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Changes in Soil Properties under Different Land Use Covers in Parts of Odukpani, Cross River State, Nigeria

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Abstract

Land management practices provide the basis for evaluating sustainability and monitoring environmental impacts. In Calabar, the current land management practice of grass planting along major routes as a way of beautifying and managing degraded areas has not received much research attention. The study examined the dynamics in soil physical and chemical

properties under different land use covers in parts of Odukpani in Cross River State, Nigeria. The quadrat approach was used to randomly collect soil samples from fifteen plots of 5m x 5m across three identified land use covers: roadside soil, 16 year-old rubber plantation soil and a secondary forest soil. Result showed that the contents of CEC, available phosphorus, Ca, Mg and K were considerably higher in the roadside soil than in the rubber and secondary forest soils as a result of road construction and landscaping activities resulting in the introduction of soil with high quantity of clay. The result further revealed that organic carbon and total nitrogen contents were higher in the secondary forest soil than in other land cover soils due to the dense canopy cover that helped in nutrient accretion in the soil by minimizing the loss of nutrients through soil erosion and leaching. To maintain soil nutrient for ecological sustainability in line with the changing landscape in the area, trees along with grasses are encouraged to be planted, instead of grasses alone as can be seen along major routes in the state.

Keywords: Land use cover, Tree planting, Soil properties, Grass planting, Oduklpani, Road construction, Landscaping

1. Introduction

At different spatial and time scales, vegetation cover helps in protecting the soil from harsh climatic conditions mostly soil erosion. The presence of dense vegetation affords the soil adequate cover thereby reducing the loss in macro and micro nutrients that are essential for plants growth and energy fluxes (Iwara *et al.*, 2011). However, the continuous conversion of vegetal areas to non-vegetal surfaces reduces soil productivity as a result of increased soil erosion and changes in moisture content. Indeed, the concentration of nutrient in the soil is depleted when vegetation is destroyed through numerous anthropogenic activities such as deforestation and land preparation for agricultural production, and road construction among others (Elliot, 2003; Thornley and Cannel, 2000). The change in forest cover to other forms of land cover such as plantation and grassland results in the tremendous modification of canopy cover, thereby making the area affected susceptible to soil erosion; this affects the stock of soil organic carbon (SOC). The conversion of forest ecosystem to other forms of land cover may decrease the stock of SOC due to changes in soil moisture and temperature regimes, and succession of plant species with differences in quantity and quality of biomass returned to the soil (Offiong and Iwara, 2012).

Indeed, changes in land use cover have significant effect on the amount and diversity of biomass returned to the soil, which also disrupt the richness of nutrient restored to the soil. It is perhaps a known fact that soil erosion intensity and amount of nutrient element loss varies depending on the vegetation type at a particular place and time. This is so because, the rate of nutrient element loss in both dissolved and sediment bound forms will depend on the ability of vegetation canopy to effectively intercept the direct impact of raindrops that strike the soil surface (Iwara, 2011). If the canopy is not dense enough or well developed, low quantity of nutrients will be returned to the soil as well as large quantities of nutrient will be removed from the soil surface during periods of heavy rainstorm when the soil is saturated. Earlier studies have emphasized the negative effect of land use/cover change on soil properties. For example, Agoume and Birang (2009) examined the impact of land-use systems on some physical and chemical soil properties of an Oxisol in the humid forest zone of southern Cameroon. Result showed that land-use systems significantly affected the clay, the silt and the sand fractions. Sand and silt decreased with the soil depth whereas clay increased with it. Soil pH, total N, organic carbon, available P, exchangeable Ca, exchangeable Al, sum of bases, ECEC and Al saturation significantly differed with the land-use systems. Al saturation increased with soil depth, and the top-soils presented acidity problems while the sub-soils exhibited Al toxicity. *Chromolaena odorata* fallows presented relative higher soil fertility, secondary forests and cocoa plantations the lower. Lal (1996) and Shepherd et al. (2000) noted that land use change in tropical ecosystems could cause significant modifications in soil properties. In stressing the effect of this phenomenon on the ecosystem, Schipper and Sparling (2000) posited that land use change modifications are biologically and chemically more rapid than physically, as forest ecosystems are important both ecologically and economically. Forest soils are one of the major sequesters of carbon on earth due to their high organic matter status (Dixon et al. 1994), as such any land development effort or landscaping activities such as what is obtainable in the study area must mimic the characteristics of forest

ecosystem. It is only through such healthy practice that the ecological components such as soil can be enhanced and sustained.

Furthermore, Gol (2009) investigated the effects of land use change on soil properties and organic carbon at Dagdami river catchment in Turkey. Result indicated that saturated hydraulic conductivity (Ksat), bulk density (BD), water stable aggregates (WSA), soil organic matter (SOM), soil organic carbon (SOC) and total nitrogen significantly changed with land use type and aspect. In addition, the study reported significantly higher values of saturated hydraulic conductivity (Ksat) in natural forest top soil (82.4 $cm^3 h^{-1}$ on average) compared to grasslands soils (8.4 $cm^3 h^{-1}$) and hazelnut garden soils (11.5 cm^3 h-1) and corn field soils (30.0 $cm^3 h^{-1}$). WSA was greater in the pasture and forest soils than in cultivated soils. In addition, Ksat had the highest value in the forest soils at all aspects while, SOM and SOC of forest soils were higher than other land use types. Furthermore, the amount of SOM and SOC of soils of grassland, hazelnut garden and cornfield were low level and close to each other. Offiong *et al.,* (2009) compared soil properties in undisturbed secondary forest and soil adjoining the road in Tinapa area of Cross River State. Result indicated that the levels of organic matter, total nitrogen and cation exchange capacity were substantially higher in soils of the undisturbed secondary forest than in soils adjoining the road. Zhao *et al.,* (2008) studied the effect of land cover change on soil phosphorus fractions in Southeastern Horqin sandy land, northern China. Results showed that organic P dominated and was the principal source of available P. The degradation of elm savanna to grassland significantly reduced soil pH and resulted in an overall reduction in soil fertility, although slightly increased labile inorganic P. Grassland afforestation had no significant influence on soil pH, organic carbon, and total N but significantly reduced total P. Impacts of grassland afforestation on soil P fractions depended on tree species. Natural elm savanna had higher soil P conserving ability than artificial plantations. The study suggested the planting of trees with low nutrient demand (particularly P) and efficient nutrient cycling as being more suitable for ecosystem restoration. The above studies reveal that change in land use/cover can cause significant variations in soil properties, terrestrial cycles and reduction in soil output.

In Odukpani Local Government Area of Cross River State, just like in other parts of the state, change in land use cover is an emerging phenomenon as a result of the state government's drive to making the state the ideal tourism destination in Nigeria. In this regard, a lot of landscaping work has been embarked upon by the government like the planting of grasses along road verges as a way of beautifying the state and to control soil erosion among other ecological services. The landscaping activities are characterized by the introduction of sand in degraded areas, to ease the planting exercise. In some areas, trees are felled to make way for grasses; such a practice could be ecological unwise in terms of its ability to suppress soil erosion. Different studies have examined the effects of land use/cover change on soil physico-chemical properties (Lal, 1996; Bossuyt *et al.,* 1999; Eneji *et al.,* 2003; Evrendileka *et al.,* 2004; Igue, 2007; Emadi *et al.,* 2008; Zhao *et al.,* 2008; Agoume and Birang, 2009, Gol, 2009; Offiong *et al.,* 2009). These studies nevertheless characterized changes in soil properties in relations to emerging land use/cover change in their respective ecosystems. On this note, more studies are indeed required to understand the effect of emerging land

management practices such as landscaping characterized by grass planting on soil nutrient sustainability. According to Gol (2009), land management practices provide essential information for assessing sustainability and monitoring environmental impacts. In Calabar, with the current changing pattern of land use cover, mostly the introduction of grass planting, there seems to be paucity of literature on the ecological implication of this emerging phenomenon on the soil. It therefore becomes perturbing to investigate the impact of this current land management practice on soil fertility in order to suggest possible ways through which the inherent land-use system can be ecologically sustainable.

2. Materials & Methods

2.1 Study Area

This study was conducted in Odukpani community in Cross River State, Nigeria. Odukpani is a Local Government Area in Cross River State, Nigeria. Odukpani Local Government Area lies between latitude 5^0 25^1N and longitude 25^0 00^1E. Odukpani falls within the rainforest zone of Cross River State where the rainy season lasts for about 10-11 months with the dry months having less than 60 mm of rainfall. It has temperature with average daily maximum of 35^0C. The rainy season has a short dry period called "August Break" or short dry season, which last between 2 to 4 weeks. The topography of the area is undulating with gradual rise and fall. The area is well drained such that run-off water disappears 30 minutes after a typical rainstorm (Eze, 2008). The highest elevation is about 300 meters and lowest of about 50 meters above sea level. The soils in Odukpani are generally deep, porous, weakly structured, well drained with low to moderate status, and where vegetation cover is removed due to human activities, the soil is vulnerable to active sheet and gully erosion. The area serves as a corridor of development to complement the tourism development initiatives of the state. The area is currently undergoing rapid development and changes in vegetation cover as a result of the influx of people into the state and the increasing need for housing. Presently, people prefer residing in the area as a result of its low social vices and serene environment.

2.2 Sampling Procedure

This study evaluated the effects of vegetation cover on soil properties by comparing the properties of soils of 16 year-old rubber plantation, roadside vegetation and a secondary forest. The 16 year-old rubber plantation plot is a monoculture land with undergrowths located in Pamoil Nigeria Ltd; the roadside vegetation comprised a stretch of land dominated by grasses with few tree stands, while the secondary forest plot is characterized by a dense vegetation (tall trees/shrubs) with numerous undergrowth, at Odukpani which is less than 3km from the 16 year-old rubber plantation plot. The study sites have similar soil parent materials, topography and climate. Field survey and soil sampling was carried out using the quadrat approach. In each identified and delineated land use cover, five plots of 5m by 5m were established, after which soil samples were randomly collected from the 0 – 10 cm layer of the soil using a soil auger. In all, 15 soil samples covering the three study sites were collected.

2.3 Laboratory Analysis

The soils were stored in zip-loc bags and placed in a cooler to keep the samples at a moderate temperature. They were then taken to the laboratory for analysis of soil physical and chemical properties. Particle size composition was determined using the hydrometer method (Bouyoucos 1926); organic carbon by the Walkley-Black method (1934); total nitrogen by the Kjeldahl method (Bremner and Mulvaney 1982); available phosphorus was determined by the method of Bray and Kurtz (1945). The soils were leached with 1M neutral ammonium acetate to obtain leachates used to determine exchangeable bases and soil cation exchange capacity, while pH values were determined using a glass electrode testronic digital pH meter with a soil: water ratio of 1:2.

2.4 Data Analysis

The obtained soil data were analyzed using tables, averages, Pearson's correlation and One-Way analysis of variance. The One-Way analysis of variance was performed to determine if the properties of soil varied significantly among the various land covers, while Pearson's correlation was employed to determine the nature of association between the soil variables in order to understand the possible factors that affected their buildup in the soil

3. Result and Discussion

3.1 Physical Properties of Soils

The particle size composition of soil in the three land covers are depicted in Table 1. The soils are principally sandy; with sand accounting for more than 75% of the inorganic mineral fragment in the soil. The proportion of sand was higher in the secondary forest and 16 year-old rubber plantation soils. This is so as the study area is a part of the coastal plain of southern Nigeria which is characterized by very sandy soils over wide expanses of land (Aweto and Enaruvbe, 2010). There was significant variation in sand content under soils of different land cover ($p<0.01$). The amount of silt and clay in the three soil communities was small compared to the value obtained for sand; silt contents were higher in the secondary forest soil and 16 year-old plantation soil with mean values of 8.22% and 8.20% respectively, but in roadside soil the mean value was 4.60%. The increase in silt content in the secondary forest and 16 year-old old plantation soils is attributed to the development of dense cover which helps to suppress soil erosion. Silt content varied significantly under soils of different land cover ($p<0.05$). Clay content was much higher in the roadside soil than in the other land covers with mean value of 16.80% (Table 1). The high amount of clay in the roadside soil is attributed to road construction and landscaping activities, during which soil with probably large amount of clay is introduced. There was significant variation in clay content under soils of different land cover ($p<0.05$). However, the particle size composition of soils in the different land cover is insignificant; as soils in the area are texturally similar, being loamy-sand and having been derived from the same parent material (granite) under the same climate and topography.

Table 1. Physical properties of the soils[a]

Soil properties	Secondary forest soil	Rubber soil	Roadside soil	F-values
Sand (%)	85.80±0.80	86.80±0.20	78.60±1.41	22.40*
Silt (%)	8.22±0.49	8.20±0.49	4.60±0.80	11.57+
Clay (%)	5.78±1.01	5.00±0.49	16.80±2.06	23.27+

[a] values are means ± standard errors.

* Difference between means is significant at 1% alpha level.

+ Difference between means is significant at 5% alpha level

3.2 Chemical Properties of Soils

The chemical properties of soils under different land cover are shown in Table 2. The soils of the area are acidic with a pH range of 4.06 to 5.20. The acidic nature of the studied soils is attributed to the high rainfall resulting in the leaching of some basic cations especially calcium from the surface horizons of the soils (Foth 2006; Abua *et al.*, 2010; Iwara *et al.*, 2011). The content of pH varied significantly under soils of different land covers ($p<0.01$) (Table 2). The pH value obtained in this study agrees with the findings of Agbede (2008) that the pH in Nigeria derived savanna and forest soils falls with the range 4.5 - 7.5. The contents of organic carbon (OC) and total nitrogen (TN) were high in the secondary forest soil, and low in roadside soil with mean values of 1.93% and 0.46% as well as 0.97% and 0.24% respectively. The mean OC contents of the studied soils ranged from 0.97 – 1.92% and were rated as low (below 2%) (Chude *et al.*, 2011; Reid and Dirou, 2004). While, TN content of the soils ranged from 0.24 to 0.46% (Table 2); this range of value was rated as medium when compared to the medium range of 0.10 to 0.45% recommended by Holland *et al.*, (1989). This range is however, consistent with the works of Ukaegbu and Akamigbo (2005) who reported average total N percentage of 0.08 in soils of the Cross River Coastal plain sands. The increase in the contents of OC and TN in the secondary forest soil is attributable to the increase in plant density and cover which provides large amount of biomass that decomposes to form nutrient in the soil. The proportion of OC and TN varied significantly under soils of different land covers (Table 2).

Table 2. Chemical properties of the soils[a]

Soil properties	Secondary forest soil	Rubber soil	Roadside soil	F-values
pH	4.07±0.16	4.06±0.02	5.20±0.39	8.60*
OC (%)	1.93±0.28	1.04±0.19	0.97±0.05	7.31*
TN (%)	0.46±0.07	0.25±0.05	0.24±0.01	5.31+
Av. P (mg/kg)	8.65±0.99	21.90±6.31	48.85±1.68	28.85*
CEC (cmol/kg)	4.45±0.27	4.96±0.22	7.47±1.53	3.94 ns
Ca (cmol/kg)	0.77±0.05	0.38±0.05	1.43±0.09	63.84*
Mg (cmol/kg)	0.23±0.02	0.16±0.01	0.75±0.02	447.91*
Na (cmol/kg)	0.39±0.02	0.72±0.02	0.10±0.01	448.86*
K (cmol/kg)	0.08±0.01	0.07±0.00	0.49±1.33	1.15 ns

[a] values are means ± standard errors.

* Difference between means is significant at 1% alpha level.

+ Difference between means is significant at 5% alpha level

Ns= Not significant at 5% alpha level

The content of cation exchange capacity (CEC) happened to be higher in the roadside soil with a mean value of 7.47cmol/kg than in other land cover soils. The high content of CEC in roadside soil may be attributed to road construction and landscaping activities resulting in the introduction of soil with high clay content. Reid and Dirou, (2004) opined that both clay and organic matter serve as potential sources of nutrients by attracting cations; as such, soils with large amounts of clay or organic matter have higher exchange capacities than sandy soils, which are usually low in organic matter. The proportion of CEC did not vary under soils of different land covers ($p>0.05$). In similar way, the content of Av. P was highest in roadside soil followed by the 16 year-old rubber soil and the secondary forest soil with mean values of 48.85mg/kg, 21.90mg/kg and 8.65mg/kg respectively. This result is spurious and may be attributed to the increase in CEC content in the roadside soil. The proportion of available phosphorus (Av. P) varied significantly under soils of different land cover. The available P content in the secondary forest soil was rated as moderate as values are below 15mgkg (FPDD, 1990). This range of value is consistent with the findings of Ekundayo (2004) who reported near mean value of 10mgkg for arable soils of south-eastern Nigeria; while Av. P contents in the rubber and roadside soils were rated as high with mean values above 15mgkg. In addition, the higher Av. P content in the 16 year-old rubber plantation compared to the secondary forest soil may be attributed to the addition of supplement (agro-chemicals) to enhance soil fertility (Ekukinam, 2010). The proportions of exchangeable bases (Ca, Mg, Na and K) were low across the studied soils. Low values of Ca, Mg and K have however been reported for most Nigerian soils (Akinirinde and Obigbesan, 2000; Uzoho *et al.*, 2007) and are attributed to leaching losses by the high tropical rainfall as well as low content in the parent rock. However, critical values of exchangeable cations have been reported by various researchers. For instance, Adeoye and Agboola (1984) reported critical values of 2.0, 0.4 and 0.20 cmol/kg for Ca, Mg and K respectively. These figures when compared with the values obtained for the studied soils, show high values for the roadside soil and low values for the rubber and secondary forest soils. The contents of Ca, Mg and Na varied significantly under

soils of different land covers ($p<0.01$), while the content of K did not vary ($p>0.05$) (Table 2). However, the high Ca, Mg and K contents in roadside soil may be attributed to the clay proportion of the soil layer (Reid and Dirou, 2004).

3.3 Pearson's Correlation Matrix of Soil Properties

The Pearson's correlation matrix in Table 3 shows that clay content had high, positive and significant relationship with silt ($r = 0.99$, $p<0.05$), while it also indicates high, negative and significant relationship with sand ($r = -0.99$, $p<0.05$). This implies that increase in clay significantly increases the amount of silt in the soil, but decreases the proportion of sand. In addition, TN had high, positive and significant relationship with OC ($r = 0.99$, $p<0.05$). This is obvious as the contents of TN in the soil are a function of the amount of organic matter (OM) and vice versa. Peaceful Valley Farm Supply Technical Booklet (2004) noted that the higher the organic matter the higher the potential N released in the soil. In addition, it implies that both are influenced by the accumulation of biomass in the soil layer. The Pearson's result also indicates that Mg and K had high, positive and significant relationships with clay ($r = 0.99$, $p<0.05$), but negative and significant relationships with sand and silt respectively ($r = -0.99$, $p<0.01$). This is evident as the proportion of clay in the soil is recognized to positively increase the amount of nutrients in the soil (Reid and Dirou, 2004; Peaceful Valley Farm Supply Technical Booklet, 2004; Aweto and and Enaruvbe, 2010). The Pearson result further depicts that high, positive and insignificant relations were found between sand and silt, sand and Na, clay and Ca, clay and Av. P, between Av. P and CEC as well as K, pH and CEC amongst others, while high, negative and insignificant associations were found between sand and CEC, pH, K and Ca, clay and Na, as well as between Ca and Na (Table 3). The high positive associations imply that the soil properties are influenced by similar climatic, pedogenic and biotic factors that are likely to influence the buildup of nutrients in the soil, while the negative associations mean that the soil properties are not influenced by similar climatic, pedogenic and biotic factors.

Table 3. Pearson's correlation matrix of soil properties

	Sand	Silt	Clay	OC	TN	Av. P	Ca	Mg	Na	K	CEC	pH
Sand	1.00											
Silt	0.99	1.00										
Clay	-0.99*	0.99*	1.00									
OC	0.46	0.55	-0.52	1.00								
TN	0.45	0.55	-0.51	0.99^{+}	1.00							
Av. P	-0.90	-0.95	0.93	-0.79	-0.79	1.00						
Ca	-0.97	-0.93	0.95	-0.21	-0.20	0.76	1.00					
Mg	-0.99^{+}	-0.99	0.99*	-0.45	-0.44	0.90	0.97	1.00				
Na	0.90	0.85	-0.87	0.03	0.02	-0.63	-0.98	-0.91	1.00			
K	-0.99	-0.99^{+}	0.99*	-0.54	-0.54	0.94	0.93	0.99	-0.85	1.00		
CEC	-0.96	-0.98	0.90	-0.68	-0.67	0.99	0.86	0.96	-0.74	0.99		
pH	-0.99	-0.99^{+}	0.99	-0.55	-0.55	0.95	0.93	0.99	-0.85	0.99^{+}	0.99	1.00

*. Correlation is significant at 0.05 level (2- tailed)

$^{+}$. Correlation is significant at 0.01 level (2-tailed)

4. Conclusion/Recommendations

It is apparent from the study that changes in land use cover have significant impact on the availability of nutrients in the soil. This is evident as areas with sparse vegetation cover are susceptible to soil erosion processes resulting in the loss of organic matter and other essential nutrient from the soil layer. This is observed in the roadside soil with low vegetation and sparse cover resulting in the low OC and TN contents. However, the high contents of CEC, available phosphorus, Ca, Mg and K in the roadside soil are attributable to road construction and landscaping activities resulting in the introduction of sand with high clay content. The high quantities of OC and TN in the secondary forest soil show that land areas that mimic forest ecosystem have significant effect on the buildup of nutrients in the soil; this is because dense canopy cover helps in nutrient accretion in the soil by minimizing the loss of nutrients through soil erosion and leaching. It also enhances the production of more litter as well as provides the needed temperature for bacteria, fungi, micro-fauna and other soil microbes that facilitate organic matter decomposition, thereby facilitating carbon sequestration in the soil. However, to maintain the stock of soil organic carbon in soil in line with changing landscape, trees whose height are controllable should be planted along with grasses, instead of grasses alone as could be seen in major routes in Calabar. The planting of trees with controllable heights will help in carbon sequestration and the maintenance of nutrient in the soil for continuous energy fluxes. Tree planting perhaps should be the major priority. Proper afforestation of land according to Lal (2005) can reverse some of the degradation processes and cause enhancement or sequestration of SOC stock and nutrient in the soil. Furthermore, residues from the clearing of grasses/undergrowths should be used to cover the soil surface in order to minimize the effects of erosion in relation to the addition of nutrients in the soil.

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