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Determination of the impact of Long-term Poultry manure use on selected soil nutrients

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ABSTRACT

In this study, the long-term impacts of poultry manure (PM) on vertical distribution of soil macronutrients (N, P, K, Ca and Mg) have been determined. In addition, change in other soil fertility indicators such as organic matter (OM) and cation exchange capacity (CEC) levels were assessed. Soil samples from four depths (0-15, 15-30, 30-60, and 60-120 cm) from the sites were analyzed. Generally, the mean total soil nitrogen increased with depth in the cultivated poultry manure amended soils up to 60cm depth and decreased sharply at depth range 60-120 cm in both wet and dry seasons. At both the cultivated and uncultivated sites at Deduako, available P levels were highest at the top 15 cm depth of the soil and decreased rapidly with increasing depths for both seasons in both the cultivated and uncultivated sites. The exchangeable K content at Deduako during the wet and dry season was significantly higher at all sampling depths than the corresponding depths of uncultivated land. Generally, the exchangeable Ca levels were significantly higher in cultivated soils at the experimental sites than those of the uncultivated land. There were significantly higher exchangeable Ca levels in wet season than that of dry season at both sites. Significantly higher ($p < 0.05$) Mg levels recorded in wet season. The OM contents at all sampling depths of cultivated site were also higher than that of the uncultivated sites. At the Deduako vegetable site, during the wet season, the CEC in cultivated soils at the various sampling depth were significantly higher ($p < 0.05$) than those of uncultivated soil. Increases in all selected soil properties were, generally, higher in the wet season than the dry season.

Introduction

Animal manures have been used effectively as fertilizers for centuries. Poultry manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content. In addition, manures supply other essential plant nutrients and serve as a soil amendment by adding organic matter. Organic matter persistence will vary with temperature, drainage, rainfall, and other environmental factors. Organic matter in soil improves moisture and nutrient retention. The utilization of manure is an integral part of sustainable agriculture (Sloan, Kidder and Jacobs, 2003.)

The United Nations estimates that about 67% of the world's population will reside in urban areas by the year 2025, an increase from 50% in 1995 estimates (UNFPA, 1996). In Ghana, the number of people living in urban areas is increasing due to the influx of rural dwellers. As a result, there has been a corresponding struggle for sustained livelihoods by majority of the urban population. This situation has forced most farmers to go into vegetable production as a means of livelihood since there is a high demand for vegetables like lettuce, cabbage, spring onions, and carrot in the urban markets. This has made farmers traditionally practicing shifting cultivation with fallow periods to regenerate nutrients, to continually cultivate the same piece of land all year round. The intensive cultivation alters soil properties, distribution of nutrients, and soil organic matter in the soil profile resulting in the degradation of physical, chemical and the biological nature of the soil (Anderson et al., 1990; Schjonning et al., 1994). A study conducted by Aggarwal et al. (1995) reveals that under such situations the application of organic manures helps in regeneration of soil structure, improving its fertility and ensuring high crop yield. Most vegetable farmers in Ghana use poultry manure as soil amendments for agricultural crops as it provides appreciable quantities of all important plant nutrients (Sims and Wolf, 1994). Poultry litter has successfully been used as a fertilizer for the production of vegetables (Bitzer and Sims, 1988; Wood et al., 1993; Evers, 1998). It is a relatively cheaper source of both macro nutrients (N, P, K, Ca, Mg,) and micro nutrients (Cu, Fe, Mn, B). It improves soil tilt, increase water-holding capacity, lessen wind and water erosion, improve aeration, and promote beneficial organisms (Gagliardi and Karns, 2002). Generally, poultry manure (% fresh weight) produced in Kumasi contains, 1.46-1.90% N, 0.17-0.6% P and 0.17-0.84% K (Kindness, 1999) but the contribution that the poultry manure makes to the vertical distribution of nutrients within these soils has received limited study.

Materials and Methods

Study Area

The site is located at longitude1˚34'36"W and latitude 06˚39' 45"N and is about 11 km from the center of Kumasi and has been under cultivation for four (4) years now and receives an estimated average of 100 tonnes of PM $ha^{-1}yr^{-1}$. The soils are

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predominantly loamy sand. The site is in a low land area with water available during most part of the year.

Sampling and Analysis

Each of the sampling sites was divided into three portions according to the size of the farm. Samples of cultivated soils with PM were collected from randomly selected beds in each of the three portions at each site at depth intervals of 0-15, 15-30, 30-60, and 60-120 cm from the surface of the beds. Sample from the upper 60 cm were taken from horizontal sections from chisel holes and the 60-120 cm sample were taken using the auger. They were bulked to get four soil samples per site representing soils from 0-15 cm, 15-30 cm, 30-60 cm, and 60-120 cm. Three composite samples from similar depths were also taken from adjacent plots with no history of manure use but were preparing for vegetable cultivation. The soil samples were air dried for a period of one week. Large clods were crushed and the soils were then passed through a 2 mm mesh sieve to remove all particles larger than 2 mm in diameter. Sampling was done for two seasons: wet season (September-November) and dry season (January-March). Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described by Walkley and Black (1934). Exchangeable bases (calcium, magnesium, potassium,) in the soil were determined in 1.0 M ammonium acetate (NH_4OAc) extract and the exchangeable acidity (hydrogen and aluminum) was determined in 1.0 M KCl extract as described by Page et al. (1982). The readily acid – soluble forms of P were extracted with HCl: NH_4F mixture called the Bray's No. 1 method as described by Bray and Kurtz (1945) and Olsen and Sommers (1982). Effective cation exchange capacity was determined by the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, and Na^+) and exchangeable acidity (Al^{3+}+ H^+).

Results and Discussion

There are significantly higher total nitrogen concentrations in cultivated sites in both wet and dry seasons as compared with total nitrogen concentrations in the uncultivated sites as depicted in figure 1.This can obviously be attributed to the regular poultry manure use at the cultivated sites. This also confirms the recognition of Poultry manure as perhaps the most desirable of natural fertilizers because of its high nitrogen content (Sloan et al, 2003).

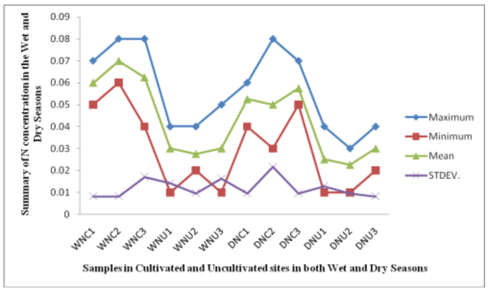

Figure1. Summary of Total Nitrogen levels in cultivated and uncultivated land in Deduako:
W= wet season; N=nitrogen; C=cultivated; U=uncultivated; C=cultivated

Generally, the mean total soil nitrogen increased with depth in the cultivated poultry manure amended soils up to 60cm depth and decreased sharply at depth range 60-120 cm in both wet and dry seasons.(Figure 2a and 2b). There was no regular pattern observed in the uncultivated sites. The higher total nitrogen at the top 60 cm depth could be explained by continuous ploughing, which at such depths leads to compacting in the lower layers over a period of time reducing leaching rate in the subsequent depth in sandy loam soils (Kukal and Aggarwal , 2003). The higher total N content observed at the various sampling depths of vegetable cultivation sites during wet season might have resulted from rapid oxidation of organic matter content of poultry manure, followed by leaching of mineral N down the profile. The movement of N in the soil is governed by mass flow in moving solution and diffusion within the soil solution (Jury and Nielsen, 1988).

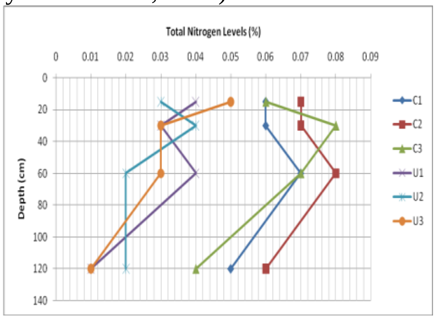

Figure 2a: Variation of total nitrogen with depth in the Wet Season: C=cultivated land; U=uncultivated land

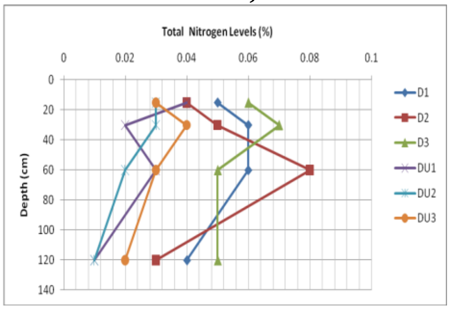

Figure 2b: Variation of total nitrogen with depth in the Dry Season: D=cultivated land; DU=uncultivated land

Phosphorus

According to Barber (1995) Phosphorus (P) is an important nutrient in crop production since many soils in their native state do not contain sufficient available P to maximize crop yield.

At both the cultivated and uncultivated sites at Deduako, available P levels were highest at the top 15 cm depth of the soil and decreased rapidly with increasing depths for both seasons in both the cultivated and uncultivated sites (Figure 3a and 3b). The accumulation of soil P in the plough layer and in the subsoil can be associated with increased in P solubility in water (Simard et al., 1995; Dormaar and Chang 1995) and decreased P retention capacity (Sharpley et al., 1984; Mozaffari and Sims 1994; Simard et al., 1995).

The accumulation of phosphorus at lower depth can also be attributed to the fact that phosphate is immobile in most soils because of precipitation and adsorption to mineral surfaces, and leaching is therefore negligible, except in certain very sandy and organic soils (Wild, 1988).

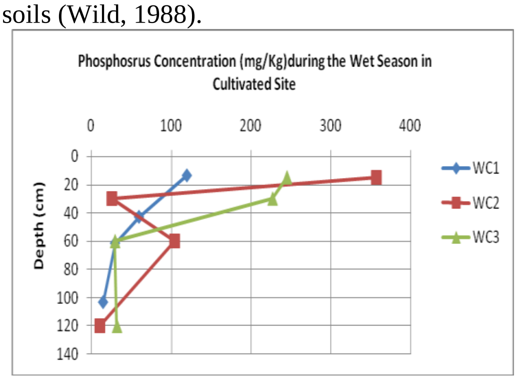

Figure 3a: Phosphorus concentration with depth in cultivated site

There is a wide difference between phosphorus concentration in the cultivated sites and uncultivated sites for both seasons (figure 4a and 4b). The comparatively higher concentration of phosphorus in the cultivated site is a clear indication of the significant amounts of phosphorus added to the soil as a result of the poultry manure application. Addition of poultry manure is important because Phosphorus (P) is an important nutrient in crop production since many soils in their native state do not contain sufficient available P to maximize crop yield and also a large fraction of the P present is in mineral form and not readily available for plants absorption. P concentrations are usually low whether the soil is acidic, neutral or alkaline (Barber, 1995).

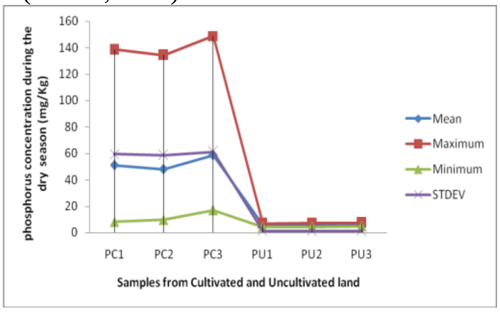

Figure 4a:Statistical Comparison of P leves in Cultivated and Uncultivated sites in the dry season

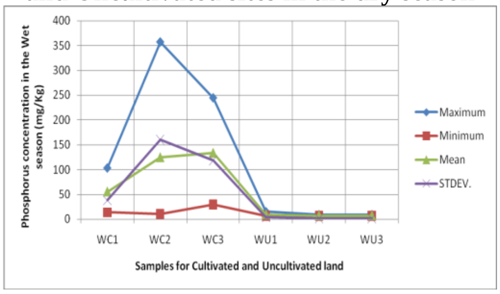

Figure 4b:Statistical Comparison of P leves in Cultivated and Uncultivated sites in the wet season

Potassium (K)

The exchangeable K content was significantly higher in cultivated soils sites than those of the uncultivated land, an indication of additional potassium from the poultry manure. The exchangeable K content at Deduako during the wet season was significantly higher at all sampling depths than the corresponding depths of uncultivated land except the 15-30 cm depth. In the dry season at the same location, exchangeable K levels in cultivated soils was statistically higher than the uncultivated soils only at the 30-60 cm depth. Figure 5a, 5b and 5c shows the statistical comparison of K in cultivated and uncultivated sites, K distribution with depth in wet season and K distribution with depth in the dry season respectively.

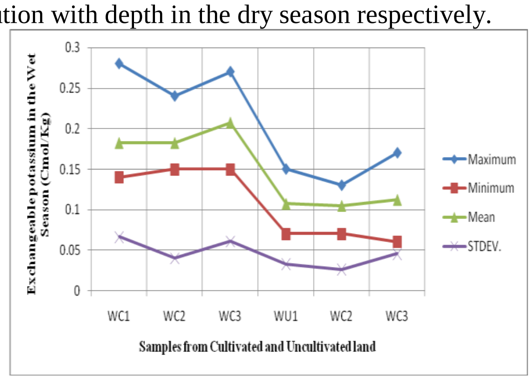

Figure 5a: Statistical comparison of K in cultivated and uncultivated sites

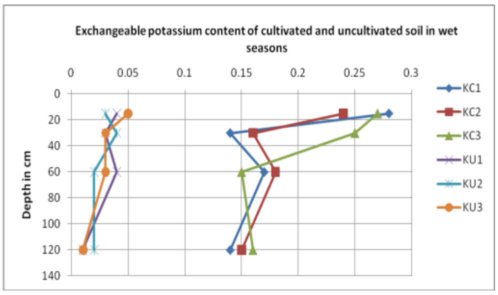

Figure 5b: K distribution with depth in wet season

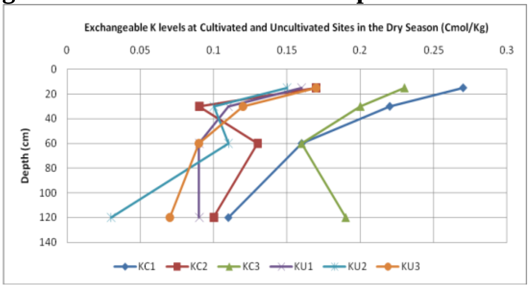

Figure 5c: K distribution with depth in the dry season respectively.

Exchangeable Calcium (Ca)

Ca occurs in minerals such as calcite ($CaCO_3$), gypsum ($CaSO_4.H_2O$), apatite, feldspars, plagioclase and amphibole (Troeh, 1993; Olaitan and Lombin, 1984). Ca minerals weather slightly faster than the average minerals. There is therefore a tendency for the percent Ca in a soil to gradually decline as weathering and leaching progress. A very low Ca content occurs in highly leached soils with low cation exchange capacities (Troeh, 1993). Mean exchangeable Ca decreased in surface soil (0-15 cm) but increased at the depths below 30 cm for the dry and wet seasons. Generally, the exchangeable Ca levels were significantly higher in cultivated soils at the experimental sites than those of the uncultivated land. There were significantly higher exchangeable Ca levels in wet season than that of dry season at both sites. The exchangeable Ca levels in cultivated soils at wet season were significantly higher at 15-30 and 30-60 cm sampling depths than the corresponding depths of uncultivated land. Figure 6a and 6b show Ca distribution with depth.

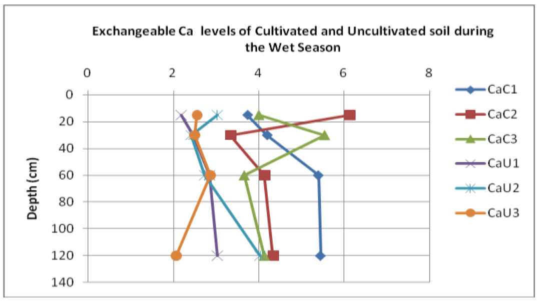

Figure 6a: Ca distribution with depth in the wet season

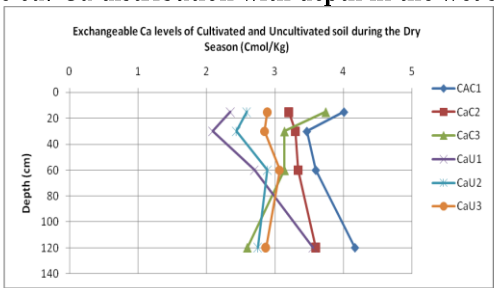

Figure 6b: Ca distribution with depth in the dry season

Magnesium (Mg)

Magnesium is also one of the dominant exchangeable cations in most soils particularly those of the tropics. Mg is released from primary minerals by weathering. Mg minerals include biotite, hornblende, serpentine, dolomite and silicate clays. Mg is absorbed as Mg^{2+} (Olaitan and Lombin, 1984; Troeh, 1993). Mg content in soils varies widely and range from about 250 ppm in soils derived from sandstones to nearly 400 ppm in soils derived from volcanic ash. 20-50% of the total Mg in soil usually occurs in exchangeable form. Gradual increase in exchangeable Mg levels with increasing sampling depth was recorded in some cultivated sites. This is similar to the observation made by Wright et al. (2007) in silt clay loam. Franzluebbers and Hons (1996) also made the assertion that the distribution of Mg, like that of Ca distribution, appeared more related to the nature and distribution of soil minerals therefore were not influenced by crop management in long-term studies on the same soil. Significantly higher ($p < 0.05$) Mg levels recorded in wet season was expected since higher levels of nutrients like Mg are released with moisture from PM (Nyakatawa et al., 2001). Higher Mg levels observed in cultivated soils at various sampling depths at the two sites buttresses the point that addition of PM improved Mg concentrations in cultivated soils (Fig. 7a, 7b, 7c, 7d).

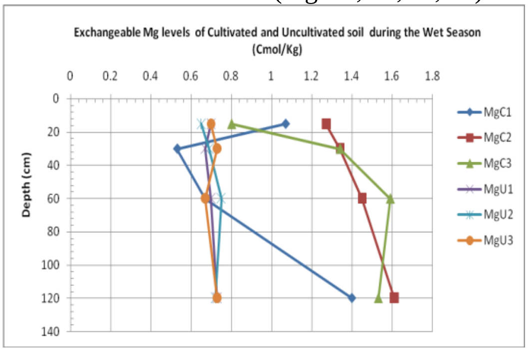

Figure 7a: Mg distribution with depth during the wet season

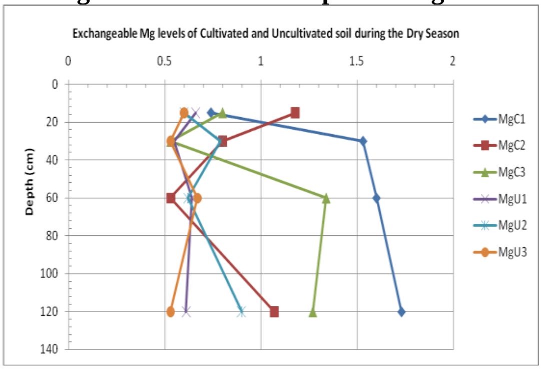

Figure 7b: Mg distribution with depth during the dry season

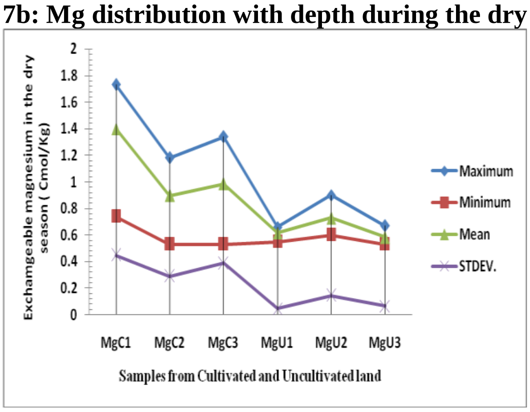

Figure 7c : Statistical comparison of Mg levels in dry season

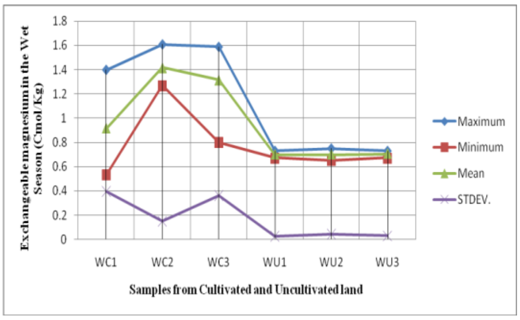

Figure 7d : Statistical comparison of Mg levels in wet season

Soil Organic Matter and Cation Exchange Capacity

Soil Organic Matter, which functions as a reservoir of plant nutrient elements, holds and conserves moisture, helps to preserve soil structure, and provide a favourable environment for various micro-organisms (Oades, 1984). It is an important constituent of the 'exchange complex' of most agricultural soils and dominant in many. Not only does the soil organic matter hold exchangeable cations- Ca, Mg, Na, and K, as well as Mn and Zn against loss by leaching, but its mineralization results in the gradual release of such important plant nutrient elements as non-metals, C, N, P and S. (Paul and Clark, 1996). The organic matter contents were significantly higher in cultivated soils than that of uncultivated sites. This shows an obvious addition of significant amounts of organic matter in the poultry manure. In both seasons, there were significant changes in OM within the soil profile of the vegetable production sites.

The OM contents at all sampling depths of cultivated site were also higher than that of the uncultivated sites.

A soil's CEC (cation exchange capacity) depends on the amount and kind(s) of colloid(s) present. Although type of clay is important, in general, the more clay or organic matter presents, the higher the CEC (Olaitan and Lombin, 1984). At the Deduako vegetable site, during the wet season, the CEC in cultivated soils at the various sampling depth were significantly higher ($p < 0.05$) than those of uncultivated soil. During dry season at the same location, the CEC of the cultivated soils were significantly higher ($p < 0.05$) at the depth ranges 0-15 and 15-30 cm than those of uncultivated soil, but this was not the case for the 30-60 and 60-120 cm depth ranges. Mean values and probability of significance of variations of soil Organic matter (OM) and cation exchange capacity (CEC) in the profile at Deduako vegetable production site during wet and dry seasons are shown in table 1.

Conclusion

Results indicate that long-term (≥4 years) vegetable cultivation with repeated poultry manure application as soil amendments in a peri urban (Deduako) area have caused significant changes in selected soil properties. CEC, total N, Bray P, exchangeable K, Ca and Mg and OM concentrations increased significantly. This suggests that sustainability of organic agriculture can be ensured even in the face of land scarcity with the use of PM. Increases in all selected soil properties were observed during wet season than the dry season which can be attributed to high mineralization rate during the wet season. Significant changes were also observed in the soil profile for total N, Bray P, and exchangeable K, and OM at the experimental sites. The Poultry manure could, therefore be a good material for improving soil quality although research into the effect of repeated manure applications on surface and groundwater is very important in areas where significant amounts of manure are applied.

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Table 1: Mean values and probability of significance of variations of soil Organic matter (OM) and cation exchange capacity (CEC)

	Wet Season			Dry Season	
Depth (cm)	Plot	OM (%)	CEC (Cmol/Kg)	OM (%)	CEC (Cmol/Kg)
0-15	T	1.47±0.56	6.53 ±1.52	0.99±0.04	5.06±0.27
	C	0.50±0.02	3.67 ±0.38	0.48±0.02	3.93±0.08
Fpr		<0.001	0.047	<0.001	0.002
15-30	T	0.90±0.02	5.94±1.28	0.66±0.02	4.75±0.67
	C	0.37±0.01	3.56±0.096	0.39±0.01	3.49±0.39
Fpr		<0.001	0.033	<0.001	0.05
30-60	T	0.79±0.05	6.16±0.43	0.50±0.02	4.99±0.65
	C	0.30±0.01	3.91±0.02	0.30±0.34	3.92±0.21
Fpr		<0.001	<0.001	<0.001	0.054
60-120	T	0.70±0.04	6.79±0.62	0.47±0.02	5.41±1.00
	C	0.27±0.07	4.22±1.00	0.28±0.02	4.17±0.41
Fpr		<0.001	0.019	<0.001	0.117

T= Cultivated soils with history of PM use, C = Control, Fpr = F probability

Appendix

Table 2: Changes in soil N, P, K, Ca and Mg levels during the wet season at Deduako

						Nutrient levels						
Depth			cultivated						uncultivated			
(cm)		C1	C2	C3		Mean, sd		Rep 1	Rep 2	Rep 3		Mean, sd
Total N levels (%)												
0-15		0.06	0.07	0.06		0.063±0.006		0.04	0.03	0.05		0.040±0.010
15-30		0.06	0.07	0.08		0.070±0.010		0.03	0.04	0.03		0.033±.0.006
30-60		0.07	0.08	0.07		0.073±0.006		0.04	0.02	0.03		0.030±0.007
60-120		0.05	0.06	0.04		0.050±0.010		0.01	0.02	0.01		0.013±0.006
Bray 1 P (mg/Kg)												
0-15		103.36	357.62	244.96		235.313±127.404		15	9	9.15		11.050±3.421
15-30		61.5	25.84	226.87		104.737±107.263		8.03	7.02	6.01		7.020±1.010
30-60		42.89	104.39	29.61		58.963±39.897		7.2	7	6.98		7.060±0.014
60-120		13.54	10.44	32.04		18.673±11.679		6.5	6.63	6.46		6.530±0.089
Exchangeable K (Cmol/Kg)												
0-15		0.28	0.24	0.27		0.263±0.021		0.15	0.13	0.17		0.150±0.020
15-30		0.14	0.16	0.25		0.183±0.059		0.11	0.1	0.12		0.110±0.010
30-60		0.17	0.18	0.15		0.167±0.015		0.1	0.12	0.1		0.107±0.014
60-120		0.14	0.15	0.16		0150±0.010		0.07	0.07	0.06		0.067±0.006
Exchangeable Ca (Cmol/Kg)												
0-15		3.74	6.14	4.01		4.630±1.315		2.19	3.03	2.56		2.593±0.421
15-30		4.2	3.34	5.54		4.360±1.109		2.48	2.42	2.5		2.467±0.416
30-60		5.4	4.14	3.67		4.403±0.895		2.85	2.74	2.87		2.820±0.092
60-120		5.45	4.34	4.14		4.643±0.706		3.04	4.03	2.07		3.045±0.980
Exchangeable Mg (Cmol/Kg)												
0-15		1.07	1.27	0.8		1.05±0.240		0.7	0.65	0.7		0.68±0.020
15-30		0.53	1.34	1.34		1.070±0.468		0.67	0.69	0.73		0.697±0.030
30-60		0.67	1.45	1.59		1.237±0.496		0.7	0.75	0.67		0.707±0.056
60-120		1.4	1.61	1.53		1.513±0.106		0.73	0.72	0.73		0.726±0.006

Table 3: Changes in soil N, P, K, Ca and Mg levels during the dry season at Deduako

Nutrient levels												
			cultivated						uncultivated			
Depth (cm)		Rep.1	Rep 2	Rep 3		Mean, sd		Rep1	Rep2	Rep 3		Mean, sd
Total N levels (%)												
0-15		0.05	0.04	0.06		0.050±0.010		0.04	0.03	0.03		0.033±0.006
15-30		0.06	0.05	0.07		0.060±0.010		0.02	0.03	0.04		0.030±0.010
30-60		0.06	0.08	0.05		0.063±0.015		0.03	0.02	0.03		0.027±0.006
60-120		0.04	0.03	0.05		0.040±0.010		0.01	0.01	0.02		0.013±0.006
Bray 1 P (mg/Kg)												
0-15		138.5	134.37	148.84		140.570±7.453		6.70	6.95	6.72		6.790±0.139
15-30		35.97	34.62	41.86		37.483±3.850		6.00	6.10	5.32		5.807±0.424
30-60		21.34	13.49	26.56		20.463±6.579		6.60	5.63	4.74		5.657±0.930
60-120		8.01	9.56	17.05		11.540±4.834		4.20	4.22	7.34		5.253±1.807
Exchangeable K (Cmol/Kg)												
0-15		0.27	0.17	0.23		0.233±0.050		0.16	0.15	0.17		0.160±0.010
15-30		0.22	0.09	0.20		0.170±0.070		0.11	0.1	0.12		0.110±0.010
30-60		0.16	0.13	0.16		0.150±0.017		0.09	0.11	0.09		0.097±0.012
60-120		0.11	0.10	0.19		0.133±0.049		0.09	0.03	0.07		0.063±0.031
Exchangeable Ca (Cmol/Kg)												
0-15		4.01	3.20	3.74		3.65±0.412		2.35	2.59	2.89		2.610±0.271
15-30		3.47	3.3	3.14		3.303±0.165		2.09	2.44	2.85		2.460±0.380
30-60		3.60	3.34	3.14		3.360±0.231		2.70	2.89	3.07		2.887±0.185
60-120		4.17	3.60	2.60		3.450±0.795		3.56	2.75	2.87		3.060±0.437
Exchangeable Mg (Cmol/Kg)												
0-15		0.74	1.18	0.80		0.907±0.239		0.66	0.6	0.60		0.620±0.035
15-30		1.53	0.80	0.53		0.953±0.517		0.55	0.79	0.53		0.623±0.145
30-60		1.60	0.53	1.34		1.157±0.558		0.64	0.62	0.67		0.643±0.025
60-120		1.73	1.07	1.27		1.357±0.338		0.61	0.90	0.53		0.680±0.195