MICROBIAL POPULATION AND COMPOSITION IN SOILS IRRIGATED WITH MUNICIPAL WASTE WATER UNDER PERI – URBAN AGRICULTURE IN MINNA, SOUTHERN GUINEA SAVANNAH ZONE OF NIGERIA

*Uzoma, A.O., Jimoh, S.O., Bala, A., Adeboye, M.K.A, Afolabi, S. G. and Osunde, A.O.
Department of Soil Science, Federal University of Technology, Minna.
*Correspondence: uzo_ozo@yahoo.com.

ABSTRACT

The source of irrigation water and its management have profound influence on soil microbial population and diversity with depth. This study was designed to determine the effect of soil depth, soil physico-chemical properties and source of irrigation water on microbial population under peri-urban agriculture around Minna, Niger State. The experiment was based on 4 by 3 factorial combinations in a complete randomized design (CRD) i.e. soils from 4 sites under different land uses (Keteren gwari Mechanic village, Chanchaga Bridge, Chanchaga Tributary and Morris Fertilizer) sampled at 3 soil depths of 0-5, 5-10 and 10-15 cm. Regression analysis was used to correlate the physico-chemical properties with microbial population and the experiment was subjected to two-way analysis of variance (ANOVA). The microbial population was estimated by using nutrient agar for bacteria, potato dextrose agar for fungi and caseine-asparagin agar for actinomycetes. Plate count method was used to estimate the colony forming unit (cfu) in g-1 soil. The mean of microbial population across the four sites indicated that bacteria have the highest count followed by actinomycetes and fungi in that order. The highest microbial counts for the three groups of microorganisms were recorded at 0 to 5 cm depth and the lowest at 10 to 15 cm depth. The highest bacterial count (cfu. $4.4 \times 10^8 g^{-1}$ soil) was obtained at Morris Fertilizer while the highest fungi (cfu. $2.2 \times 10^4 g^{-1}$ soil) and actinomycetes (cfu $3.0 \times 10^8 g^{-1}$ soil) counts were recorded at Keteren-gwari. This study indicated that Keteren-gwari and Morris Fertilizer recorded the highest microbial count, the bacterial count (cfu. $4.4 \times 10^8 g^{-1}$ soil) and fungi count (cfu. $2.2 \times 10^4 g^{-1}$ soil) were statistically significant ($p < 0.05$) at 0-5 cm soil depth while the lowest microbial count was obtained at Chanchaga Bridge and Chanchaga Tributary in which fungi count (cfu. $2.2 \times 10^4 g^{-1}$ soil) was significant ($p < 0.05$).

Key words: Soil microbes, Fungi, Sewage, Guinea Savanna.

1. INTRODUCTION

The soil is a living system that contains a rich and diverse array of microbial species. Olson *et al.* (2000) described soil as a complex ecosystem, delimited by physicochemical parameters that holds enormous amount of diverse living organisms. Biologically, normal fertile soils teem with soil microbes and there may be hundreds of millions to billions of microbes in a single gram (Ranjard and Richaume, 2001). Thus, each soil has an indigenous microbial population that is selected by the prevailing biotic and abiotic factor unique to that soil (Nelson, 1997).

Quantitatively, the most numerous microbes in soil are the bacteria followed in decreasing numerical order by actinomycetes, the fungi, soil algae, cyanobacteria and soil protozoa (Sylvia *et al.*, 1997). Additionally, hundreds of thousands and millions of microbial cells were initially counted in one gram of soil, at present, with improved methods of investigation, hundreds of millions and billions were determined (Baath *et al.*, 1998). Along with bacterial, a large number of actinomycetes, fungi, algae, protozoa, ultra-microbes, phages, insects, worms and other living creatures, inhabit the soil (Schimel *et al.*, 2004).

Functionally, these organisms are essential for globally important ecosystem processes such as decomposition and nutrient recycling and usually they make up 2% of the soil organic matter. Hence, the principal property of soil fertility is determined by biological factors, mainly by microorganisms (Sparks, 2003).

According to Nelson (1997), an understanding of what it takes to support growth and activity of soil microbes enables one to make logical decision about soil management. The health of microbial communities is very important for proper growth and propagation. Soil microbes, like every other living organism, have their basic needs for their survival. The use of wastewater for irrigation over a long period may cause imbalance in soil microbial population and thereby affect the biological properties of soil leading to soil degradation (Manickam and Ventataraman, 1992).

In most peri-urban areas of Nigeria, municipal wastewater is widely used as a low-cost alternative to conventional irrigation. Specifically, in Minna, Niger State of Nigeria, the demand for all season production of vegetables and other arable crops in peri-urban areas makes irrigation necessary;

consequently, farmers in search of irrigation water often rely on municipal wastewater. The ultimate recipient of waste and effluents produced in the residences, industries, commercial and farm establishments is the "soil" (Agboola. 1978).

Given the role of soil microbes in controlling most biogeochemical processes and ecosystem productivity, it is important to know how long term application of municipal wastewater affects the microbes in such soil. The objective of this study is, therefore, to examine population dynamics of three microbial groups (bacteria, fungi and actinomycetes) in soils under irrigation with municipal wastewater relative to soils irrigated with water from natural water bodies and to determine the relationship between the physico-chemical properties of soil and microbial population size and relative dominance of various microbial groups.

2. MATERIALS AND METHODS

2.1 Site Description

The study was conducted in Minna, the capital city of Niger State. Nigeria with an estimated population of 2million (NPC, 2000). The areas under study include Chanchaga Tributary, Chanchaga Bridge, Morris Fertilizer, and Keteren-gwari Mechanic Village. Minna lies on latitude 9°41' North and longitude 6°31' East of the equator while the elevation of the location is about 400m above the sea level (FDALR, 1990). It has a total land area of about 6764 sq. km (NMLH, 2002).

2.2 Study sites

Chanchaga Tributary

The area covered by this soil generally under cultivation with sugar-cane/maize was irrigated mainly from a perennial stream which derived its source from Chanchaga River tributary. The land use system was shifting cultivation while the cropping pattern was intercropping system. Maize (Zea mays) and sugar-cane (Saccharum officinarum) are the dominant crops on the cultivated field. Other plants include yam (Dioscorea spp), cassava (Manihot esculentus, jute malo (Corchorus olitorus), sweet pepper (Capsicum spp), banana (Musa spp), orange (Citrus spp) and mango (Mangifera spp), oil palm (Elaesis spp), while the dominant weeds on the fallow field were spear grass (Impereta cylindrical, Cyperus rotundus interspersed with pioneered maize plant (Zea mays).

Chanchaga Bridge

The deep, well-drained and steep soil covering this area was also irrigated mainly from a perennial stream which derived its source from Chanchaga River. The field was already under cultivation and

the cropping pattern was mixed cropping. The dominant crops were maize (Zea mays) and vegetables such as amaranthus (Amaranthus app), egg plant (Solanum melongena) tomato (Lycospersicum esculentum), sweet pepper (Capsicum annum). okra (Abelmoschus esculentus) and bitter leaf (Vernonia amygdalina). The dominant species of trees and shrubs include mango (Mangifera indica), cashew (Anacardium occidentale)and shea butter (Butyrospermum parkii) while the common weeds include Sida acuta interspersed with spear grass (Impereta cylindrica).

Morris Fertilizer

This site was located at the south-eastern part of Minna metropolis. The soils are deep well drained, and steep and easily prone to runoff. There are two sugar-cane plantations and they were demarcated by a stream characterized with greenish colour which runs across the farm. The farming system and cropping pattern under this land use was shifting cultivation and mono-cropping system respectively. The dominant crop was sugar-cane (Saccharum officinarum) while the tree plants include cashew (Anacardium occidentale), mango (Mangifera spp), banana (Musa spp), pawpaw (Carica papaya), neem (Azadirachta indica), and guava (Psidium guajava). The common weeds on the fallow field include Tridax procumbens, elephant grass (Pennisetum purpureum) and spear grass (Impereta cylindrica).

Keteren-Gwari Mechanic Village

This is the central area of Minna metropolis popularly called Mechanic Village about a half kilometer away from the Central market (Gwari market). The soils in this site are black, very deep, well drained with gentle slope. The source of irrigation water is a canal separating the study site from the Mechanic workshop. This canal conveys dark-greenish water due to effluents being produced from the central market dumping ground, Mechanic workshop, General hospital and the residences located within the area. The cropping pattern under this land-use was the monocropping system. The only cultivated crop on the field was maize (Zea mays) and the tree plants include mango . (Mangifera spp), banana (Musa spp), guava (Psidium guajava) and neem (Azadirachta indica). The common weeds include spear grass (Impereta cylindrica), Sida acuta and Tridax procumbens. Prior to this study, the soil had received some levels of nitrogen fertilizer

2.3 Experimental design, Soil sampling and Analysis

The experiment was a 4 x 3 factorial experiment in a randomized complete block design (RCBD) i.e. Soils from four peri-urban locations (Keteren-gwari, Mechanic village, Chanchaga bridge, Chanchaga Tributary and Morris Fertilizer) sampled at three soil depths of 0 - 5.5 - 10 and 10 – 15 cm in the month of

June, 2009. In each location, soil samples were collected with the aid of sterilized augers and in each plot, soil samples were collected from 15 points. Each soil composite was thoroughly mixed and divided into four equal parts and a fraction of the prepared soil sample for microbiological study was stored in well labeled polythene bags prior to refrigeration. The remaining soil samples were air-dried, sieved through either 0.5 mm sieves for OC and N determination or 2 mm sieve for the determination of other physico-chemical properties (Anderson and Ingram, 1993).

Wastewater samples were also collected from the streams used for irrigating the earlier-mentioned crop fields and they were stored in plastic bottles, well labeled and kept in refrigerator for the determination of heavy metals. All the analyses were carried out in replicates.

2. 3.1 Physico-chemical and Microbiological Properties Determination

Standard laboratory procedures described by IIT A (1979) were used to determine the physico-chemical properties of soil samples as highlighted below. Soil moisture content was determined by using gravimetric method. Soil pH was determined in both soil : distilled water (1:1) and soil : 0.01 M $CaCl_2$ (1:2) suspensions, using a glass electrode pH meter. Particle size was determined by applying Bouyocous hydrometer method and the textural class was determined with the aid of the USDA textural triangle. Organic carbon was determined using Walkley-Black method (Nelson and Sommer 1996). The organic carbon data were converted to organic matter by multiplying organic carbon by a factor of 1.729. Determination of exchangeable bases was done by using ammonium acetate (NH_4OAc) displacement method. Na^+ and K^+ by a flame photometric method while Ca^{2+} and Mg^{2+} by EDTA Titrimetric method. The soil samples were treated with IN KCl to extract the exchangeable H and AI. The KCl extract was subsequently titrated with 0.05N NaOH. cation exchange capacity (CEC) was measured by neutral IN potassium acetate (K0Ac) saturation and neutral IN ammonium acetate (NH_4OAc) displacement and the displaced potassium was determined by flame photometer method. Available phosphorus was extracted with the Bray P 1 method and measured calorimetrically. Total nitrogen was measured by using the modified Micro-Kjeldhal method. Heavy metal fractions in the soil and wastewater samples were sequentially extracted and analyzed by using the Atomic Absorption Spectrophotometer (AAS) according to the method of Emmerich et al. (1982) and Chang et al. (1984).

Microbial counts were carried out using the procedure described by (Curl and Truelove. 1986 as follows: Bacteria, fungi and actinomycetes colonies developed on petridishes were counted with the help of plate count method and expressed as number of colony forming units (CFUs) g^{-1} soil (Pandey, 2004).

2.4 Statistical Analysis.

The data collected were subjected to two-way analysis of variance (ANOVA) to determine treatment effect at 5% level of significance. Duncan multiple test was used to separate means. Correlation-regression analysis was used to correlate physico-chemical properties with microbial population. The statistical analysis package used was SAS 2002 (window version 8.1 copy right). .

Table. 1   Physical properties of soil under different landuse systems

Land use! Depth (crn)	Sand	Silt $(g\ kg^{-1})$	Clay	Texture	Moisture (%)
CT 0-5	482^{cd}	273^{cd}	245^{abcd}	Sandy clay loam	1.99^{b}
5 - 10	442^{cd}	333^{cd}	225^{abcd}	Sandy clay loam	2.04^{a}
10 - 15	462^{cd}	292^{cd}	245^{a}	Sandy clay loam	2.00^{b}
CB 0 -5	462^{bc}	273^{bc}	265^{cde}	Sandy clay loam	0.98^{e}
5 - 10	562^{b}	233^{de}	205^{de}	Sandy clay loam	1.03^{cd}
10 - 15	535^{b}	240^{cd}	225^{bcd}	Sandy clay loam	1.00^{de}
MF 0-5	442^{e}	293^{a}	285^{ab}	Loam	0.75^{g}
5 - 10	462^{e}	293^{a}	205^{abc}	Loam	0.79^{f}
10 -15	442^{d}	293^{bc}	265^{a}	Loam	0.77^{fg}
KG 0-5	675^{a}	170^{e}	155^{g}	Sandy loam	0.99^{e}
5 - 10	645^{a}	193^{de}	165^{fg}	Sandy loam	1.05^{c}
10 - 15	642^{a}	167^{e}	191^{fg}	Sandy loam	0.93^{e}

Means of the Same letter within the same column are statistically the same at $P < 0.05$

CT chanchaga tributary,CB chanchaga bridge,MF morris fertilizer,KG keteren gwari

Table 2 Chemical properties of soil under different landuse systems

Land use/depth (cm)	pH (H₂O)	EX.AC Cmol kg⁻¹	OC g kg⁻¹	N g kg⁻¹	P Mg kg⁻¹	Na	K	Mg Cmol kg⁻¹	Ca	CEC
CT 0-5	5.00ⁱ	0.55de	1.37f	0.17h	21.10cde	0.53de	0.15f	0.35a	2.62a	3.66d
5-10	5.02ij	0.39f	1.45e	0.68i	22.07bc	0.39f	0.15f	0.33ab	2.62a	3.50d
10-15	5.03j	0.45ef	1.45e	0.66i	21.43cd	0.4Sf	5.15f	0.30bc	2.59a	3.50d
CB 0-5	5.47h	0.55de	1.68c	0.98f	19.77e	0.55d	1.53b	033ab	2.65a	5.06a
5-10	5.50g	0.47ef	1.64c	0.95g	20.20de	0.47edf	1.54a	0.25d	2.64a	4.97a
10-15	5.52g	0.66d	1.59d	0.93g	23.13b	0,66c	1.55a	0.28cd	2.64a	5.12a
MF 0-5	5.62f	0.97c	1.26g	1.24d	18.00f	0.55d	0.21e	0.25d	1.32d	2.30e
5-10	5.64e	1.04c	1.22g	1.11e	17.10f	0.47edf	0.21e	0.25d	1.38d	2.33e
10-15	5.72d	0.97c	1.17h	0.95g	16.87f	0.66c	0.21e	0.20e	1.38d	2.42e
KG 0-5	6.57c	2.00b	2.17b	1.38b	26.50a	2.00b	0.30d	0.21e	1.57d	4.08c
5-10	6.64b	2.11ab	2.11ab	1.47a	25.77a	2.11a	036c	0.20e	1.83b	4.51b
10-15	7.00a	2.18a	2.18a	1.32c	25.00a	2.19a	0.36c	0.21e	1.81b	4.56b

Means followed by the same letter within the same column are statistically the same at P < 0.05

CT chanchaga tributary,CB chanchaga bridge,MF morris fertilizer,KG keteren gwari

Table 3. Heavy metals in soil under different landuse systems.

Land use/depth(cm)	Fe	Zn	Cu Mg kg⁻¹	Pb	Mn
CT 0-5	1.60g	2.20e	0.27g	2.23f	0.19f
5-10	2.00ef	2.40de	0.28f	2.57ef	0.84a
10-15	2.33cd	2.33e	0.26g	2.27f	0.16d
CB 0-5	1.77fg	2.20e	0.31ef	2.67e	0.23ed
5-10	1.77fg	2.20e	0.35d	2.87e	0.19d
10-15	1.73fg	2.50d	0.32e	3.30d	0.19d
MF 0-5	2.27cde	5.63a	0.32e	3.30d	0.52b
5-10	2.47cde	5.63a	0.43c	3.87c	0.48bc
10-15	2.31e	5.57a	0.45c	3.43d	0.48bc
KG 0-5	3.80a	3.67b	0.68b	4.63b	0.92a
5-10	3.70ab	3.37c	0.71a	4.63a	0.90a
10-15	3.47b	3.20c	0.74a	4.33ab	0.85a

Means having the same letter within the same column are significantly the same at P<0.05

CT chanchaga tributary.CB chanchaga bridge.MF morris fertilizer, KG keteren gwari

Table 4 Correlations of soil parameters and microbial populations in soil under different land use systems.(n=10^n in bact, fungi and Act = 10^8, 10^4, 10^8).

	Bact	Fungi	Actin	pH	Moist Cont	OC (gkg⁻¹)	N	P (mgkg⁻¹	Na	K	Mg	Ca Cmol	CEC	Ex.ac	Sand	Silt gkg⁻¹	Clay
Bact																	
fungi	0.746**																
Act	0.677**	0.797**															
PH	0.389*	0.364*	0.049														
Moist	-	-	-	-													
OC	0.026	0.030	0.103	0.283*	-0.138												
N	0.617*.	0.591**	0.269	0.904*	-0- 721**	0.645**											
P	-0.104	0.175	0.118	0.56**	0.179	0.873**	0.386*										
Na	0.293	0.304	0.106	0-939**	-0.29	0.889**	0.797**	0.765*									
K	. -0.469**	-0.093	-0.22	-0.092	-0.302	0.139	-0.062	0.005	-0.189								
Mg	-0.481*	-0.203	-0.095	-0.792*	0.616*	-0.387*	-0.758*	-0.208	-0.679**	0-30							
Ca	- 0.814**	-0.393	-0.247	-0.552	0.645*	0.006	-0.674*	0.273	-0.371*	0.515*	0.76**						
CEC	- 0.546**	-0.026	-0.182	0.232	0.322	0.664*	0.086	0.606*	0.327	0.734*	0.189	0.639**					
Ex.ac	0.489**	0.371*	0.135	0.963*	0.446*	0.752**	0.882*	0.593*	0.957**	-0.302	-0.797*	-0.60**	0.101				
Sand	-0.196	-0.112	-0.60	0.639*	-0.048	0.899**	0.430*	-0.818*	0.74**	0.249	0.272*	0.163	0.729**	0.578**			
Silt	0.325	0.046	0.196	0.525	-0.480	-0.791**	-0.269	-0.756*	-0.654**	-0.248	0.368*	-0.250	-0.760	-0.459**	-0.961**		
Clay	-0.117	-	-	0.702*	0.232	-	-	-	-0.708	-0.149	-	0.092	-	-0.678	-	0.676**	

P>-0.05 Not significant; * P < 0.05 Significant; **P< 0.001 Highly Significant

Table. 5. Relationship between heavy metals and microbial population in soil under different land use systems. (n=10^n in bact, fungi and Act = 10^8, 10^4, 10^8)

	Bact	Fungi (cfu. X10^n g^{-1} soil)	Act	Fe	Zn Mgkg^{-1}	Cu	Pb	Mn
Bact								
Fungi	0.746**							
Act	0.677**	0.794**						
Fe	0.474*	0.366*	0.195					
Zn	0.748**	0.303	0.163	0.235				
Cu	0.477*	0.369*	0.114	0.912**	0.323^{ns}			
Pb	0.618**	0.50*	0.19	0.802**.	0.547**	0.887**		
Mn	0.466**	0.309	0.275	0.717**	0.277	0.704**	0.645**	

P> 0.05 not significant; *P< 0.05 significant; ** P<0.01 highly significant.
10^n in bact, fungi and Act = 10^8, 10^4, 10^8

Table 6 Microbial population counts in soil under different land use systems

Soil depth (cm)	Bacteria	Fungi (cfu. X 10^ng^{-1} soil)	Actinomycetes
	Chanchaga Tributary		
0-5	22.00fg	10.33d	22.67bc
5-10	14.00h	7.00e	16.00d
10-15	8.6i	3.33f	4.33g
	Chanchaga Bridge		
0-5	18.66g	15.33c	17.33cd
5-10	10.00hi	11.63d	9.00efg
10-15	7.33i	11.00d	4.67g
	Morris Fertilizer		
0-5	44.00a	18.33b	28.33ab
5-10	36.33bc	14.00c	12.67def
10-15	28.00de	7.67e	4.00g
	Keteren Gwari		
0-5	38.00b	22.00a	30.00a
5-10	32.00cd	16.33bc	15.00dc
10-15	24.00ef	11.50d	8.50fg

Means having the same letter within the same column are significantly the same at P<0.05. 10^n in bact, fungi and Act = 10^8, 10^4, 10^8

3.0 RESULTS AND DISCUSSION

3.1 Soil Properties

The results of the physical and chemical properties of the soil at 0-20cm (Tables 1 to 3) revealed that these properties varied with land use, the variation of soil properties of Moris Fertilizer and Keteren gwari were significant (p=0.05) . Landuse systems at the same locations had the same texture averagely(Table 1) That explains why the textural class of soil under landuse systems in both Chanchaga tributary and Chanchaga bridge were sandy clay loam suggesting that texture is a fixed property of soil (Lim and Pong. 1983).The decrease in moisture content in soil under Morris Fertilizer and Keteren-Gwari land use systems may however be attributed to lower clay contents of their soil compared to landuse system located at Chanchaga (Table 1).This is consistent with the report of Olaitan et al. 1984 who maintained that one of the two principal factors determining the amount of water a soil can hold is soil texture.

The soil pH result indicated that averagely, soils across the land use systems were slightly acidic, tending towards neutrality (5.0 to 7.0) (Table 2). This change may be due to variation in the concentration of sodium with location. Lim and Pong, 1983 had earlier reported that the presence of Na$^+$ in effluent materials caused slight increase in soil pH. The slight increase in total soil Nitrogen recorded in Keteren-gwari soil may be due to contaminations from effluent materials containing petroleum products that are N-based.The automobile activities and maintenance often carried out in Keteren-gwari was most likely the source of such contaminations and this also suggest that nitrification and mineralization were enhanced at Keterengwari(John et al.,2006). This partly explains why soil p content was greater at Keteren-gwari eventhiough Brady and Weil,1999 attributed soil P increment to change in pH within the range of 6.0 to 7.0.Exchangeable Na in soils under Chanchaga bridge and Chanchaga tributary were

1600

lowest most likely because of their low pH(<5.5).Ironically, they were calcareous to an extent(John et al.,2006). The slightly acidic pH of their soil is ideal for the cultivation of most arable crops and posses no threat to the ecosystem except where microorganisms that proliferate under this condition compete with higher plants for available nutrients (Kloke,1984).Nitrifying bacteria depend on Ca and may compete with plants for its uptake(Kloke,1984).

3.2 Heavy metal concentration correlated with microbial population and diversity

Heavy metal concentration in the form of Fe, Zn, Cu, Pb and Mn were positively correlated with bacteria (Table 5) indicating a high tolerance of the predominant bacteria stain to heavy metal concentration. Microbial tolerance to heavy metal contaminations have being reported by several authors (Yamamoto et al., 1981). This is in agreement with our report that revealed a significant positive correlation of fungi with Zn and Mn concentrations.Our result have clearly demonstrated that tolerance to heavy metals was in the order: Bacteria>Fungi>Actinomycetes.

3.3 Microbial Population as affected by Land use

The mean of microbial population across the landuse indicated that bacteria had the highest count followed by actinomycetes and fungi in that arrangement. The highest microbial counts recorded at 0 to 5cm depth and the lowest at 10 to 15cm depth may be a response to organic carbon variation with depth. This implied that the micro-organisms were averagely heterotrophic and obligate aerobes. The highest bacterial count (cfu $4.4 \times 10^{8} \, g^{-1}$ soil) obtained at Morris Fertilizer and the highest fungi count (cfu $2.2 \times 10^{4} \, g^{-1}$ soil) and actinomycetes count (cfu $3.0 \times 10^{8} g^{-1}$ soil) recorded at Keteren-gwari (Table 6) may also be a response to higher accumulation of organic carbon, total nitrogen and moderate moisture content recorded in soils under these locations(Tiedje et al., 2001). Conversely, a reduction in microbial size in soils of Chanchaga Tributary and Chanchaga Bridge is a response to a lower organic carbon (OC), total Nitrogen (TN) and moisture content(MC) or may be due to a negative correlation between micro-organisms understudied. Actinomycetes through the production of streptomycin and aeromycin may suppress bacteria and fungi (John et al., 2006) or through the competition for OC, TN, and Moisture content may reduce microbial count (Bossio et al., 2005)

4. CONCLUSIONS:

The present study has demonstrated that waste water management is crucial for irrigation agriculture. Heavy metal contamination can impact soil ecosystems sufficiently to result in significant losses in soil quality. The negative impact of heavy metals

results from their toxicity to biological processes like those catalyzed by soil microbes. Therefore it is postulated that the soil microbial community could serve as an indicator of soil quality resulting from reclaimation. Should that be the case, the health of soil under the four landuse understudied is in the order: Keteren gwari, Morris Fertilizer, Chanchaga soils. Although Keteren gwari soils had the highest heavy metal contaminations, they probably had more microorganisms with high tolerance to heavy metal contaminations.

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Microbial Population Dynamics Along a Toposequence in the Southern Guinea Savannah Zone of Nigeria

Uzoma, A.O., Bala, A., Ajiboye, R. O., Afolabi, S. G., Adekanmbi, A. A and
Osunde, A. O.
Department of Soil Science,
Federal University of Technology, P.M.B. 65, Minna
E-mail: uzo_ozo@yahoo.com

ABSTRACT
A study was carried out at the Soil Science Laboratory of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna situated at Bosso in the month of June, 2009. The aim was to evaluate the population of bacteria, fungi and actinomycetes along a toposequence under four different land use positions (Teak, Gmelina, Cashew and Fallow) at three soil depths (0 - 5 cm, 5 -10 cm, 10 - 15 cm) representing a 4 x 3 factorial experiment in a complete randomized design (CRD). Soil samples were collected with auger and sterilized after each collection. Soil samples from the same position and depth were bulked, mixed and labeled. One part was air dried for physico-chemical properties while the other part was refrigerated for microbial counts using the plate count methods. Results revealed that the interactive effect of land use and depth significantly affected microbial counts (cfu x 10^7/g soil) at P = 0.05. Bacterial count (cfu x 10^8/g soil) and fungi count (cfu 10^4/g soil) decreased with depth in all the land uses. Fallow soils recorded the highest bacterial count, followed by Teak, Cashew and Gmelina in that sequence. Similarly, Fallow soils recorded the highest fungi count, followed by Teak, Gmelina and Cashew in that order. The trend observed for actinomycetes count (cfu x 10^7 / g soil) was same as those for bacteria and fungi counts, except that Gmelina soil was higher in actinomycetes count than Cashew soil. Present study clearly shows that land uses have significant effect on microbial population. Further studies should be carried out to include other forms of land uses in order to detect detrimental ecosystem changes and possibly prevent further degradation.

Keywords: Land use systems, Guinea savanna, Soil microbes.

1.0   Introduction
The advent of molecular genetics tools in microbial ecology has shown that we know only a very small part of the diversity of the microbial world. Much of this unexplored microbial diversity seems to be part of the apparently high amount of the yet uncultured bacteria. New direct methods, independent from cultivation, based on the genotype and phenotype of the microbes allow a deeper understanding of the composition of microbial communities. Nevertheless, the conventional methods of culturing microbial organisms have remained relevant in elucidating our understanding of changes in microbial diversity due to variation in land-use and management practices. Some studies demonstrated clear effect of changes in farm management of a site on the total microbial community structures. They found a higher diversity in soil which was under organic farming management.

The number of bacteria in soil is influenced primarily by the amount and quality of food available. Other factors affecting their numbers include physical factors (moisture and temperature), biotic factors (predation and competition), chemical characteristics of the soil (acidity, dissolved nutrients and salinity). A similar range of fixed factors (like climate, stoniness, mineralogy, texture, cultivation) has been identified controlling the maximum potential of soil organic matter content (Siwana and Lucas, 2002). The number of microbial organisms varies with the habitat in which they are found. Despite these variations, there are a few generalization that can be made, for example, cultivated fields are generally lower than undisturbed native lands in numbers of soil organisms (Zelles et al., 1996).

The current trend in global agriculture is to search for highly productive, sustainable and environmentally-friendly cropping systems (Crew arid Peoples, 2004) that do not only increase crop yield but also maintain soil health. For example, monocultures or even common crop rotations greatly reduce the number of species and so provide a much narrower range of plant material and rhizosphere environment than nature provides in the forest or grassland(Crew arid Peoples.2004). The main tropical cropping system is inter-cropping, where inter-specific competition or facilitation between plants may occur (Vandermer, 1989; Zhang et al., 2003). In such crop mixtures, the yield increases are not only due to improved nitrogen nutrition, but also to other causes (Connolly, et al., 2001). Many of unknown and less researched processes occur in the rhizosphere of mixtures (Zhang et al., 2003). So far, however, little attention has been paid to rhizosphere effect on crops grown in

mixtures, where interaction between different organisms is maximal (Connolly *et al.*, 2001).

The data on soil microorganism in several tropical soils are very limited and grossly underestimated (Ayanaba and Sanders, 1981). Most of the available reports did not consider the effect of some soil properties, cropping history, cropping system and waste disposal on microbial population (Isirimah *et al.*, 2006). In view of this, a study was conducted to estimate the microbial population in different cropping systems and to determine which cropping system has the highest microbial population distribution.

2.0   Materials and Methods

The research was carried out in the Soil Science Laboratory of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna in the month of June, 2009. The experimental area is underlain by undifferentiated Basement Complex rocks (FDALR, 1990). Physico-chemical properties of the soils were determined using the methods of IITA (1989). The exchangeable Ca^{2+}, Mg^{2+} and K^+ were low. The experiment was a 4 x 3 factorial experiment in a complete randomized block (CRD) with four land use systems of Gmelina, Teak, Fallow and Cashew and three soil depths of 0-15, 5-10, 10-15 cm. Microbial populations were determined by soil dilution plating technique using agar media. For each of six sub-samples from each composite soil sample, 10 g of soil was weighed and added to 90ml sterile deionized water, thoroughly stirred and serially diluted and plated on 1% nutrient agar for total bacteria counts and potato dextrose agar (PDA) with $1mg\ ml^{-1}$ of streptomycin for total fungal counts (Harrigan and Mc Cance, 1990). Serial dilution was 10- fold up to 10^{-7} dilution and aliquots (0.5 ml) of 10^{-5}, 10^{-6} and 10^{-7} dilutions were used for plating. Inoculated plates were incubated at 28°C for 3 and 10 d prior to the enumeration of viable colonies of bacteria and fungi, respectively.

Statistical Analysis

Analysis of variance (ANOVA) was used to assess treatment difference. Least significant difference (LSD) was used to separate means where significant differences were observed at $p=0.05$ probability level.

Table 1: Chemical Properties of Soil and their Relationship with Different Land-Use Systems

Depth (cm)	m	pH CaCl$_2$	Acidity (cmol kg^{-1})	OC (g kg^{-1})	K (cmol kg^{-1})	Na (cmol kg^{-1})	Ca Mg (cmol kg^{-1})	P (mg kg^{-1})	Ca$^+$ (cmol kg^{-1})	N (g kg^{-1})
					Teak					
0-5		5.93^e	6.40^c	13.80^{bc}	0.89^c	0.51^{cd}	23.47^a	37.33^a	7.47^a	3.20^{ab}
5-10		6.03^d	5.67^{cde}	12.50^c	3.32^a	0.31^a	18.29^c	22.53^{de}	5.20^c	2.80^{ab}
10-15		6.10^c	4.67^{def}	13.80^{bc}	0.55^d	0.63^b	22.20^b	36.17^a	6.60^b	3.10^{ab}
					Gmelina					
0-5		5.94^e	3.33^f	15.40^{ab}	0.48^{de}	0.87^b	2.87^b	19.50^e	4.87^e	3.00^{ab}
5-10		6.85^f	6.00^{cd}	12.60^c	1.96^b	0.19^f	22.40^b	32.67^{abc}	2.80^d	2.60^{ab}
10-15		6.07^{cd}	9.33^{ab}	12.90^c	0.83^c	0.39^e	14.00^e	28.37^{abcd}	1.27^e	1.70^c
					Cashew					
0-5		4.73^f	10.00^a	13.60^{bc}	0.48^{de}	0.27^b	21.87^b	31.50^{abc}	7.40^{ab}	3.30^{ab}
5-10		5.44^g	4.50^{ef}	13.60^{bc}	0.33^f	0.30^{gh}	16.80^d	23.83^{cde}	7.60^a	2.60^{ab}
10-15		5.42^g	6.00^{cd}	9.40^d	0.28^f	0.49^d	22.20^b	33.83^{ab}	6.87^{ab}	2.50^{ab}
					Fallow					
0-5		6.44^a	8.00^b	14.40^{bc}	0.38^{ef}	0.41^e	14.08^e	26.13^{cde}	5.27^c	3.50^a
5-10		6.22^b	9.00^{ab}	17.00^a	0.48^{de}	0.35^f	14.53^e	32.67^{abc}	4.67^c	2.50^c
10-15		5.26^h	5.33^{cde}	16.50^a	0.35^{ef}	0.54^c	13.33^f	31.97^{abc}	2.80^d	2.60^{ab}

Mean with the same letter are not significantly different p <0.05

Table 2: Physical Properties of Soil and their Relationship with Different Land-Use Systems

Depth (cm)	Sand $(g\,kg^{-1})$	Silt $(g\,kg^{-1})$	Clay $(g\,kg^{-1})$	Textural Class	Moisture Content (%)
			Teak		
0 - 5	700^{ab}	200^{ab}	100^{cd}	Sandy loam	4.02^{b}
5-10	720^{a}	170^{abc}	110^{cd}	Sandy loam	3.09^{c}
10-15	680^{b}	180^{ab}	140^{a}	Sandy loam	4.49^{b}
			Gmelina		
0 - 5	700^{ab}	210^{ab}	90^{d}	Sandy loam	2.92^{cd}
5-10	680^{b}	200^{ab}	120^{abc}	Sandy loam	2.88^{cd}
10-15	710^{a}	170^{bc}	$1\,20^{abc}$	Sandy loam	2.64^{de}
			Cashew		
0 - 5	710^{ab}	170^{abc}	120^{abc}	Sandy loam	3.20^{c}
5-10	700^{ab}	170^{bc}	130^{ab}	Sandy loam	3.95^{b}
10-15	720^{a}	140^{c}	140^{a}	Sandy loam	4.46^{a}
			Fallow		
0 - 5cm	700^{ab}	200^{ab}	100^{bcd}	Sandy loam	2.28^{e}
5-10cm	720^{a}	170^{bc}	110^{bcd}	Sandy loam	1.25^{e}
10-15cm	700^{ab}	170^{abc}	130^{abc}	Sandy loam	1.79^{f}

Mean with the same letter are not significantly different p <0.05

Table 3: Relationship between soil physico-chemical properties and microbial population. (n=10^n in bact, fungi and Act = 10^8, 10^4, 10^7).

	Bact	Fungi	Actino	PHC	Acid	OC	MO	K	Na	CaMg	P	Ca	Sand	Silt	Clay	N
Bact		0.79**	0.58*	0.18	0.30	0.35*	-0.25	-0.12	-0.003	-0.061	0.06	0.31	0.102	0.36*	-0.45	0.47**
Fungi			0.60**	0.34*	0.29	0.41*	-0.43	-0.29	0.01	-0.29	0.028	0.07	0.12	0.32	-0.33*	0.22
Act				0.29	0.10	0.21	-0.24	-0.05	0.07	-0.03	-0.18	0.15	0.03	0.39*	-0.42*	0.38*
PHC					-0.06	0.16	-0.20	0.23	0.18	-0.23	-0.12	-0.28*	-0.07	0.31*	-0.28	-0.037
Acid						0.05	-0.39*	-0.10	-0.51**	-0.31	0.25	-0.16	0.32*	-0.17	-0.03	-0.14
O.C							0.61**	-0.24	0.21	-0.42*	-0.10	-0.20	-0.04	0.29	-0.32	0.10
MO								-0.01	-0.39	0.07**	0.13	0.61**	-0.19	-0.15	0.37*	0.18
K									0.39*	0.14	-0.20	-0.21	-0.04	0.13	-0.27	0.05
Na										0.19	-0.09	0.07	-0.08	0.19	-0.18	0.15
CaMg											0.23	0.51**	-0.27	0.17	-0.01	0.31
P												0.13	-0.09	-0.16	0.32*	0.04
Ca													0.0005	-0.10	0.17	0.52**
Sand														0.64**	-0.18	-0.27
Silt															-0.58**	0.29
Clay																-0.01
N																

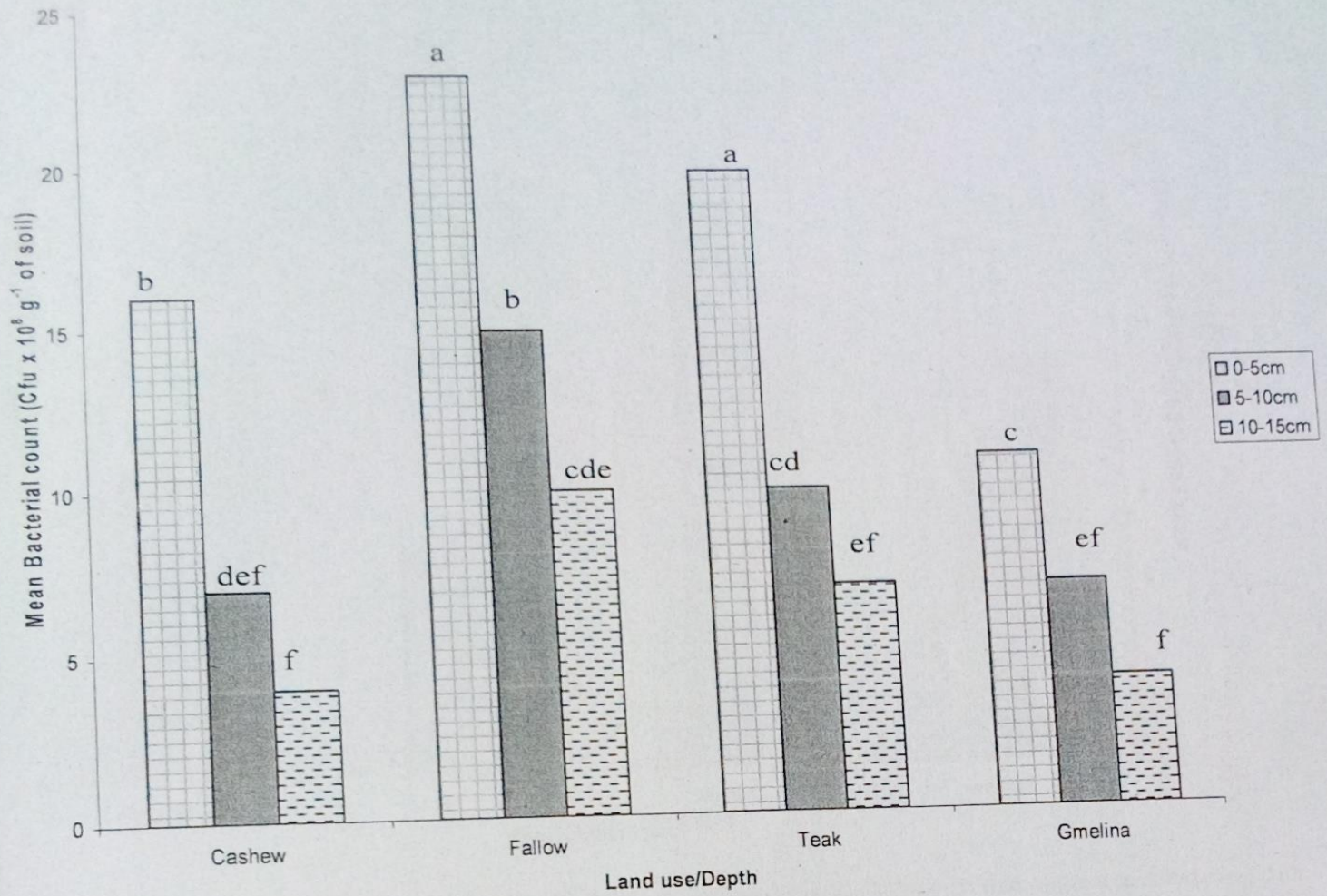Ns = Not significant; ** Significant at p < 0.01; * Significant at p < 0.05

Fig. 1: Bacterial Population Count (Cfu x 10^8 g^{-1} of soil) as affected by land use systems at different soil depths.

Bars of the same depths with different letters are significantly different.
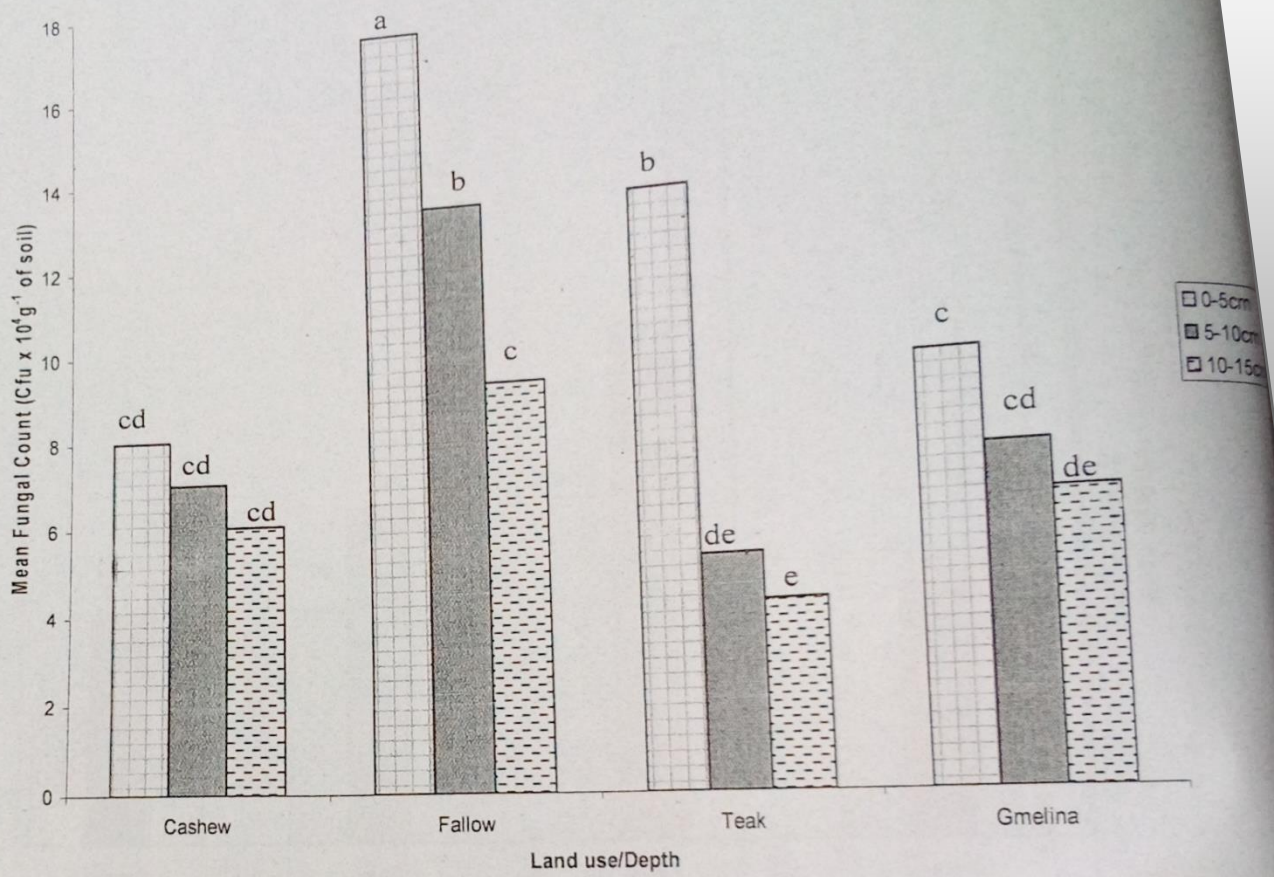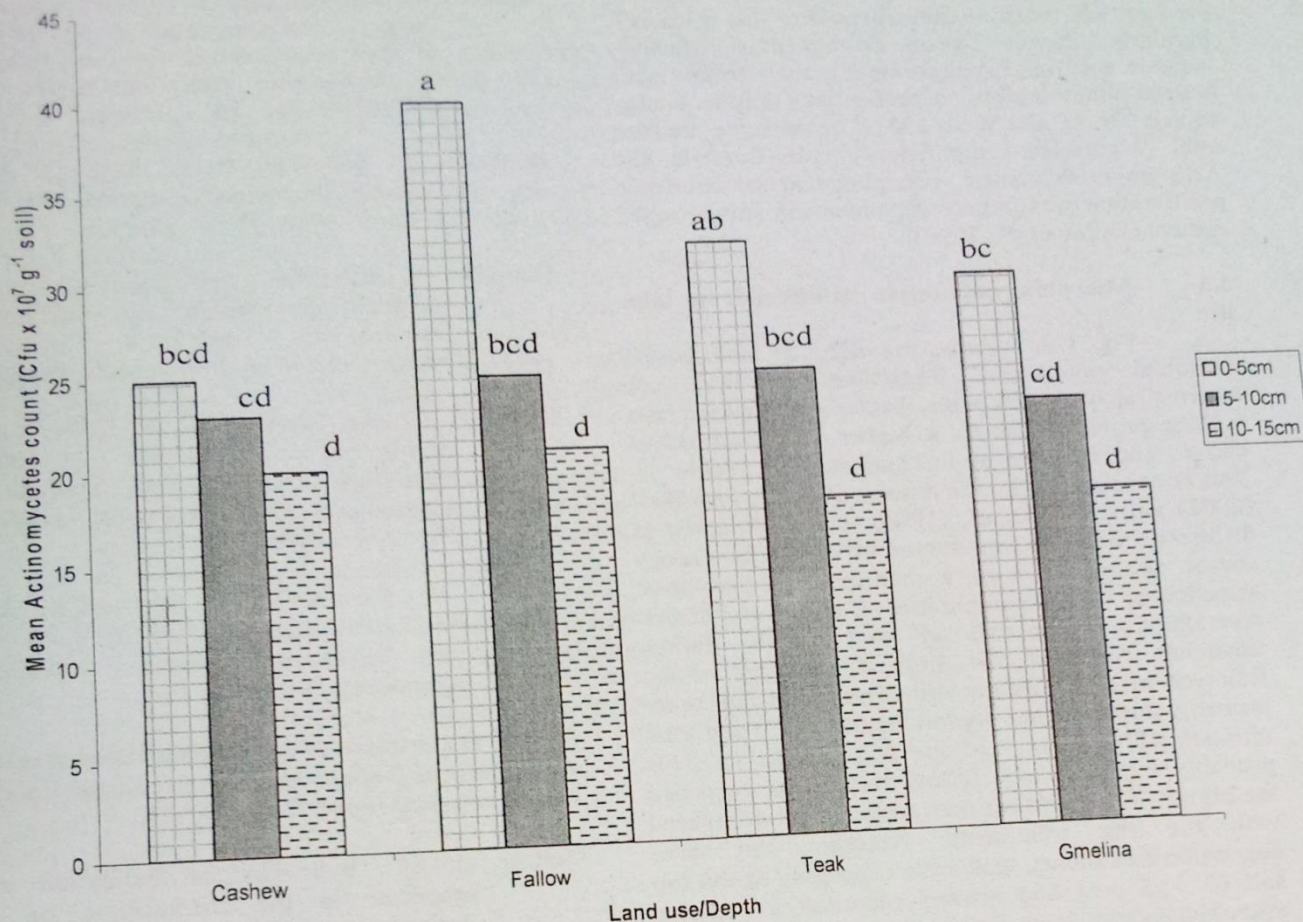
Fig. 2: Fungal Population Count (Cfu x 10^4 g^{-1} of soil) as affected by land use systems at different soil depths.

Bars of the same depths with different letters are significantly different.

Fig. 3: Actinomycetes Population Count (Cfu x 10^7 g^{-1} of soil) as affected by land use systems at different soil depths.

Bars of the same depths with different letters are significantly different.

3.0 Result and Discussion
3.1 Soil Texture, Reaction and Exchangeable Bases.
Differences in physical and chemical properties of the soils of the land use systems were observed across depths (Tables 1 and 2). The textural class of soil did not however change because texture is a fixed properly of soil (Lim and Pong,1983). Soil physicochemical properties under the cropping systems shows that the soil was sandy loam, with the exception of rice field that was sandy clay loam. Soil reaction was slightly acidic, the organic matter was generally low and the available P was very low. The pH in Cacl$_2$ across vegetation type was in the range of 4.73 to 6.85 suggesting that vegetation increased the pH of soil probably as a result of the release of root exudates. At the top soil, fallow treatment had the highest organic carbon followed by Teak,

Gmelina and cashew in that sequence indicating that a period of fallow allows for carbon accumulation and that depletion of carbon increases with use of land. Averagely, the N content (gkg^{-1} of soil) was highest under Teak vegetation, followed by fallow treatment suggesting that most vegetation types will reduce soil N composed with that obtained under fallow unless they have inherent abilities through associations with root microorganisms to improve the supply of N (N-mineralization). The Ca Mg content (cmol Kg^{-1})of soil under vegetation was higher than that under fallow implying that leaf litter fall supplied their soil with Ca and Mg otherwise the root exudates must have improved the solubilization of Ca and Mg that were complexes as CaHPO$_4$ or MgHPO$_4$. Clay content increased with depth across land use system resulting to sandy loam textural class of soils which did not translate into higher moisture content of the soils across various land use; although soil under cashew vegetation was an exception (Table 1)

3.2 Soil physico chemical properties correlated with microbial population
The significant correlation of clay content with bacteria, actinomycetes and fungal counts (Table 3)

1610

implied that clay probably served as a nutrient medium or moisture absorbent for the microbes. Similarly organic carbon correlated significantly bacteria and fungi suggesting that their strains were hetrotrophic therefore the carbon was only an energy source (Brady and Weil, 2002). In the same manner, total N correlated significantly with Bacteria and Actinomycetes content indicating that selection and proliferation was largely dependent on soil nitrogen content (Doran et al., 1996).

3.3   Microbial population as affected by land use
Fig. 1 to 3 shows the effect of land use on microbial population. Regardless of land use systems, at 0 – 5 cm depth, bacteria population was highest probably due to a higher accumulation of carbon and nitrogen at the soil surface (Table 1). This is consistent with the reports of Brady and Weil (2002) and Doran et al; (1996) who maintained at different times, the importance of carbon as energy source and nitrogen as a medium for qualitative selection of whole communities of micro organisms. Averagely, irrespective of soil depth, fallow treatment recorded the highest bacterial count followed by teak, cashew and Gmelina in that order probably due to higher organic carbon (OC) and total nitrogen (TN) content of the soil (Table 1). This probably explains why fallow treatments recorded the highest fungi and actinomycetes count compared with the rest treatments. Amongst the three vegetation treatments, teak soils especially at the top soil (0 – 5 cm) had always recorded a superior microbial count most likely because of a higher quality of its root exudates or a better association with microbes that mediate C and N transformations. Conversely, cashew soils, especially at the top soil recorded lower microbial counts probably due to its acid pH value of 4.73 (Table 1). Other vegetation treatments recorded a near neutral soil pH ideal for maximum microbial activities (Hutchinson and Collins, 1978; Acosta-Martinez, 2000).

Conclusion
The results have demonstrated that the population of bacteria was higher than that of actinomycetes and fungi. Fallow and Teak land use system recorded the highest soil microbial population, while cashew and Gmelina gave the lowest. Fallow and Teak land use systems are hereby considered healthier than cashew and Gmelina treatment and therefore provide essential baseline information regarding soil health maintenance reported previously in the tropics.

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