Assessment of Soil Degradation under Agricultural Land Use Sites: Emerging Evidence from the Savanna Region of North Eastern Nigeria

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Abstract

Soil degradation remains a global environmental phenomenon that is interpreted differently in different environments, despite its global dimension in terms of loss of soil fertility from crop fields in most of the major agricultural regions of the word. This study reports the results of a quantitative index (indices) developed to assess soil degradation associated with agricultural land uses for two contrasting topographies. The study also, identifies the basic underlying pattern of the interrelationship between the soil properties in a part of the Northern Guinea Savanna belt of Nigeria. Using thirteen soil properties, three indices are developed namely: organic nutrients, cation exchange capacity, and soil texture. The indices range from 34.3 % for Ca and 33.7 % for CEC for fallow land to 68.8 % for Na and 57.8 % for OC for continuously cultivated farms on hillslope and flatland sites, respectively. The organic nutrients index was the most degraded index in both sites. The results of the analysis of factor scores for the three land Use types on both sites show two to three basic underlying relationships among the soil properties analyzed, with continuously cultivated farms being the worst degraded then fallow plots with forest fields being the least degraded. The study recommends that the agricultural quality of the soil be evaluated by monitoring only these few soil properties in the study region.

Keywords: Soil degradation, Agricultural Landuse sites, Quantitative index, Nigeria

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Introduction

Despite, the wealth of literature that exists on the prevalence (Kiryushin, 2007, Lal, 2009, Romanov, 2009, Gorokhova & Kupriyanova, 2012, Molchanov, 2015), causes (Zaidel'man, 2009, Babacv *et al.*, 2015), and impacts of soil degradation (Pimentel, 2006, Kuznetsova *et al.* 2009), and the global dimension of the loss of soil fertility from crop fields in most of the major agricultural regions of the world (Mueller *et al.* 2010), soil degradation remains a global environmental phenomenon that is interpreted differently in different environments. For the most part, soil degradation is seen as the loss of land productivity, quantitatively and qualitatively, through many processes, such as soil erosion, overgrazing, cultivation, and cropping, leaching, water logging and pollution. Kiryushin (2007), Romanvov, (2009), Molchanov *et al.* (2015), defined "soil degradation as the gradual or complete reduction of soil fertility (quality) through the physical removal of soil by erosion without actual loss of soil or a combination of both with a resultant decline in crop productivity." Importantly, soil degradation is a gradual process that may take several years or decades to be recognized, and when noticed, it may be difficult or take a very long time to fully reclaim the land.

Soil degradation processes, or mechanisms, that set in motion the degradation include physical, chemical and biological processes (Pimentel, 2006, Lal, 2009, Gorobtsova *et al.* 2016). Prominent among the physical processes are deforestation, desertification, and deterioration of soil structure, leading to crusting, compaction, and erosion (Muchena *et al.* 2005,Yusuf *et al.* 2015). Significant chemical processes include acidification, leaching, soil salinity, and a decrease in cation retention capacity and fertility exhaustion (Gurbanov, 2010, Ahukaemere *et al.* 2012). The biological processes include a reduction in the total biomass carbon and a decline in soil biodiversity (Tilman, et al., 2002, Vasil'evskaya *et al.* 2006, Lal, 2013).

In the study region, as elsewhere in tropical regions, physical, as well as biochemical degradation, is experienced as a result of cultivation and harvesting, burning, overgrazing and soil erosion (Cobo, *et al.* 2010, Yusuf *et al.* 2015). Martensson (2009) identifies the most common types of physical and biochemical soil degradation in Nigeria as soil desiccation, soil compaction, and salinization. It is apparent from the above that, the concept of soil degradation is a complex one for which there is no one single universal method or index of assessment. This is probably because, as Pimentel (2006), noted, it comes in different forms depending on land use and sites.

Numerous studies have been conducted on the effects of the processes of soil degradation, such as cultivation and erosion of soil fertility (Ogidiolu, 2000, Cobo *et al.* 2010, Malgwi & Abu, 2011, Eni, 2012, Senjobi *et al.* 2013, Sotona, *et al.* 2013), using different soil properties perceived by the authors as being relevant to examining a similar problem. This seems to indicate the absence of acceptable indices for the tropical environment and, in particular, two contrasting topographies. The importance of an index for assessing changes in soil associated with agricultural land use cannot be over-emphasized. It will, among other things, ensure comparability among land uses (Qi *et al*. 2009, Gorobtsova *et al.*2016), and rapid evaluation and assessment of the resource quality of the soil between and within contrasting topographies (Gorokhova *et al.* 2012). This paper, therefore, seeks to develop a quantitative index (indices) for assessing soil degradation associated with agricultural land use between two contrasting topographies in similar geographical settings and to identify the basic underlying pattern of the interrelationship between the soil properties. This is imperative because such indices, as pointed out earlier, are useful for rapid mapping of soil the resource quality of vast areas for management purposes.

Material and Methods

Study Location

Nigeria has a total surface land area of 923.769 square kilometers, out of which 86% (794,441 km^2) belongs to the Savanna region (Martensson, 2009). The Savanna region is sub-divided into four major ecological zones, namely: Derived Savanna, Guinea Savanna, Sudan, and Sahel Savanna. Martensson (2009) further subdivided the Guinea Savanna into the Southern Guinea Savanna and the Northern Guinea Savanna. The later covers about 600,252 km^2, representing about 60% of the country’s total land area.

The study region, the Northern part of Taraba State ($6^0 30^1$ and $9^0 36^1$ N; $9^0 10^1$ and $11^0 50^1$ E), is situated in North-Eastern Nigeria, along the Nigerian-Cameroun border and falls within the Northern Guinea Savanna region (Fig.4.1).

It is bordered on the North by Bauchi State, in the East by Adamawa State and Plateau State to the West, and in the Northeast and Southwest by Gombe State and Gassol local government area respectively. Thus, the area delineated as Northern part of Taraba State falls within the Northern Guinea Savanna region.

In terms of vegetation, a mixture of short grasses and fewer trees characterizes the area, and forest reserves are protected areas. The climate of the study region is characteristic of a tropical humid region. It is characterized by alternate periods of dry and wet spells with a mean annual rainfall of about 1300 mm, which is distributed over seven months (April to October), with a peak in August (Yusuf *et al.* 2017). It has a mean minimal and maximum temperature of about 21.30 ^{0}C and 34 ^{0}C in December and April, respectively and an earth temperature at 0-20cm soil depth of 25-30 ^{0}C. The mean annual evaporation is approximately 10mm; relative humidity could be as high as 77.9% and as low as 16.3% between the months of August/September and February/ March, respectively. The area receives high radiation of 5.7 hours per day and moderate to light wind speed/run (Yusuf *et al.* 2017).

The soil types are of the tropical ferruginous and lithosol soil groups derived from basement complex formations and deposits of Tertiary rocks. Characterized by a sandy surface horizon, with clay subsoil. The soil is naturally fertile for agricultural productivity and susceptible to erosion (Martensson, 2009), especially on hillslopes and flood plains, where land is used beyond its capabilities, using techniques of soil and crop management that are ecologically incompatible.

Farming is the major traditional occupation of the people of Northern part of Taraba State (Yusuf & Ray, 2011). The farming system and farming practice are characteristically of the subsistence type and involve predominantly mixed or single cropping. Farm sizes vary with location, reflecting population density, accessibility to the farm and the personal preferences of the occupants. Guinea corn, maize, and yam are the major crops, cultivated by almost every farm family. Other crops cultivated include millet, rice, cassava, potatoes, groundnuts, beans, and vegetables. To lessen the risk of soil erosion, and safeguard soil and crop productivity, the farmers, typically grow a variety of crops. Farming operations are generally labour–intensive and largely a reflection of traditional methods, using drudgery- enhancing primitive tools such as hoes, cutlasses, machetes, and axes, which have been passed from generation to generation (Yusuf & Ray, 2011). The study region has large number of livestock especially, cattle, goats, sheep, pigs, and poultry. The growing of crops and rearing of livestock threaten the natural resilience of the vegetation of the region and, hence, soil degradation.

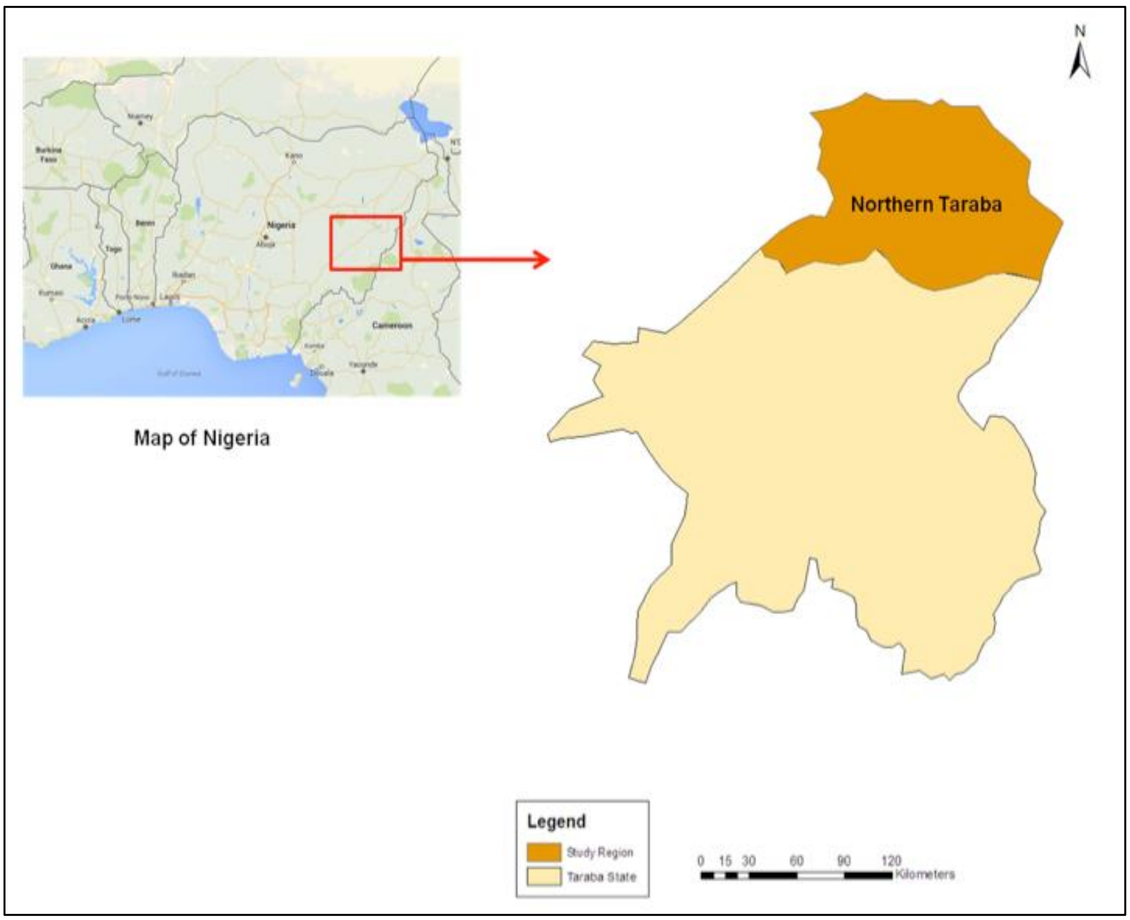

Figure 1: Map of the study region

Method

In order to attain the objective of this study, a reconnaissance survey of the study region was undertaken to gain an understanding of the components of the production system, and the biophysical and environmental situation. During this stage, two contrasting land use sites, with six survey plots were identified. The surveyed plots were farmlands which had been under continuous cultivation for more than ten years, located in both the flatland and hillside areas, with a slope angle range of 0-4% and 5-22%, respectively. Land which, had been fallow 7-10 years in both sites, and a protected area (forest) which had been intact as long as the local people can remember.

The forest soil from the flatland site was used as the control against which changes in soil properties arising from the establishment of other land uses were assessed. To ensure uniformity in the soil samples collected from the surveyed sites, the sites were selected from a similar geographical setting with respect to climate, soil and land use types. *Vitellariaparadoxa, Tamarindysindica, Parkia species, Aegyptiaca, and Balantie species* were the dominant tree species in the forest areas. Shrubs, with little useful wood mixed with some grasses, are dominant plant species in fallow fields (*Myparrhemiaviolescensspp, Penisetumpedicellatum, Schizachyrium exile, Typha, wind sorghum, Calotropisproceras, and Ipomeas spp*). Guinea corn, millet, yam, cassava were the major crops grown in both sites.

Administratively, the study region falls into six local government areas of Taraba State: Ardo-Kola, Jalingo, Lau, Karim-Lamido, Yorro, and Zing. There are a total of sixty-two (62) districts in the six local government areas. Within each district, there was a range of between 21 to 47 major villages with each village having approximately a range of between 305 to 874-farm families (TADP, 2013) village listening form. One village was purposively selected for soil sample collections based on: - (i). The seriousness of the soil erosion problem, (ii). Accessibility, (iii). The need to have two comparable slope and flatland farms representative of the study area, and, (iv). The selection considered land use types, rather than soil types.

Subsequently, from the six surveyed plots, eight surveyed positions (5 from the hillslope and three on the flat land area) were randomly selected for soil sample collection. The five surveyed position on the hillslope sites is one each from the upslope, mid-slope and downslope of continuously cultivated farms, a fallow, and forest fields, and on the flat land are one each from farmlands under continuous cultivation, fallow, and forest plots.

In order to cover, representatively, all the surveyed plots, Grids were imposed over the surveyed position. Each surveyed position was 50m x 50m and the area was later divided into one-meter square grids. Ten of these one-meter square grids were selected using a table of random numbers, and a soil sample was collected from each of the selected grids from a depth of 0-20cm. At each surveyed position, samples were obtained at three successive intervals, before, during, and after the peak of rainfall, and composite samples were made by carefully mixing twenty-five soil samples. Soil sampling was restricted to the uppermost soil profile because most of the significant changes in soil physiochemical properties, especially in a tropical environment, are limited to the topmost ploughable layer, 0-20 cm of the soil profile (Ogidiolu, 2000, Adejuwon, 2008, Cyril & Difference, 2012). A total of six hundred soil samples (24 composite samples) were obtained with the aid of a soil auger and each composite sample was placed in a new well-labeled polythene bag. The soil samples were then air-dried at a room temperature of 28^0C, lightly ground and sieved using a 2mm mesh sieve, and analyzed using standard laboratory procedures, with utmost care to avoid differential loss of fine dust.

The particle size distribution was obtained using the Bouyocous hydrometer method. In sequence, the textural class of the soils was determined by subjecting the obtained particle size distribution to Marshall's textural triangle. The bulk density was determined by the clod method. The soil pH was measured in 1:2.5 soils: water suspension ratio with the use of a glass electrode pH meter. The electrical conductivity (EC) of the saturation extracted was determined by the sequence alongside the pH in the same suspension using the EC meter. Organic carbon (OC) was determined using Walkley & Black's (1934) potassium dichromate wet oxidation method, in which the soil organic matter content is obtained by multiplying the organic carbon content by a conversion factor of 1,724. Similarly, total nitrogen (TN), available phosphorus (P) , available potassium (K) and sodium (Na) were determined by the Kjeldahl method (Bremner & Mulvaney, 1982), Bray extraction method, (Bray & Kurtz, 1945) and flame photometry (Jacson,1965), respectively. Exchangeable (Ca), was determined by the titrimetric method, while, (CEC), was computed from the analyzed results of the soil bases, for soil property for forest lands on the one hand and for other land use types on the other, to show the extent of soil degradation resulting from the opening up of natural vegetation to cropping.

The computed differences were then expressed as a percentage of the mean value of the forest soil property. The index of the soil degradation was computed based on the assumption that the soil fertility status of any land use types on both sites was once the same as that for the flatland forest before the commencement of cultivation. Statistical analysis of variance (ANOVA) and principal component analysis (PCA) were used to determine whether there were any significant differences in each of the elements analyzed in the soils according to different land use type.

Results and Discussion

Soil physiochemical properties

The mean values of various soil properties revealed that there were differences between and within the land use sites. The mean values of sand and silt contents were significantly higher in farms under continuous cultivation and fallow plots on the hillslopes compared to those on a comparable flatland (Table 1). These results concurred with the explanation provided by Cobo *et al.,* (2010), Amuyou *et al.* (2013), Senjobi *et al.* (2013), and Sotona *et al.* (2013), that soil textural properties (sand, silt and clay contents) were higher in soils under cropping located at high altitudes compared to soils under pure crops on lower slopes. In contrast, insignificant differences in textural properties were reported by Ogidiolu, (2000), Adejuwon, (2008), with respect to contrasting land use type.

However, the chemical properties showed an opposite trend to the physical properties. The areas surveyed on flat land had a significantly higher mean content in relation to most chemical properties, in particular, OC, TN, P, and CEC, suggesting, that erosion in the form of water erosion is higher in farms under continuous cultivation and in fallow plots on hillslopes than those on flatland. The variation in these soil properties can be associated with the differences in topography, intensive leaching, and erosion. However, Ahukaemere *et al.* (2012) noted that lower OC content accelerates soil erosion, which in turn threatens valuable soil nutrients and creates serious soil management problems.

Table 1a: Statistical summary and changes in study soil properties 0 - 20 cm for forest field, fallow plots and farms under continuous cultivation on the hillslope site (significant at 0.01confidence level; CV = coefficient of variation: < 25% = low variation; 25-50% = moderate

Variable					
Forest Field	**Mean**	**SD**	**C.V**	**Min**	**Max**
Sand %	52.00	1.00	1.92	51.00	53.00
Silt %	21.67	1.16	5.33	21.00	23.00
Clay %	26.67	.58	2.17	26.00	27.00
PH(H2O)(1.2.5)	7.43	.21	2.80	7.20	7.60
EC (dSm-1)	.18	.01	5.56	.17	.19
OC (g kg-1)	20.23	2.16	10.67	18.20	22.50
TN (g kg-1)	.08	.003	3.19	.08	.09
P (mg/kg-1)	7.73	.72	9.36	6.90	8.20
K Cmol(+)kg-1	.14	.01	7.14	.13	.15
Na Cmol(+)kg-1	.16	.02	10.83	.14	.17
Ca Cmol(+)kg-1	3.53	.06	1.63	3.50	3.60
CEC Cmol(+)kg-1	11.47	.95	8.24	10.40	12.20
BS %	33.43	2.15	6.43	31.30	35.60
Fallow plot					
Sand %	62.00	2.00	3.23	60.00	64.00
Silt %	18.67	1.16	6.19	18.00	20.00
Clay %	20.00	2.00	10.00	18.00	22.00
PH(H2O)(1.2.5)	6.53	.25	3.85	6.30	6.80
EC (dSm-1)	.15	.01	7.53	.14	.16
OC (g kg-1)	12.50	1.77	14.15	10.90	14.40
TN (g kg-1)	.08	.01	7.18	.071	.08
P (mg/kg-1)	9.47	.95	9.98	8.40	10.20
K Cmol(+)kg-1	.1333	.01	8.67	.12	.14
Na Cmol(+)kg-1	.13	.01	7.69	.120	.14
Ca Cmol(+)kg-1	3.30	.36	10.93	2.90	3.60
CEC Cmol(+)kg-1	7.60	.27	3.48	7.40	7.90
BS %	40.30	.27	.66	40.10	40.60
Continuous Cultivation Farm					
Sand %	71.33	2.08	2.92	69.00	73.00
Silt %	18.33	1.15	6.30	17.00	19.00
Clay %	10.67	3.06	28.64	8.00	14.00
PH(H2O)(1.2.5)	5.23	.15	2.92	5.10	5.40
EC (dSm-1)	.13	.01	3.73	.13	.14
OC (g kg-1)	8.53	.29	3.38	8.20	8.70
TN (g kg-1)	.06	.00	5.43	.06	.07
P (mg/kg-1)	10.50	.36	3.43	10.10	10.80
K Cmol(+)kg-1	.11	.01	9.09	.10	.12
Na Cmol(+)kg-1	.09	.01	13.32	.08	.10
Ca Cmol(+)kg-1	2.47	.29	11.70	2.30	2.80
CEC Cmol(+)kg-1	5.85	.23	3.92	5.65	6.10
BS %	42.40	1.25	2.96	41.20	43.70

Table 1b: Statistical summary and changes in study soil properties 0 - 20 cm for forest field, fallow plots and farms under continuous cultivation on the flatland site (significant at 0.01confidence level; CV = coefficient of variation: < 25% = low variation; 25-50% = moderate variation; > 50% = high variation)

Variable	Mean	SD	C.V	Min	Max
Forest field					
Sand %	57.33	1.16	2.01	56.00	58.00
Silt %	22.67	5.09	5.09	22.00	24.00
Clay %	20.67	1.16	5.59	20.00	22.00
PH(H2O)(1.2.5)	5.60	.36	6.44	5.30	6.00
EC (dSm-1)	.13	.02	11.46	.12	.15
OC (g kg-1)	9.37	.25	2.69	9.10	9.60
TN (g kg-1)	.07	.004	6.06	.06	.07
P (mg/kg-1)	9.73	.91	9.32	8.70	10.40
K Cmol(+)kg-1	.12	.01	4.94	.11	.12
Na Cmol(+)kg-1	.07	.01	7.87	.07	.08
CaCmol(+)kg-1	2.44	.26	10.55	2.20	2.71
CEC Cmol(+)kg-1	6.30	.95	15.15	5.70	7.40
BS %	32.00	2.77	8.66	30.40	35.20
Fallow plot					
Sand %	63.33	2.31	3.65	62.00	66.00
Silt %	21.00	1.73	8.25	20.00	23.00
Clay %	15.67	2.08	13.29	14.00	18.00
PH(H2O)(1.2.5)	5.43	.15	2.81	5.30	5.60
EC (dSm-1)	.11	.01	9.09	.10	.12
OC (g kg-1)	9.00	.17	1.92	8.90	9.20
TN (g kg-1)	.06	.004	5.89	.06	.06
P (mg/kg-1)	9.93	.46	4.65	9.40	10.20
K Cmol(+)kg-1	.11	.01	5.09	.11	.12
Na Cmol(+)kg-1	.06	.001	1.90	.06	.06
CaCmol(+)kg-1	2.32	.28	12.27	2.00	2.55
CEC Cmol(+)kg-1	5.10	.17	3.40	5.00	5.30
BS %	33.00	2.31	6.99	30.60	35.20
Continuous Cultivation farm					
Sand %	71.56	3.71	5.19	66.00	77.00
Silt %	18.67	4.00	21.43	13.00	24.00
Clay %	10.17	1.12	11.00	8.00	12.00
PH(H2O)(1.2.5)	4.62	.42	9.10	4.20	5.30
EC (dSm-1)	.07	.02	21.43	.05	.09
OC (g kg-1)	8.23	.23	2.78	7.90	8.50
TN (g kg-1)	.04	.02	37.50	.01	.06
P (mg/kg-1)	10.96	.50	4.52	10.10	11.60
K Cmol(+)kg-1	.09	.04	48.56	.02	.13
Na Cmol(+)kg-1	.05	.01	15.30	.04	.06
CaCmol(+)kg-1	1.79	.53	29.77	1.00	2.40
CEC Cmol(+)kg-1	4.36	.240	5.52	4.10	4.80
BS %	36.63	2.61	7.13	32.10	40.10

Soil degradation indices

The levels in percentage of soil degradation between and within the two land use sites, as presented in Table 2, show that: Na, CEC, clay, EC OC, and TN were the most degraded soil properties in farms under continuous cultivation and OC, Na, and CEC in fallow farms on the hillslope site. In the farms under continuous cultivation on the flatland site, clay, OC, CEC, and Na were the most degraded soil properties, and none was recorded for fallow plots.

The degree of degradation was highest in farms under continuous cultivation compared to fallow plots on both sites. However, continuously cultivated and fallow farms on the hillslope had a higher proportion of degradation than those on the flatland. The degradation indices ranged from 34.3 % for Ca and 33.7 % for CEC for fallow land to 68.8 % for Na and 57.8 % for OC for continuously cultivated farms on the hillslope and flatland sites respectively. Similarly, a noticeable increase in the degradation index of OC and CEC 57.84% and 49.00% for farms under continuous cultivation on the flatland to 59.32% and 61.99% for those on the hillslope site was recorded. However, the degradation indices were low for soil textural properties between and within the different land use types.

The computed results for the level of degradation associated with each soil property for either site revealed that; the degree of degradation was highest for variables on the hillslope than those on the flatland site, as shown in Table 2. However, both sites were constrained by a similar response mechanism; where OC, and TN, which can be collectively referred to as the organic nutrient index, and Na, CEC, and Ca, which can together be referred to as cation exchange capacity index, are the soil properties with the most degradation between and within the two contrasting sites. In addition, soil properties with minimum deterioration rates can be used as indices (Ogidiolu, 2000). In this regard, the study shows that soil texture is a useful index.

Table 2: Statistical summary of degradation indices (%) of soil properties in the hillslope and flatland sites under continuous cultivation and fallow farms

Variable	Hillslope Site		Flatland Site	
	Cultivated Farm	Fallow Farm	Cultivated Farm	Fallow Farm
Sand %	-37.62	-21.79	31.17	-19.23
Silt %	13.84	3.09	15.41	13.85
Clay %	61.87	41.25	59.99	25.00
PH(H2O)(1.2.5)	37.82	26.92	29.61	12.11
EC (dSm-1)	61.11	38.89	27.78	14.83
OC (g kg-1)	59.32	55.51	57.84	38.22
TN (g kg-1)	50.00	25.00	25.00	7.63
P (mg/kg-1)	-41.79	-28.46	-35.83	-22.42
K Cmol(+)kg-1	35.71	21.43	21.43	4.79
Na Cmol(+)kg-1	68.75	62.50	43.75	18.75
CaCmol(+)kg-1	49.29	34.28	30.03	6.60
CEC Cmol(+)kg-1	61.99	55.54	49.00	33.72
BS %	-8.59	1.29	-26.83	-20.54

The underlying interrelationship among the soil variables

To understand the associations among soil properties, the basic underlying interrelationship among the soil variables were identified. This was achieved using factor analysis, which helped us to achieve a parsimonious exposition of the underlying relationship by reducing a large number of variables into fewer uncorrelated variables, which accounted for maximum variance in the original variable sets and were taken as a surrogate for the original variables.

The Eigenvalue structure of the soil properties in Table 3 shows the number of factors or underlying pattern of relationships. Although several suggestions have been made as to the number of factors that should be retained for interpretation, only those with Eigenvalues greater than one have been chosen for analysis in this study. On account of this, only three factors are significant, and these account for 82% of the total variation in the phenomenon being examined on the hillslope site and only one factor on the flatland land site, accounting for 86.4%.

Table 3: Eigenvalue Structure of the Soil Properties under the Hillslope and flatland sites

Factor	Hillslope Site			Flatland Site		
	Eigen Value	**PCT of Var**	**CUM PCT**	**Eigen Value**	**PCT of Var**	**CUM PCT**
1	7.896	60.737	60.737	11.232	86.398	86.398
2	1.724	13.264	74.002	.818	6.291	92.689
3	1.045	8.042	82.044	.446	3.427	96.116
4	.968	7.442	89.486	.241	1.851	97.967
5	.453	3.481	92.967	.129	.992	98.959
6	.388	2.988	95.956	.078	.597	99.556
7	.233	1.792	97.748	.043	.333	99.889
8	.141	1.084	98.832	.014	.111	100.000
9	.074	.572	99.404	1.822E-16	1.402E-15	100.000
10	.043	.330	99.734	3.453E-17	2.656E-16	100.000
11	.028	.216	99.951	-7.643E-17	-5.879E-16	100.000
12	.004	.032	99.982	-3.179E-16	-2.446E-15	100.000
13	.002	.018	100.000	-9.695E-16	-7.457E-15	100.000

Table 4 shows the factor loadings of the soil variables. In the continuously cultivated farm, on the hillslope, Table 4a, the first factor has positive loadings on sand, soil pH, EC and K, the second factor on silt, clay, soil pH, and EC, the third factor contains high loadings on TN, Na, and BS, the fourth factor loads positively on Soil pH and Na, and there are no high positive loadings recorded on the fifth factor. Only two factors were extracted in the fallow and forest plots. The pattern of factor loading for fallow land shows that, the first factor has high loadings on sand, pH, K, Ca, CEC, and % BS, and the second loads on clay, EC, and OC, while, in the forest fields, the loading patterns reveal that the first factor has a high positive loading on silt, OC, TN, K, Ca, CEC and BS, and the second factor on clay, pH, Na and Ca.

The patterns for land use types on flatland are shown in Table 5b, indicating that, the first factors for continuously cultivated farms load positively high on seven variables Clay, OC, TN, K, Na, Ca and CEC and the second factor on three pH, EC and OC. For the fallow plots, a significant positive loading was recorded for six soil variables, silt, EC, TN, K, Ca and BS for the first factor, and on four soil variables sand, pH, Ca and CEC for the second factor. While, for the forest field, the first factor loaded positively high on six soil variables silt, pH, OC, TN, K, Na and Ca, and the second factor only on three soil variables TN, Na and BS.

As a whole, the factor loadings patterns of each soil property are similar between and within the three agricultural land use types and sites. A noticeable difference, however, was the higher number of negative loadings in continuously cultivated farms on both sites compared to other land use types. This suggests, therefore, that, interpreting the factor loading of soil variables may be complex and it may be sometimes impossible to assign an exact definition to a factor because many soil properties may load highly on that factor. Hence, in this study, a simple structure that preserved the total variation was obtained by carrying out varimax rotation (Table 4a & 4b).

Table 5a shows the rotated factor matrix of these properties on each factor for the hillslope site. The first rotated factor has the highest positive loading for silt, the second for clay and pH, the third for total nitrogen and BS, while, the fourth and fifth for P and OC respectively, for continuously cultivated farms. For the fallow farms, the first rotated factor has the highest positive loading for clay, K, and CEC, and the second rotated factor for Ca, BS and pH. For forest soil, the first rotated factor has the highest positive loading for silt, Ca, CEC and BS and the second rotated factor positively loads on K, EC, OC, and TN.

For the land use types on the flatland site, Table 4b, only clay positively loads higher on the first factor, pH, EC and OC on the second rotated factor for continuously cultivated farm land. For fallow land, the first rotated factor has the highest positive loading for silt, OC, Na and % BS. The second rotated factor loads on pH, EC, K, and Ca, while, for forest land, clay, P, CEC, and BS positively load high on the first factor and pH, TN, and Na on the second rotated factor.

Table 4a: Factor Loadings and Rotated Factor Matrix for Soil Properties of the three Landuse Types on the Hillslope Site

Factor Loadings	**Cultivated**					**Fallow**		**Forest**	
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 1**	**Factor 2**	**Factor 1**	**Factor 2**
Sand %	.749	-.630	-.083	.132	.034	.978	-.207	-.957	-.290
Silt %	-.747	.574	.247	-.093	-.197	-.668	-.744	.957	.290
Clay %	.321	.866	.011	.159	.257	-.529	.848	-.730	.684
PH(H2O)(1.2.5)	.530	.556	.193	.562	.050	.992	.125	.839	.544
EC (dSm-1)	.657	.649	.013	-.086	-.263	-.744	.668	.104	-.995
OC (g kg-1)	.207	-.054	.418	.167	-.842	-.310	.951	.941	-.338
TN (g kg-1)	.221	-.175	.845	-.222	.027	-.126	-.992	.974	-.227
P (mg/kg-1)	.178	.478	.110	-.795	.277	-.978	.207	-.992	-.128
K Cmol(+)kg-1	.598	-.698	.239	-.141	.206	.978	-.207	.730	-.684
Na Cmol(+)kg-1	.080	.109	.650	.533	.494	-.668	-.744	-.730	.684
Ca Cmol(+)kg-1	-.448	-.070	-.538	.177	.203	.841	.541	.769	.639
CEC Cmol(+)kg-1	-.817	-.214	.203	.360	.009	.978	-.207	.971	.239
BS %	-.547	-.126	.787	-.204	.099	.925	.381	.957	.290
Rotated Factor Matrix									
Sand %	-.978	.009	-.054	-.046	.146	.875	.484	-.963	-.270
Silt %	.982	-.030	.165	-.022	.056	-.019	-1.000	.963	.270
Clay %	.257	.826	-.107	.408	-.128	-.955	.295	-.248	-.969
PH(H2O)(1.2.5)	-.070	.947	-.030	.033	.202	.669	.744	1.000	-.008
EC (dSm-1)	-.016	.569	-.198	.630	.412	-1.000	.019	-.447	.895
OC (g kg-1)	-.009	.026	.126	-.116	.962	-.856	.516	.612	.791
TN (g kg-1)	-.195	.012	.841	.159	.269	.554	-.833	.699	.715
P (mg/kg-1)	.187	-.015	.223	.917	-.238	-.875	-.484	-.905	-.425
K Cmol(+)kg-1	-.896	-.161	.361	.064	.023	.875	.484	.248	.969
Na Cmol(+)kg-1	-.065	.650	.626	-.339	-.187	-.019	-1.000	-.248	-.969
Ca Cmol(+)kg-1	.193	-.177	-.429	-.335	-.450	.282	.959	.992	-.126
CEC Cmol(+)kg-1	.457	-.232	.231	-.742	-.130	.875	.484	.947	.320
BS %	.385	-.271	.858	-.165	-.012	.450	.893	.963	.270

Table 4b: Factor Loadings and Rotated Factor Matrix for Soil Properties of the three Landuse Types on the Flatland Site

Factor Loadings	**Cultivated Farm**		**Fallow Farm**		**Forest Field**	
Variable	**Factor 1**	**Factor 2**	**Factor 1**	**Factor 2**	**Factor 1**	**Factor 2**
Sand %	-.979	-.203	-.482	.876	-.972	-.235
Silt %	-.999	.038	.855	-.518	.959	-.282
Clay %	.957	.291	-.518	-.855	-.959	.282
PH(H2O)(1.2.5)	-.152	.988	.417	.909	.869	.496
EC (dSm-1)	-.077	.997	.876	.482	-.972	-.235
OC (g kg-1)	.533	.846	.605	-.796	.754	-.656
TN (g kg-1)	.800	-.600	1.000	.031	.581	.814
P (mg/kg-1)	-.971	-.241	-.946	.325	-.977	.215
K Cmol(+)kg-1	.846	-.533	.876	.482	.972	.235
Na Cmol(+)kg-1	.999	-.038	.482	-.876	.724	.690
Ca Cmol(+)kg-1	.999	-.038	.708	.706	.959	-.282
CEC Cmol(+)kg-1	.932	-.363	.210	.978	-.997	.073
BS %	-.850	-.527	.938	-.347	-.680	.733
Rotated Factor Matrix						
Sand %	-.993	-.120	-.931	.364	.580	-.815
Silt %	-.992	.122	.989	.150	-.910	.416
Clay %	.978	.209	.150	-.989	.910	-.416
PH(H2O)(1.2.5)	-.067	.998	-.263	.965	-.331	.944
EC (dSm-1)	.008	1.000	.364	.931	.580	-.815
OC (g kg-1)	.602	.798	.975	-.224	-1.000	-.001
TN (g kg-1)	.746	-.666	.747	.664	.095	.995
P (mg/kg-1)	-.987	-.158	-.935	-.356	.879	-.478
K Cmol(+)kg-1	.798	-.602	.364	.931	-.580	.815
Na Cmol(+)kg-1	.992	-.122	.931	-.364	-.095	.996
Ca Cmol(+)kg-1	.992	-.122	.092	.996	-.910	.416
CEC Cmol(+)kg-1	.898	-.441	-.465	.885	.801	-.599
BS %	-.892	-.453	.942	.334	.994	.108

Table 5 shows the factor score patterns that reflect the spatial characteristics of the underlying relationship among soil properties within and between the two contrasting sites. The results reveal that the first two factors for continuously cultivated farms score negatively for most variables on both land use sites, while, fallow plots and forest fields on both land use sites have progressively decreasing numbers of negative scores for factor one, and decreasing negative scores from fallow lands to the forest for factor two. This implies that continuously cultivated farms on both sites are the most degraded of the three land use types with regards to soil properties. In comparison with other land use types, the results further showed that the forest area on the flatland, which was used as the control, suffered little or no degradation in terms of soil properties. This situation is a reflection of the balanced and undisturbed nature of the nutrient cycling process within a natural forest.

As a whole, most factors recorded the highest number of negative scores for continuously cultivated farms, and the number decreased from fallow plots to forest fields within and between land use sites. This, suggests that continuously cultivated farms are the worst degraded with respect to these soil properties followed by fallow plots and then forest fields.

Table 5: Factor Scores for topsoil of the three Land Use Types on the Hillslope and Flatland Sites

Site	Cultivated Farm					Fallow Farm		Forest Field	
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 1	Factor 2	Factor 1	Factor 2
Hillslope Site	-1.22334	.79945	-1.44903	-.99073	1.16503	1.01066	.55848	1.11189	.31149
	-.19050	-.37740	1.26453	-1.13419	-.39337	-.98899	.59602	-.28618	-1.11867
	1.02267	-.17166	-.98746	-1.37224	-1.32310	-.02167	-1.15450	-.82571	.80718
	-.99282	-.89088	-.48907	1.06109	.15465				
	-.38679	-1.36086	1.13854	-.36302	.85087				
	1.48710	-.85128	-.59464	.69626	.38317				
	-.87024	1.07082	.73306	.51497	-1.43519				
	.00624	.15450	-.45061	1.33278	-.59661				
	1.14768	1.62732	.83468	.25508	1.19455				
Flatland Site	1.14602	-.14134				1.14162	.17330	-1.05021	.48000
	-.45060	1.06315				-.42073	-1.07532	.10941	-1.14951
	-.69542	-.92181				-.72089	.90202	.94079	.66951

Conclusion

Soil degradation under agricultural land use in two contrasting topographies in a part of the Northern Guinea Savanna belt of Nigeria was assessed. This was done by collecting and analyzing thirteen different soil properties sampled from three-land use types on two contrasting topographies (hillslope and flatland sites). Indices of degradation were computed for each soil property. The results of these steps revealed that a number of soil properties could be used as indices of soil degradation. Three important groups of soil properties were identified as indices of soil degradation between and within the two contrasting sites namely: organic nutrients, cation exchange capacity, and soil texture. The results for these simple indices were confirmed by the results of factor analysis that show that there are two or three basic underlying relationships among the soil properties analyzed. For this reason, in the Savanna environment the agricultural quality of the soil can be evaluated or assessed by monitoring only these few soil properties. These indices are easily measured both qualitatively and quantitatively and can even be evaluated cheaply, hence it is beneficial. We recommend that researchers venture into similar studies in particular in relation to the entire Savanna region of Nigeria, because of the agricultural, residential industrial and engineering support potential.

Limitation

A major factor that may constrain the generalizability of the present study is the sample size for each land use type; a larger size would have been more reliable. However, despite the small sub-sample sizes, the fact is that the study is the first of its kind to develop a quantitative index (indices) for assessing soil degradation associated with agricultural land uses between two contrasting topographies and identify the basic underlying pattern of the interrelationship between the soil properties in northern Guinea Savanna Region of Nigeria. It is hoped that future researchers will contribute by examining with larger sample size.

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