ECOLOGICAL DEGRADATION UNDER SELECTED TREE CROP ECOSYSTEMS IN ONDO STATE, SOUTHWESTERN NIGERIA

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Abstract
Soil and vegetation samples from different tree crop ecosystems over Itagunmodi and Iwo association were collected and analysed to determine the degree and pattern of deterioration of edaphic and biotic elements under these ecosystems. This was carried out to assess the land use planning and management techniques that could be adopted in reducing the rate of soil nutrient deterioration under tree crop ecosystems of the study area. Both primary and secondary data were employed for the study. The field experiment was carried out in five different tree crop ecosystems namely Cocoa I, Cocoa II, Coffee, Cocoa, Kolanut and forest that serve as control. A plot size of 40 m x 25 m was demarcated under each of the six treatments and 60 soil samples at soil depths 0-15 cm and 15-45 cm were collected and analysed. Vegetation parameters such as tree density, tree height, tree girth, basal area and volume of wood were determined within the sampling plots. Descriptive and inferential statistics were used to analyse the data collected. In terms of deterioration index used, the results showed that as much as 90% degradation of nitrogen was recorded under cocoa while organic and exchangeable calcium had over 70% deterioration indices respectively. But under kola a deterioration index of 80% was recorded for exchangeable magnesium. In case of biotic elements, the result showed that cocoa ecosystems were the most degraded, between 80% and over 90%, followed by kolanut (70%) and the coffee (over 50%). The study concluded that the substitution of tropical forest with tree crop resulted in ecological degradation.

Keywords: Ecological degradation, management techniques, soil types, tree crops, tropical forest.

Introduction

The most common human-induced soil degradation practices in Nigeria are those related to deforestation, bush burning and improper agricultural practices (Ekanade and Orimoogunje 2012). Deforestation is pronounced in the forest areas of eastern and western Nigeria where tree crops are commonly planted, for example, cocoa, oil palm, coffee, kola, cashew and rubber (Ekanade and Orimoogunje 2012; Orimoogunje 2014). The cultivation of these crops and other crops and fibres involve the removal of the natural vegetation, thereby exposing the soil to erosion and leaching. The physiognomy of tree crops in the forest areas appears to look like that of the tropical rainforest, as they remain evergreen almost all year round. This gives an impression that trees are growing on a nutrient rich soil although this is not particularly true. In fact studies have shown

that they never maintain the environmental element as does the tropical rainforest (Adejuwon 1987; Ekanade 1991; Ekanade and Orimoogunje 2012). Much attention has been paid in recent times to mitigating soil erosion through physical conservation measures; such are aimed at providing supplementary nutrients and water to meet the crops' needs. Despite this, difficulties are being faced in terms of sustaining productivity because the rates at which the soils are deteriorating seem to be far greater than the rate at which the nutrients are being replenished.

As far as crop production is concerned, the problem of sustaining soil productivity is manifested in two main dimensions. These are declining productivity per unit area of tree crop farms and the dieback. This observation was reflected in the earlier studies of Aweto (1981), Areola (1984), Ekanade (1985), Adejuwon and Ekanade (1987) under different tree cropping systems. They pointed out that soil properties degenerated in quality after the climax vegetation had been removed in humid environment. This phenomenon does not appear to discriminate against a particular type of cultivation because it occurs under both food and tree cropping systems. It is obvious from the ongoing that many studies have been carried out on soil degradation, particularly in the tropics but most of these have been directed towards studying the effects of tree crops on a particular soil type and no comparison with other soil has been documented. In the process of studying the effects of tree crops cultivation on a particular soil type, there is also a need to compare tree crops cultivation on different soil types. Therefore, this study is intended to compare the influence of selected tree crops on the changes of the biotic structure of the environment and suggests appropriate land use planning and management techniques to help reduce the rate of soil nutrient degradation in the study area.

Materials and Methods

Study Area

The study area is the south-western part of Nigeria, which encompasses the Cocoa Research Institute of Nigeria (CRIN) substation in Owena and Akure South Local Government Area of Ondo State. The study area lies between latitudes 07^0 05' and 07^0 15' N and longitudes 005^0 01' and 005^0 05' E. The area is part of the western plains and ranges of Nigeria with much of the area lying approximately between 300 and 600 metres above the sea level (Iloeje 1981). Mean annual rainfall ranges from 1,200 mm to 1450 mm and temperatures are high throughout the year with a mean of about 27°C with annual range of 30°C (Nigeria Meteorological Observation 1962). The natural vegetation of the area is tropical rainforest

characterized by emergence with multiple canopies and lianas. Some of the most commonly found trees in the area include *Melicia excels, Afzeliabipindensis, Antiaris Africana, Brachystegianigerica, Lophiraalata, Lovoatrihiliodes, Terminaliaivorensi, T. superba, Triplochitonscleroxylon,* etc. however, the natural vegetation of the area with the exception of the areas devoted to forest reserve has now been reduced to secondary regrowth thickets and fallow regrowth at ranging stages of development or replaced by perennial and annual crops (Osunade 1991). These perennial crops include cocoa, kolanut and citrus.

Data Collection

Both primary and secondary data were employed for the study. Primary data were obtained from field experiment carried out using six different tree crop ecosystems namely: Cocoa I, Cocoa II, Coffee, Cocoa, Kolanut and forest that serve as control with two different soil associations, namely *Itagunmodi* and *Iwo* associations. A plot size of 40 m x 25 m was demarcated under each of the six treatments and 60 soil samples at soil depths 0-15 cm and 15-45 cm were collected and analysed. Vegetation parameters such as tree density, tree height, tree girth, basal area and volume of wood were determined within the sampling plots. Descriptive and inferential statistics were used to analyse the data collected. In order to quantify the extent of biotic and edaphic degradation resulting from opening up of the tropical rainforest to cultivation of tree crops, the deterioration indices of the soil and vegetation properties were calculated for the various ecosystems. This was calculated as the difference between the mean values of the soil and the vegetation properties in the forest on the one hand and the tree crop plant community on the other. The computed differences were then expressed as the percentage of the mean value of such a forest property. The computation of the index of deterioration is based on the assumption that the status of any property whether soil or vegetation in a cultivated plant community was once the same as that in the forest before the removal of the original vegetation. In essence, the mean level of a soil or vegetation property in the forest is regarded as the optimal level.

Results and Discussion

Soil Properties

The mean values of soil properties under forest, cocoa, kola and coffee at the Owena and Ibule study areas are given in tables 2 and 3 for both topsoil and subsoil respectively. Table 2 showed that most of the topsoil properties were lower under cocoa, kola and coffee units than that of

forest unit. For example, moisture content under forest topsoil is 2.99%, whereas it is 2.67% under coffee, 2.54% under cocoa in Ibule and as low as 1.91% under kola. It can also be seen that, most of the degraded topsoil properties under cocoa, kola and coffee are the chemical and nutrient elements, these include organic matter, whose content under forest topsoil is 4.4%, 2.26% under coffee but it is as low as 1.47% under kola, and 1.1% under cocoa in Ibule. Also, total nitrogen is high under forest compared to the rest of the tree crops ecosystem (forest, 1.11%; kola, 0.9%; coffee, 0.9% and cocoa in Ibule, 0.8%). It is evident from table 1 that the magnesium (3.79 mol/kg) and calcium (10.14 mol/kg) are higher under forest than under the tree crops ecosystems. However, it could be observed that while potassium (0.73 mol/kg) and sodium (0.39 mol/kg) are higher under forest than most of the tree crops. The mean values of potassium (1.05 mol/kg) and sodium (1.17 mol/kg) are higher under coffee. Similarly, exchangeable potassium is higher under cocoa in Owena. Although, available phosphorus (18.62 ppm) under kola is higher than that under forest (14.51 ppm), it is lower under other ecosystems. Clay content was higher under forest while sand and silt contents were similar under forest and the tree crops ecosystem as shown in table 2. Also, most of the nutrient elements were higher under coffee than under other tree crops ecosystems.

Table 1: Mean Value of Topsoil Properties under Forest and Selected Tree Crops Ecosystem

Properties	**Forest**	**Cocoa I (Ibule)**	**Cocoa II (Ibule)**	**Cocoa (Owena)**	**Coffee**	**Kola**
Sand (%)	65.27	68.20	62.60	69.70	63.20	64.40
Silt (%)	20.32	22.50	26.20	20.90	24.60	24.80
Clay (%)	14.41	9.03	11.20	9.40	12.20	10.80
Moisture content (%)	2.99	2.20	2.54	2.11	2.67	1.91
pH ($CaCl_2$)	6.79	6.49	6.44	6.59	6.73	6.55
Organic matter (%)	4.40	1.10	1.29	1.74	2.26	1.47
Phosphorus (ppm)	14.51	5.63	5.75	7.33	6.08	18.62
Total nitrogen (ppm)	1.11	0.08	0.10	0.10	0.90	0.90
Potassium (mol/kg)	0.73	0.56	0.64	0.90	1.05	1.03
Sodium (mol/kg)	0.39	0.14	0.15	0.17	1.17	0.15
Magnesium (mol/kg)	3.79	1.20	1.48	1.19	1.52	1.07
Calcium (mol/kg)	10.14	2.25	2.57	3.20	4.14	2.96

The mean values of soil properties were lower in the subsoil than in the topsoil under all ecosystems (tables 1 and 2). Furthermore, the moisture content and chemical properties under forest were higher than under other tree crops ecosystem while exchangeable potassium was higher under cocoa in Owena site (1.01 mol/kg) and kola (0.89 mol/kg) than under forest (0.88 mol/kg).

Table 2: Mean Value of Subsoil Properties under Forest and Selected Tree Crops Ecosystem

Properties	Forest	Cocoa I (Ibule)	Cocoa II (Ibule)	Cocoa (Owena)	Coffee	Kola
Sand (%)	55.75	75.20	61.00	64.90	62.80	61.80
Silt (%)	24.01	17.20	24.20	23.50	22.60	22.60
Clay (%)	20.04	7.60	14.80	11.60	14.60	15.60
Moisture content (%)	3.07	1.85	1.86	2.25	2.09	2.92
pH($CaCl_2$)	7.01	6.40	6.50	6.47	6.38	6.58
Organic matter (%)	2.30	1.17	1.34	1.06	1.26	1.60
Phosphorus (ppm)	12.61	6.32	6.00	6.22	6.01	5.90
Nitrogen (ppm)	0.53	0.09	0.11	0.11	0.10	0.11
Potassium (mol/kg)	0.88	0.51	0.58	1.01	0.52	0.89
Sodium (mol/kg)	0.18	0.14	0.15	0.15	0.15	0.16
Magnesium(mol/kg)	2.52	0.96	0.84	1.00	1.19	0.93
Calcium (mol/kg)	4.67	2.18	2.14	2.66	2.60	3.30

Vegetation Properties

Table 3 showed the mean values of biomass elements under all the ecosystems in the study area. The forest ecosystem had the highest mean values in terms of tree height, 11.14 m; tree girth, 1.5 m; tree basal area, 0.18 m^2; volume of wood, 1.99 m^3. Cocoa on Itagumodi soil association had the highest value for tree height (8.04 m) among the other tree crop ecosystems.

Table 3: Mean Values of Biomass Elements under Forest, Cocoa, Coffee and Kola in the Study Area

Tree Crop	Tree Height (m)	Tree Girth (m)	Tree Basal Area (m^2)	Volume of Wood (m^3)
Cocoa I (Itagumodi)	5.09	0.66	0.035	0.178
Cocoa II (Itagumodi)	8.04	0.82	0.053	0.426
Cocoa (Iwo)	7.45	0.64	0.033	0.246
Coffee (Iwo)	5.32	1.41	0.158	0.841
Kola (Iwo)	6.43	1.00	0.080	0.514
Forest	11.14	1.50	0.179	1.993

However, coffee on Iwo association had the higher mean values for tree girth (1.41 m), tree basal area (0.16 m^2), and volume of wood, (0.84 m^3) than those of cocoa and kola on Iwo association.

Deterioration of Components under Selected Tree Crops Ecosystems

Table 4 showed the mean values of soil properties of selected tree crops in the study area. Most of the topsoil properties were significantly ($p < 0.05$) lower under cocoa than the rest of the tree crops ecosystem. The exchangeable cations, especially sodium magnesium and calcium had significantly deteriorated while organic matter, moisture content, phosphorus and nitrogen also reduced. But nitrogen appeared to be the only element that was highly degraded under the entire tree crops ecosystem when compared together. This established the fact that nitrogen is highly required by many crops. The soil (Itagunmodi) under cocoa had the highest level of soil quality degradation followed by kola (Iwo Association). There was no significant difference in potassium for the entre tree crops ecosystem. Comparable pattern of degradation of exchangeable cations under cocoa, precisely sodium, magnesium and calcium at 1% level of significance were recorded, while they are less degraded under coffee and kola. Phosphorus is substantially degraded only under cocoa (Itagunmodi).

Table 4: T-test calculated Values per Plot of Topsoil Properties of Tree crops Ecosystems

Properties	Cocoa I (Itagunmodi)	Cocoa II (Itagunmodi)	Cocoa (Iwo)	Coffee (Iwo)	Kola (Iwo)
Sand	0.06	0.07	0.14	0.11	0.02
Silt	0.48	0.20	0.31	0.23	0.40
Clay	0.04	0.65	0.01	0.67	0.17
Moisture content	9.19**	1.72	9.26**	1.37	18.00**
pH	0.68	0.88	0.48	0.02	0.60
Organic matter	4.31*	1.96	1.09	1.37	4.07**
Phosphorus	2.77*	2.61*	1.31	0.27	0.20
Nitrogen	396.15**	415.09**	392.86**	80.76**	84.00**
Potassium	0.06	0.75	0.11	0.86	1.25
Sodium	62.50**	6.00**	44.00**	195.00**	7.06**
Magnesium	5.89**	3.67**	5.65**	0.05	2.16
Calcium	10.52**	7.80**	2.67*	0.19	7.40**

*Significant at the 5% level ** Significant at the 1% level

Table 4 shows that topsoil is mostly deteriorated under cocoa followed by kola while the soils are less deteriorated under coffee. It can be inferred that there is higher level of nutrient uptake by cocoa than the rest of the tree crops ecosystem. Table 5 shows the result of vegetation properties in the selected tree crops ecosystem.

Table 5: T-test calculated Values per Plot of Vegetation Properties of Selected Tree Crops Ecosystem

Tree Crop	Tree Height	Tree Girth	Tree Basal	Volume of wood
Cocoa I (Itagumodi)	7.90**	4.31**	12.34**	12.17**
Cocoa II (Itagumodi)	2.29*	2.34*	5.73**	3.22**
Cocoa (Iwo)	5.32**	17.88**	12.98**	7.32**
Coffee (Iwo)	22.28**	0.03	0.009	3.44**
Kola (Iwo)	17.23**	2.82*	10.32**	8.43**

*significance at the 5% level ***significance at the 1% level

The table indicates that the tree height, tree girth, tree basal area and volume of wood are significantly lower under all tree crops ecosystems. However, all the biotic elements are mostly deteriorated under cocoa followed by kola while tree height and volume of wood are deteriorated under coffee when compared with our control, forest.

Implication of the Study

The study showed that both the edaphic and biotic elements of tree crop communities had been significantly degraded. The degradation of these environmental components in the tree crop communities has not yet been given enough attention, despite the problems being faced (Adejuwon 1971; Ekanade and Orimoogunje 2012). The removal of the forest vegetation leads to land exposure, and hence, soil quality reduction. It is a common practice in the Nigerian Cocoa Belt for peasant farmers to plant tree crops in the early period of cocoa cultivation (Are and Gwynne 1974; Ekanade and Orimoogunje 2012). This practice aggravates the openness of the land consequent upon the forest removal. Also, in the management of food crops, such as maize, cassava and yams, many trees are cut down in order to reduce shade since these crops do not require shade for high production. In addition, the constant weeding of plots also contributes to their susceptibility to soil erosion process. Ekanade (1985) suggested that the degradation of soil's physical properties, especially under cocoa, could

be an indication of mechanical eluviation. He was of the opinion that erosion by surface run-off could have occurred, during the first few years, when the plots used to cultivate tree crops were simultaneously used to cultivate arable crops, so that when the land is later used for tree crop cultivation, it could have failed to completely recover from the earlier erosive processes. One important reason for the high level of edaphic degradation under cocoa is that, the rate of nutrient uptake by cocoa probably exceeds the rate of nutrient return to the soil since certain crucial nutrients in the cocoa pods, beans and nuts are immobilized (Lorkard and Burridge 1965; Ogutuga 1975) and eventually removed from the cocoa ecosystem and the nutrient cycling process. However, nutrient return from vegetation to the soil depends on the nutrient uptake by the biomass of each plant community (Bazilevich and Rodin 1967).

Therefore, in a homogeneous environment, the stages of development of plant communities will affect both the nutrient uptake and nutrient return of the vegetation, which could cause differentiation of soil properties under various plant communities as evident under the tree crops. In the case of the latter, the tendency in most cases is that the rate of nutrient uptake exceeds the rate of nutrient return to the soil thereby causing a decline in soil nutrient status. It seems that nutrient immobilization in the tissues of these tree crops is not matched by the rate of nutrient return to the soil through the fall and mineralization of litter (Lal 1975). The overview of the Nigerian Cocoa Belt shows that the biotic and edaphic components of the rural areas have almost been totally destroyed in this tropical rainforest environment. It also appears that the process of this land degradation has been systematic in the rural areas of the Nigerian Cocoa Belt.

Another important reason for the observed degradation of edaphic and biotic elements of the tree crop communities relates to the management practice of these plant communities. The clearing of these plantations is usually done by fire during the dry season. Although, this method has some agronomic advantages, its effect on the edaphic elements is most adverse. When fire is applied in the dry season, which is the period of high litter accumulation, the subsequent decomposition and mineralization of the litter at a later time is not possible since the litter has been burnt. In addition, most organic life, for example, the macro-fauna such as termites and earthworms are destroyed thereby greatly impairing their role in the nutrient cycling process. Fire could also affect the physical properties of soil adversely (Oyeniyi and Aweto 1986).

Conclusion

This study concluded that the opening of the rainforest to the cultivation of tree crops leads to the degradation of the biotic elements of their ecosystems. This is particularly so with the cocoa ecosystem but to a lesser extent with coffee and kola ecosystems. For instance, deterioration indices under cocoa agro-ecosystems indicated a highly significant degradation of soil and vegetal elements. Furthermore, the soil constituents were related to different land management practices which in turn were associated with different types and degrees of land degradation. The rate of degradation of these elements is bound to continue because, as rightly observed by Kaey (1977), who opined that it is impossible to cultivate any crop or to effect any development process at all without removing the natural vegetation. From this study therefore, sustainable agriculture includes commitment to proper soil management and the application of some measures that can mitigate the biotic and edaphic degradation of the ecosystem.

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