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Evaluation of Soil Quality in Relation to Landuse Effect in Akamkpa, Cross River State – Nigeria

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Abstract Soil quality variation in the tropical rainforest zone of Akamkpa upon conversion from the natural vegetation to other landuse types (natural forest, reforested lands, cultivated upland soils, swamps, soils around quarry sites, built-up areas and fallow lands) was evaluated with a view to ascertain the changes in physical, chemical and biological characteristics of the soils and determine to what extent these changes affects soil quality degradation rates and vulnerability potential. Surface soil samples were collected from four points in each landuse type at the depth of 0-15cm and mixed to obtain a composite sample for routine laboratory analysis of selected soil quality parameters. The soils were generally sandy loam to clay loam on the surface and lateritic clay at the subsurface. Bulk density varied from 1.12-1.48mgcm^3, soil porosity was higher in cultivated soil (78.83%) and lower in the swamps (25.22%) water holding capacity was highest in swamps (72.9%) and lowest in the built-up areas (33.6%). Aggregate stability index was lower in the cultivated soils (0.44) and higher in the natural forest (0.69). pH value varied from 4.2-6.0, organic carbon levels were higher in the natural forest (9.84gkg) and lowest in built-up areas (4.16gkg^{-1}). Total nitrogen varied from 0.42-0.72gkg, the value was lowest in built-up areas and highest in the natural forest soils. C:N ratio varied from 8.63-13.12. these values were lowest in cultivated soils than natural forest and reforested soils. Available P was highest in fallow lands and lowest in built-up areas. Exchangeable bases show variability across landuse types with calclium, potassium, ECEC higher in natural forest soils. Al^{3+}, SAR, Fe, Mn, Cu and S higher were in soils around quarry mines than any other landuse type. Reforested lands, cultivated uplands and fallow lands showed a slight variability in the selected chemical parameters. The biological properties were highly correlated with soil quality status in response to landuse change types. Total microbial biomass was higher in reforested lands and lowest in built-up areas, while active microbial biomas was higher in fallow lands. Higher rates of qCO_2:T for the cultivated soils, qCO_2:A rates was higher for fallow lands. Resuts revealed that built-up areas and soils around quarry mines has a significantly ower SDR/VP than any other landuse type. Percentage soil quality rating was higher in the fallow land (88.0%), forested lands and reforested lands (83.3%), cultivated uplands (66.0%) swamps (56%), soils around quarry mines (44%) and built-up areas (33%). The findings suggest that the soils under fallow are slightly capable to resist degradation. Management practices such as planting leguminous crops, increased fallow period, organic manuring, planting of fast growing vegetative species and returning crop residues to the soil as a way of building up used carbon stocks.

Keywords: *soil quality, landuse change, tropical rainforest, soil degradation and vulnerability potential*

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1. Introduction

Landuse changes especially cultivation of deforested land may rapidly diminish soil quality, as ecologically sensitive components of the tropical rainforest ecosystem are not able to buffer the effects of agricultural practices and other landuse changes [28]. Population increase is the chief driving force for landuse change in Nigeria. [18] investigated the effects of landuse on soil quality and reported a 41-89% less dispersible clay in the forest than in cultivated areas. The study aversed that frequent cultivation leads to deterioration of soil quality.

Studies carried out by [22,35,40] reported a positive correlation between landuse changes and loss of soil quality especially chemical properties and soil aggregate stability which is considered a soil quality indicator that provides information on the soils ability to function as a basic component of the ecosystem. [39] reported a strong dependence of tropical rainforest soils. [4,19] also reported changes in soil properties such as porosity, soil organic matter, bulk density, due to changes in landuse practices. In another related study [33] & [34] reported correlation between reduced crop yields and decline in soil organic matter content and erodibility of the soils.

Soil microbial biomas has been reported by [2,3,27,44,45,47] as fundamental to maintaining soil function because it is the main source of soil enzymes that regulates transformation processes in soils. It is a potent tool for detecting early indicator of changes in soil chemical and physical properties resulting from land use change and soil management. This study has not been investigated and reported in this area, assessment of soil properties upon conversion of natural forests for varying landuses is of great importance to food security and detecting early changes in soil quality. The study therefore assess and compare the changes in soil properties in response to landuse changes in the tropical rainforest area of Akamkpa.

2. Materials and Methods

2.1. Description of Study Area

This study area is Akamkpa (5°45'-8°21'N and 5°43' and 9°00'E) as a tropical rainforest. The natural forest has been exploited through cleaning and felling to meet demands for food, timber and fuel wood. Over the years this forest has witnessed intense human activities such as farming, lumbering and quarrying activities which has hampered regeneration. The geology of the study area is Oban Massif which is made up of basement complex rocks. Soil properties vary with topography and orientation of the hill-slope. The soils are generally sandy loam soil to lateritic clay soils. The climate of the area is humid tropical, characterized by double maxima rainfall, which starts from the month of April to October, reaching its climax in the month of June and September. The annual average is about 1500-3000mm. temperature ranges from 21°C-23°C in the wet season and 24°C-27°C in the dry season. The area records a relative humidity between 80-100% and vapour pressure in air average 29 millibars throughout the year (NAN, Weather Reports, 2014, CRBDA report 2006).

2.2. Soil Sampling and Processing

Surface soil samples were collected from four points in each landuse type (Natural forest, reforested lands, cultivated upland soils, Swamps, soils were sampled (0-15 depth) and mixed to obtained a composite sample that was sealed in a plastic bag. Field moist soil samples generally sieved to remove stones, big roots and organic residues and sealed in plastic bags and stored at 4°C. Soil biological analyses were carried out within 1 week of sampling.

2.3. Soil Physical and Chemical Properties

Soil particle size analysis was done by the hydrometer method. Soil bulk density (pb) was determined by the core method and total porosity was calculated, Gravimeter water holding capacity (WHC) of soil, was measured by tube method [49]. Aggregate stability (AS) was determined on 1-2mm sieved air-dried soil aggregates by a modified turbid metric method [50]. Soil pH was determined in 1:2.5 soil-water slurry, using a combination glass electrode. Total carbon (C_T) and Nitrogen (N_T) contents were determined by Walkley and Black method as modified by [37,48]. Exchangeable bases: Ca, Mg, Na, K, were extracted using normal ammonium acetate (Thomas, 1982). Exchangeable K and Na were determined by flame photometer while Ca and Mg were determined by atomic absorption spectrophotometer. Exchangeable sodium percentage (ESP) and sodium absorption ratio (SAR) were obtained by calculation.

2.4. Soil Degradation Rating (SDR)

The rating scheme for soil degradation (SDR) developed by [33] based on soil properties was applied in this study. Vulnerability potential (V_P) of the soil quality was added to the scheme. The critical levels of the soil properties were weighted on a scale of 1 to 5 (Table 4) In SDR, a weight of 1 was given when there were no limitations and 5 when limitation was extreme. Reverse was the case for V_P values. In this was good soils have least SDR and poor soils have the highest SDR, whereas in A (V_P) good soils have the highest value (5) and least value (1) for poor soils.

2.5. Soil Biological Properties

The microbial biomases (GmB) was determined by chloroform fumigation incubation method (Jenkinson and Prolson, 1976). The GmB was calclulated as follows:

$$C_{TmB} = \frac{[CO_2 - C_{fum} - CO_2 - C_{unfum}]}{K_C} = \frac{F_C}{K_C} \quad 1$$

Where: F_C is the ‘flush’ of CO_2 (i.e. evolution of CO_2 in fumigated soils minus the evolution of CO_2 in unfumigated soil and K_C in the fraction (0.45) of the microbial biomass C mineralized as CO_2 for 10 days incubation at 25°C.

Active microbial biomas (CAmB) of soil was measured by the glucose – nutrient induced respiration method (Van de Werf and Verstrate, 1987). The CAmB was measured as follows:

$$C_{AMB} = \left[YCO_2 - C_{10_{amend}} - YCO_2 - C_{10_{unamend}}\right] AC \quad 2$$

Where: yCO_2 – $C_{10amend}$ and yCO_2 – $C_{10unamend}$ are the evolution are the evolution of CO_2 from the glucose-nutrient amended and unamended soils during a 10hr incubation respectively and AC in the coefficient (0.283) to convert CO_2-C into CAmB. Basal respiration (BR) was measured as CO_2 evolution from unnamed field-moist soil adjusted to 60% WHC for an invubation period of 10days at 25±1°C in the dark. The BR was calculated as follows:

$$B_R = \frac{[CO_2 - C_{soil} - CO_2 - C_{air}]}{10 days} \quad 3$$

Where is the evolution of CO_2 from soil and is the atmospheric CO_2 absorbed by IM NaOH in a blank Manson jar.

2.6. Statistical Analyses

The LSD procedure was used to separate the means of soil physico-chemical and biological properties at <0.05.

3. Results and Discussion

3.1. Physical Properties of Soils

The physical properties of soils are presented in Table 1. The soils generally have sandy loam to clay loam on the surface and lateritic clay at the subsoil. The sand content varied from 21.80-38.0%, silt (11.60-24.8) and clay (4.2-50.4). The sand content was highest in soils around quarry mines and cultivated uplands, the soils around quarry mines areas and swamps recorded the highest silt content while highest clay content was recorded in swamps and fallow lands. Generally, the silt-clay ratio of the soils was low (0.42-0.59) indicating the advanced stage of weathering of parent materials from which the soils are developed the lower silt and slightly lower clay in other landuse types is probably due to the factor of toposequence as most of the natural forests and swamps are located at the two ends of land height (Upper slope and lower-slope), also preferential removal of silt by accelerated water erosion during high precipitation months [10,32,36,38]. The results of this study indicate high pedogenesis under intensive landuses.

Bulk density varied from 1.12-1.48mgcm^{-3}. The mean value of 1.30mgcm^{-3} was regarded favourable for agronomic purposes, since it enhances root penetration, good aeration and infiltration. Bulk density was higher in soils under cultivation and fallow lands. These values observed in lands under cultivation and fallow may be associated with cultivation and seasonal flooding of lowlands leading to surface crusting and compaction. Soil porosity was higher in cultivated soils (78.83%) and lower in the swamps (25.22%), water holding capacity (WHC) of the soil was highest in the swamps (72.9%) and lowest in built-up area (33.6%). Aggregate stability index is lower in the cultivated soils (0.44) and higher in the natural forest (0.69). Thus enhanced aggregate stability reported in natural forest soils is consistent with findings as reported by [5,6,14,17,32].

3.2. Chemical Properties of Soils

Chemical properties of soils were presented in Table 2. The pH value in the soils varied significantly from 4.2-6.0. Natural forest and reforested areas planted with Gmelina and teak were more acidic than other landuse types. This may be due to amphoteric nature of Al3t in these soils, high rainfall intensity and leaching of basic cations during periods of high precipitation. Organic carbon levels were higher in the natural forest (9.84kg) and lowest in built-up areas (4.16gkg^{-1}). Total nitrogen varied from 0.42-0.72gkg. The values was lowest in built-up areas and soils around quarry mines, and highest in the natural forest soils. This result is consistent with the findings as reported by [8-51]. Plansible reasons for these scenario is due to high quality litterfall, root exudating by some plants and greater input of liable C into the soil.

The C:N ratio varied from 8.83-13.12. These values are lower in cultivated soils than the natural forests, but lowest in built-up areas. This may be dueto combination of lower C inputs into the soil after crop plants are harvested, losses in C due to bush burning, aggregate disruption arising from tillage and accelerated erosion [1], [2,7-13]. Available phosophorus (P) was highest in fallow lands and lowest in built-up areas. Available P is low taking into cognisance the critical value of 15g/kg reported for productive tropical soils by [12,13,16]. The low available P could probably be due to P-fixation by Iron and Alluminium sesquoxides under acidic conditions.

Exchangeable bases (Calcium, magnesium, sodium and potassium) showed variability across the land use change types as presented in Table 2. Calcium ranged from 3.0-6.6Cmolkg^{-1}. Calcium is not likely to be a limitation to agronomic practices in these soils. Magnesium (Mg) content vied from 0.6-2.8Cmolkg^{-1}. These values were above 0.3-1.4 Cmolkg^{-1} regard as the critical value for Mg for tropical productive soils (FAO, 1976; Landon, 1991). Sodium (Na) content varied from 0.16-0.68Cmolkg^{-1}. The concentration of sodium is below the critical limit 1.0Cmolkg^{-1} [23,26,31]. Thus the soil has sodicity problem. Exchangeable potassium (K) varied 0.08-0.54Cmolkg^{-1}. These values are lower than the critical limit of 0.2Cmolkg^{-1} reported for different landuses in Nigeria [20,24,30]. Exchangeable hydrogen (H^+) ranged from 0.88-1.52Cmolkg^{-1} their variation is not considered to be a limitation to areable crop production because values are lower than the critical limits [11,21,29,40]. The effective cation exchange capacity (ECEC) varied from 3.98-10.21Cmolkg^{-1}. These values is indicative of the low capacity of these soils to retain nutrient elements due to the insufficient amount of organic matter and soil pH chemistry [43,46-50]. The values of SAR and EA (Sodium Absoption Ration and Exchangeable Acidity) were considerably higher in the reforested lands than the natural forests. Sulphur (S) varied from 6.4-15.0mgkg^{-1}. These levels of sulphur in the soils was considered not below the critical limit but still requires external supply to augment the amount of sulphur loss through crop removal and bush burning.

Micro-nutrients present in the soils (Zn, Fe, Mn, Cu) varied from Zn (1.4-3.4mgk^{-1}), Fe 121-263mgk^{-1}), Mn (43-80mgk^{-1}), and Cu (16.8-39.4mgk^{-1}). On the average, the observed levels were moderate, however, the reported variation across landuse change types may be probably due to lower organic matter content and the soil pH chemistry.

3.3. Soil Biological Properties

The values of most of the measured biological properties were significantly lower in built-up areas, soils around quarry mines and swamps than cultivated uplands and natural forest (Table 3). The Total micronial biomass (C_{TMB}) was higher in fallow lands (380.4mg/Ckg^{-1}) and lowest in built-up areas (92.7mg/Ckg^{-1}). Active microbial biomass C_{AMB} also followed some trend. This results may be due to the sensitive response of microbial biomass C to conversion of natural forest and cropping areas. Higher proportion of microbial biomass (C_{TMB} and C_{AMB}) is an indication of aggregation of available organic carbon in soils [41-51]. The respond pattern of C_{TMB} and C_{AMB} to landuse change types were highly congruent, Basal respiration (BR) rates vary significantly among landuse change types, but was higher in soils under fallow and reforested lands and lower in built-up areas and soils around quarry mines. High rate of BR can occur either as a result of large pools of liable substrates or rapid oxidation of smaller pool. Thus high BR may indicate a high level of ecosystem productivity [6]. Higher ratio of qCO_2 was observed for the cultivated upland and fallow lands. Although it has been used to express growth efficiency in agricultural systems and also as indicator of microbial stress [19]. Furthermore, it may also connote intense competition for the available C as a result of cultivated soils and fallow lands favours bacteria based food webs which have low C assimilation efficiencies and faster turnover rates than the more efficient fungal-based food webs dominant in undisturbed or natural forest ecosystems [42]. 3:3 soil degradation rate (SDR) and Vulnerability potential (V_P).

Table 1. Landuse change effect on selected physical properties

Landuse types	**Soil texture**	**Sand %**	**Clay %**	**Soil %**	**Silt/Clay ratio**	**Porosity %**	**WHC (%)**	**Aggregate Stability index**	**Bulk density**
Natural forest	Clay loam	29.8	44.0	26.20	0.59	50.51	68.8	0.69	1.12
Reforested lands	Clay loam	30.2	44.8	25.00	0.56	53.93	68.5	0.63	1.26
Cultivated uplands	Sandy clay loam	33.9	46.2	19.90	0.43	78.83	50.6	0.44	1.48
Swamps	Silty clay	21.80	50.4	27.8	0.55	23.22	72.9	0.57	1.32
Soils around quarry mines	Lateritic clay	45.60	45.0	11.60	0.26	57.02	47.4	0.45	1.39
Built-up areas	Sandy clay	38.0	41.2	20.80	0.50	76.00	33.6	0.56	1.44
Fallow lands	Sandy clay loam	29.60	49.7	20.70	0.42	70.48	59.2	0.68	1.46

WHC=Water holding capacity.

Table 2. Land use change effects of selected chemical properties

Landuse change type	**pH**	**OC gkg^{-1}**	**Total N (gkg^{-1})**	**C:N ratio**	**Avail P gkg^{-1}**	**Ca**	**Mg**	**K**	**Na**	**Al^{3+}**	**H^+**	**ECEC**	**EA**	**SAR**	**Zn**	**Fe**	**Mn**	**Cu**	**S**
						(Cmol/kg)				(Cmol/kg)				%	(mg/kg)				
Natural forest	4.2	9.84	0.72	13.12	5.50	6.6	2.5	0.54	0.68	2.02	1.32	10.21	1.20	0.059	2.6	188	43	22.7	8.1
Reforested lands	4.5	7.50	0.64	11.72	6.05	5.8	2.8	0.41	0.59	2.16	1.48	9.23	2.64	0.078	3.4	134	50	20.4	8.5
Cultivated uplands	5.0	6.90	0.60	11.50	4.62	6.0	2.0	0.38	0.46	1.72	1.52	8.59	2.24	0.067	2.0	166	52	28.0	11.6
Swamps	5.2	5.39	0.55	9.80	3.12	4.54	1.8	0.19	0.48	1.96	1.47	6.75	2.20	0.072	1.6	185	66	36.0	15.0
Soil around quarry mines	6.0	4.10	0.42	9.76	5.80	5.70	1.3	0.12	0.21	4.18	1.35	7.21	2.37	0.081	2.2	263	77	39.4	13.8
Built-up Areas	4.8	4.06	0.46	8.83	2.44	3.0	0.6	0.08	0.16	1.04	0.08	3.98	2.04	0.071	1.4	121	45	16.8	6.4
Fallow lands	4.6	7.09	0.68	10.40	6.12	6.3	2.6	0.41	0.52	2.64	1.38	9.55	2.16	0.061	2.9	160	80	34.5	10.2

Table 3. Landuse change effect on selected biological soil properties

Landuse type	**C_{TMB} ($mgCkg^{-1}$)**	**C_{AMB} ($mgCkg^{-1}$)**	**C_{TMB}/C_{org} (%)**	**(%)**	**(%)**	**BR ($mgCO_2$ C/kg/d)**	**qCO_2:T ($mgCO_2$ – C/mg biomass/d)**	**qCO2:A ($mgCO_2$ – C/mg biomass/d)**
Natural forest	273.9	81.2	2.78	0.83	33.49	6.4	0.068	0.218
Reforested lands	324.6	66.5	4.33	0.89	48.81	8.8	0.072	0.244
Cultivated uplands	176.6	51.4	2.55	0.74	34.24	6.2	0.070	0.262
Swamps	298.2	43.0	5.53	0.79	69.34	5.5	0.056	0.158
Soil around quarry mines	155.0	37.4	3.78	0.91	41.44	4.0	0.049	0.109
Built-up Areas	92.7	17.8	2.27	0.44	52.08	2.6	0.031	0.076
Fallow lands	380.4	102.6	5.36	0.14	37.07	9.1	0.080	0.252

G_{TMB}=Total microbial biomass; C_{AMB}=Active microbial biomass; BR=Basal respiration;
Corg=Total Organic Carbon; qCO_2:T and qCO_2:A=Specific maintenance respiration rates for G_{TMB} and C_{AMB}.

Table 4. Scheme for soil degradation rating (SDR) and vulnerability Potential (V_P)

SDR Limitation	Relative weighting Scale (RWS)	Vulnerability potential	RWS
None	1	None	5
Slight	2	Low	4
Moderate	3	Moderate	3
Severe	4	High	2
Extreme	5	Very High	1

Source: Lal, (1994).

Table 5A. Critical limits for interpreting levels of soil chemical properties from literatures

Soil properties	Very low	Low	Moderate	High
pH	<3.0	4.0-5.0	5.5-7.5	>7.5
Organic carbon (gkg^{-1})	<2.0	2.0-5.0	5.5-10	>10
Total nitrogen (gkg^{-1})	<1.5	1.5-2.0	2.0-5.0	>5.0
Available phosphorus (gkg^{-1})	<2.0	2.0-5.0	8.0-20	>20
Potassium (Cmolkg)	<2.2	0.2-0.5	0.6-0.90	>1.10
Calcium (Cmolkg)	2.0	2.0-5.0	5.0-10	>10.0
Magnesium (Cmolkg)	<0.5	0.5-3.0	3.0-5.0	>10.0
Iron ($mgkg^{-1}$)	<50	55-75	75-105	>105
Zinc ($mgkg^{-1}$)	<2.0	2.0-3.0	3.0-5.0	>5.0
Manganese ($mgkg^{-1}$)	<10	20-40	40-100	>100
Copper ($mgkg^{-1}$)	<10	10-20	25-40	>40
ECEC ($Cmolkg^{-1}$)	<10	10-15	15-2x0	>20

Source: Hazelton & Murphy, (2007); Kparmwang & Malgwi, (1979); Isirima et al., (2003); Abe et al., (2010); FAO (1996); Holland et al., (1989); Uquetan, (2013).

Table 5B. Critical limits for interpreting levels of soil physical properties

Critical levels	Rwf	Bulk density (Mgm^{-3})		Soil structure	Consistence	Texture
		Light texture	Heavy texture	Morphology		
None	1	<1.3	<1.2	Sb to c	Loose	Loam
Slight	2	1.3-1.4	1.2-1.3	Sb	Very friable	Sil, Si, Sicl
Moderate	3	1.4-1.5	1.3-1.6	Msb	Friable	Cl, Sl
Severe	4	1.5-1.6	1.4-1.5	Wsb	Hard	Scl, Ls
Extreme	5	>1.6	>1.5	M or sg	Harsh/extreme hard	C, S

N/B: Rwf = relative weighing factor, Sb to c = subangular to crumb, Sb = subangular blocky, Msb = Moderate subangular blocky, Wsb = weak subangular blocky, Sil = Silt loam, Si = Silt, Sicl = silt clay loam, Cl = clay loam, Si = sandy loam, Scl = silty clay, Ls = loamy sand, C = clay, S = sand. pH, EC= Electrical conductivity, Al=Aluminium, Mn=Manganese, SOC=Soil Organic Carbon. Rwf I = none, Rwf 2 = slight, Fwf 3 = moderate, Rwf 4 = Severe, Rwf 5 = extreme.
Source: (Lal, 1994; Landon, 1984).

Table 6. Soil degradation rates (SDR) and vulnerability potential (V_P) rating scheme of selected soil qualities in the study area

Parameters	Landuse change types						
Soil physical properties	**NF**	**RF**	**CL**	**SW**	**Sqm**	**BUA**	**FL**
Texture	3(3)	3(3)	3(3)	3(4)	3(3)	3(2)	3(3)
Bulk density	2(4)	2(4)	2(4)	2(4)	2(4)	2(3)	2(4)
Porosity	2(5)	2(5)	3(2)	2(4)	3(3)	4(2)	2(3)
Aggregate stability	1(5)	1(5)	2(3)	3(2)	2(4)	2(4)	2(3)
Soil Chemical Properties							
Soil pH	1(5)	1(5)	2(4)	2(3)	2(4)	2(4)	1(5)
Organic Carbon	3(2)	3(2)	2(3)	2(3)	2(4)	2(4)	3(3)
Total Nitrogen	3(3)	3(3)	2(3)	2(3)	2(4)	2(4)	3(3)
Available P	2(4)	2(3)	2(4)	2(4)	2(4)	2(4)	3(3)
Carbon : Nitrogen ratio	1(5)	1(5)	2(4)	2(3)	4(2)	2(3)	1(5)
Potassium	4(2)	4(2)	2(3)	2(4)	1(4)	1(5)	2(3)
Calcium	2(4)	2(4)	2(4)	2(4)	2(3)	2(5)	2(4)
Magnesium	2(3)	2(3)	2(3)	1(4)	3(2)	4(2)	2(4)
ECEC	2(3)	2(3)	2(4)	2(4)	3(2)	1(5)	2(3)
Iron	2(4)	2(4)	3(2)	3(3)	4(2)	1(4)	2(4)
Zinc	1(5)	1(5)	2(4)	2(4)	3(3)	1(5)	1(5)
Manganese	2(4)	2(4)	2(3)	3(3)	3(1)	1(5)	2(4)
Copper	2(3)	2(3)	3(3)	3(2)	3(2)	2(4)	3(3)
Sulphur	3(3)	3(3)	2(3)	4(2)	3(2)	1(5)	2(3)

NB: 1=none; 2=slight; 3=moderate; 4=severe; 5=extreme – for SDR, 5=none; 4=low; 3=moderate; 2=high; 1=very high – for VP (values in bracket), Ratings based on mean soil quality and critical limits established in Table 5 and literature, [52] Soil degradation rate (SDR) and vulnerability potential (V_P) results are presented in Table 6 while the critical limits for interpreting limits of soil properties are presented in Table 5A and B. The results generally show that the soil qualities have varied potentials for degradation. The results in Table 6 indicates that soil pH is a better quality SDR=1:V_P=5) for natural forest. Reforested and fallow lands while soils under cultivation swamps, around quarry mines and built-up areas had SDR-2; V_P=4 had more. Potential vulnerability to erosion than soil in the natural forest, reforested and fallo lands. C:N ratio aggregate stability and availability of Zinc follow the same trend. Bulk density recorded SDR/V_P of 2(3) – 2(4) implying that the soils have better structural conditions for crop production. The bulk densities obtained in these soils are in tandem with findings reported by [12,24-47]. Organic carbon and Total Nitrogen generally follow a similar SDR trend with natural forest reforested lands and fallow land SDR=3; V_P=2 for Organic carbon and SDR=3; Vp=3 for total nitrogen whereas cultivated lands swamps SDR=2; Vp=3, soil around quarry mines and built-up areas had SDR=2; Vp=4. These values sugget that continuous cultivation with reduced fallow period and scanty vegetation cover may tend to deplete soil carbon stocks available and ability of soil microbes to respond to Nitrogen mineralization which will adversely affect the soil quality [32].

Basic cations (Calcium, Potassium and Magnessium) had SDR2; Vp=4, SDR 4; Vp=2, SDR 2; Vp=3 respectively. These basic cations were less prone to degradation risk less than critical levels of K in some locations especially in landuse type covered with less or no vegetation. Patassium is a key element in soil fertility and it is one of the cations lost in large quantities through leaching (Kyuma et al., 1986). ECEC values were considered marginally adequate and suitable for agronomic production. These scenario may be attributed to frequent supply of basic cations, intense rainfall, leaching, organic cation and clay content.

The principle that good soil quality has least SDR and poor quality has the highest SDR and vice cersa for V_P implies that the best soil quality is of the decreasing order. Using the multiple variable indicator transform (MVIT) by [28] to determine the percentage soil quality rating:

$$\%\ Q.Rating = \frac{\text{no.of Indicators that attain CL}}{\text{no.of Indicators assessed}} \text{x100}$$

Where Q = Soil quality, CL = Critical limit;

The indicators were transformed on the basis of their ability to attain a critical level or range. Any indicator that is equal to or above the critical level for crop production is scored 1 and any below the critical level is scored zero. These later is integrated into percentage quality rating. Results from the analysis show that built-up areas and soil around quarry mines had a significant lower SDR/V_P and percentage soil quality rating of 33 percent and 44 percent while swamp and cultivatable upland soils had (56 and 66 percent, soil under natural forest and reforested areas had 83.3 percent, and soil under fallow for (5-10 years) had 88 percent). From the results presented above, the percentage soil quality rating shows that soil qualities in the various landuse type have varied potentials for degradation with built-up areas and soils around quarry mines showing high susceptibility to degradation, while swamps and cultivable upland soils indicating moderate potential degradation or vulnerability. Soil in the fallow areas appear to be slightly more capable to resist degradation.

4. Conclusion

The removal of native vegetation through agronomic production results in a significant reduction in soil quality of tropical rainforest of Akamkpa. The results in this study have shown spatial variability of soils under different landuse types (natural forested, reforested lands, cultivated uplands, swamps, soils around quarry mines, built-up areas and fallow lands) and their soil property vulnerability potentials. The results of this study indicate high pedogenesis under intensive landuses. Bulk density was regarded as favourable for agronomic purposes. Aggregate stability index was higher in the natural forest and lower in the cultivated uplands. Chemical soil properties variation was reported and values were compared with reported critical liits for soil quality rating across landuse types in the study area. Measured biological properties were significantly lower in built-up areas, soil around quarry mines and swamps than cultivated uplands and natural forest. The biological properties were highly correlated with soil quality status in response to different landuse types. Based on the findings of the study, it can be suggested that biological properties has a more promising potential to predict future changes in soil quality compared to the physico-chemical properties.

The study therefore recommends management practices that will reduce indiscriminate destruction of vegetation cover and protection of the top soils.

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