COMPARATIVE ANALYSIS OF SOIL NUTRIENT DEGRADATION IN HYBRID AND INDIGENOUS COCOA PLANTATIONS IN SOUTHWEST NIGERIA

By

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ABSTRACT

The mainstay agro-based economic activity in southwest Nigeria, especially among the peasant farmers is cocoa (Theobroma cacao) production. Cocoa could be broadly divided into indigenous and hybrid in terms of varieties. Indigenous type had been cultivated over the decades but for more than two decades ago now, the grown of hybrid has been rapidly predominated. From the previous studies, comparative analysis of the soil nutrient degradation between cocoa varieties are not available particularly those that differentiate hybrid from indigenous. This paper examines the difference between both varieties in terms of nutrient concentration in leaf, bean and pod husk in relation to their impacts on soil nutrient degradation. Multiple regression analysis shows that cocoa outputs immensely contributed to the soil nutrient degradation under hybrid than indigenous varieties in old cocoa plantations. Finding shows that pod husk and cocoa bean are the main determinants of soil nutrient degradation in both varieties. To ameliorate the problem of soil nutrient degradation to the nearest minimum, the study recommends seasonal application of chemical or pod husk fertilizers to complement the impact of litterfall.

Key words: Degradation, Indigenous, Hybrid, Nutrient, Plantation.

INTRODUCTION

In each of the land uses, plants absorb nutrients for the manufacture of food, metabolic processes, assimilation, maintenance and reproduction for sustainability. The nutrients are returned to the soil through litterfall, decomposes to release mineral nutrients for re-absorption (Vitousek and Sanford, 1986; Rhoade, 1997; Hartermink, 2005 and Owusu *et al*, 2006). Removal of nutrients from cocoa ecosystems includes yield (beans and husk), immobilization in stems and branches, and leaching of nutrient below the rooting zone. Most nutrients in cocoa ecosystems are received by the harvest of beans and husk. The main losses of nitrogen, phosphorus and potassium from a cocoa plantation are through harvesting (Boyer, 1973; Thong and Ng, 1978). Study revealed that cocoa bean and pod husk are the main agents of nutrient removal from mature cocoa plantation. The loss is considerably higher when pod husk which is usually left at the pod-breaking points on the farms is included.

Among the cash crops in Nigeria (cotton, ground nut, oil palm and others), cocoa made significant contributions to exports and contributed greatly to Nation's economy. Being an important cash crop for foreign exchange, it remains the second largest foreign earner after crude oil (Oluyole, 2010). But Nigeria's contribution in term of cocoa production in the world market has been drastically reduced in recent years. Reduction in soil nutrient due to annual yield harvest without replacement via fertilizer application, aging, black pod disease, and global price fluctuation and government negligence have been causing setback to the production of cocoa in Nigeria over the years.

In practical production, according to Asiedu (1987) three varieties of cocoa are distinguished; criollos from Central America to Columbia, Forasteros from the upper Amazon, with the group Amelonados originating from Guyana and the lower Amazon and Trinitarious, a hybrid result from natural crosses between Criollos and Forstero types. An idea of solving the problem of slow growth and development, low yield and disease resistance which are familiar features of native varieties brought about the breeding of hybrid varieties, yet the problem of soil fertility decline in consonance with the lifespan of the cocoa plantation has never been solved. Findings revealed that rapid growth and development of hybrid tree varieties is synonymous with the uptake of the soil nutrient (Aweto, 2001). New farms are dominated by hybrid varieties due to its rapid growth, better annual yield, size of the beans and ability to resist certain diseases. However, the impacts of the hybrid on soil nutrient status were not considered. Nutrient deficiencies of potassium, zinc and boron were detected at the Cocoa Research Institute of Ghana (CRIG) when new cocoa varieties with higher yields were cultivated (Ahenkorah, 1969). In most old farms in cocoa producing areas, cultivation of native species has been reduced to the extent of its replacement with a hybrid in existing cocoa farms. In Nigeria and other tropical region where cocoa production is highly predominant, replacement of old plantations with hybrid cocoa varieties in many farms is yet to solve the problem of nutrient loss through annual yield harvest. The aim of this study is to examine the contribution of outputs (cocoa leaf, bean and pod husk) in soil nutrient degradation under indigenous and hybrid cocoa plantations. The outcomes of the study may serve as the basis for agroforestry management strategies for the cultivation and maintenance of cocoa plantation in southwest Nigeria.

STUDY AREA

Ondo State is located in the south-western Nigeria approximately between latitudes 5^0 45' and 7^0 52'N and longitudes 4^0 20' and 6^0 05'E. The State is bounded on the east by Edo and Delta States, on the west by Ogun and Osun States, on the north by Ekiti and Kogi States and to the south by the Bight of Benin and Atlantic Ocean (Fig. 1). The State covers an area of 15,820 sq km^2. From eighteen (18) Local Government Areas in Ondo State, three (3) of them which are Idanre (Alade), Owo (Ijeguma) and Odigbo (Oniparaga) are the main study areas base on their annual rate of cocoa production over the years.

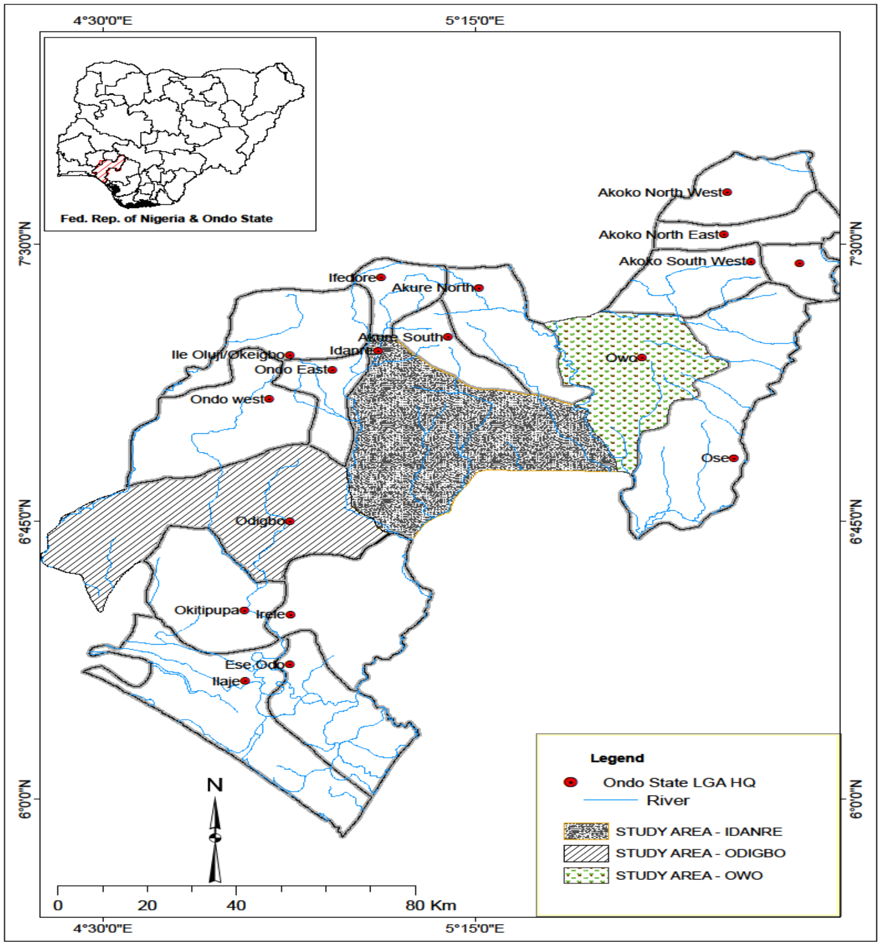

Fig. 1 Ondo State showing Idanre, Owo and Odigbo LGA
Sources: Modified from the Nigerian Geological Survey Agency, 2006

MATERIALS AND METHODS

Sampling

Sampling and data collection under this study were subdivided into soil and plant sampling. Both were sampled for laboratory analysis. Physico-chemical parameters from both were used as primary data for further analysis. The selected physicochemical parameters are the basis for the growth and development of cocoa as well as determinant factors of soil fertility in cocoa ecosystem.

Soil Sampling

From 25m by 25m quadrat selected in indigenous and hybrid cocoa farms in each of the selected location, twelve (12) soil samples were randomly sampled from two different depths 0-15cm and 15-30cm considered as topsoil and subsoil respectively. Twelve (12) samples from each depth were bulked together to form a composite sample. For each farm, two (2) composites made up of topsoil and subsoil was taken for further analysis. Altogether were six (6) composites samples for laboratory analysis The sampling was limited to this area due to the fact that the most feeding roots of cocoa are concentrated in that depth (Thong and Ng, 1978; Wood and Lass, 1985; De Oliveira and Valle, 1990 and Hartemink, 2005; Aikpokpodion 2010). Soil particles were air-dried, mixed up together, sieved with 2.0mm sieve and analyzed using standard laboratory techniques at Step-B Central Research Laboratory, Federal University of Technology, Akure. Soil samples were analyzed for particle size, composition using the hydrometer method (Bouyoucos, 1962). Soil pH was determined potentiometrically in 0.01M calcium chloride solution ratio of 1:2 according to Peech (1965). Organic carbon was determined using the chromic acid digestion method (Walkley and Black, 1934). Organic matter values were obtained by multiplying organic carbon value by 1.724 according to Smith (1998); Roger (2008); and Musa *et al*. (2009). After ash and digestion of soil sample with 5ml of nitric acid ($HN0_3$) exchangeable cations which include calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}) and sodium (Na^+) were determined with the aid of Atomic Absorption Spectrophotometer (AAS). Total nitrogen (N) was extracted with Bray-P solution according to Kjedahl Method (Bremmer, 1996). Extractable trace elements (Zn, Cu, Fe and Mn) were digested and measured after extraction with 0.02M using EDTA Atomic Absorption Spectrophotometer according to Isaac and Korber (1971).

Plant Sampling

In each of the quadrat from 25m by 25m plot of coco plantation with an average age of 55 years, the cocoa plant variables which have been identified as outputs in cocoa plantation were sampled. They were made up of fresh leaf, cocoa bean and pod husk from hybrid and indigenous varieties. The fresh leaf samples were air-dried and pulverized before chemical analysis. Cocoa beans were fermented for five days and sun-dried. In line with Aikpokpodion (2010), dried cocoa bean and pod husk were grinded while leave pulverized before subject to laboratory analysis for the specified physicochemical and trace parameters. Cocoa fresh leaves were air-dried while pod husks were sun-dried to laboratory required standard. To examine the impact of cocoa outputs on soil fertility loss, average mean values of the physicochemical parameters considered under cocoa plant variables were descriptively explained. Multiple regression analysis was used to examine the impact of cocoa bean, pod husk and fresh leaf on soil properties status.

RESULTS AND DISCUSSION

In cocoa ecosystem, annual harvest of the yield removes essential nutrients from the soil. In this study the main variables considered as output are fresh leaf, pod husk and cocoa bean (Table 1). Ability of cocoa plant outputs to store nutrient exceeds the available soil nutrient under both varieties.

Table 1: Average Nutrient Storage in Cocoa Varieties

Properties	Soil		Fresh Leaf		Bean		Pod Husk	
	ID	HB	ID	HB	ID	HB	ID	HB
pH	5.81	5.74	6.47	6.49	5.80	5.62	5.84	5.75
OM (%)	3.79	3.27	9.00	8.53	9.61	9.44	9.11	9.14
N (%)	0.64	0.52	0.40	0.49	0.32	0.26	0.30	0.35
OC (%)	2.23	1.90	5.24	4.96	5.50	5.49	5.29	5.31
K (cm01/kg)	0.03	0.01	55.48	25.69	33.82	28.35	112.45	70.23
Ca (cm01/kg)	0.29	0.34	51.51	108.70	2.13	3.45	8.00	18.40
Mg (cm01/kg)	0.01	0.01	21.67	3.58	2.78	1.25	8.10	1.31
Na (cm01/kg)	0.01	0.01	10.82	5.93	3.35	5.21	6.38	2.43
P (mg/kg)	8.10	7.19	28.81	12.35	22.51	21.66	9.57	8.15
Zn (mg/kg)	1.34	1.70	0.50	0.24	0.40	0.90	0.49	0.32
Mn (mg/kg)	0.16	0.20	1.28	1.29	0.13	0.18	0.13	0.24
Fe (mg/kg)	1.26	1.25	0.36	0.22	0.27	0.41	0.25	0.13
Cu (mg/kg)	1.38	1.56	0.38	0.16	0.23	0.31	0.53	0.18

Source: Authors Fieldwork and Data Analysis, 2014
Note; ID: Indigenous, HB: Hybrid

The results from correlation analysis indicate positive and high relationship between the examined variables under both species. The order of relationship in their nutrient storage were cocoa bean (r = 0.99), soils (r = 0.99), pod husk (r=0.97) and fresh leaf (r = 0.74) respectively. Contribution of cocoa outputs to soil nutrient degradation varied from indigenous to hybrid cocoa. The adjusted R^2 ranges from 52% to 82% under hybrid and 39% to 86% in indigenous cocoa plantation. From both varieties, Idanre (39% indigenous and 52% hybrid) recorded the lowest contribution to nutrient loss while Owo (86% indigenous and 82% hybrid) accounts for the highest (Table 2).

Table 2: Regression Analysis on Cocoa Varieties

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Hybrid				
Idanre	.803[a]	.645	.526	1.57746
Owo	.933[a]	.871	.828	1.70023
Odigbo	.904[a]	.818	.757	1.55325
Indigenous				
Idanre	.737[a]	.543	.391	1.61094
Owo	.948[a]	.899	.866	1.18293
Odigbo	.862[a]	.744	.658	1.37849

a. Predictors: (Constant), Pod Husk, Fresh Leaf, Bean
Source: Authors Data Analysis (2014)

Table 3 and 4 present the multiple regression result of the relationship between soil nutrient loss and cocoa output under indigenous and hybrid cocoa plantations. The models are significant, indicating that cocoa outputs (bean, pod husk and fresh leaf) are accountable for the soil nutrient loss in the aged cocoa plantations. From indigenous cocoa plantations, the result shows that variation in cocoa output accounts for a very high proportion (73%, 86% and 94%) and hybrid (80%, 93% and 90%) of the variation in the soil nutrient loss. In summary, average contribution of the examined variables was 63% (indigenous) and 70% (Hybrid). It can also be deduced from the result that nutrient storage in hybrid cocoa outputs (fresh leaf, cocoa bean and pod husk) aggravate soil nutrient degradation than native varieties.

Nutrient concentration in leaves according to Robert (1996) and Edward (1996) serves as an index of the influence of soil fertility since all leaves have the basic function and all use the same nutrients in photosynthesis and construction of organic materials. Therefore, it can be deduced that the nutrient return from vegetation to the soil depends on the nutrient uptake by the plant parts. The result from this study shows that the magnitude of nutrient concentration in aboveground cocoa plant ranges from fresh leaf to cocoa bean. Thus, the order of nutrient concentration in cocoa plant can easily be expressed as follows: *fresh leaf>litterfall; pod husk>cocoa bean.*

Table 3: Regression Coefficient of Soil Nutrient Loss in Indigenous Cocoa Plantations

	Model	Unstandardized Coefficient		Standardized Coefficient		
		B	St. Error	Beta	t	sig.
Idanre	(Constant)	.825	.607		1.360	.207
	Fresh Leaf	.003	.035	.017	.093	.928
	Bean	.495	.079	1.568	6.273	.000
	Pod Husk	-.209	.042	-1.410	-4.950	.001
Owo	(Constant)	.680	.455		1.495	.169
	Fresh Leaf	-.110	.083	-.748	-1.324	.218
	Bean	.657	.084	1.908	7.838	.000
	Pod Husk	-.099	.048	-1.011	-2.083	.067
Odigbo	(Constant)	.995	.497		2.000	.076
	Fresh Leaf	-.014	.029	-.125	-.497	.631
	Bean	.371	.075	1.605	4.950	.001
	Pod Husk	-.112	.026	-1.441	-4.307	.002

a. Dependent Variable: Soil Properties, P<0.05
Source: Authors Data Analysis (2014)

P-values of cocoa bean and pod husk (0.00, 0.001 and 0.002) are less than significant value (P<0.005) in all cocoa producing communities under this study. This implies that the contribution of cocoa bean and pod husk in soil nutrient loss is statistical significant compared to the negligible impact of the fresh leaf. The lowest contribution in Idanre may be attributed to the influence of weathered parent materials and ideal location (tropical rainforest). Idanre is found to be at the central part of cocoa producing region with viable and suitable environmental conditions favourable to cocoa production compared to Owo. Owo is located close to the northern part of the state, hence, the impact of climatic in terms of high temperature and low rainfall which directly influenced soil properties cannot be ruled out. Literature revealed that there is correlation between climate, vegetation and soil alignment from the north to the south. The regression coefficient result, predictive model of soil nutrient loss was generated for each location. From the model, pod husk has the highest contribution rate to the soil degradation, followed by cocoa bean in all locations. Hence, soil fertility degradation under indigenous and hybrid cocoa plantations can better be explained in order of pod husk > cocoa bean > fresh leaf.

Table 4: Regression Coefficient of Soil Nutrient Loss in Hybrid Cocoa Plantations

	Model	Unstandardized Coefficient		Standardized Coefficient		
		B	St. Error	Beta	t	sig.
Idanre	(Constant)	.919	.590		1.556	.154
	Fresh Leaf	.010	.017	.124	.563	.587
	Bean	.350	.089	1.353	3.929	.003
	Pod Husk	-.155	.044	-1.285	-3.518	.007
Owo	(Constant)	.853	.613		1.390	.198
	Fresh Leaf	.194	.062	.780	3.104	.013
	Bean	.670	.087	3.070	7.677	.000
	Pod Husk	-.640	.087	-3.679	-7.369	.000
Odigbo	(Constant)	.825	.607		1.360	.207
	Fresh Leaf	.003	.035	.017	.093	.928
	Bean	.495	.079	1.568	6.273	.000
	Pod Husk	-.209	.042	-1.410	-4.950	.001

a. Dependent Variable: Soil Properties, P<0.05
Source: Authors Data Analysis (2014)

P-values of 0.587, 0.013 and 0.928 for fresh leaf shows that nutrient removed for the fresh leaf development is not statistical significant in terms of its contribution to the soil nutrient loss. This may be attributed to the fact that the removed nutrient for formation and development returns back to the soil through litterfall. Therefore, its negligible impact may not adversely affect the soil fertility unlike cocoa bean and pod husk. However, impact of the fresh leaf was negligible. From nutrient cycle processes, parts of the nutrient remove from the soil for plant physiognomy development return back to the soil via litterfall. Therefore, there exist positive and perfect relationship (r = 0.99) between nutrient storage in cocoa fresh leaf and litterfall. Available nutrient in litterfall directly depend on the quantity and quality initially uptake from the soil.

Predictive Multiple Regression Equations on Nutrient Loss

Hybrid Cocoa Plantations

Idanre: Y = 0.919 + 0.124 (FL) + 1.353 (CB) – 1.285 (PH) --------Equation 1

Owo: Y = 0.853 + 0.780 (FL) + 3.070 (CB) – 3.679 (PH) --------Equation 2

Odigbo: Y = 0.825 + 0.017 (FL) + 1.568 (CB) – 1.410 (PH) --------Equation 3

Indigenous Cocoa Plantations

Idanre: Y = 0.825 + 0.017 (FL) + 1.568 (CB) – 1.410 (PH) --------Equation 4

Owo: Y = 0.680 – 0.748 (FL) + 1.908 (CB) – 1.011 (PH) --------Equation 5

Odigbo: Y = 0.995 – 0.125 (FL) + 1.605 (CB) – 1.441 (PH) --------Equation 6

CONCLUSION

There is evidence to proof that soils in these areas are moderately fertile. Perfect and positive relation also exist between the examined variables under indigenous and hybrid cocoa varieties. From the examined cocoa outputs, negative impact of pod husk and cocoa bean cannot be ruled out. Soil nutrient degradation in cocoa plantation directly linked with the quantity and quality of nutrient storage in cocoa bean and its pod husk. The study discovered that hybrid cocoa variables have the capability to degrade soil nutrient than indigenous in cocoa plantation. Hence, to avoid rapid loss of the nutrient, early aging of the plantation and low production, farmers need to adopt the application of pod husk or chemical fertilizers to complement the impact of litterfall.

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