aggregates < 0.25 mm in diameter are defined as micro-aggregates.

2.2.3. Particle-size distribution, total porosity, bulk density and water holding capacity

Soil samples were sieved through 2 mm mesh sieve and used to determine the particle size-distribution by the hydrometer method [24] after dispersing the soil samples with sodium hexa-metaphosphate. Total porosity was calculated with core samples using the method of Flint and Flint [25] as:

$$\%Total\ porosity = \frac{volume\ of\ water\ at\ 0\ kPa}{volume\ of\ bulk\ soil} \times \frac{100}{1} \quad (3)$$

Bulk density was determined by the method of Black and Hartge [26] and calculated as:

$$Bulk\ density = \frac{mass\ of\ oven\ dried\ soil\ (\mathrm{g})}{volume\ of\ bulk\ soil\ (\mathrm{cm}^3)} \quad (4)$$

Gravimetric water content at saturation was calculated as:

$$\theta m\ (\mathrm{g\ g}^{-1}) = \frac{Mw - Md}{Md} \quad (5)$$

where θm is the gravimetric water content ($g\ g^{-1}$), Mw is mass of wet soil at saturation (g), and Md is mass of oven-dry soil (g).

2.2.4. Determination of saturated hydraulic conductivity

Saturated hydraulic conductivity was measured by the constant-head permeability test procedure, and calculated using the transposed Darcy's equation for vertical flow of liquid [27]. Volume of water draining out was measured over time period until flow was constant, at which time; the flow rate was determined by the equation:

$$Ksat = \frac{Q}{AT} \times \frac{L}{\Delta H} \tag{6}$$

where Q is the volume of water collected (cm^3), A is area of core (cm^2), T is time elapse (s), L is length of core (cm), ΔH is the hydraulic head difference (cm). Permeability class was according to the Soil Survey Staff [28].

2.3. Data analysis

Statistical analyses were carried out using the SAS software [29]. Analysis of variance (ANOVA) was used for treatment comparison at $p < 0.05$, with separation of means by the least significant differences using Fisher's protected test [30]. Correlation analysis was used to determine the relationships among soil physical properties. Significant correlation coefficients were tested at 5% probability.

3. Results

3.1. Effects on structural properties and C:N ratio of the soils

In Table 2, significant differences in structural properties of the soil such as bulk density, total porosity and saturated hydraulic conductivity (K_{sat}) and water holding capacity were observed following the grass and legume fallow. Mean soil bulk density fluctuated from 1.41 to 1.55 $g\ cm^{-3}$ at 0–15 cm and from 1.44 to 1.62 $g\ cm^{-3}$ at 15–30 cm depths compared with 1.57 $g\ cm^{-3}$ and 1.59 $g\ cm^{-3}$ respectively, in the non-fallowed (Table 1). Using the non-fallowed plots as basis for comparison, we observed that *Calopogonium* and *Centrosema* increased total porosity and reduced bulk densities, while goose grass tended to increase bulk density and reduced total porosity. Soils under *Calopogonium* and *Centrosema* had lower bulk densities and greater Ksat and θm than the Guinea grass and goose grass soil. The K_{sat} ranged between 24.9 and 50.4 $cm\ h^{-1}$ at 0–15 cm, and 19.4 and 39.4 $cm\ h^{-1}$ at the 15–30 cm depths. The highest K_{sat} value of 50.4 $cm\ h^{-1}$ was found in soils under Guinea grass, and with significant ($p < 0.05$) increase in water holding capacity.

The lowest K_{sat} and water holding capacity values were found in goose grass soil at 0–15 cm and 15–30 cm depths in comparison to Guinea grass with the highest K_{sat} value of 50.4 $cm\ h^{-1}$, followed by *Calopogonium* and *Centrosema* (Table 2). Subsoil saturated hydraulic conductivity was rapid in Guinea grass and moderately rapid in *Calopogonium*, *Centrosema* and goose grass soils. The root characteristics and microbial activities may have led to the observed differences. Generally, C:N ratio was wider in grasses than in legume fallowed soils. For grasses, C:N ratios were significantly wider in the surface 0–15 cm soils under Guinea grass than goose grass, i.e. 24.5 and 14.9 respectively.

Table 2
Effect of legume and grass cover on bulk density, total porosity, saturated hydraulic conductivity and water holding capacity of the soil.

Land cover	BD ($g\ cm^{-3}$)	Total porosity (%)	K_{sat} ($cm\ h^{-1}$)	WHC ($g\ g^{-1}$)	C:N	Permeability class[a]
0–15 cm						
Calopogonium	1.41^b	41.6^a	46.2^b	36.2^a	5.8^c	Rapid
Centrosema	1.43^b	40.9^a	41.1^{ab}	38.5^b	4^c	Rapid
Guinea grass	1.41^b	39.1^a	50.4^a	36.5^a	24.5^a	Very rapid
Goose grass	1.59^a	21.6^b	24.9^c	15.5^{ab}	14.9^b	Moderately rapid
15–30 cm						
Calopogonium	1.44^b	40.0^a	24.0^b	29.0^b	12^c	Moderately rapid
Centrosema	1.47^b	39.8^a	22.6^b	33.8^a	13^c	Moderately rapid
Guinea grass	1.51^a	33.6^b	39.8^a	22.0^{ab}	35.5^a	Rapid
Goose grass	1.62^a	18.1^{ab}	19.4ab	16.8^c	17^b	Moderately slow

Ksat - saturated hydraulic conductivity; means followed by the same letter for each parameter were not significantly different at $p < 0.05$.
[a] Soil Survey Staff [28] classification.

3.2. Effects on aggregate stability

Larger stable aggregates (0.5 to 4.75 mm) which are most valuable aggregates for agronomy, were in the order of Guinea grass > *Calopogonium* > *Centrosema* > goose grass soils (Table 3). The legumes and grass fallow had statistically significant influence on water stable aggregates in the 4.75–2.0 mm and 0.5–0.25 mm size classes. On the other hand, no significant ($p < 0.05$) influence was found on water-stable aggregates < 0.25 mm of the surface 0–15 cm. *Calopogonium* and *Centrosema* had significant increases in water stable aggregates > 0.25 mm, most probably due to fine-particle humus fractions usually associated with organic litter decomposition of leguminous plants. In the surface 0–15 cm soil, 62% of the water stable aggregates were in the 1.0–2.0 and 0.5–1.0 mm size classes for *Calopogonium*, indicating the possible positive contribution of *Calopogonium* in organization of soil structure. The mean weight diameter (MWD) of water stable aggregates were in the order of *Calopogonium* > Guinea grass > *Centrosema* > goose grass in the surface 0–15 cm soil (Table 3). Macro-aggregates stability was 48% higher in *Calopogonium*, compared to Guinea grass and *Centrosema*, which also increased MWD by 44% in the 0–15 cm depth. The mean value of MWD fluctuated by 35% in the subsoil for all the plant covers, reflecting low amount of soil organic matter content found in the subsoil.

3.3. Organic carbon, total N and C:N ratio in whole soil and dry aggregates

In Fig. 1, goose grass gave highest soil organic carbon (SOC) content in whole soils and dry aggregates at 0–15. Soil organic carbon content was particularly higher in larger aggregates than smaller aggregates < 0.25 mm. Soils fallowed with goose grass gave highest SOC content in aggregates > 0.5 mm, while Guinea grass had significant SOC content in 0.5–0.25 mm and <0.25 mm aggregates at 0–15 cm and 15–30 cm

Table 3
Water stable aggregates and aggregate stability of the soil under different legumes and grass cover.

Land cover	Aggregate sizes (mm)					
	4.75–2	2–1	1–0.5	0.5–0.25	<0.25	MWD (mm)
0–15 cm						
Calopogonium	26a	8a	28a	28c	10a	1.34a
Centrosema	14b	6a	26a	40b	14a	0.94b
Guinea grass	18b	9a	24a	32c	17a	1.09b
Goose grass	12b	8a	22a	48a	10a	0.93b
15–30 cm						
Calopogonium	8b	6b	24c	42a	20b	0.75b
Centrosema	4c	4b	28b	48a	16b	0.63c
Guinea grass	10a	12a	23c	32b	23b	0.87a
Goose grass	6c	6b	30a	20c	38a	0.69c

MWD - mean weight diameter.

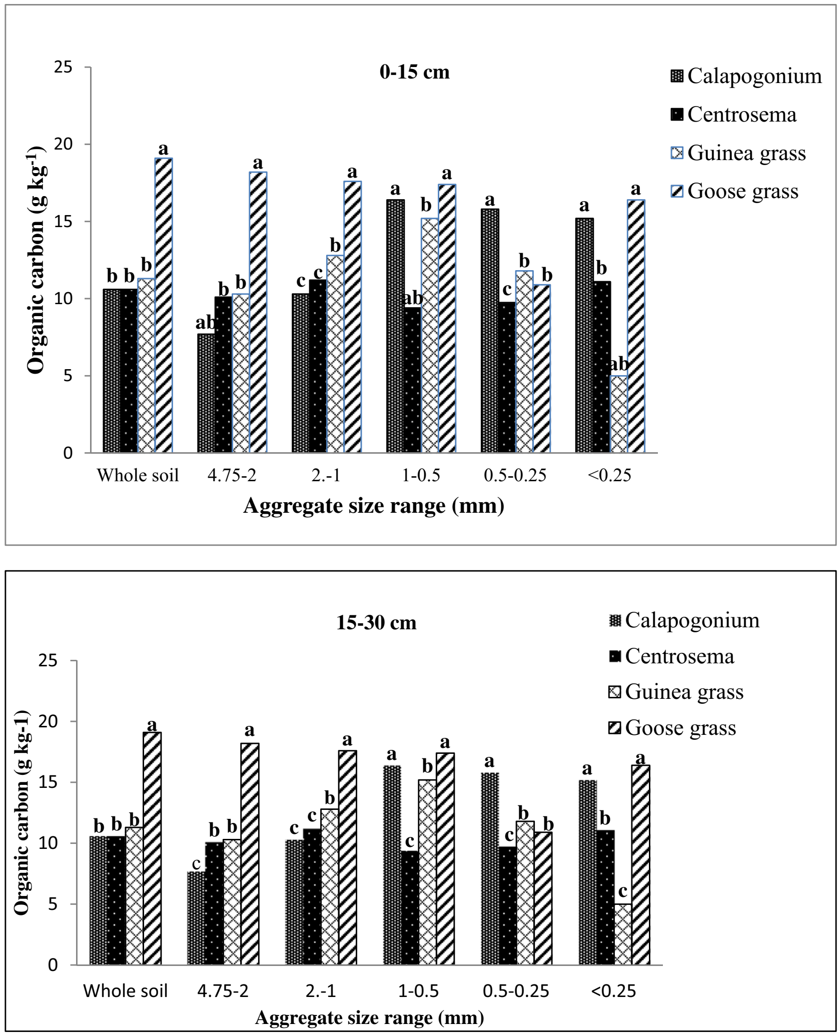


Fig. 1. Soil organic carbon distributions in whole soil and dry aggregate sizes under different Legume and grass covers at 0–15 cm and 15–30 cm depths. Columns followed by the same letters for each aggregate size range were not significantly different at $p < 0.5$.

depths. The results also showed that SOC content in macro-aggregates > 1 mm were 41% and 45% higher in goose grass soils than *Centrosema* and *Calopogonium* respectively, at 0–15 cm depth. However, this did not translate to concomitant improvement in soil structural indices compared with Guinea grass and the legumes. Similarly, SOC content in stable aggregates 1–5 mm was 41% higher in Guinea grass than in *Centrosema* and *Calopogonium*.

In Fig. 2, total N was significantly higher ($p < 0.5$) in whole soil and dry aggregates in legumes compared with the grasses. Generally, total N was significantly higher in *Calopogonium* followed by *Centrosema* in all aggregate size classes (Fig. 2). Significant ($p < 0.05$) N was found in micro-aggregates < 0.25 mm at 15–30 cm soil. In the surface 0–15 cm, *Calopogonium* also had significant total N content in macro-aggregates. The results further showed that total N content in whole soil was 60% and 32% greater in *Calopogonium* than goose grass and *Centrosema*, respectively at depth 0–15 cm. Carbon/nitrogen distribution in stable aggregates varied significantly between legumes and grass cover (Fig. 2). Carbon: nitrogen ratio was significantly higher in the grass fallowed soils than in leguminous cover (Fig. 3). Gosse grass showed the highest C:N ratio of 32 in aggregates > 1.0 mm at 0–15 cm depth, while *Calopogonium* had C:N ratio of 7.2 in similar aggregate sizes. This showed a 4-fold increase in C:N content in both larger and smaller aggregates in grass fallowed soils.

3.4. Relationships among saturated hydraulic conductivity, water-stable aggregate, soil organic matter and water holding capacity

Relationships showed that mean weight diameter (MWD) of water-stable aggregates followed a positive linear relationship ($R^2 = 0.695$, $p < 0.05$) with K_{sat} (Table 4). The relationship between SOC and MWD showed that organic C in these soils during the fallow period acted as aggregating agents in the soil. Saturated hydraulic conductivity (K_{sat}) increased as SOC increases ($R^2 = 0.516$, $p < 0.05$). The positive linear model between SOC and WHC accounted for a non-significant 60% in the model. The model $Y = 22.962 + 2.365x$ accounted for 83% in predicting the positive role of aggregate stability in increasing K_{sat}.

4. Discussion

The structural properties of the soils were positively influenced by the legume and grass fallow, consistent with the hypothesis that increases in soil C and N from plant cover during fallow period would improve the soil structure, resulting in decreased bulk density, increased porosity and K_{sat} and water holding capacity (WHC). This study agreed with this hypothesis for these physical properties. The study also corroborated the assertion that significant C and N which could have been lost in the soil after crop harvesting were occluded in stable

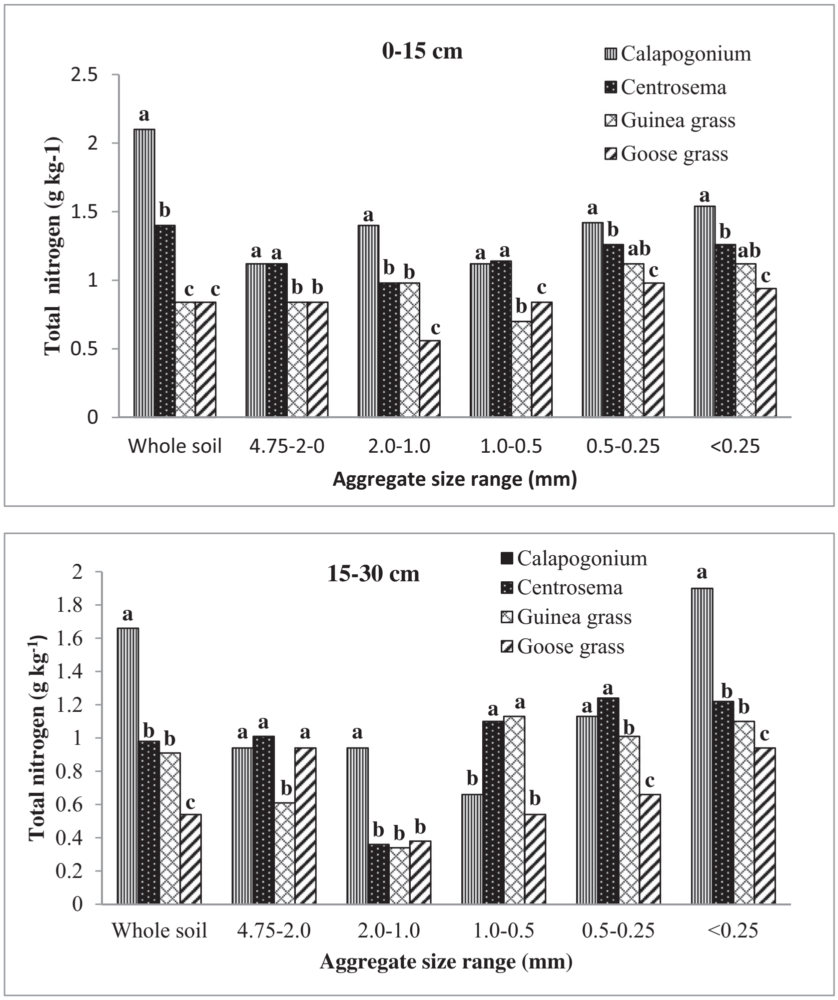


Fig. 2. Nitrogen concentration in whole soil and dry aggregate sizes under different grass and legume covers at 0–15 cm and 15–30 cm. Columns followed by the same letters for each aggregate size range were not significantly different at p < 0.5.

aggregates and protected from losses. In this case, the fallow period allowed natural processes to rebuild the soil's store of C and N, improved the soil pore system, and improve the soil water relations [2, 31].

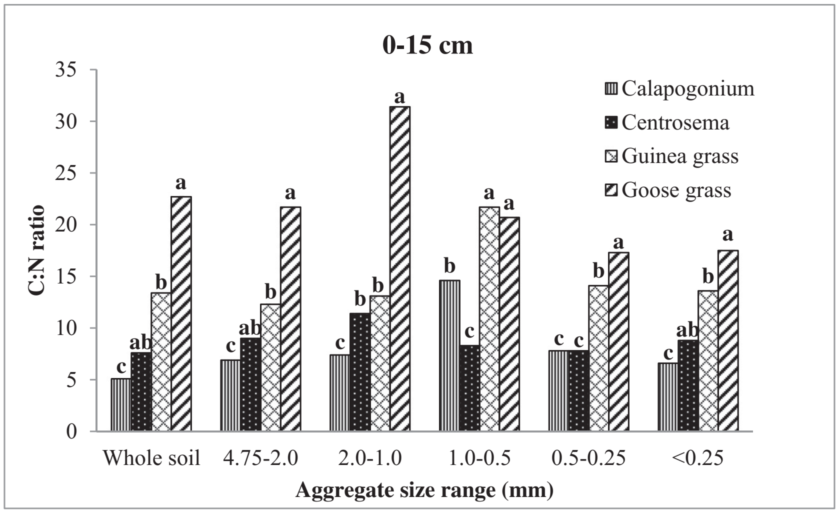
Our results suggest that the high decomposable organic litter falls by the *Calopogonium* and *Centrosema* increased the soil organic matter on the surface 0–15 cm and maintained the soil structural stability. This is consistent with studies of Miline and Fey [32] and Souza et al. [3], who suggested that traditional measurements such as aggregate stability and Ksat can be used to highlight the critical importance of soil organic matter in structural stability indices of humid tropical soils. Researchers agreed that removal of organic residues following continuous cropping of tropical soils usually result in low organic matter and suggested the use of short fallow periods with legumes or grasses to keep the soil N and C [12, 33].

Significant increases in macro-aggregate stability by the *Calopogonium* and Guinea grass in both the 0–15 cm and 15–30 cm depths explained the positive roles of these plants in fallow management to improve water-stable aggregates and keep the soil healthy. This tends to suggests that their massive root systems and vigorous biomass production could be responsible for this result, consistent with previous findings by Smith et al. [31] that plant cover with high residue production usually facilitates improvement in soil physical condition, particularly in the upper soil layer.

It is noteworthy that our results serve to de-emphasize the widely held assertion that detectable differences in soil physical properties such as bulk density and aggregate stability are usually observed in long-term experiments with legume and grass covers, especially in the tropics with high residue decomposition [5, 34]. In this study, the 2-year fallow showed significant changes in these physical soil properties under the different grass and legume covers.

In Figs. 1, 2, and 3, soil organic C, N and C:N ratio concentrations in whole soils and dry-aggregate size classes differed significantly according to plant cover effects. Soil organic carbon (SOC) and C:N ratios were higher in macro-aggregates than in micro-aggregates while N was preferentially stored in micro-aggregates. The significantly greater SOC content in stable aggregates < 0.25 mm in Guinea grass soils, and similar higher content in stable aggregates > 0.5 mm in goose grass soils highlighted their differences in promoting formation and/or stability of certain aggregate-size fractions. In legume fallowed soils, micro-aggregates tended to protect N in 0.5–0.25 mm and <0.25 mm size classes, while SOC promoted formation of macro-aggregates stability.

Macro-aggregates have greater influence on SOC storage in goose grass soils, while micro-aggregates have greater influence on storage of SOC in *Calopogonium*. This supposes that fungi hyphae and bacteria participated in the formation of larger aggregates through the short-time fallow period by the binding agents such as fungi hyphae, consistent with the results of Six et al.[35] and Barreto et al. [36]. Stabilization of micro-aggregates in macro-aggregates through short-time fallow with *Calopogonium* and Guinea grass is important in the physical protection of C and N in soils. In situations in which conditions for the



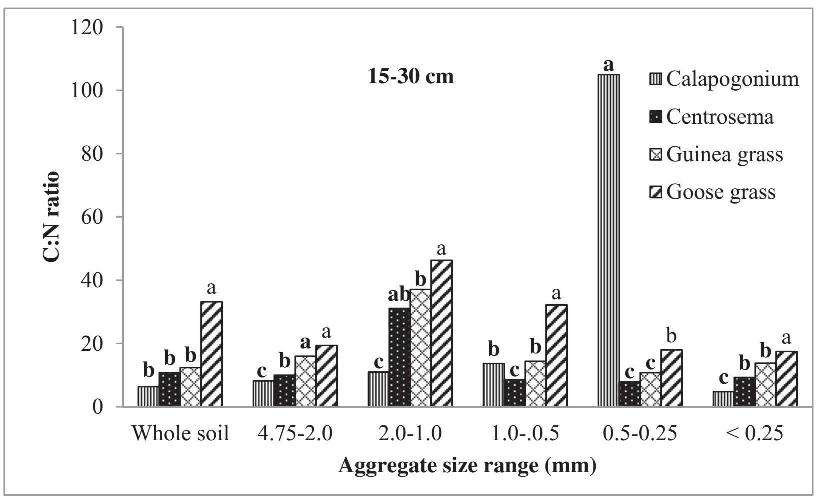


Fig. 3. C:N ratio of whole soil and dry aggregate sizes under different grass and legume covers at 0–15 cm and 15–30 cm. Columns followed by the same letters for each aggregate size range were not significantly different at $p < 0.5$.

physical protection of C and N do not exist, a more stabilized organic substances in relation to stable aggregates become more important. This knowledge is important in soil C and N management especially in tropical soils with low activity clays and organic matter.

The positive linear relationships between SOC and MWD and Ksat indicated that organic C acted as an aggregating agent in the soil. Explanation may be that organic substances of plant origin, such as polysaccharides and carbohydrates act as aggregating agents in the production of soil aggregates. This is consistent with many studies, such as Spaccini et al. [37], Liu et al. [38], and Mirjam et al. [39] that have demonstrated the importance of polysaccharides in organic-binding agents, which are important for the stabilization of macro-aggregates.

Table 4
Relationships between MWD, SOC and K_{sat} and water holding capacity.

Dependent	Independent	Equation	R^2	R
Ksat	MWD	Y = 22.962 + 2.365x	0.695*	0.834*
WHC	SOC	Y = 17.892 + 0.537x	0.354ns	0.595ns
MWD	SOC	Y = 0.875 + 0.012x	0.529*	0.727*
Ksat	SOC	Y = 0.564 + 0.095x	0.516*	0.718*

ns - non-significant, R^2 - coefficient of determination, R - coefficient of correlation, MWD - mean weight diameter, K_{sat} – saturated hydraulic conductivity, WHC - water holding capacity.
* Significant at $p < 0.05$.

5. Conclusion

This study demonstrated that: (1) Legume and grass fallow increased the soil organic C and N in whole soil and dry-sieved aggregates which led to improvement in soil structure as shown by the decreased bulk density, increased K_{sat} and WHC. (2). Higher content of SOC was associated with 4.75–2, 2–1, and 1–0.5 mm dry-sieved aggregates for Guinea grass while higher content of N was associated with micro-aggregates < 0.25 mm for the *Calopogonium* and *Centrosema* soils. (3) Although goose grass added significantly higher SOC to the soil it did not correspondingly improve the soil structural properties compared with the Guinea grass, *Calopogonium* and *Centrosema*, which had high quality of soil organic matter, which induced formation of stable macro-aggregates. (4) 2-year fallow increased the MWD of water-stable aggregates through high quality organic C from the Guinea grass, *Calopogonium* and *Centrosema*. Guinea grass, *Calopogonium* and *Centrosema* stored greater soil organic C and N, and enhanced formation and stability of macro-aggregates. Therefore, they are suitable for use in fallow management and conservation of tropical sandy soils.

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