Soil Environ. 40(2): 102-109, 2021
DOI:10.25252/SE/2021/202535
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Estimating land degradation neutrality (LDN) using carbon sequestration pedotransfer function on dissimilar land use and land cover in humid tropics

Ernest Chidozie[1], Okorocha Ogechi[1], Chukwurah Michael[2], Taqi Raza[3], Muhammad Farhan Qadir[4], Uka-Onuoha Chibuikem[5], Onyechere Adaobi[1] and Iheka Winifred[1]
[1]Federal University of Technology, Owerri, Nigeria
[2]Federal College of Education, Asaba, Nigeria
[3]National Agricultural Research Centre, Islamabad, Pakistan
[4]University of Agriculture Faisalabad, Punjab, Pakistan
[5]Ahmadu Bello University, Zaria, Nigeria
[Received:** February 02, 2021 **Accepted:** October 19, 2021 **Published Online:** December 04, 2021**]

Abstract

The study assessed land degradation neutrality using carbon sequestration pedotransfer function on dissimilar landuse and landcover in tropical Nigeria. Target sampling technique guided field studies. A 12 year old restored land and a 5 year old degraded land were identified for the study while a natural forested land which served as a tool for comparison was identified and studied. Three profile pits were dug in each identified area except the degraded land where its bank was scrapped to reveal fresh soils. Samples were collected at uniform depth (cm) of 0-15, 15-30, 30-45 and 45-60 and described using FAO guidelines.Soil samples were air dried and sieved for standard laboratory analysis. Data obtained were subjected to descriptive statistics and correlation coefficient.The results showed that all soil variables were moderately skewed (-0.61 to 0.69), while kurtosis (1.5) showed that most soil properties were dissimilarly distributed among land types. Silt, clay, bulk density, organic carbon and effective cation exchange capacity (ECEC) correlated positively (p=0.05) among each other except sand. Assessing land degradation neutrality (LDN), land cover change showed that the restored and forested land had dense vegetation characterized with grooves of bamboo, shrubs and grasses while the degraded land had loss of biodiversity. Land productivity using land degradation index (LDI) showed that the restored land (30.1) recorded great appreciation in basic cations compared to the forested/control (0) and degraded land (-6.8).The restored land (22,490) also sequestered more carbon (t-ha-1), followed by the natural forest land (7,976) and the degraded land (3,820).

Keywords: Land degradation neutrality, land restoration, land productivity, carbon sequestration, tropical soils

Introduction

Land is primarily composed of soil, water and biodiversity, and the basis for sustainable subsistence, economic cohesion and social development through the consequences of their interactions, ecosystem products and services (Aynekulu *et al.,* 2017). This resource is quite indispensable and has been employed for hundred and thousands of years. However their versatile and eternal exploitation has manifold upshots: ill-suited agricultural techniques, overgrazing of grassland and deforestation leads to the barren lands, which are more susceptible to originate various kinds of land or soil degradation (Eswaran *et al.,* 2001).Soil degradation is a constant damage of the environment due to natural and anthropogenic activities (Lal *et al.*, 2001), or as mentioned by the UNCCD (United Nations Convention to Combat Desertification) a "reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes arising from human activities" (Diallo, 2008).

Soil degradation impacts living sustenance, biodiversity and ecosystem sustainability while it aggravates climate change and ultimately affects the safety and security of 1.5 billion human beings globally (Lal *et al.,* 2001). However, these consequences are not equally come across over the world, as 40% of all the land degradation takes place in poorest countries (Diallo, 2008).

Since, with the advent of 21st century, there has been a huge surge in anthropogenic soil degradation and it impairs

***Email:** taqiraza85@gmail.com
Cite This Paper: Chidozie, E., O. Ogechi, C. Michael, T. Raza, M.F. Qadir, U.O. Chibuikem, O. Adaobi and I. Winifred. 2021. Estimating land degradation neutrality (LDN) using carbon sequestration pedotransfer function on dissimilar land use and land cover in humid tropics. *Soil Environ*. 40(2): 102-109.

1/3 of worldwide arable land (Diallo, 2008). Recently, the value of mitigating soil degradation crosses about US$490 billion per annum, while it's more than the total worth to preserve it (UNCCD, 2013). That's a universal incidence, hitherto about forty percent of the global severity of degraded land appears in locals with the top poverty level (GEF, 2011). Almost one and half billion human being's health and occupations are manipulated by direct impacts of land impairment and degradation (FAO, 2011). By 2050, a projected statistics census of 9 billions people, will enhance the appetite for feed and food by 70% worldwide and by more than double (100%) in the emerging countries (FAO, 2011). Continual soil or land deterioration and degradation will more jeopardize food scarcity and water crisis, directly as climate change occurs it will reduces water availability in the rain-fed arable lands.

Recognizing that land degradation is a worldwide and well heated discussion which drags our immediate attention to restore these devalued lands, the Sustainable Development Goals (SDG) demonstrated that land degradation neutrality (LDN) as an important perspective (Aynekulu *et al.*, 2017). The first model "zero net land degradation" of LDN was introduced in a proposal tabled at Rio+2O. It is carried out through following strategies: (a) land management with high sustainability , that turns down the degradation rate; secondly (b) by enhancing the restoration rate of devalued soils or land, so these both strategies had been used to reduce overall land degradation rate to almost zero (Grainger, 2015). LDN is also known as a hybrid lay-scientific process that now being defined in same concept which is more feasible to policy makers and leads to scientific based findings (Grainger, 2010).

The typical characteristic of LDN as an approach to mitigating devalued or degraded land is the incorporation of the different activities described by the (Diallo, 2008): "minimization of land degradation and prevention", "rehabilitation of partly degraded land," and "reclamation of desertified land."

Recently, the United Nation Statistical Commission granted a worldwide draft of indicator framework stated the reviewing progresses towards achieving the SDG's. The SDG indicator and its sub-divisions are considered like appropriate models to monitor and report for land restoration, combating desertification and to attain LDN. Ground vegetation and land cover shift, land productivity and carbon stocks above and below the ground are three important indicators for land restoration (UNCCD, 2016). Currently, a number of countries do not have the basic processes, data and expertise to set baselines and monitor the report on progress against land evaluation along with degradation, hence the motive of this research is to establish this technique in the Imo State of South-Eastern Nigeria.

Materials and Methods

Experimental site

The experiment was accomplished at Imo State, South Eastern Nigeria which is situated at latitudes $5^0 10^1$N, and longitude $7^0 14^1$E of the humid tropics. The dominant parent material of the area contains coastal sands and flooded plains which results benin formation and deltaic deposits, and marine deposits also contribute a large portion. The mean temperature ranges from 26-29^{0}C. The climatic conditions are wet that most of the periodic season contains-high moisture as almost 85 % relative humidity is reported over the year. The mean annual rainfall (MAR) is reported from 2500-3000 mm that accumulated within 9 months from March to end of September, while the dry season is from November to February (Ofomata, 1975).The tropical rainforest is the natural vegetation of the site which has been highly affected by anthropogenic processes and reduced plant species.

Sample collection

A reconnaissance tour was conducted with the help of a location map of the experimental site to monitor these areas to be evaluated for research purpose. Target sampling technique guided field studies. A twelve year old restored land (soil-filled) which was previously mined was identified for the study while a five year old degraded mined land and an undisturbed secondary forest (control) were identified to serve as a tool for comparison. Three pedons of equal depth of 60cm were dug in each experimental unit to identified land except in the degraded land where its bank was scrapped to reveal fresh soils. Samples were collected at uniform depth (cm) of 0-15, 15-30, 30-45 and 45-60 and described using FAO (2006) procedures. Soil samples were placed in open air for air-drying, clods were gently crushed through pestol and mortar, and sample were sieved through 2-mm mechanical sieve and stored for further laboratory analysis.

Soil physicochemical analysis

Soil samples were analyzed for physical and chemical analysis using standard laboratory protocols.Soil BD (bulk density) was measured using core soil sampler method proposed by Grossman and Reinsch (2002). Soil texture analysis was performed by hydrometer method for soil particles i.e. sand, silt and clay determination according to the (Gee and Or, 2002). Organic carbon pool was calculated by wet oxidation method standardized by (Walkley and Black, 1934; Nelson and Sommers, 1982). Mg^{+2}, Ca^{+2}, Na^{+1}

and K^{+1} exchangeable bases were analysed, as Na^{+1} and K^{+1} were analysed through 1-Normal NH_4OAc extractant by flame photometer (Jackson, 1964), and divalent cations i.e. calcium and magnesium were calculated through EDTA(Ethylene di amine tetra-acetic acid) extractant (Thomas, 1988). Acid base titration method was stimulated to standardize the exchangeable acidity (Mclean, 1982). Cation exchange capacity (CEC) was determined by addition procedure through total exchangeable acidity and basis (Soil Survey Laboratory Staff, 1992). Computation analyses were performed to calculate the base saturation percentage (BS%) of soil.

Land degradation neutrality (LDN) assessment

LDN was assessed using the using Sustainable Development Goals (SDG's) land restoration indicators, viz. landscape/cover and soil cover change, land capability & productivity, carbon banks/atock at top and under the ground (UNCCD, 2016).

Land cover: These changes were assessed by in-situ field observations.

Land productivity: Land productivity was assessed through the index of land degradation (Barrow, 1991). The formula of land degradation index is given below:

$$LDI = \left[\frac{D}{ND} \text{ X } 100\ \% \right] - 100 \text{ .... (Eqn. 1)}$$

As:

LDI = Land Degradation Index

D = Value of soil parameter from the restored land or degraded land

ND = Value of soil parameter in the forest plot

100% = Percentage grade

100 = Constant representing ideal soil state

Carbon stock: Every site was evaluated for carbon stock/bank through commonly used formula described by (Indonesia, 2011).

$$Ct = Kd \text{ x } \rho \text{ x } \%\ C \qquad \text{(Eqn. 2)}$$

As:

Ct = Carbon Stock of soil (g cm^{-2})
Kd = Soil sampling depth (cm)
ρ = Bulk Density of soil (g cm^{-3})
% C = Total percentile value of Carbon assessed through Lab Analysis

Total organic carbon (TOC) of soil per ha (hectare) was calculated through following equation proposed by (Indonesia, 2011),

$$C\ soil = Ct * 100 \qquad \text{(Eqn. 3)}$$

As:

C soil=Total Organic Carbon content of Soil in 1 Ha (ton ha^{-1})

Ct = Soil Carbon Stock (g cm^{-2})

100 = Factor for g cm^{-2} to ton ha^{-1}

Statistical data analysis

The collected data were analysed to descriptive statistics to analyse the differences which reported in three lands studied. With analysis of variance (ANOVA), the observed relation between soil properties were analyzed at $p \leq 0.05$ using simple correlation analysis by Statistix 8.1 computer based software.

Result and Discussion

Sand was inherently dominant in the particle size distribution (Table 1) of the study area except in restored land which was soil filled with clay. However clay content was significant with the textural class of the soils studied identified as sandy clay loam, loamy sand and clay. The forest land recorded the highest mean sand content (703 g kg^{-1}), while silt (65 g kg^{-1}) and clay (232 g kg^{-1}) were irregularly distributed. The degraded land recorded mean sand and clay content of (613 g kg^{-1}) and (307 g kg^{-1}), respectively, while silt content (80 g kg^{-1}) were static in all horizons. Soils of restored land were dominated by clay (507 g kg^{-1}) which increased as depth increased while sand (238 g kg^{-1} and silt (255 g kg^{-1}) were of low content in the particle size distribution of the restored land. High clay content recorded in the restored land was due to the sub soil filling material used in the land restoration. The bulk density of all soils studied showed an indication of the predominance of mineral soil component as it ranged between 1.13-1.50 g/cm^3. Soils of the restored land recorded the highest due to subsoil filling material used in land restoration as well as compaction while forest soils recorded the least. The degraded land recorded high bulk density due to compaction resulting from mining activities using heavy duty machines. The average soil porosity of all soils studied ranged between the least (43.6%) in the restored land to the highest (56.2%) in the forest soil. Soils of the forest area had the highest porosity due to the high percentage of sand

Table 1: Mean of selected physical properties of soil

Land Type	Depth (cm)	Sand	Silt	Clay	Textural Class	MC (%)	BD g cm^{-3}	Porosity (%)
			g kg^{-1}					
Degraded Land	0-15	608.0	80.0	312.0	SCL	21.44	1.21	54.3
	15-30	588.0	80.0	332.0	SCL	23.15	1.18	55.5
	30-45	608.0	80.0	312.0	SCL	30.35	1.23	53.6
	45-60	648.0	80.0	272.0	SCL	24.31	1.45	45.3
Grand Mean		613.0	80.0	307.0	SCL	24.81	1.27	52.2
Restored Land								
	0-15	328.0	240.0	432.0	C	30.61	1.55	41.5
	15-30	208.0	260.0	532.0	C	14.74	1.40	47.2
	30-45	168.0	300.0	532.0	C	13.86	1.46	44.9
	45-60	248.0	220.0	532.0	C	16.13	1.57	40.8
Grand Mean		238.0	255.0	507.0	C	18.84	1.50	43.6
Forest/Control								
	0-15	828.0	80.0	92.0	LS	23.55	1.07	59.6
	15-30	648.0	60.0	292.0	SCL	21.44	1.14	57.0
	30-45	708.0	60.0	232.0	SCL	23.10	1.25	52.8
	45-60	628.0	60.0	312.0	SCL	20.33	1.07	59.6
Grand Mean		703.0	65.0	232.0	SCL	22.11	1.13	57.3

B.D= Bulk density, Texture: LS= Loamy Sand, SCL= Sand Clay Loam, C=Clay, MC=Moisture content

while the restored land had the least porosity due to high clay content and compaction due to soil filling. Degraded land also recorded low porosity resulted from anthropogenic activities which lead to top soil removal, compaction and surface sealing. The moisture content of the soils studied varied between 18.84-24.81%. This is an indication of the dry moisture status of the soil and dry surface humidity at the time of sample collection. However, the restored land recorded more moisture content at the epipedon compared to the degraded and forested land due the high tenacity to which clay binds soil moisture.

Soils of all areas studied showed extremely acidic reaction (Table 2). Acidic soil reaction in the areas studied contains the dominant acidic cations i.e. Al^{3+} and H^{1+} ions are present at the cation exchange site of soil complex. High acidity recorded in the degraded land (4.16) was attributed to top soil removal, leaching of basic cations out of the soil solum which regards to the forest area (4.17), while the acidity of the restored land (4.31) resulted from formation of carbonic acid through CO_2 released by roots and microorganisms.

Soils of the forest area recorded moderate mean organic matter value of (2.06%) which was higher at the epipedon due to high litter fall and decreased as horizon increased. The Restored land recorded the highest mean high organic matter values (4.30%) which were irregularly distributed within the soil profile. High organic matter recorded in restored land could be attributed to the high clay of the soil which reduced leaching and tightly held organic matter to its colloid due to its high specific surface area. Others were due to the densely populated grasses and tree canopies which increased litter fall and inhibited direct impact of sun rays thereby slowing decomposition and mineralization of organic matter. Low organic matter value (0.90%), recorded at the epipedon of the degraded land was as a result of destruction of the natural environment through mining and excavation activities. The total nitrogen levels observed in all soils studied were low in the degraded land (0.05%) while the restored land (0.20%) and forest land (0.11%) recorded high and moderate values, respectively.

The exchangeable bases, ECEC and base saturation were higher in the restored land followed by the forest and degraded land. The accumulation of organic matter due to the fallow state of the area as well as high clay content could have led to the increase in basic cations in the restored and forest land. The degraded recorded depleted basic cations due to surface soil removal, deforestation and soil disturbance, exposure of bare soil to direct temperature, high rainfall and leaching. Mean exchangeable acidity values were observed to be very high in the degraded land (2.50 cmol kg^{-1}) and high in the forest land (2.05 cmol kg^{-1}) above the critical value of 2.0 cmol kg^{-1}. This is an indication that these lands were strongly acidic which may affect sensitive crops. The restored land recorded low exchangeable acidity values (1.80 cmol kg^{-1}) which is suitable for plant growth.

Land degradation neutrality (LDN) assessment

Land cover: Field observation showed that the restored land had densely populated vegetation with clusters of

Table 2: Mean of selected chemical properties of soil

Land Type	Depth (cm)	pH KCl	O.C %	O.M %	TEA cmol kg^{-1}	T.N %	TEB cmol kg^{-1}	ECEC cmol kg^{-1}	BS %
Degraded Land	0-15	4.09	0.81	1.41	3.4	0.09	3.87	7.27	53.2
	15-30	4.15	0.50	0.86	2.2	0.04	3.76	5.96	63.1
	30-45	4.12	0.63	1.10	2.2	0.06	3.79	5.99	63.3
	45-60	4.26	0.14	0.24	2.2	0.01	4.16	6.36	65.4
Grand Mean		4.16	0.52	0.90	2.5	0.05	3.90	6.40	61.3
Restored Land									
	0-15	4.40	2.81	4.83	1.9	0.24	7.76	9.66	80.3
	15-30	4.26	2.42	4.17	1.7	0.21	6.59	8.29	79.5
	30-45	4.33	2.01	3.45	1.4	0.11	6.12	7.52	81.4
	45-60	4.25	2.75	4.73	2.5	0.24	7.77	10.27	75.7
Grand Mean		4.31	2.50	4.30	1.88	0.20	7.06	8.94	79.2
Forest/Control									
	0-15	4.18	2.62	4.51	1.3	0.23	7.32	8.62	84.9
	15-30	4.23	1.22	2.10	2.9	0.11	5.30	8.20	64.6
	30-45	4.29	0.60	1.03	2.5	0.05	3.62	6.12	59.2
	45-60	3.98	0.34	0.59	1.5	0.03	3.03	4.53	66.9
Grand Mean		4.17	1.20	2.06	2.05	0.11	4.82	6.87	68.9

OC = Organic Carbon, OM = Organic matter, TEA=Total exchangeable acidity, T.N= Total nitrogen, TEB= Total exchangeable bases, ECEC= Effective cation exchange capacity, BS= Base saturation

bamboo and shrubs. Numerous species of thick layers of identified and unidentified grasses were observed. Identified grasses contains Elephant grass (*Pennisetum purpurenum,*), Giant star grass (*Cynodon plectostachyus*), Siam weed (*Chromolaena odorata*) and Goat weed (*Ageratum conyzoides*). Krotovinal activities such as ant moulds, termite and earthworm burrows were also observed. The degraded land was observed to have been excavated to a depth of 5m and width of 25m due to mining activities. Its vegetation was destroyed and greatly depleted. Absence of fauna activities due to migration from the degraded land was also observed. The forested land was observed to have vegetation arranged in tiers of trees, shrubs and grasses. The dominant plant species observed in the forested land include Oil palm (*Elaeis guineensis*), others include; Oil bean tree (*Perntaclethra macrophyla*), Gmelina (*Gmelina aborea*), Butterfly pea (*Centrosema pubescens*), Raffia palm (*Raphia ferinifera*), Wine palm (*Butia capitata*) and Water fern (*Histiopteris incisa*). Fauna activities were also observed in the area.

Land productivity: Using Land Degradation Index (LDI), land productivity was assessed. Negative LDI values indicate degraded soil properties while positive LDI values indicate non degraded soil properties. The forested soil with zero LDI values is a separating index between degraded and non-degraded soil properties. Higher positive values showed higher appreciation while higher negative values showed higher soil depletion. Soil properties were observed to be highly degraded in soils of degraded land while soil properties appreciated greatly in the restored land more than the forested area used as the control. Organic matter (-56.3) and organic carbon (-56.7) was observed to be highly degraded in the degraded land while the restored land recorded organic matter (109) and organic carbon (108) of high appreciation. Total exchangeable bases was moderately degraded (-19.1) in the degraded land and highly appreciable (46.5) in the restored land. Base saturation (-11.0) and ECEC (-6.8) were minimally degraded in the degraded land while the restored land recorded base saturation (14.9) and ECEC (30.1) of minimally and highly appreciable. Total nitrogen was highly degraded in the degraded land (-54.5) and highly appreciable (81.8) in the restored land.

Carbon stock: There were significant results that indicate high total organic carbon sink or sequestered in various lands studied at experimental site (table 4). The maximum amount of soil total organic carbon (TOC) was 22,490 t ha^{-1} that was stored in the restored ground/soil. This land was characterized as highly calcareous soil and the difference of plant biodiversity, therefore results in enhancing the total amount of organic matter at that site, and finally improves the total organic carbon of soil. This was followed by the forest land with total carbon stock of 7,976 t ha^{-1} which had dense vegetation and low clay content as compared to the restored land. Carbon sink of 3820 t ha^{-1} was stored in the degraded land that was lowest, due to top soil removal and destruction of plant life. This study also demonstrated that total soil organic carbon was restored in upper top soil layer ranges (0-15) becomes more fertile zone across the different land types. This could be attributed to leaf litter fall at soil surface that stimulate soil biota. Also, many of the soil populations are highly reported at the top fertile zone of 0 - 20 cm of land, because carbon substrates are reported there more in that area. Soil microorganisms decompose litter like

Table 3: Land degradation index (LDI) of selected soil properties

Location	OC	OM	TN	TEB	ECEC	BS
Degraded Land	-56.7	-56.3	-54..5	-19.1	-6.8	-11.0
Restored Land	108	109	81.8	46.5	30.1	14.9
Forest/Control	0	0	0	0	0	0

Table 4: Total quantity of soil organic carbon (g cm^{-2}) stored in the studied soils

Land Type	Soil Depth (cm)	Carbon Stock (gcm^2)	Carbon Stock (t ha^{-1})	Total Carbon Stock (t ha^{-1})
Degraded Land				
	0-15	14.7	1470	
	15-30	8.85	885	
	30-45	11.6	1160	
	45-60	3.05	305	3820
Restored Land				
	0-15	65.3	6530	
	15-30	50.8	5080	
	30-45	44.0	4400	
	45-60	64.8	6480	22490
Forested Land				
	0-15	42.1	4210	
	15-30	20.9	2090	
	30-45	11.3	1130	
	45-60	5.46	546	7976

Table 5: Descriptive statistics of soils of the different lands studied

Variable	CV (%)	SD	Skewness	Kurtosis	Mean	Median
Sand	47.6	246.6	-0.60	1.5	518	613
Silt	79.2	105.6	0.69	1.5	133	80
Clay	40.8	142.0	0.49	1.5	349	307
MC	13.6	2.99	-0.12	1.5	21.9	22.1
BD	14.3	0.19	0.28	1.5	1.3	1.27
Porosity	13.6	6.92	-0.30	1.5	57.0	52.2
pH	1.99	0.08	0.69	1.5	4.21	4.17
OC	71.5	1.01	0.36	1.5	1.41	1.2
OM	71.4	1.73	0.36	1.5	2.42	2.06
TEA	16.8	0.35	0.33	1.5	2.12	2.05
TN	62.9	0.08	0.24	1.5	0.12	0.11
TEB	30.8	1.62	0.46	1.5	5.26	4.82
ECEC	18.3	1.35	0.61	1.5	7.40	6.87
BS	12.9	8.98	0.18	1.5	69.8	68.9

organic materials for respiration, that also reported that wider C:N ratio sponsor immobilization for specific time then after balance in ratio stimulate mineralization where organic compounds are mineralized that results CO_2 emission confirms their presence and inorganic elements like PO_4^{-1}, NO_3^{-1} and NH_4^{+1} are released within the soil and develop good vegetation cover as well as meetup the world need (Ndor *et al.,* 2013).

Table 6: Relationship between some soil properties

Soil Property	Sand	Silt	Clay	BD	OC	ECEC
Sand	1					
Silt	-0.99**	1				
Clay	-0.99**	0.98**	1			
BD	-0.98**	0.95**	0.99**	1		
OC	-0.86**	0.91**	0.81**	0.74**	1	
ECEC	-0.93**	0.97**	0.90**	0.84**	0.98**	1

= significant at 5% level of probability, *= significant at 1% level of probability

Statistical analysis

Table 5 showed the descriptive statistics of the different land types. The mean and median of the soil properties were used to measure central tendency while standard deviation, coefficient of variation, skewness and kurtosis were used to measure variability among the land types. Skewness showed that all soil variables were moderately skewed (-0.61 to 0.69), while kurtosis (1.5) showed that most soil properties were dissimilarly distributed among land types. Coefficient of variation showed that sand (47.6%), silt (79.2%), clay (40.8%), organic carbon (71.5%), organic matter (71.4%) and total nitrogen (62.9%) recorded high variability while moisture content (13.6%), bulk density (14.3%), total porosity (13.6%), pH (1.99%) and base saturation (12.9%) recorded low variability. However, total exchangeable acidity (16.8%), total exchangeable bases (30.8%), bulk density (14.3%) and ECEC (18.3%) recorded variability at moderate level.

Table 6 showed the relationship between some soils properties of the area studied. Simple correlation analysis (p=0.05) indicated that sand correlated negatively with silt (r= -0.90), clay (r= -0.99), silt (r= -0.90), bulk density (r= -0.98), organic carbon(r= -0.90), and ECEC (r= -0.93). Silt correlated positively with clay (r= 0.98), bulk density (r= 0.95), organic carbon (r= 0.91) and ECEC (r= 0.97). Clay correlated positively with bulk density (r= 0.99), organic carbon (r= 0.81) and ECEC(r= 0.84). While organic carbon had positive relationship (r= 0.98) with ECEC.

Conclusion

Land degradation neutrality is a noble initiative which tackles most global food and environmental problems and achieves sustainable development goals by simple human induced land and soil resilience through rehabilitation of marginal lands. Recommendations based on the research findings would opt for the use of soils with high silt and clay content in the filling of degraded lands of the tropics due to its high surface area, buffer capacity and resistance to leaching. Also its positive correlation with organic carbon and basic cations justified the high carbon sequestration and regenerated land productivity in the restored land.

References

Aynekulu, E., M. Lohbeck, R. Nijbroek, J.C. Ordóñez, K.G. Turner, T. Vågen and L. Winowiecki. 2017. Review of methodologies for land degradation neutrality baselines: Sub-national case studies from Costa Rica and Namibia. CIAT Publication No. 441. International Center for Tropical Agriculture (CIAT) and World Agroforestry Center (ICRAF), Nairobi, Kenya. 58 p. Available at: http://hdl.handle.net/10568/80563 [Accessed on 16/11/2021]

Barrow, P. 1991. Land degradation: Development and breakdown of terrestrial environments. Cambridge University Press, Cambridge, UK. 295 p.

Bremner, J.R and J.C. Yeomans. Advance in nitrogen cycling in agriculture ecosystem. 1998. p. 339-414. In: Laboratory Techniques. J.R. Wilson (ed) C.A.B Int. Willing, England.

Indonesia, B.S.N. 2011. Measurement and calculation of carbon stocks-field measurements for forest carbon stock estimation (ground-based forest carbon accounting). BSN, Jakarta.

Eswaran, H., R. Lal and P.F. Reich. 2001. Land Degradation: An Overview. Responses to Land Degradation. Proceedings of the 2nd International Conference on Land Degradation and Desertification, Khon Kaen. Oxford Press, New Delhi.

FAO, 2011. The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

Gee, G.N and D. Or. 2002. Particle size analysis. p. 225-293. In: Methods of Soil Analysis. D.I. Dan and G.C Topps (eds.), part 4 Physical Methods. Soil Science Soc. America Book series No. 5 ASA and SSA Madison, W.I.

Global Environmental Facility (GEF) and United Nations Convention to Combat Desertification (UNCCD) secretariats. (2011). Land for Life: Securing our Common Future. https://www.thegef.org/gef/sites/thegef.org/files/publication/SLM- english-1.

Grainger, A. 2015. Is land degradation neutrality feasible in dry areas?. *Journal of Arid Environments* 112: 14-24.

Grainger, A. 2010. Reducing uncertainty about hybrid lay-scientific concepts. *Current Opinion in Environmental Sustainability* 2: 444-451.

Grossman R.B and T.G. Rernisch. 2002. SSSA book series. 5 methods of soil analysis Ch2, Ed. Dane J.H. Clarke, Topp.G. Soil Science Society of America, Inc. Madison, Wisconsin, USA

Hendershot, W.H, H. Lalende and M. Duquette. 1993. Soil Reaction and Exchangeable AcidityS in Sampling and Methods of Soil Science. Lewis productions, London. 142-145 p.

Jackson, M.L. 1964. Chemical composition of soil. p. 71-144. In: Chemistry of Soil, Bean, F.E (ed.) Van Nostrand C.O, New York.

Lal, R. 2001. Soil degradation by erosion. *Land Degradation and Development* 12. 519–539.

Mclean, E.O. 1982. Soil pH and lime requirement. p.199-224. In: Methods of Soil Analysis part 22nd Ed. A.L. Page (ed). Agron. Mono. ASA and SSAA.

Ndor, E. and S.A Iorkua. 2013. Effect of Agricultural Land Use on Carbon Sequestration and Chemical Properties of Soil in Lafia, Southern Guinea Savanna Agroecological Zone, Nigeria. *Global Journal of Biodiversity Science and Management* 3(1): 68-72.

Nelson, D.N and L.E. Sommers. 1982. Total carbon, organic carbon and matter. p. 539-579. In: Methods of Soil Analysis part 2. A.D. Miller and D.K.M. Keeney (eds.). American Society of Agronomy.

Ofomata, G.E.K. 1975. Nigeria in maps. Eastern States, Ethiope Publishing House, Benin City, Nigeria. 88 p.

Olsen, S.R and I.E. Sommers. 1982. Soil available phosphorus. p. 403-430. In: Soil Survey Laboratory Staff (1992). Survey Laboratory Methods Manual. D.L. Sparks, A.L. Pages, P.A. Hennke (eds.) USDA- SCS Soil Survey.

Investigation Report N0 42 Version 2.0 US Govt. Print. Offices Washington DC, p. 400.

Thomas, G.W. 1988. Exchangeable cations. p. 9: 159-165. 1392. In: Methods of Soil Analysis, part 2. Chemical and microbiological properties 2nd edition. A.I Page (ed.) Agronomy.

United Nations Convention to Combat Desertification (UNCCD). (2013). Decision 8/COP11. http://www.unccd.int8-COP11.pdf.

Diallo, H.A. 2008. United Nations Convention to Combat Desertification (UNCCD). In The Future of Drylands. Springer, Dordrecht. 13-16 p.

UNCCD. 2016. Land Degradation Neutrality Target Setting - A Technical Guide.

Walkey, A. and I.A. Black. 1934. An examination of the different methods of determining SOM and proposed modification of the chronic acid and titration method. *Soil Science* 37: 29-