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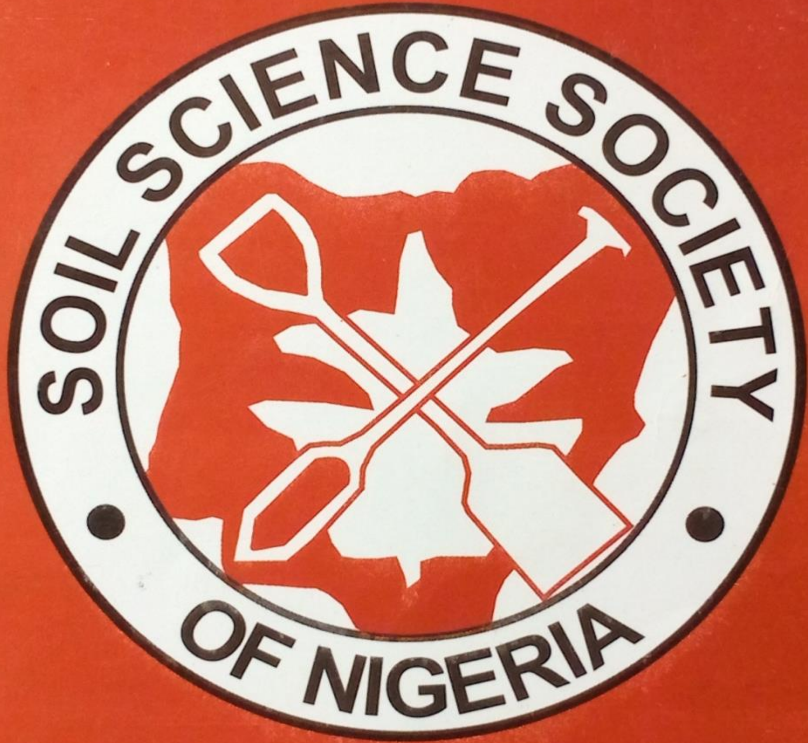

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SOIL MICROBIAL AND BIOCHEMICAL CHANGES ASSOCIATED WITH CROPPING SYSTEMS AND SOIL DEPTH IN THE SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

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ABSTRACT

Management practices under various cropping system have a significant influence on the population size and activity of microbial organisms in the soil. Little is, however, known of the impact of such effect in soil of the Nigerian savanna. A study was conducted to examine changes in soil microbial population, microbial biomass and phosphatase activity in four cropping systems (fallow, cassava, cassava/cowpea and rice) and at three soil depths (0-15cm, 15-30cm and 30-45cm) at a site in the southern guinea savannah zone of Nigeria. Soil moisture content and pH. Increased with depth, while soil organic carbon (SOC), total N and exchangeable base content decreased with depth. There was also a demonstrable effect of cropping system on soil properties, with fallow showing relatively higher pH and greater soil moisture, organic carbon and total N contents than the cultivated treatments. Among the cultivated system, rice had the most favorable effect on soil properties. Soil microbial populations, microbial biomass C (SMBC) biomass C:N ratio, as well as acid and alkaline phosphatase activities were responsive to cropping system, and were largely greater in the fallow and rice fields than in the other two systems. The soil microbial community and microbial biomass were largely dominated by fungal flora and this was probably as a result of relatively poor quality (high lignin and /or C:N ratio) of the organic matter input. Changes in microbial biomass N (SMBN) and phosphodiesterase activity, either due to cropping system or soil depth, were not significant indicating that these parameters are less useful as indicators of soil quality.

INTRODUCTION

Contemporary concerns for sustainable agricultural production underpin the need to develop appropriate crop management practice that are able to improve soil quality (Harris and bezdicek, 1994). Change in soil organic matter stock occur very slowly and it may take many years before any demonstrable changes due to disturbance or restoration become discernable (Garcia and Hernandez, 1996). There is however growing evidence that soil biological properties could serve as early and sensitive indicators of soil ecological stress or restoration (Dick and Tabatabai, 1993). Indeed, soil microbial population and biomass have been used in conjunction with enzyme activities as indicators of soil quality under various cropping systems (Ndiaye *et al.,* 2007; Monkiedje *et al*., 2006; Franchini *et al*., 2007). These microbiological parameter respond to management practices such as fertilizer application, crop residue management and crop rotation. Soil microbial biomass represents the active fraction of the soil organic matter pool, which is responsible for organic matter decomposition and, thus, soil nutrient content (Gregory *et al* 2000,Haney *et al* 2001). Microbial enzymes on the other hand play key biochemical functions in the overall process of organic matter decomposition and nutrient cycling

(Dick *et al* 1994). For example phosphatases are group of enzymes that catalyze the hydrolysis of esters and anhydrides of phosphoric acid, thus playing key roles in P cycles in the soil (Eivazi and Tabatabai, 1997; Molla *et al*., 1984; Tate, 1984).

In the southern Guinea savanna zone of Nigeria, the dominant cropping system is cereal-based with cowpea (*Vigna unguiculata)* being the major legume. crop. However, there has been a gradual increase in the area cultivated to cassava and upland rice. The likely impact of these crops on soil microbiological parameters is little know in this region. In addition, the Guinea savanna zone of Nigeria experience annual dry season periods of about 6 months during which daytime temperatures could reach as high as 45^0C. The resulting moisture deficits and high soil temperatures could adversely affect the population and activities of microbial organism in top soils. The nature of crop management practices and soil depth could thus have a significant influence on soil microbial parameters. This study was, therefore conducted to examine the impact of cropping systems on soil microbial populations, microbial biomass and phosphatase activities particularly with respect to how these parameters change with soil depth.

MATERIALS AND METHODS

Site description

The study was conducted at the experimental farm of the Federal University of Technology, Minna. The site lies within the southern Guinea savanna of Nigeria at latitude 9^0 14' N and longitude 6^0 30’ E and has minimum temperature of 36 ^{0}C in April and 22^0C in December, respectively. Mean annual rainfall is 1200mm which occurs between May and November, with July and August being the wettest months. The soil in the area is a Typic Haplustalf with a sandy loam texture. Details of soil characteristics at the site at the beginning of the experiment are presented in Table 1.

Soil subject to four different cropping systems were used in this study. The cropping system were upland rice sole, cassava sole, cassava/cowpea intercrop and fallow. All four cropping systems were located within the same soil mapping units and were arranged in a randomised complete design with three replications. The total area for each plot was 0.85 ha. The current crropping systems have been imposed for three years before the initiation of the experiment. Prior to that, the land had been under fallow for at least five years.

Table 1. Initial soil physical and chemical properties at the beginning of the study

Soil variable	
Sand (%)	76
Slit (%)	10
Clay (%)	14
Textural class	Sandy Loam
pH (H_20)	5.74
Organic Carbon (%)	0.49
Total N (%)	0.07
Available P (mg Kg^{-1})	3.89
Exchangeable Ca (C mol Kg^{-1})	2.96
Exchangeable Mg (C mol Kg^{-1})	0.67
Exchangeable K (C mol Kg^{-1})	0.20

The cropped plot underwent ploughing and ridging operations annually and each received basal application of 30kg P and 30kg K_2O every season. Nitrogen was applied in two split doses annually at the rate of 90kg ha^{-1} to each of the cropped plots. For the cassava/cowpea intercrop, the N was applied primarily to the cassava component. Weed control was by using herbicides. In rice, "Crop Star" was used as pre-emergence herbicide at the rate of 3L 200 L^{-1} water ha^{-1} and Fitsonel’ as post emergence at the rate of 4L 200 L^{-1} water ha^{-1}. Weed was controlled in the cassava and cassava/cowpea plots by spraying with ‘Cutlass’ at the rate of 5L 300 L^{-1} Water ha^{-1}. Pest control in cowpea was done using two sprays of karate and cyperdichlor at 2L 250 L^{-1} water ha^{-1}. The cropping period lasted from May to November of each year. At harvest, crop residues were left in the field to be foraged by cattle. The left over at the beginning of the season was ploughed into the soil.

Soil sampling and analysis

Soil samples were collected from treatment plots using bucket augers. Sampling took place in June 2008 just after the second rain of the season. Samples from each plot consisted of composite of soil randomly collected from 20 points within each plot. Sampling was done at 0-15 cm and 30-45 cm. Augers were sterilized by flaming before and after sampling at each point to avoid cross-contamination. Moist soil samples were bagged under aseptic conditions and taken to the laboratory where sub-samples for microbial and biochemical assays were stored at 4^oC until when needed for analysis. Soil samples for phsico-chemical analysis were air-dried and subjected to routine analysis using the methods of IITA(1989).

Microbial populations were determine by soil dilution plating techniques using agar media. For each of the six sub-samples from each composite soil samples, 10g of soil was weighed and added to 90ml sterile deionized water thoroughly stirred and serially diluted and plated on 1% nutrient agar for total bacterial counts and potato dextrose ager (PDA) with 1 mg ml^{-1} of streptomycin for total fungal counts (Harrigan and McCance, 1990). Serial dilution was 10-fold up to 10^{-7} dilution and aliquots (0.5 ml) of 10^{-5}, 10^{-6} and 10^{-7} dilution were used for plating. Inoculated plates were incubated at 28 ^oC for 3 and 10 d prior to the enumeration of viable colonies of bacteria and fungi, respectively.

Microbial biomass carbon (MBC) was determined by chloroform fumigation-incubator (jenkison and powlson, 1976) as modified by Anderson and Ingram (1993). Approximately 10g of moist soil (adjusted to oven-dry weight) was placed into 50 ml glass beaker, fumigated evacuated and incubated at 25 ^0C for 5 d, following which the soil was extracted with 50 ml 0.5 M K_2SO_4. Non-fumgated soil (10g) taken prior to incubation was also extracted with K_2SO_4. Soil MBC was calculated by method of Vance *et al.* (1987) and soil microbial biomass N (MBN) by the method of Brookes *et al.* (1985).

Phosphatase activity was determined by the method of Tabatabai (1982). Field-moist soils were sieved with 0.5 mm screen and, using l g of soil sample, the activities of acid and alkaline phosphatases were determined using the subtrates p-nitrophenyl phosphate and those of phosphodiesterase with bis (p-nitrophenyl) phosphate in modified universal buffer (MUB: 121 g Tris-hydroxymethyl aminomethane, 11.6g maleic acid, 14g citric acid, 63g boric acid in 488 ml NaOH and diluted to 1L with water) adjusted to pH 6.5, pH 11, and pH 8, respectively. Enzymes analyses were done in triplicate on each of the sample, with a corresponding control. In the controls, the substrates were added after incubation and immediately prior to analysis.

Statistical analysis

Analysis of variance (ANOVA) was determined based on randomized complete block statistical design, with means separated using Least Significant Difference (LSD). Correlation analysis and measures of significance were determined using the GLM Proc. of SAS (SAS Inst., 1999) statistical analysis package

Results

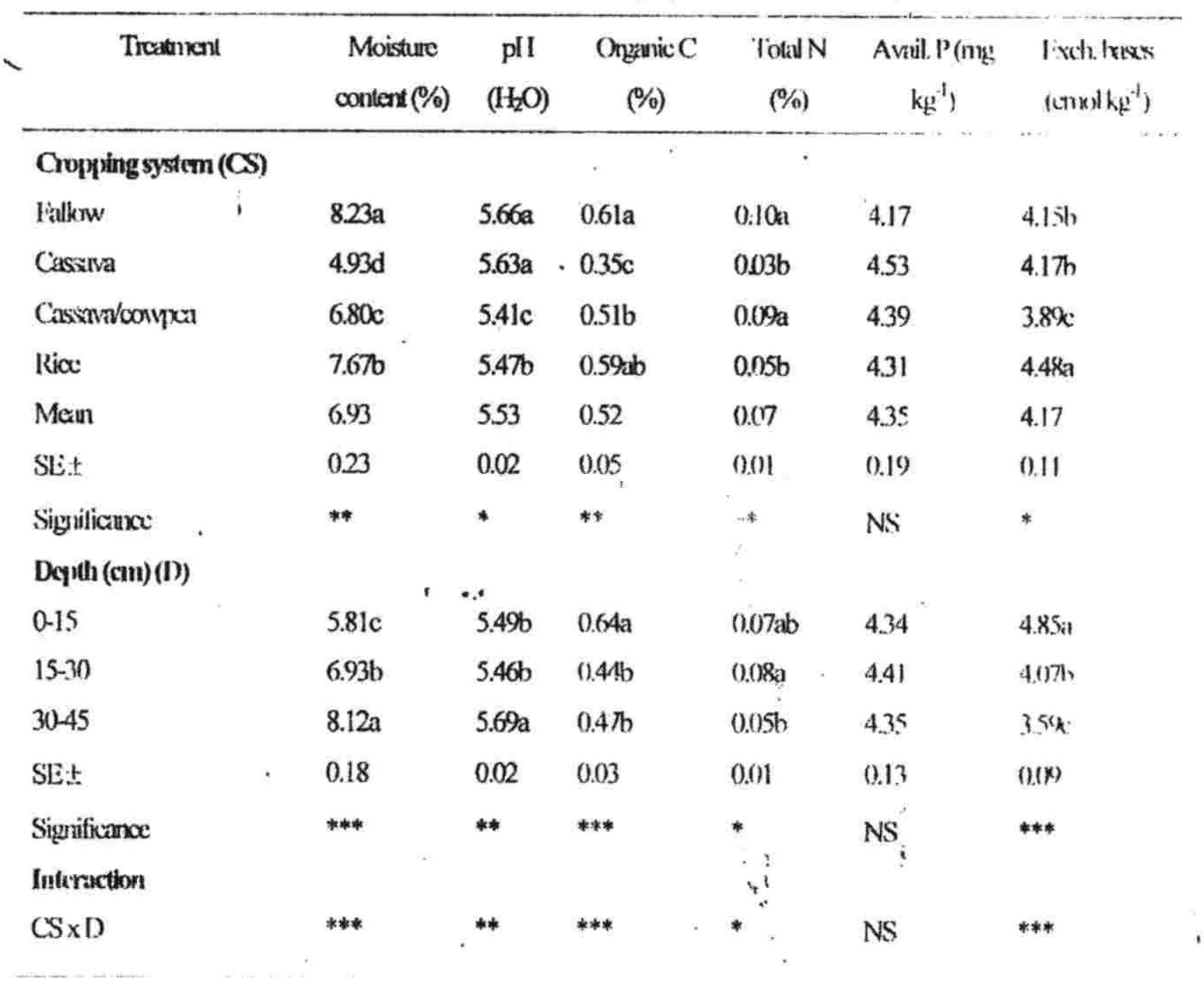
Soil chemical and physical properties

Cropping system had a significant effect on soil moisture content, pH, organic C(OC), total N and exchangeable cations (Table 2). The soil under fallow had the highest moisture content, pH, OC and total N, which were significantly ($p<0.05$) different from those of other cropping systems except for pH in cassava, OC in rice and total N in cassava/cowpea. The soil under cassava had the lowest moisture contents and OC and was also among the soils with the lowest total N content. The soil under rice had the highest exchangeable base content, while the cassava/ cowpea soil had the lowest exchangeable base content as well as the lowest pH. Top soil (0-15cm) had the highest OC and exchangeable base contents and the lowest soil moisture content. It also had one of the highest soil total N content and lowest pH. Neither cropping system, nor soil depth had a significant effect on soil available P.

Microbial population

Bacterial populations in top soil (0-15cm) ranged from $14x10^5$ to 4.9 x 10^5cfu g^{-1} soil (Figure 1). At this depth, total soil populations or culturable bacteria were most numerous in the cassava/cowpea and rice fields and least numerous in the fallow plots. At 15-30 cm depth, the population range of bacteria was 2.0 x 10^5 to 5.3 x 10^5cfu g^{-1} soil with the soil under cassava having the largest bacterial population, while the population in the fallow and cassava/cowpea plots were the smallest. The population at 30-45cm depth ranged from 1.0X10^5 to 6.0X10^5cfu g^{-1} soil. The rice plot had the highest population at this depth and the fallow plot the lowest. The highest bacterial populations in the fallow and cassava plots were sampled at 15-30 cm, while populations in the cassava/cowpea and rice plots were most numerous at the 0-15 cm and 30-45 cm depths respectively.

Table 3. Analysis of cropping system effect on soil properties at various soil depth



Treatment	Moisture content (%)	pH (H_2O)	Organic C (%)	Total N (%)	Avail. P (mg kg^{-1})	Exch. bases (cmol kg^{-1})
Cropping system (CS)						
Fallow	8.23a	5.66a	0.61a	0.10a	4.17	4.15b
Cassava	4.93d	5.63a	0.35c	0.03b	4.53	4.17b
Cassava/cowpea	6.80c	5.41c	0.51b	0.09a	4.39	3.89c
Rice	7.67b	5.47b	0.59ab	0.05b	4.31	4.48a
Mean	6.93	5.53	0.52	0.07	4.35	4.17
SE±	0.23	0.02	0.05	0.01	0.19	0.11
Significance	**	*	**	*	NS	*
Depth (cm) (D)						
0-15	5.81c	5.49b	0.64a	0.07ab	4.34	4.85a
15-30	6.93b	5.46b	0.44b	0.08a	4.41	4.07b
30-45	8.12a	5.69a	0.47b	0.05b	4.35	3.59c
SE±	0.18	0.02	0.03	0.01	0.13	0.09
Significance	***	**	***	*	NS	***
Interaction						
CS x D	***	**	***	*	NS	***

Means bearing the same letter (s) under the same treatment are not statistically different at p>0.05. NS = Not significant *** Significant at P<0.001; **Significant at P< 0.01; * Significant at P<0.05.

Culturable fungal population ranged from 4.0X105 to 8.0X10^5cfu g^{-1} soil at 15-30 cm depth and from 2.3 x 10^5 - 6.0 x 10^5 cfu g^{-1} soil at 15-30cm depth (Figure 1). The populations of fungi at these two depths were highest in soil under fallow and rice and lowest under cassava/cowpea. Fungal populations at 30-45cm depth had a range of 3.3x 10^5 to 5.6x 10^5cfu g^{-1} soil with the populations in the cassava/cowpea and rice plots being the most numerous. Fungal populations were generally greater than those of bacteria across the various cropping systems especially in soils under fallow.

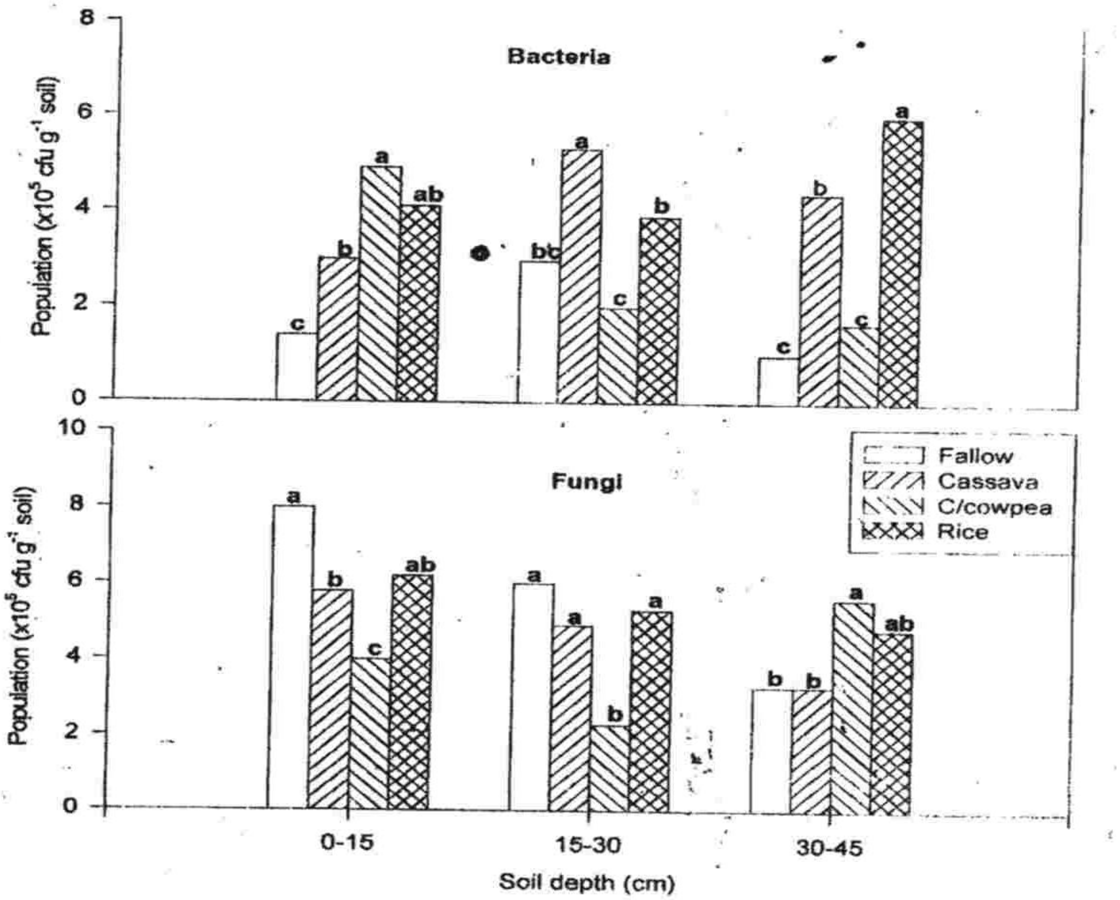


Figure 1. Bacterial and fungal populations at three soil depth and under different cropping systems in a soil of the southern Guinea savanna of Nigeria. Bars with the same letter (s) at each soil depth are not statistically different at $p<0.05$.

Microbial Biomass

Microbial biomass carbon (MBC) in top soils under the various cropping systems ranged from 170 mg kg^{-1} to 300 mg kg^{-1} (Figure 2) MBC generally declined with depth in each of the cropping systems. At 0-15 cm depth, MBC was higher in soil under fallow than in other cropping systems, The cassava/cowpea plots had the lowest MBC at that depth. Rice and fallow had highest MBC and cassava and cassava/cowpea the lowest at 15-30cm and 30-45cm depths.

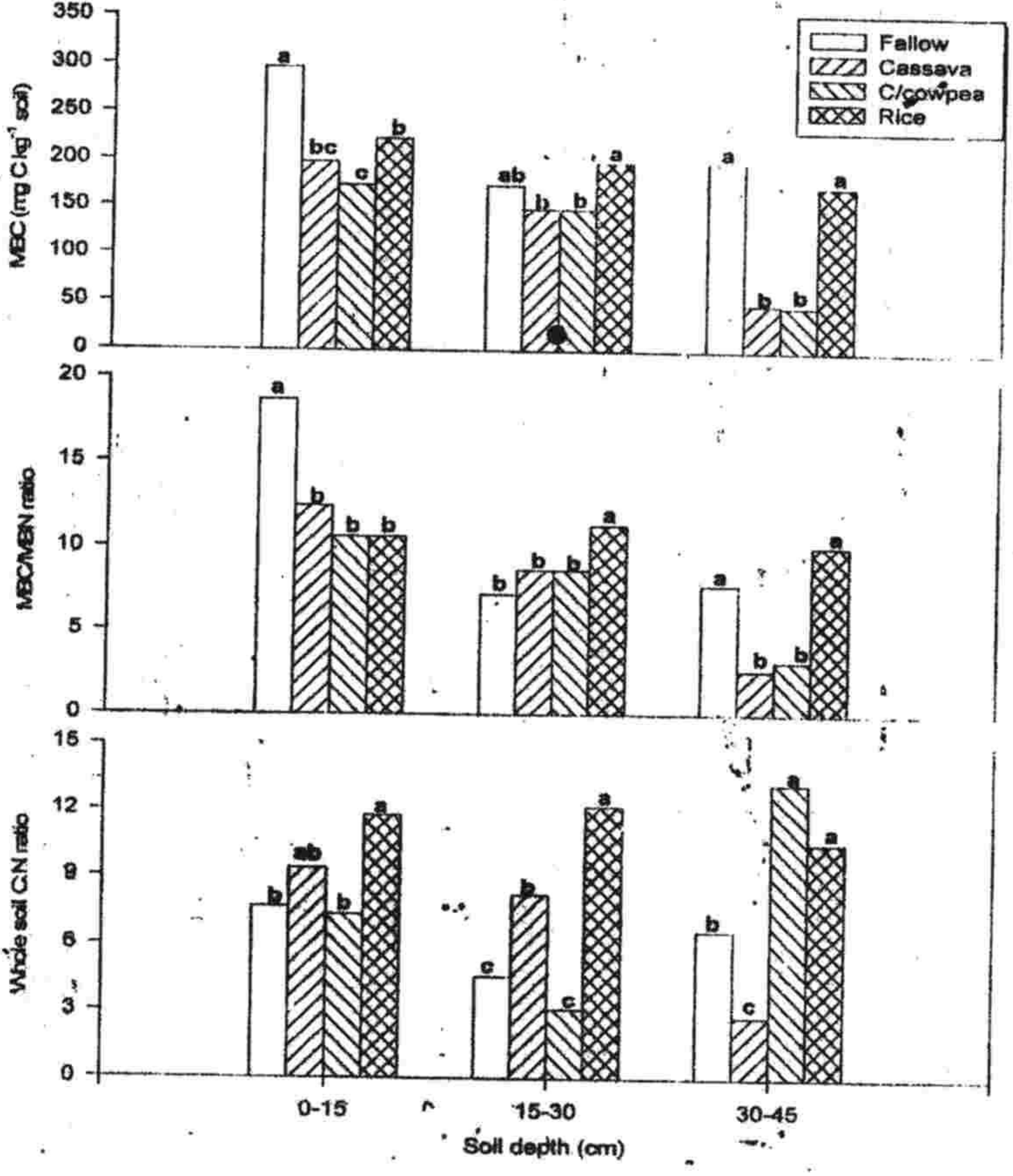


Figure 2. Microbial biomass carbon (MBC), biomass C:N (MBC/MBN) ratio, and bulk soil C:N ratio at three depth and under different cropping systems. Bars at the same depth carrying different letters are significantly different.

Microbial Biomass nitrogen (MBN) at 0-15cm depth ranged from 4to 12 mgkg-1 (data not shown) Neither cropping system, nor soil depth had a significant effect on changes in microbial biomass (MBN). However, the MBC/MBN ratio differed with cropping system and depth (Figure 2). The ratios ranged from 11 to 19 in top soil and from 3 to 11 at 15 – 45 cm depth. MBC/MBN ratios generally declined with depth except in the rice cropping system. Fallow had the highest MBC/MBN ratio at 0-15cn depth and rice at 15-30 cm. both fallow and rice had the largest ratio at 30-45 cm depth. There were no differences in MBC/MBN ratio between cassava and the cassava/cowpea plots of any of the depths.

C:N ratios of bulk soil ranged from 7 to 12 at 0-15cm depth and from 3 to 13 at lower depths (Figure 2). The ratios at 0-15cm were similar in the various cropping system except the rice plot which had a higher ratio (Figure 2). Similarly, rice had the highest soil C:N ratio at 15-30 cm depth, while the fallow and cassava/cowpea plots had the lowest ratio. Rice and cassava/cowpea had the highest ratio at 30-45cm depth, followed by fallow and cassava in that order.

MBC constituted 2-5% of the soil organic C (SOC) fraction at 0-15 cm, 3-5% at 15-30 cm and 1-4 % at 30-45 cm depths (Table 3). The cassava plot had the highest proportion of SOC as MBC at 0-15 cm and 15-30 cm, while the highest proportion at 30-45 cm depth was in the rice plot. The cassava/cowpea plots had the lowest proportion of MBC as SOC at all depths. MBC as percentage of SOC decreased with depth in fallow, cassava and cassava/cowpea, and increased with depth in rice.

Acid phosphatase (AcP) activities in the top soils of the various cropping systems ranged from 3 to 41 Ug g-1 (Figure 3). At 0-15 cm, soil under rice rice had the highest AcP activity, while those under cassava and cassava/cowpea had the lowest. At 15-30 cm, rice and cassava/cowpea cropping systems had the highest activity and cassava the lowest. The rice cropping system also had the highest Acp activity while the other cropping systems had similar activities at 30-45 cm depth.

Alkalne phosphate (Alp) activities in top soils under the various cropping systems ranged from 7ug g^{-1} to 31 ug g^{-1} (Figure 3). Irrespective of soil depth, the soil under fallow had the highest AlP activities. Cassava and cassava/cowpea systems had the lowest AlP activities at the 0-15cm and 15-30cm depths respectively. AlP activities in soils under fallow and rice did not differ significantly with depth in contrast with activities in the cassava and cassava/cowpea plots. Activities of phosphodiesterases in top soils under the various cropping systems ranged from 14 ug g^{-1} to 24 ug g^{-1} (Figure 3). Phosphodiesterase activity in top soil was highest in the rice plot. There were no significant differences in activity between the cropping systems at other soil depths

Table 3. The proportion of soil organic carbon (OC) and total nitrogen as biomass at three depths and under different cropping systems

Soil depth	Fallow	Cassava	Cassava/cowpea	Rice
		MBC as a proportion of soil OC (%)		
0-15 cm	4.26	5.16	2.41	3.01
15-30 cm	3.81	5.04	3.32	3.66
30-45 cm	3.06	1.28	1.11	3.93
		MBN as a proportion of total soil N (%)		
0-15 cm	1.34	2.91	1.04	2.54
15-30 cm	1.77	3.74	1.27	2.72
30-45 cm	1.99	1.01	3.53	3.11

Relationships between soil parameters

Correlation analysis of some soil parameters revealed significant relationships existing among some of the parameters assayed (Table 4). Bacteria population correlated negatively with MBN, and soil N and positively with extractable P and percent clay content. Fungal population was positively correlated with MBC, Phosphomonoesterase activities, soil organic carbon (SOC) and whole soil C:N ratio, and negatively correlated with phosphodiesterase (Dip) activity, soil pH, soil N and extractable P. MBC also correlated positively with phosphomonesterase activities, SOC and total N, and negatively with Dip activity and Bray- P. There was a positive correlation between MBN and each of ALP and DiP activities, SOC and total soil N, while MBN correlated negatively with soil pH, soil C:N ratio and Bray-P. In addition to its relationships with the other biological parameters, AcP activity correlated positively with soil pH, SOC and C:N ratio and clay, and negatively with extractable P. AlP activity also had positive relationship with Dip activity and SOC and negative relationship with extractable P. DiP activity was positively affected by soil pH, soil C:N ratio and clay. There also existed significant relationship among the selected soil chemical and physical properties to varying degrees or instance, soil pH was significantly correlated with SOC, soil C:N ratio and clay. SOC was also correlated with C:N ratio and Bray-P, while total N in soil was correlated with C:N ratio and clay content.

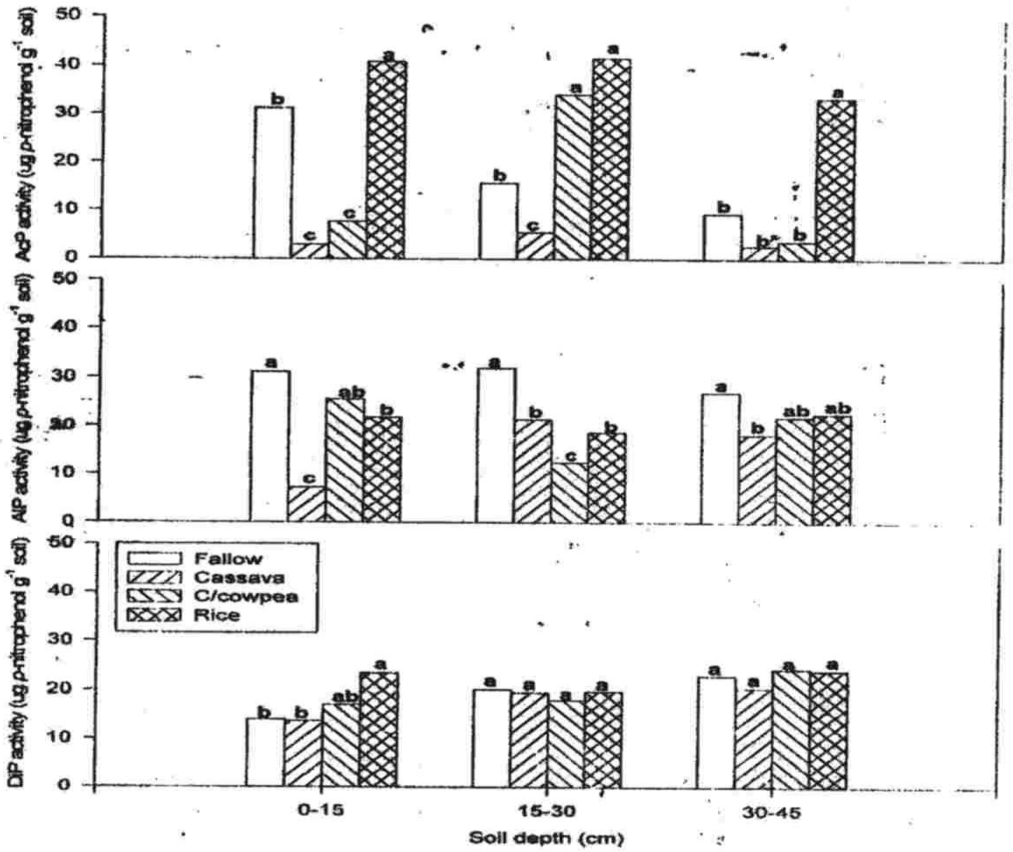
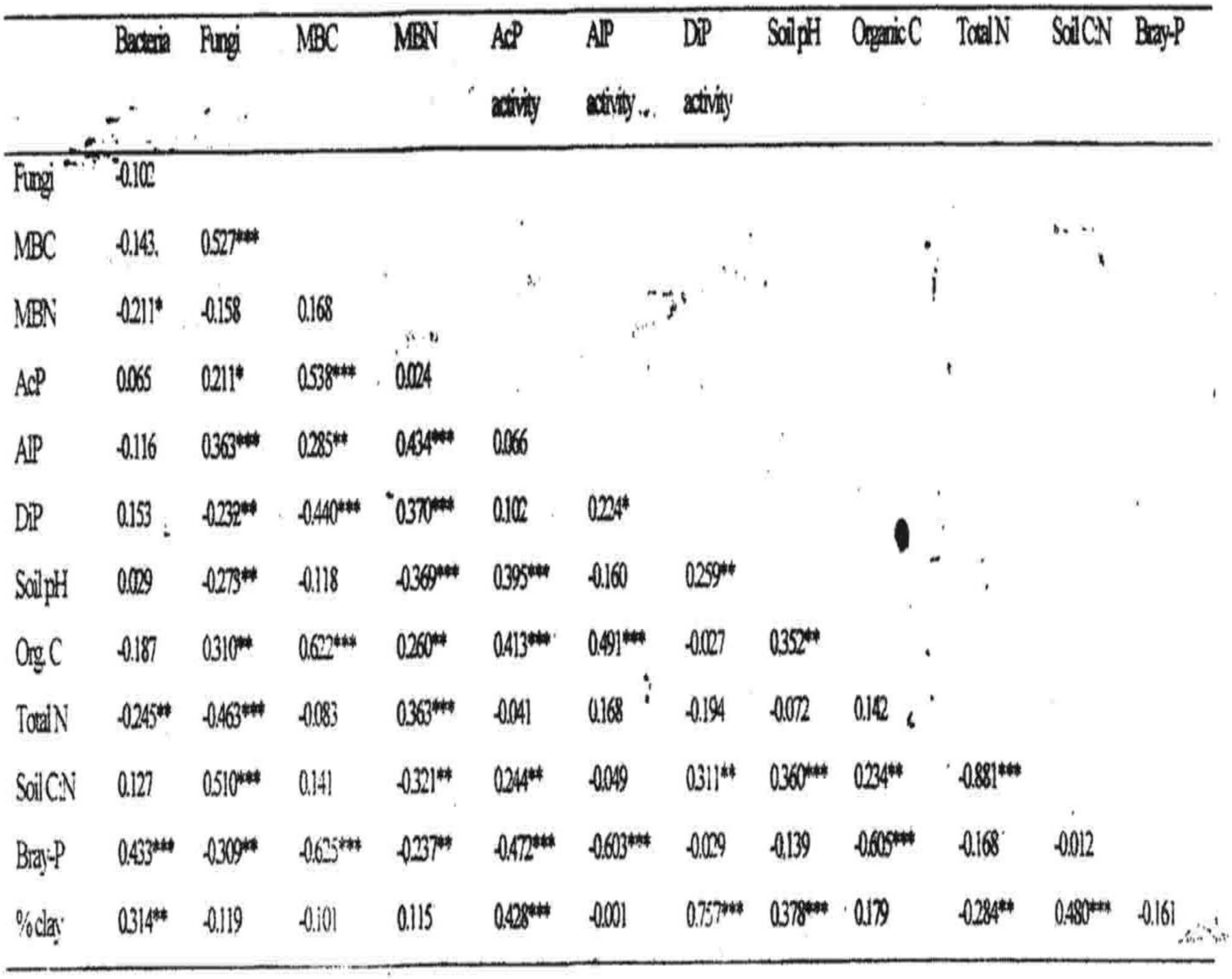


Figure 3. Acid phosphatase (AcP), alkaline phosphatase (AlP) and phosphodiesterase (DiP) activities at three soil depths and under different cropping systems. Bars at the same depth carrying different letters are significantly different.

Table 4. Matrix of correlation for biological, physical and chemical properties of soil under different cropping systems



	Bacteria	Fungi	MBC	MBN	AcP activity	AlP activity	DiP activity	Soil pH	Organic C	Total N	Soil C:N	Bray-P
Fungi	-0.102											
MBC	-0.143	0.527***										
MBN	-0.211*	-0.158	0.168									
AcP	0.065	0.211*	0.538***	0.024								
AlP	-0.116	0.363***	0.285**	0.434***	0.066							
DiP	0.153	-0.232**	-0.440***	0.370***	0.102	0.224*						
Soil pH	0.029	-0.273**	-0.118	-0.369***	0.395***	-0.160	0.259**					
Org. C	-0.187	0.310**	0.622***	0.260**	0.413***	0.491***	-0.027	0.352**				
Total N	-0.245**	-0.463***	-0.083	0.363***	-0.041	0.168	-0.194	-0.072	0.142			
Soil C:N	0.127	0.510***	0.141	-0.321**	0.244**	-0.049	0.311**	0.360***	0.234**	-0.881***		
Bray-P	0.433***	-0.309**	-0.625***	-0.237**	-0.472***	-0.603***	-0.029	-0.139	-0.605***	-0.168	-0.012	
% clay	0.314**	-0.119	-0.101	0.115	0.428***	-0.001	0.757***	0.378***	0.179	-0.284**	0.480***	-0.161

DISCUSSION

The results of this study showed significant differences in soil physical and chemical properties due to the cropping systems imposed, which resulted in distinct changes in microbial populations directly associated with the various cropping systems. The regenerative effect of fallow led to higher soil pH and greater organic matter and total N accumulation in the fallow plot than the cultivated treatments. Plants significantly influence microbial population due primarily to the variation in the quality and quantity of organic and chemical compounds they secrete into the rhizosphere (Grayston et al 1998; Miethling et al 2000). Given the more favorable soil properties in the fallow soil, microbial population and activity were expected to be greater in the fallow than the cultivated soils (Dick *et al* 1988; Larkin, 2000). However, bacteria population in the cultivated plots were generally greater than or similar to the populations in the fallow plots irrespective of the soil depth, suggesting a favorable effect of cultivation on this group of organisms. Fungal populations on the other hand, did not exhibit such favorable effects of cultivation and were generally greater in the fallow and rice fields, especially at upper soil depths. Both fungal and bacteria population were consistently most numerous in the rice plots irrespective of depth, while the cassava/cowpea plots had greater bacteria and lower fungal populations in top soils than sole cassava plots, suggesting a causal relationship between organic matter quality and the dominance of specific microbial groups. The fallowed field was dominated by shrubby species such as *Isoberlina Doka and Piliostigma Spp* thus resulting in large inputs of woody substrate that would have favored the growth of fungi. Inputs of rice bran, which are less easily degradable, would have had similar effect in the rice field.

Microbial population are affected by soil properties such as pH, organic carbon and soil N (Larkin, 2000). In the current study, bacteria population was only correlated with soil N, P and clay, while the fungi were significantly affected by soil pH, organic C soil N and P and C:N ratio, again suggesting the prominence of fungi in the soils studied, especially given the high positive correlation with soil C:N ratio, indicating large population of fungi in the presence of poor-quality organic substrates.

Top soil population of bacteria ranged from $1.4\times 10^5$to 4.9×10^5 cfu g^{-1} soil and those of fungi were 4.0×10^5 to 8.0×10^5 cfu g^{-1} soil. These ranges are below the 1.37×10^7 to 1.68×10^8cfu g^{-1} soil and 7.49×10^6 to 5.26×10^7 cfu g^{-1} soil reported for bacteria an fungi respectively, in arable soils of humid forest zone of Nigeria (Isirimah *et al* 2006). This is to be expected given the higher precipitation and organic matter input in the soils of the humid forest compared to the Guinea savanna zone. Consistent with the result of these authors, microbial population varied with soil depth, although there was no single trend observed. Unfortunately, there is no available data for the savanna region that could form the basis of comparison with the result observed in the current study.

Expectedly, soil moisture content increased with depth, while SOC, total N and exchangeable base contents decreased with depth (Table 2). The results of this study also clearly show significant population of bacteria and fungi at soil depth below the root zone. Given the high soil temperatures and low moisture levels in the soil at the time of soil sampling, our initial hypothesis was that microbial populations would significantly be greater at deeper soil layers than the top soil. This was only apparent in the bacterial populations under fallow and cassava; otherwise, both fungal and bacterial populations in top soil were as high as or higher than those in deeper layers.

Soil microbial biomass C (SMBC) in top sol ranged from 170 mg kg $^{-1}$ to 300 mg kg. This compares well with the values of 187-383 mg kg^{-1} reported for soils in Northern Guinea savanna zone of Nigeria (Adeboye *et al.,* 2006) but is slightly lower than the range of 250-445 mg kg^{-1} observed by Yusuf (2007) in the same agro-ecological zone. The two studies both reported higher SMBC in soils under legume rotation than in fallow soils. In the current study, however SMBC in fallow soil was greater than in cropped soils expect in the rice plot. Given the significantly smaller bacteria and larger fungi populations in the fallow plots and, to some extent, the rice plots, it would appear that these plots had larger input of less degradable materials and thus higher fungal activity than the cassava and cassava/cowpea plots.

The relatively higher MBC/MBN ratio in the fallow and rice plots also suggest a greater fungal activity than in the cassava and cassava/cowpea plots. Biomass C:N ratio of fungi ranged from 7 to 12, while those of bacteria are in the range of 3-6 (Jenkinson,1976; Anderson and Domsch, 1980). Thus a high MBC/MBN ratio is indicative of fungal dominance of a microbial community while a low ratio suggest the prevalence of bacteria (Campbell *et al.*, 1991). The biomass C:N ratios of the current study ranged from 11 to 19 in top soils and 3 to 12 at lower depths. These values are comparable with the 9-21 reported for soils under legume rotation in the Northern Guinea savannah of Nigeria (Adeboye *et al.,* 2006; Yusuf 2007.

The top soil (0-15 cm) biomass C:N ratio in the fallowed soil was significantly greater than those of the cultivated soils (Figure 2). This may be due to a number of oil factors, which include the degree of N incorporation in fungi, substrate quality and quantity, pH, moisture content and the ratio of active to dormant microorganisms (Anderson and Domsch, 1980; Campbell *et al* 1991 Adeboye *et al* 2006). Cultivation may have also played a role by enhancing the rate of organic matter mineralization in cultivated soils and thus resulting in relatively lower biomass C:N ratios in cultivated than fallow soils especially in top soils, were generally greater than the respective bulk soil C:N ratios except in the rice plots which had greater soil C:N ratio than biomass C:N ratio (Figure 2) .The convergence of the biomass C:N ratio with that of the bulk soil represent a microbial biomass in stable state following the mineralization of labile component during decomposition (Dalal and Mayer, 1987). The huge differences between both ratios in the fallow, cassava and cassava/cowpea plots suggest an active stage of biomass C and N turnover as opposed to a relatively stable state in the rice plot.

Our results show that biomass C accounted for 1-5% of soil organic C. This range is consistent with the 2-5 % reported by Smith and Paul (1990) and also compares well with the 4-6% observed by Adeboye *et al*.(2006) in soil under legume rotation in the Northern Guinea savanna zone of Nigeria. Adeboye *et al*. (2006) observed higher proportion under legume rotation than fallow and alluded this to high quality (low C:N ratio) organic matter input In the legume rotation. In the current study, however, the proportion was lowest in the cassava/cowpea mixture, which supposedly should have had higher quality organic matter input than the other three systems. Although high quality organic substrate supports greater microbial growth and survival, and hence higher incorporation of carbon by microbial cells (Anderson and Domsch, 1980), it may in the long run lead to more rapid SOC turnover and therefore higher in diminition of biomass C. The fact that the proportion of SOC as biomass C declined with depth seems to support this suggestion, given that SOC also declined with depth.

Previous studies have estimated biomass N to be 1-5% of total soil N (Smith and Paul, 1990; Adeboye *et al*., 2006). In the present study, biomass N accounted for 1-4% of total N, which compares well with the above range of 1-5%. The proportion was affected by cropping system, with higher values in the cassava, rice and fallow soils than in the cassava/cowpea. The proportion also increased with depth, suggesting lower biomass N retention in soil with high quality organic C input due to high organic matter turn-over mineralization and greater plant uptake within the root zone.

Consistent with the report of Eivazi and Tabatabai (1997), acid phosphatase activity was correlated with pH. However, contrary to their observation, alkaline phosphatase activity had no significant correlation with pH and in spite of the relatively low pH values of soils under various cropping systems, alkaline phosphatase activity was greater than that of acid phosphatase in all cropping system, except rice, and at most depths. A study by Monkiedje *et al*. (2006) showed that the dominance of acid- or alkaline phosphomonesterases in acid soils depended on the cropping system and management practice. Phosphatase enzyme activities are also known to vary with soil chemical and physical properties as well as vegetation types (Dick, 1993; Colvan *et al*., 2001; Izaguirre-Mayoral *et al*., 2002). This relationship was also evident in the present study, thus suggesting that the effect of pH on phosphatase activity might in some cases be masked by other environmental variables.

Fallow and rice plots had as high as, or relatively higher, acid and alkaline phosphatase activities than the other cropping systems across the various depths. This may probably be due to a number of reasons. The higher moisture content in the fallow and rice plots might have favored greater microbial activity and hence higher enzyme activity. This would be consistent with the observed differences in enzyme activity between soils subjected to different cropping systems with greater activity linked to a more favorable water status for microbial activity (Fraser *et al*., 1998; Dick, 1993). Secondly, both the fallow and rice soils had relatively higher SOC contents than the other treatments. The activities of acid and alkaline phosphatases have been found to correlate with organic matter in various studies, with increasing SOC enhancing biological activity and increasing the capacity to immobilize available P and increase phosphatase activity (Dick *et al*., 1988; Colvan *et al*., 2021). This is consistent with the result of the present study showing negative correlation between SOC and extractable P and positive correlations between SOC and phosphatase activities. The relatively higher SOC contents in the fallow and rice plots may also have engendered the stabilization, and hence activity, of extra-cellular enzymes through complexation, with humic substances (Nannipieri *et al*. 1996; Rao et al., 1998). Fourthly, the amount of acid phosphatase secreted by plant is genetically controlled and differs with crop species and varieties (Izaguirre-Mayoral *et al*., 2002). Additionally, Tarafdar and Claassen (1988) demonstrated an increase in acid and alkaline phosphatase activities in the presence of living plants. Such an effect could have been responsible for the observed differences especially with respect to the fallow plots.

CONCLUSION

The study has shown demonstrable effect of cropping system on soil properties, with fallow showing relatively higher pH and greater soil moisture, organic carbon and total N contents than the cultivated treatments. Among the cultivated systems, rice had the most favorable effect on soil properties. Microbial populations were generally most numerous in rice and fallow systems; with fungi being the most dominant microbial groups, perhaps due to the low substrate quality in the fallow and rice fields. In spite of clear evidence of changes in soil properties due to soil depth, bacterial and fungal populations were generally of the same order of magnitude in both the top soil and subsoil. Soil microbial biomass N was not sensitive to cropping systems, but biomass C was greater in fallow and rice plots than in the other plots. Acid and alkaline phosphatase activities, but not phosphodiesterase, were responsive to cropping system showing greater activity in the fallow and rice plots.

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