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The Nutrient Status of Soils Under Banana (*Musa acuminate*) Plantations of Varying Ages in South Western Cameroon

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Abstract
Plantation agriculture is an important economic activity in Cameroon, yet their long-term impacts on the environment have not been adequately documented. The pattern of change of soil nutrient status under banana plantations aged between 7and 23 years of age were investigated. Soil samples collected from the banana plantations and the adjacent forestland were analyzed in the laboratory. Analysis of variance was used to determine the strength and nature of the relationship between the plantations and control. Soil properties. The study revealed a significant difference in K^+, Mg^{2+}, Na^+, the sum of bases, and pH between the banana plantations and adjacent forestland, with the plantation having lower values. With the exception of total N and P, a significant difference was observed in all the other elements among the different plantation age series. The pattern of change over time under the banana, however, showed a rise at the age of 19 years and followed by a decline to the twenty-third year. In order to maintain the nutrient status of the soil beyond the ninetieth year, it is recommended that plantations can use organic manure as a mulch for banana plantation management.

Keywords: *Banana plantation, plant age, soil chemical properties, soil physical properties*

I. Introduction

Plantation agriculture is an important form of land use in the tropics and in many countries where the area under plantation crops has expanded rapidly in the past decades (Hartemink, 2003). The surface area occupied by plantations in South Western Cameroon increased from about 20,000 in 1960 to over 40,000 ha in 2006 (CDC Report, 2006). Banana (*Musa acuminate*) is one of the most important plantation crops cultivated, and the country is ranked the 18th position in the world with an annual production of 1,187,547 tonnes. Plantation agriculture is an important economic activity in the area and the second-largest employer after the government with 22,000 employees and has contributed to the growth and development of the nation's economy. The 2002 statistics of the Consultative Group for International Agricultural Research (CGIAR) estimates that agriculture accounts for 43% of the GDP of the area.

Soil is the main resource base for agriculture and a vital part of the earth's system, impacting the hydrological, biological, and geochemical cycles and also offering goods and services to mankind as highlighted by (Decock et al., 2015; Brevik et al., 2015; Berendse et al., 2015). One common feature of plantation crops is that they can be grown for many years while harvesting continues until probably when yields begin to decline. These crops constantly take up nutrients from the soil, and some are returned back through litterfall and decomposition. The deterioration of soil nutrients occurs when the nutrient output (yield) exceeds nutrient input (litter and fertilizer) over the years (Hertamink, 2005). Banana plantations in the area are productive for about 25 years and have been grown in the forest zone of South Western Cameroon for close to a century (CDC 1999 Report). Underdeveloped high forests within the tropical rain forest zone of Africa, vegetation and soil together produce almost closed cycling of nutrients (Moss, 1969). Whenever the forest is opened up for cultivation, this plant-soil relationship is disrupted. Studies have shown that plantation agriculture affects soil properties (Gyasi, 2000; Hartemink,2003; Hartemink, 2005. One of the greatest limitations of these studies is, however, that they do not show the dynamics of soil under plantations of varying ages. However, the long-term effects of banana cultivation on the soil have not received any attention in the area. Taking into consideration the fact that the Millennium Development Goals of eradicating poverty and hunger on the one hand and ensuring environmental sustainability, on the other hand, must be met, a balance has to be struck between safe resource exploitation and economic growth. It is therefore imperative that studies be carried out. For this reason, an analysis of soil chemical and physical properties under banana plantations of varying ages was carried out to assess the impact on soils in the area. The results will provide a better understanding of the plant-soil relationships of the banana plant so that measures could be taken without delay to enhance the environmental sustainability of banana plantations.

.II. Materials and methods

A. Study area

The study area is located approximately between latitude 4º and 6º and longitude 8º and 9º 45′ East of the equator, covering an area of approximately 24,571km^2. It is bounded to the north by the Federal Republic of Nigeria, to the east by the North West Region, to the west by the Atlantic Ocean, and to the south Littoral Region (Figure 1). The area is characterized by a humid equatorial climatic type with high rainfall with an annual rainfall average of 4050mm, (Neba, 1987). Rainfall reaches a peak of about 7000mm in July and August. The maximum annual temperature is 25ºC, while the minimum is 24.7ºC suggesting a relatively high constant temperature with a low range. Neba, (1987). The vegetation of the area is characterized by the equatorial rainforest and the swampy vegetation, which is dominant along the Cameroon coastline (Neba, 1987). The area has also been subjected to volcanic activity at various times. Two main volcanic activities have been visible in the area (Geze, 1943). The first phase of volcanic activity in the area occurred during the cretaceous time and consisted of basalts that covered most of the area. These have been weathered and are partly covered by more recent deposits. The second phase consisting of more acid volcanic rocks like trachyte, is virtually absent in the area. The third phase of volcanic activity, which started in the Pleistocene, continues to the present. This series consists of basalts, mainly pyroclastic material deposited especially on the West Coast in recent times. The plantations in the area are located at the foot of Mount Cameroon, as shown in Figure 1. The region is characterized by deep rich volcanic soils, which have attracted plantation agriculture in the area. The soils are made up mostly of pyroclastic material supplied mainly from the Cameroon Mountains.

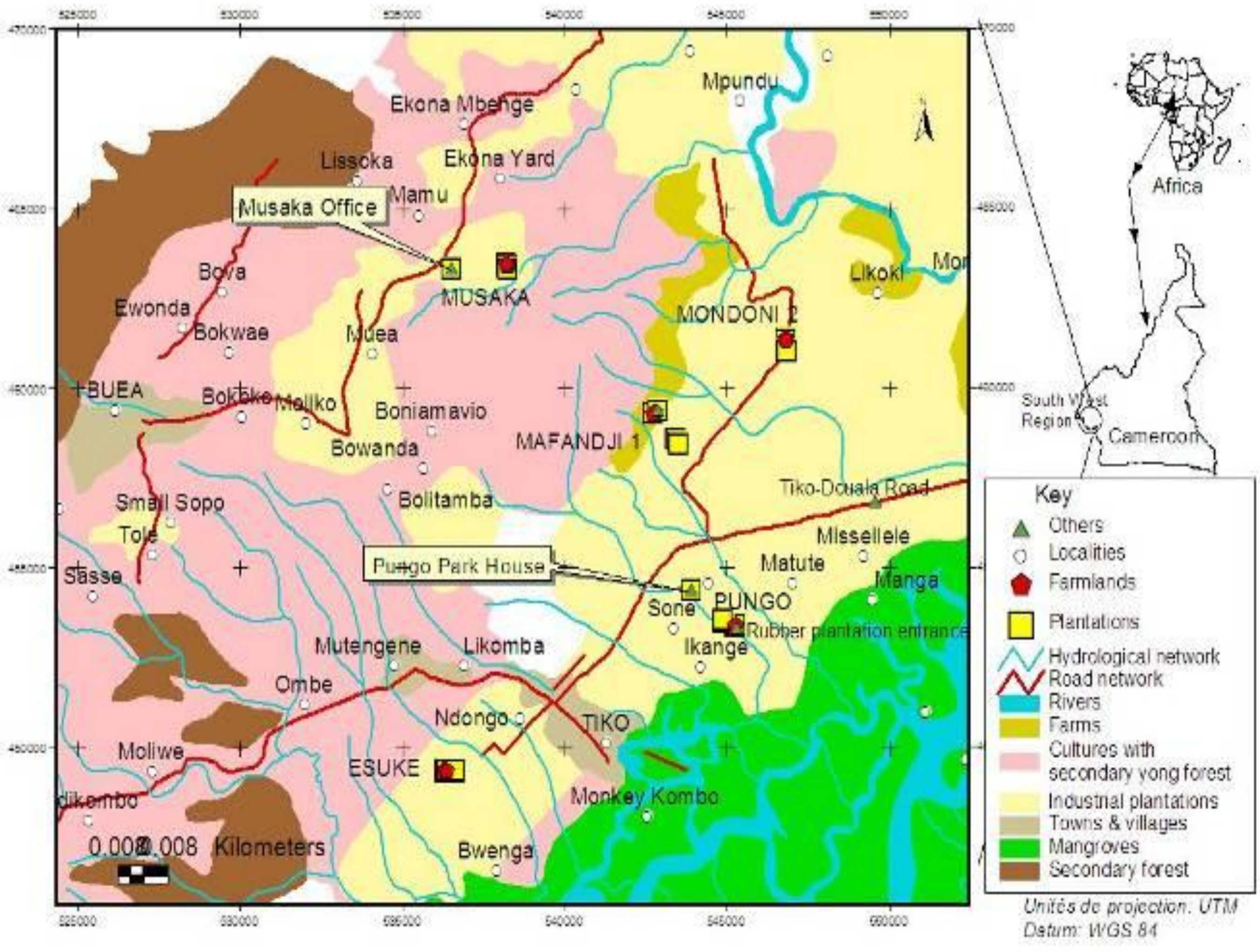

Figure 1: Location of banana plantations in the study area

B. Data collection

Data for the study was collected from both primary and secondary sources. Primary data sets were collected from the field through the selection of different banana plantation age series where soil parameters were assessed. Interviews and Focus Group Discussions were also held with various plantation management staff to understand better the management practices within the plantations. Secondary data included data collection from documented sources, especially plantation records of the Cameroon Development Corporation on (plantation ages, areal extent, cultural practices, yields, economics, among others).

C. Sampling scheme and experimental design

Banana plots of five age series (7, 12, 19, 21, and 23 years) were selected for the study. Adjacent farm/agroforest lands observations served as control. In this study, a stratified random sampling design was adopted for the banana plantation crop, with stratification based on age followed by a single-stage subsampling for soil survey. Square grids of 50m x 50m (0.25ha) were superimposed on the map of the plantation area, making sure the entire area was covered. The coordinates of the grids were noted for easy identification in the field using the Global Positioning System (GPS). Ten grids were then randomly selected from each plantation age series for study. A purposive sampling method was adopted in the selection of the age series to be able to ascertain the progressive changes in soil parameters following the establishment of banana plantations. Each selected grid (50m x 50m) in each plantation age series was subdivided into 25 square plots of 10 m × 10 m (100m^2) with one plot randomly selected for field observations making a total of 10 plots per age series (five inside plantation and five adjacent farm/agro forestlands laid at 10m interval along 100m transect oriented at a random angular bearing 10m from the first selected plantation plot boundary into adjacent farm/agro forest stands (Figure 2). A total of 50 plots for the five-age series in the experiment were used for the study.

The study adopted a randomized design with equal replications of five plots (10m x 10m) within six treatment levels: five crop treatment levels (plantation crop age series) and adjacent farm/agroforest land control. These were evaluated for the parameters: soil nutrient status.

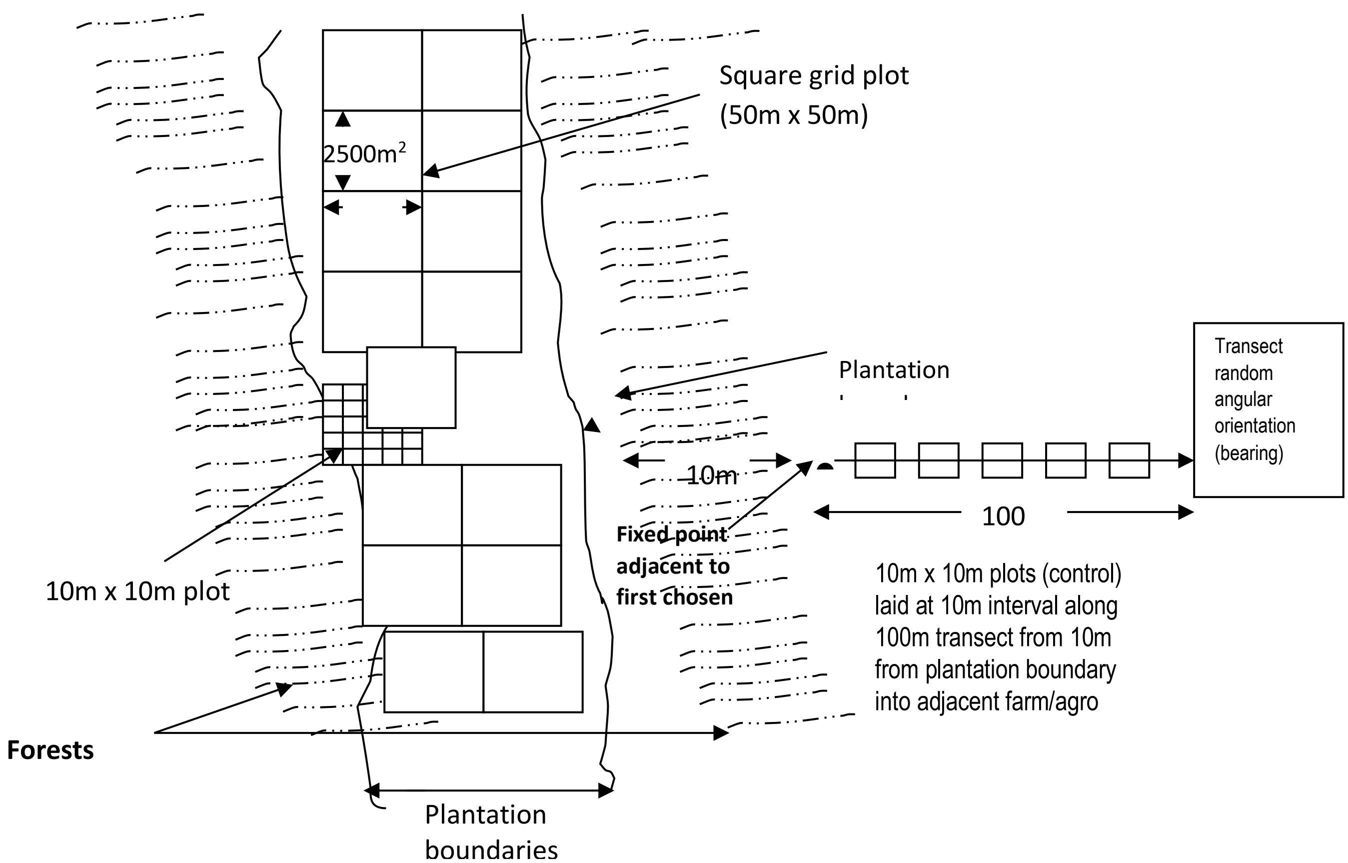

Figure 2: Ground Plan of Sampling Unit

D. Soil sampling

Soil samples were collected from five points in each of the selected plots and mixed to form a composite sample per plot. From each plot, 1 composite sample was collected. The soil samples were collected at a depth of 0-20cm for both the banana plantations and the adjacent forest plots. This soil depth was chosen because the banana is a surface feeder. This depth will make it possible to have a comparative analysis between the banana plantations and adjacent agroforest plots. Overall, a total of 50 composite soil samples were collected for the study.

E. Soil analysis

The soils were analyzed for particle size composition by the hydrometer method (Bouyoucos, 1926), total nitrogen using the Kjeldahl method, and organic carbon using the method of Walkley & Black (1934). The soil was leached with neutral I M ammonium acetate to obtain soil extracts that were used for determining exchangeable cations. Exchangeable calcium, potassium, and sodium were determined by flame photometry, while exchangeable magnesium was determined by atomic absorption spectrophotometry. Soil pH was determined potentiometrically in 0"01M calcium chloride solution, using a soil-to-solution ratio of 1:2. The bulk density was analyzed using the oven-drying method (Blake, 1965). Total porosity values were calculated from bulk density values using an assumed particle density value of 2.65g/cm a (Vomocil, 1965). The physical and chemical properties of soils under the different age categories of bananas were analyzed and compared in order to examine the changes in soil properties during the first 30 years of plantation establishment. Soils under adjacent agroforest/farmlands were collected and analyzed to serve as the control for assessing the impact of banana cultivation on the soil. It is important to point out that the banana plots were established by clearing the forest, burning the trash, and subsequently planting the crops on the cleared sites. All sampled sites had the same parent material (basalt) and were located on comparable flat sites to ensure that catenary variations in soil properties are minimized.

F. Statistical Analysis of data

The data were subjected to various descriptive and inferential statistical methods. The SPSS statistical package was used for one-way ANOVA followed by multiple comparisons to further separate significant levels if overall significant treatment differences exist. Simple bivariate correlations (in correlation matrices) were used to determine the strength and nature of the relationship between banana ages and soil properties.

III. Results and discussion

Table 1 shows the mean and coefficient of variations of soil properties under the plantations and adjacent agroforest lands, and Table 2, 3, and 4 show the results of the ANOVA test for comparing soil properties within the plantations and adjacent farmlands and also within the different banana age series respectively.

A. Comparison of mean values of soil physical properties under banana plantations and adjacent farmlands and across the age of plantation

Particle Size Distribution

Particle size distribution shows that the soil is sandy loam (Table 1). The mean values of sand, silt, and clay under banana plantations and adjacent farmlands were 79%, 6%, 15%, and 78%, 4%, and 20%, respectively.

Field results revealed that no significant difference existed between soils under the different banana age series and the adjacent farmlands with respect to the proportion of sand, silt, and clay. This indicates that banana plantations do not significantly modify soil textural composition over time. This contradicts the work of Ekanade (1988), who observed that cocoa cultivation resulted in significant changes in soil texture. The findings here are in line with the work of Faniran and Areola (1978), who observed that plants are not capable of modifying particle size distribution. Therefore, banana plantations have no significant impact on the textural composition of soils in the area.

Bulk Density

The mean soil bulk density was lowest under the forest ($1.2g/cm^3$) and highest under the plantations ($1.3g/cm^3$). Results also showed no significant change in bulk density between the plantations and adjacent farmlands (Table 2). This is contrary to the work of Ekanade (1988), who observed a significant change of this soil property between the forest and cocoa plantations in South-Western Nigeria. The results also show that variations in soil bulk density values in the area were moderate for the adjacent farmlands (33.7%) and high for the plantation (58.2%) (Table 1).

Bulk density values also varied across the plantation ages. It is generally low in plantations of 7, 19, and 21 years of age and high under plantations of 23years (Table 1). The ANOVA results showed that soil bulk density is significantly different under the banana age series at a 1% confidence level (Table 3). This shows that the soil becomes more compact with the increasing age of banana plantations. This is to be expected because banana plantations have no overhead canopy that can protect the soil from the direct impact of falling raindrops and other adverse weather conditions. This finding contradicts that of Aweto (1987), who observed no significant difference in bulk density with the age of rubber plantations in Nigeria. The Pearson correlation coefficient (Table 4) shows a negative non-significant relationship of soil compaction with the age of plantation. Soil compaction problems have been said to occur whenever the forest is opened up for cultivation (Ekanade, 1998, Wessel, 1969). The study, therefore, reveals that banana plantations over the years may result in soil bulk density values higher than the maximum (of 1.35g/cm^3 and 1.59g/cm^3) suitable for crop performance (Falade, 1975).

Table 1: Summary statistics for soil properties under plantations and adjacent agroforest lands

Age (years)	Plot location	Statistics	pH KCL	OC (%)	Org Mat (%)	Total N (g/kg)	Ca (meq/100g)	Mg (meq/100g)	Base saturation (%)	Bulk Density	P Bray II (mg/kg)	CEC	K (meq/100g)	Na (meg/100g)	% Sand	% Silt	% Clay
23	Ad	Mean	6.08	4.11	7.08	1.76	3.54	1.55	53.06	0.33	22.54	5.18	0.08	0.01	63.8	13.4	22.8
		CV (%)	4.4	15.1	15.1	40.2	49.7	38.6	15.2	33.7	74.1	42.7	29.4	0	6.3	7.6	13.2
	P	Mean	6.13	0.88	1.51	0.62	1.25	0.32	18.9	0.02	5.66	1.8	0.03	0.21	68.8	10.2	21
		CV (%)	0.8	38	38	46.8	32.9	30.6	19.5	58.2	58.2	23	27.3	44.9	7,2	9.6	14
21	Ad	Mean	6.02	4.47	7.71	2.38	3.62	2.26	72.31	0.36	27.32	6.3	0.19	0.02	66.4	8.6	25
		CV (%)	1	5.1	5.1	20.9	31	24	48	8.3	4.8	21	81.9	74.5	6	1	4
	P	Mean	6.09	1.86	3.2	0.33	3.27	0.91	72.31	0.36	27.32	6.3	0.19	0.02	66.4	8.6	25
		CV (%)	1.5	34.6	34.6	9.4	36	35.7	26.1	8	28.2	34	16.3	22.8	4	2.5	0.9
19	Ad	Mean	5.76	4.1	7.07	1.66	1.45	0.85	27.3	0.4	8.72	2.66	0.08	0.21	67.9	12.1	20
		CV (%)	3.2	37.6	37.6	32.8	17.1	68.9	38.9	8.4	53.1	17.7	76.1	56.5	4.5	6.6	3
	P	Mean	5.73	4.37	7.54	1.85	1.33	0.63	22.89	0.37	10.14	2.22	0.06	0.21	67.5	12.2	20.3
		CV (%)	1.2	15	15	24.9	19.3	33.6	9.6	9.5	35.4	7.6	23	14.8	4.1	6.5	2
12	Ad	Mean	6.03	1.35	2.33	1.36	1.87	0.48	15.03	0.01	5.39	6.5	0.24	0.02	70.1	11.8	18.1
		CV (%)	2.2	23.8	23.8	36.9	15.7	61.9	13.5	32.3	32.3	21.5	24.9	0	5.7	7.6	4
	P	Mean	6.32	2.48	4.28	1.49	2.35	0.61	22.66	0.02	6.06	3.11	0.28	0.02	69	9.8	20.6
		CV (%)	3.5	82	82.1	31.3	12.9	17.7	9.2	38.3	38.3	53.6	27.8	0	7.3	10.2	11.6
7	Ad	Mean	6.08	1.7	2.93	1.26	2.16	0.6	24.38	0.37	3.98	4.15	0.2	0.06	67.7	12.9	19.4
		CV (%)	0.8	27.4	27.3	19.9	36.5	41.8	58.6	7.7	34.6	73.8	0	143.7	8.8	7.5	4
	P	Mean	6.07	2.48	4.28	2.44	2.18	0.75	23.92	0.36	3.00	4.15	0.1	0.05	65	11.9	17
		CV (%)	3.5	30.8	30.8	30.3	15.6	23.1	45.4	5.5	17.6	47.3	0	49.1	8	10	5.8

Ad: Adjacent farmland
P: Plantation

Table 2: ANOVA soil properties within the plantation and adjacent areas

Soil properties	Component of variation	Sum of Squares	df	Mean Square	F	Sig.	Significance
pH KCL	Between Groups	0.07	1	0.07	1.529	0.222	ns
	Within Groups	2.196	48	0.046			
	Total	2.266	49				
OC (%)	Between Groups	6.683	1	6.683	2.856	0.098	ns
	Within Groups	112.328	48	2.34			
	Total	119.011	49				
Org Mat (%)	Between Groups	19.866	1	19.866	2.855	0.098	ns
	Within Groups	333.981	48	6.958			
	Total	353.846	49				
Total N (g/kg)	Between Groups	1.414	1	1.414	2.361	0.131	ns
	Within Groups	28.742	48	0.599			
	Total	30.156	49				
Calcium (meq/100g)	Between Groups	2.564	1	2.564	2.005	0.163	ns
	Within Groups	61.371	48	1.279			
	Total	63.935	49				
Magnesium (meq/100g)	Between Groups	3.176	1	3.176	8.697	0.005	**
	Within Groups	17.53	48	0.365			
	Total	20.706	49				
Potassium (meq/100g)	Between Groups	0	1	0	0.002	0.967	ns
	Within Groups	0.533	48	0.011			
	Total	0.533	49				
Sodium (me/100g)	Between Groups	0.045	1	0.045	4.464	0.04	*
	Within Groups	0.479	48	0.01			
	Total	0.523	49				
Sum of Bases (meq/100g)	Between Groups	10.358	1	10.358	4.264	0.044	*
	Within Groups	116.591	48	2.429			
	Total	126.948	49				
CEC pH 7	Between Groups	1.332	1	1.332	0.039	0.845	ns

	Within Groups	1652.517	48	34.427			
	Total	1653.849	49				
Base saturation (%)	Between Groups	1362.123	1	1362.12	2.622	0.112	ns
	Within Groups	24934.034	48	519.459			
	Total	26296.157	49				
Phosphorus Bray II (mg/kg)	Between Groups	618.921	1	618.921	7.703	0.008	**
	Within Groups	3856.463	48	80.343			
	Total	4475.384	49				
CEC effective	Between Groups	42.258	1	42.258	11.003	0.002	**
	Within Groups	184.355	48	3.841			
	Total	226.613	49				
Bulk Density (g/cm3)	Between Groups	0.068	1	0.068	2.533	0.118	ns
	Within Groups	1.294	48	0.027			
	Total	1.362	49				
Sand (%)	Between Groups	1.488	1	1.488	2.12	0.193	ns
	Within Groups	9.334	48	0.7			
	Total	10.822	49				
Silt (%)	Between Groups	1.567	1	1.567	2.9	0.121	ns
	Within Groups	8.452	48	0.53			
	Total	10.019	49				
clay (%)	Between Groups	1.345	1	1.345	2.12	0.193	ns
	Within Groups	8.631	48	0.261			
	Total	9.976	49				

* significant (p<0.05)   ** significant (P<0.01)   ns: Not significant (p>0.05)

Table 3: ANOVA soil properties across plantation ages

Soil properties	Component of variation	Sum of Squares	df	Mean Square	F	Sig.	Significance
pH Water	Between Groups	.457	4	.114	5.453	0.0011	**
	Within Groups	.944	45	.021			
	Total	1.401	49				
pH KCL	Between Groups	1.105	4	.276	10.699	0.0000	**
	Within Groups	1.161	45	.026			
	Total	2.266	49				
OC (%)	Between Groups	35.644	4	8.911	4.810	0.0026	**
	Within Groups	83.367	45	1.853			
	Total	119.011	49				
Org Mat (%)	Between Groups	105.948	4	26.487	4.808	0.0026	**
	Within Groups	247.898	45	5.509			
	Total	353.846	49				
Total N (g/kg)	Between Groups	3.083	4	.771	1.281	0.2915	Ns
	Within Groups	27.072	45	.602			
	Total	30.156	49				
Bulk density	Between Groups	4124.749	4	1031.187	6.181	0.0005	**
	Within Groups	7507.241	45	166.828			
	Total	11631.990	49				
Calcium (meq/100g)	Between Groups	22.064	4	5.516	5.928	0.0006	**
	Within Groups	41.871	45	.930			
	Total	63.935	49				
Magnesium (meq/100g)	Between Groups	6.755	4	1.689	5.447	0.0012	**
	Within Groups	13.951	45	.310			
	Total	20.706	49				
Sum of Bases (meq/100g)	Between Groups	47.023	4	11.756	6.619	0.0003	**
	Within Groups	79.925	45	1.776			
	Total	126.948	49				
CEC pH 7	Between Groups	713.126	4	178.282	8.528	0.0000	**
	Within Groups	940.723	45	20.905			
	Total	1653.849	49				
Base saturation (%)	Between Groups	14966.167	4	3741.542	14.861	0.0000	**
	Within Groups	11329.990	45	251.778			
	Total	26296.157	49				
BulkD(g/cm3)	Between Groups	1.039	4	.260	36.186	0.0000	**
	Within Groups	.323	45	.007			
	Total	1.362	49				

Phosphorus Bray II (mg/kg)	Between Groups	657.109	4	164.277	1.936	0.1208	Ns
	Within Groups	3818.275	45	84.851			
	Total	4475.384	49				
CEC effective	Between Groups	52.057	4	13.014	3.355	0.0174	*
	Within Groups	174.556	45	3.879			
	Total	226.613	49				
Potassium (meq/100g)	Between Groups	.352	4	.088	21.935	0.0000	**
	Within Groups	.181	45	.004			
	Total	.533	49				
Sodium (me/100g)	Between Groups	.246	4	.062	9.999	0.0000	**
	Within Groups	.277	45	.006			
	Total	.523	49				

* significant (p<0.05) ** significant (P<0.01) ns: not significant (p>0.05)

Table 4: Correlation coefficients of soil properties across plantation age series

	pH KCL	OM (%)	Total N (g/kg)	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)	Na (me/100g)	Sum of Bases (meq/100g)	Base saturation (%)	P Bray II (mg/kg)	CEC	Bulk Density (g/cm3)
Pearson Correlation	0.18	-0.3	0.21	-0.17	-0.35	0.48	-0.09	-0.23	-0.48	-0.34	0.09	-0.08
Sig. (2-tailed)	0.209	0.033	0.135	0.253	0.014	0	0.55	0.104	0	0.016	0.555	0.578
Significance	ns	*	ns	Ns	*	**	ns	ns	**	*	Ns	ns
N	50	50	50	50	50	50	50	50	50	50	50	50

B. Comparison of mean values of soil chemical-physical properties under banana plantations and adjacent farmlands and across the age of plantation

Soil pH

Results revealed that the mean pH level was lower within adjacent farmlands (5.32) than the plantation (6.07). The coefficient of variation is low within the plantations and adjacent farmlands and across plantation ages (Table 1). No significant difference in pH was observed between the plantations and adjacent farmlands.

Changes in soil pH following the establishment of plantations have been documented. On rubber plantations in Malaysia, it was found that the soil reaction increased slightly after clearing due to the addition of ash and decreased slightly thereafter and remained at the same level as that of the forest after 16 years (Sanchez *et al.*, 1985). Duah-Yentumi *et al.* (1998) found at Kade (Ghana) that the pH of soils under virgin forest and 40years old rubber plantations were about the same, whereas the pH of Ultisols under cocoa was about 0.5 unit higher. The increase in pH can be attributed to higher levels of exchangeable cations within the plantations.

Soil Organic Matter

As observed in Table 1, the mean level of organic matter was higher within adjacent farmlands (4.95%) than the plantation (4.18%). Generally, organic matter variations were low within the plantation and adjacent farmlands and across plantation ages. No significant difference was observed in the level of organic matter between the plantations and adjacent farmlands. ANOVA results showed a significant difference (1%) in organic matter across the different plantation age series (Table 3).

The correlation between banana age and organic matter is negative and significant (1%), indicating that organic matter in the soil decreases with the increasing age of banana plantations. The high nutrient demands of plantation crops have been well documented. According to PORIM (1994), the level of nutrients was found to increase in the early years under oil palm plantations because of the fertilizer applications and N fixation by the leguminous cover crop. However, longer-term trends reveal a decrease in nutrients due to palm uptake and retention exceeding fertilizer applications. It is clear from the results that the ages of banana plantations negatively affect the level of organic matter in the soil in South Western Cameroon.

Total Nitrogen

Mean values of nitrogen under the plantations and adjacent farmlands ranged from 0.21 to 2.44 g/kg and 1.26 to 2.38 g/kg, respectively. The distribution of nitrogen is moderately variable in the area. Results of the ANOVA test show no significant difference in this soil property between the plantations and adjacent farmlands and also across plantation ages (Table 2).

The correlation results reveal a positive non-significant relationship between total nitrogen and age of plantation. Thus, as banana plantations grow old, the level of nitrogen increases. Hence banana plantations have no significant impact on the level of total nitrogen in the soil.

Available Phosphorus

Table 1 shows that the range of this property under the plantation and adjacent farmland was 1.50 to 10.1ppm and 3.98 to 27.3 ppm, respectively. The mean value was 5.8ppm for the plantations and 15.6ppm for adjacent farmlands, with the farmlands having a higher mean value. There is a significant difference (1%) in available phosphorus between the plantations and adjacent farmlands, as pointed out by the ANOVA test (Table 2).

Table 3 shows no significant difference in available phosphorus with plantation age. The Pearson correlation coefficient shows a significant negative relationship of available phosphorus with the age of banana plantations in the region. As the plantations grow older, available P decreases. The results show that as the tropical rainforest is destroyed for banana plantations in the area, there is a significant decline in available phosphorus. Though fertilizers are used to augment deficiencies observed, the decline appears not easily replenished because of the high demand of this macronutrient by most plantation crops (Henao and Baanante, 1999; Stoorvogel and Smaling, 1990).

Exchangeable Cations

The range of calcium, magnesium and potassium observed under the plantations and adjacent farmlands were 1.25 to 3.27 me/100g and 0.08 to 0.24 me/100g for Ca, 0.03 to 0.28 me/100g and 0.08 to 0.24 for K, 0.02 to 0.21 me/100g for Na ,0.32 to 0.91 me/100g and 0.48 to 2.28 me/100g for Mg. The mean values of calcium, magnesium, and potassium observed under the plantations were 3.27, 0.6, and 0.51 me/100g, respectively. The values observed under adjacent farmlands were 3.62, 1.38, and 0.16 me/100g for calcium, magnesium, and potassium, respectively. The mean values of calcium and magnesium were higher under adjacent farmlands than was the case under plantations. (Table 1). The ANOVA results show a significant difference (1%) in the level of Ca, K, and Na between the plantation and adjacent farmlands (Table 2). A highly significant difference was observed between the exchangeable cations and the various banana age groups. The Pearson's correlation coefficient shows a negative relationship between Mg, Na, and Ca and a positive one for K with the age of plantations. This relationship was significant for Mg and K. That is, as the plantations advance in age, Mg levels in soil decrease, and K levels increase significantly (Table 4).

Based on the results, it can be seen that the level of exchangeable cations in the soil is lowered when the forest is converted to plantation agriculture (Wessel, 1969; Ekanade, 1988). The rate of loss may be greater either through plant absorption or due to leaching. Erabor and Filson (1999) and Simanjutak (2008) also explained that nutrients in the soil are influenced by nutrient absorption, leaching, type, and quantity of fertilizer. The loss of nutrients due to leaching is estimated as quite significant due to the high rainfall in the area, which is 2,563 mm/year. Based on the above analysis, banana plantations result in a decrease in the level of exchangeable cations in the soil in South Western Cameroon. The coefficient of variation of the cations in the area was moderate for Ca, Mg, and K and high for Na (Table 1). With the exception of the high variation of sodium under adjacent farmlands and plantations of 7years old, variations in the distributions of calcium, magnesium, and potassium within the plantations and adjacent farmlands were moderate

Base Saturation

Base saturation ranged from 16.4 to 59% and 15.4 to 72.3% under plantations and adjacent farmlands, respectively. The mean values observed for the plantations and adjacent farmlands were 37.7% and 43.8%. The mean value of concentration was higher under adjacent farmlands than was on the plantations. The coefficient of variation was generally moderate under the plantations and adjacent farmlands. No significant difference was observed in base saturation within the plantations and adjacent farmlands (Table 2).

ANOVA results revealed a significant difference in base saturation with the age of banana plantations. The Pearson correlation coefficient revealed a significant negative relationship of base saturation with plantation age. As the plantations grow older, the level of bases in the soil decreases. The changing pattern of base saturation is determined by the changing pattern of relative comparison between base cations against the total base and acid cation (Agusalim et al., 2010). This trend is expected based on the results of exchangeable cations, which shows that whenever the forest is transformed to plantations, the level of bases in the soil is depleted.

Cation Exchange Capacity

The results show that cation exchange capacity was higher under adjacent farmlands (5.02 me/100g) than under the plantations (3.19 me/100g). The variation in the distribution of CEC was moderate for the two sites and across plantation ages (Table 1). ANOVA results revealed a highly significant difference in CEC within the plantations and adjacent farmlands.

A significant difference in CEC was also observed across plantations of different ages (Table 4). The Pearson correlation coefficient shows a non-significant positive relationship of this element with the age of plantation. Many studies have shown that soil acidification is accompanied by a decrease in exchangeable bases and CEC (Hartemink, 1998). Thus, the high nutrient uptake of banana plantations is responsible for this observed pattern.

IV. Conclusion and recommendations

Soil nutrients declined considerably with the age of banana plantations in spite of the application of compound fertilizers NPK 20 10 10 in the area. The significant deterioration of soil nutrients under banana plantations, when compared to the adjacent farmlands partially, results from the assimilation of nutrient ions in the process of flowering and fruit development. Most of the observed decline occurs during the early years of plantation establishment, which coincides with the rapid phase of banana growth. It is probable that the rate of nutrient uptake by bananas exceeds the rate of nutrient return to the soil through litterfall and mineralization during this rapid phase of banana growth. This presumably explains why a substantial decline in soil nutrients occur during the first 12 years of banana plantation establishment. Banana plantations do not function as natural bush fallows that recycle mineral nutrients in the soil. The trend of a steady decline in soil nutrients over time suggests that soil nutrient deficiency may limit banana yields if appropriate measures are not put in place. Consequently, the level of organic matter for better soil CEC and water holding capacity. Under plantations can be increased through the addition of organic manure, green manures, and/or crop residues. It is also recommended that bananas be interplanted with tree species that are soil improvers, such as Gliricidia *sepium* or *Leucaena lucocephala*.

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