



# Land-use changes and management impact on soil quality indicators in tropical ecosystem

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## Abstract

The decline in soil quality and unsustainable productivity of tropical ecosystems has made the investigation of land use induce changes essential for effective management options. The objective of the work was to describe the variations in the soil quality indicators as affected by land-use changes and management within Kyayya, Guinea Savanna Agro-ecological Zone of Nigeria. Soil quality was assessed using the physical and chemical analyses of soil under cultivated and deforested at 0–20 cm and forested land at 0–30 cm depths. The results revealed that the soil is sandy loam with significant differences ( $p=0.01$ ) among the particle sizes. Soil organic carbon and organic matter decreased following the conversion from forested land to cultivated land at 42% and 43%, respectively. Soil pH under cultivated area was slightly acidic and also recorded the lowest available phosphorus value (28.0 ppm). Results of the simple correlation coefficients displayed the interaction between the soil variables showed the influence of land-use changes and management patterns. The conversion from Forested to Cultivated land-use management types had a detrimental impact on the studied soil quality indicators. Therefore, there is an urgent need for national policies to prevent the remaining forested areas from being converted into cultivated areas and agroforestry practices as a viable option to ensure food security.

**Keywords** Land-use management · Soil quality indicator · Tropical ecosystem · Kyayya · Organic carbon

## 1 Introduction

Effective management of tropical lands is imperative for maintaining and preserving its fragile ecosystem and sustaining productivity. In addition, Atiyong and Michael (2022) suggested embracing effective management as the best option for improving

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environmental sustainability, economic development, and food security thereby attaining poverty reduction. Tropical lands have serious problems involving a decline in soil fertility and productivity, pollution, forms of water and wind erosion, salinization, acidification, water logging, and compaction. The problems are majorly affected by lithological processes, soil properties, climate, topography, and land use (Abrishamkesh et al., 2011; Kirkby et al., 2000). The importance of land use is greater than that of other factors because land-use changes and mismanagement are the main causes of environmental and soil quality degradation (Pacheco et al., 2018). Consequently, sustainable use of land resources in the tropics requires adequate understanding and monitoring of soil properties.

According to FAO (2005) and IPPC (2007), land-use changes and mismanagement are the second largest sources of human-induced greenhouse gas emissions accounting for 12–20% and significantly changing ecosystem functioning and biodiversity across biomes (Delelegn et al., 2017). The prevalent type of land-use change is the conversion of forest and grasslands into agricultural land with about 2.6% being converted annually in Nigeria (World Bank, 2001). This change has many interlinked effects causing significant alteration in the soil's physical, chemical and biological characteristics which in turn affects soil quality and sustainable productivity. Soil quality, as defined by Larson and Pierce (1991), is the ability of a soil to function within its boundaries in promoting plant and animal production. It also interacts positively with surrounding ecosystem boundaries by enhancing water and air quality (Doran, 2002). Soil quality can be ascertained using interactive indicators that characterize the soil. Physical (texture, bulk density and aggregate stability), chemical (organic carbon, CEC, nitrogen, macro- and microelements) and biological (microbial biomass and enzyme activities) indicators are useful for monitoring soil quality (Karlen et al. 1997; Doran & Zeiss, 2000; Delelegn et al., 2017).

The distribution and supply of soil nutrients are directly altered by the quality of soil indicators resulting from the cultivation of forest land. Soil carbon storage and mineralizable nitrogen are diminished within a few years of initial conversion (Majaliwa et al., 2010). Several authors have investigated the effects of the conversion of the forest ecosystem to cultivated land on soil quality. Lemenih (2004) studied the effects of land-use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia. Results showed that long-term cultivation caused a decrease in organic matter and total nitrogen and also indicated changes in soil surface (0–10 cm) phosphorous, potassium, available potassium, and cation exchange capacity. Yousefifard et al. (2007) assessed soil quality as a result of forest cultivation in the Cheshmeh Ali region. Results showed that organic matter, available phosphorous, cation exchange capacity, microbial respiration and mean weight diameter (MWD) decreased. The study of the effect of rangeland change on cultivated land on some soil's physical and chemical properties in the South of Isfahan showed significant changes in bulk density, pH, EC and mean weight diameter (Hajabasi et al., 2007). Studying the changes in soil quality and aggregate stability led Delelegn et al. (2017) to the conclusion that unsustainable and sedentary farming practices are detrimental to soil quality indicators. This conclusion was a result of the significant reduction in organic matter, aggregate stability and enzyme activities when comparing cropland to natural forest. The research work by Obidike-Ugwu et al. (2021) revealed the impact of land-use management-induced changes on the fertility of the soil of Bokkos. Their results showed evidence of poor soil fertility especially under the cultivated land compared to the grazed and forested lands. Therefore, land-use changes and management are believed to diminish soil quality and can lead to the degradation of land productivity (Mojiri et al., 2011).

Although there have been attempts to investigate the impact of land-use changes and management on soil quality in the tropics, little work has been done in the study area. Hence, the objective of the study was to describe the variations in the soil quality indicators about different land-use changes and management types within Kyayya, Guinea Savanna Agro-ecological Zone of Nigeria. Then, the specific research questions to be addressed in this study are (1) what is the influence of land-use types on physical and chemical soil quality indicators? (2) How do the soil quality indicators relate to each other at different land-use management types?

## 2 Materials and methods

### 2.1 Site description

The study was conducted in Kyayya (9° 21' 16" N, 8° 6' 54" E), Jema'a Local Government Area of Kaduna State (Fig. 1). It is within the Guinea Savanna Agro-ecological Zone of Nigeria which lies between Latitudes 9° 00' 00" and 10° 45' 00" North of the Equator and Longitudes 7° 10' 00" and 8° 45' 00" East of the Greenwich Meridian. The area is designated with two distinct seasons, a wet season and a dry season. Rainfall occurs between April and October and peaks in August with an annual rainfall of approximately 1200 mm, while the dry season occurs from November of one calendar year to March of the next. The mean monthly temperature is 28 °C, while the mean atmospheric relative humidity is about 63% (Abaje et al., 2010, 2016). The soil moisture and temperature regimes are udic and thermic, respectively. The main type of soil is the ferruginous tropical soil, well-drained and shallow, with texture mainly loamy sand to sandy loam at the top surface. The topography is relatively flat and undulating affecting the drainage pattern of the area (Abaje et al., 2009). The nature of the area supports a wide variety of annual and perennial tree crop productivity (Eroarome, 2005). The people are mainly farmers converting forest land to sustain their livelihood with no sustainable management practices to compensate for the changes. The traditional strategy of using natural fallow to restore soil quality has been completely abandoned or practised in a manner not long enough for effectiveness (Magaji & Shat, 2019).

### 2.2 Land-use selection, soil sampling, laboratory and data analysis

Three land-use management types (Cultivated, Deforested and Forested area) were located within the Kyayya settlement area. The selected locations are relatively similar in terms of soil, physiography and parent material. This was done to minimize the difference in soil conditions except those resulting from the uses or conditions to which the soils are subjected. The Cultivated area has been under intensive cultivation for more than five years with maize, guinea corn and soybeans intercropped. The Deforested area was cleared, cultivated for sometimes then left with vegetative cover. The forested area is predominantly covered with *Anogeissus leiocarpus* species, a few stands of *Parkia biglobosa* and shrubs. Each land-use type was divided into five plots, and disturbed soil samples were taken from each plot using soil auger. Random sampling techniques were used. Triplicate soil samples were collected from each plot at 0–30 cm (Deforested and Forested) and 0–20 cm (Cultivated area) soil. The sampling depth is a recommended ploughing depth for most cultivated soils as suggested by Richard et al. (1999). A total of 45 disturbed soil samples were

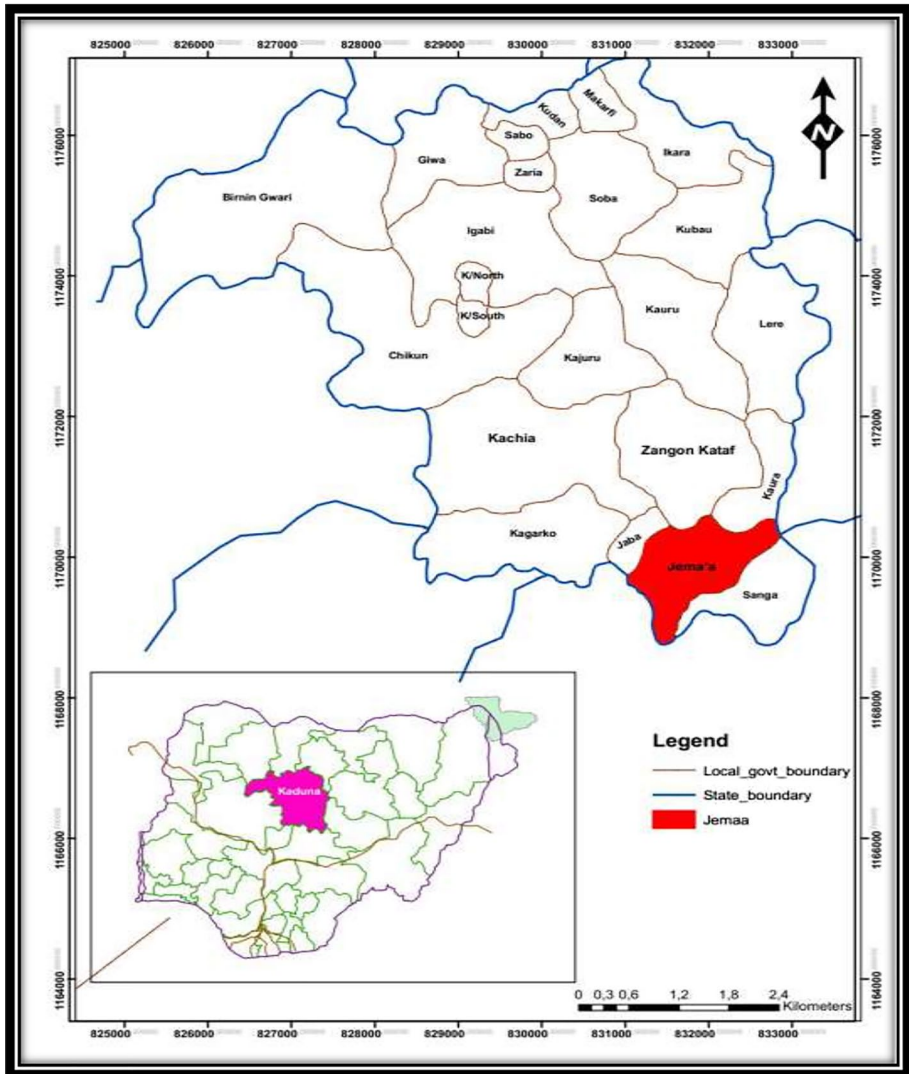


Fig. 1 Map of Kaduna state with Jema'a Local Government Area. Source: Magaji and Shat (2019)

taken from the field to produce 15 composite soil samples. The samples were carefully labelled and taken to the laboratory for analysis.

The samples were air-dried, gently crushed and passed through a 2 mm sieve and used for the assessment of some soil quality indicators. Soil texture (clay, silt and sand) was determined by the hydrometer method with sodium hexametaphosphate (Calgon) as a dispersant (Kroetsch & Wang, 2007). A calculated ratio of silt and clay (SCR) was done to estimate soil susceptibility to weathering and the age of the soil (Yakubu et al., 2008). Organic carbon was estimated by Nelson and Sommers (1982) by the modified Walkley/Black procedure and multiplied by the van Bammeller factor of 1.724 to

calculate organic matter content. Total nitrogen by Kjeldahl distillation method (Bremner & Mulvaney, 1996), pH in water and calcium chloride were determined in a 1:2.5 solution and measured by the glass electrode pH meter (Mclean, 1982), and available phosphorus extracted by Bray II method as outlined in Olsen (1982).

The soil data obtained were subjected to analysis of variance (ANOVA) in the Agricolae procedure (RStudio Core Team 2022) to compare the effect of land-use management types on various soil quality indicators presented. Significant effects were identified at the  $p$  value  $< 0.05$  probability level, and comparisons between mean values were based on the least significant difference (LSD) test. The simple correlation between various soil indices was evaluated using Pearson's correlation coefficient in the GGally and psych packages in RStudio software.

### 3 Results and discussion

#### 3.1 Land-use management type's effects on soil quality indicators

##### 3.1.1 Land-use management types and soil physical indicators.

The ANOVA compared all the studied soil quality indices at the three locations (Cultivated, Deforested and Forested) and is presented in Table 1. The result revealed significant differences ( $p = 0.01$ ) among the particle sizes (clay, silt and sand contents). The cultivated area had the lowest values for clay and silt, and the highest value for sand when compared to the Deforested and Forested areas. The general trend of the particle size distribution showed that after cultivation, there was a significant decrease in silt content from 22.8% in the Forested area to 18.4% in the Cultivated area. On the other hand, sand content increased significantly from 64.0% for the soil in the Forested area to 70.0% for the soil in the Cultivated area. Nevertheless, the soil textures within the studied areas were classified as sandy loam. The SCR significantly differs at  $p = 0.01$  with the Forested area having the highest value (1.733) though statistically similar to the Cultivated area (1.587) which was also similar to the Deforested area (1.469).

The homogeneity in the soil types was an indication that any changes observed in the soil quality can largely be attributed to the land-use management types. Changes observed in the soil particle size distribution where Cultivated land had higher sand fraction are the results of tillage which favours the production of finest soil particles (silt and clay) and the removal of the same by erosion process due to high rainfall leading to soil degradation. This is in agreement with several studies (Amanuel et al., 2018; Assefa et al., 2020; Gülser et al., 2021; Yuksek et al., 2009) though contradicts the study of Obidike-Ugwu et al., (2021). The SCR is an indication of the age of the parent material and the weathering potentials of soil according to Young (1976) and Ayolagha, (2001). The SCR result revealed a young parent material with high weathering potential following their ranking ( $SCR > 0.15 =$  young parent material and  $> 0.2 =$  high weathering potentials). SCR of above 0.2 has also been reported by other researchers in Northern Nigeria (Yakubu et al., 2008; Imodejemu et al. 2017; Osujieke et al., 2020) and could be attributed to the high-temperature regime of the area which encourages high and intense weathering influenced by the textural composition of the soil.

**Table 1** Analysis of variance (ANOVA) of land-use management types' effect on selected soil quality indicators

LMT	Clay (%)	Silt (%)	Sand (%)	TC	SCR	OC (%)	OM (%)	TN (%)	pHw	pHc	AP (ppm)
Cultivated	11.6 <sup>b</sup>	18.4 <sup>b</sup>	70.0 <sup>a</sup>	SL	1.587 <sup>ab</sup>	1.072 <sup>b</sup>	1.850 <sup>b</sup>	0.126 <sup>a</sup>	6.54 <sup>a</sup>	5.56 <sup>b</sup>	28.0 <sup>b</sup>
Deforested	14.0 <sup>a</sup>	20.4 <sup>ab</sup>	65.6 <sup>b</sup>	SL	1.469 <sup>b</sup>	1.248 <sup>b</sup>	2.152 <sup>b</sup>	0.181 <sup>a</sup>	6.42 <sup>a</sup>	5.90 <sup>a</sup>	50.4 <sup>a</sup>
Forested	13.2 <sup>a</sup>	22.8 <sup>a</sup>	64.0 <sup>b</sup>	SL	1.733 <sup>a</sup>	1.526 <sup>a</sup>	2.642 <sup>a</sup>	0.102 <sup>a</sup>	6.68 <sup>a</sup>	5.98 <sup>a</sup>	30.8 <sup>b</sup>
LSD	1.6	3.06	3.79	–	0.25	0.25	0.44	0.21	0.35	0.20	17.22
<i>p</i> value	**	**	**	–	**	***	***	ns	ns	***	**

*LMT* Land management types, *TC* Textural class, *SL* Sandy loam, *SCR* Silt clay ratio, *OC* Organic carbon, *OM* Organic matter, *TN* Total nitrogen, *pHw* pH in water, *pHc* pH in CaCl<sub>2</sub> and *AP* Available phosphorus

*p* Value significant at 0.05 (<sup>a</sup>), 0.01 (<sup>ab</sup>), 0.001 (<sup>b</sup>), 0.001 (<sup>\*\*\*</sup>) and *ns* Non-significant at 5% level of probability

### 3.1.2 Land-use management types and soil chemical indicators.

There is significant variation in organic carbon (OC) and organic matter (OM) at  $p > 0.001$  under the land-use management types studied (Table 1). The forested area had higher OC and OM values than the Deforested and Cultivated areas. Deforested and Cultivated areas though were not significantly different, but the Deforested area was 14.10% (OC) and 14.03% (OM) higher than the Cultivated area. The higher proportion of OC in the Forested area could be a result of litter falling from the forest trees and input from root biomass (Yimer et al., 2007). This also validates the use of forest ecosystems as a carbon sink to reduce global warming as opted by other works (Tchienkoua & Zech, 2004; Yao et al., 2010). In the same vein, lower value recorded under Cultivated areas can be attributed to intensive cultivation and tillage operation resulting in low organic material and exposure to high oxidation rate (Girmay et al., 2008). The Deforested area with a 14.10% increase in OC when compared to the Cultivated area could be a result of the fallow period enjoyed by the land area. However, the OC of the study area is low when compared to the critical value of 3.0% suggested for tropical soil (Akinrinde & Obigbesan, 2000; Enwezor et al., 1990). On the other hand, the lowest value of OM under Cultivated areas confirmed the findings of Greenland et al. (1992) and Adegbite et al. (2019) that intensive cultivation activities deplete soil organic matter content. Decreasing OC will in turn decrease the accumulation of OM leading to the deterioration of soil structure, yielding greater amounts of dispersed clay and affecting microbial activities (Amezketta, 1999) if not properly handled through effective land management. Values of TN 0.102%, 0.126% and 0.181% being the increasing order for Forested, Cultivated and Deforested areas showed no variation (Table 1). Though not significant, the value under the Deforested area was above the critical value of 0.15% as proposed by Chude et al. (2011). This is also consistent with the work of Obidike-Ugwu et al. (2021) though contradicts reports by Awdenege et al. (2013) and Khresat et al. (2008) whose works showed significant TN values.

Soil pH is a measure of hydrogen ion concentration in soil solution (McCauley et al., 2009) and affects nutrient availability and toxicity in soil (Benton, 2012). Soil pH was measured in distilled water and 1 mol CaCl<sub>2</sub> solutions and is tabulated in Table 1. The pH in the water solution exhibited no significant variation irrespective of the management types. Nonetheless, pH in CaCl<sub>2</sub> increased significantly ( $p > 0.001$ ) from Cultivated to Deforested and Forested areas. The low pH displayed by the soil in Cultivated areas may not be unconnected to the constant harvesting of crops. Crop harvesting encourages the leaching of exchangeable bases which are easily washed away by soil erosion due to high rainfall in the studied area. Gebrekidan and Negassa (2006) and Amanuel et al. (2018) reported the remarkable influence of management practices on soil pH. The amount of phosphorus available (AP) for plant use was determined and is also shown in Table 1. Available P under the Deforested was higher significantly at  $p > 0.01$  than under Cultivated and Forested which were the same statistically. These findings are similar to the results obtained by Hargreaves (2015) and Kharal et al. (2018). The lower values observed can greatly be attributed to the soil pH level. Soil pH greater than 6.5 is a favourable condition for P fixation with calcium to form calcium phosphate compound and thereby unavailable in the soil solution (Lindsay, 1979; Thomason, 2002). The greater available phosphorus value in soil under Deforested could be due to the residual effects of fertilizer used before the fallow period (Richardson et al., 2009) and the pH level of 6.42. Duncan (2002) implied that plants use about 20–50% of applied P, while the unused ones are retained in the soil increasing phosphorus availability in soil solute.



### 3.2 Relationship between the soil quality indicators under the land-use management types

Pearson's correlation coefficient was used to assess the interaction between the soil variables under the different land uses and tabular in Tables 2, 3 and 4 for Cultivated, Deforested and Forested areas, respectively. The interaction under the Cultivated area (Table 2) showed that clay content interacted positively with silt, pH in water and  $\text{CaCl}_2$  at  $p < 0.01$  but negatively with sand and positively with OC and OM at  $p < 0.05$ . It reacted differently under Deforested area (Table 3), interacting negatively with SCR ( $r = -0.69$ ) and pHc ( $r = -0.60$ ) at  $p < 0.01$  and with sand ( $r = -0.54$ ) and AP ( $r = -0.30$ ) at  $p < 0.05$ . Similarly, clay interacted negatively with all the other soil variables under Forested areas except with silt (Table 4). Sand, TN and pHc had highly significant interaction with clay, while silt, SCR, OC and OM were significant at a 5% probability level. Under Cultivated land, silt correlated negatively with sand ( $r = -0.98$ ,  $p < 0.01$ ), positively with OC and OM ( $r = 0.68$  and  $0.67$ ,  $p < 0.01$ ) and SCR and AP ( $r = 0.52$  and  $0.55$ ,  $p < 0.05$ ). Silt correlated with soil variable under Deforested land in the following manner, negative with sand ( $r = -0.84$ ,  $p < 0.01$ ), OC ( $r = -0.98$ ,  $p < 0.01$ ), OM ( $r = -0.98$ ,  $p < 0.01$ ), TN ( $r = -0.61$ ,  $p < 0.01$ ) and AP ( $r = -0.53$ ,  $p < 0.05$ ) but positive with SCR ( $r = 0.72$ ,  $p < 0.01$ ) and pHc ( $r = 0.49$ ,  $p < 0.05$ ). Silt under Forested land correlated negatively with sand ( $r = -0.94$ ,  $p < 0.01$ ), pHc ( $r = -0.80$ ,  $p < 0.01$ ), TN ( $r = -0.37$ ,  $p < 0.05$ ), pHw ( $r = -0.27$ ,  $p < 0.05$ ) and positively with SCR ( $r = 0.75$ ,  $p < 0.01$ ).

Sand correlated strongly with OC and OM under Cultivated and Deforested areas but weakly under Forested areas (Tables 2, 3 and 4). Sand also had a weak negative correlation with  $r = -0.33$ ,  $-0.30$ ,  $-0.37$  and  $-0.37$  for SCR, pHw, pHc and AP, respectively. Under Deforested areas, sand correlated strongly with AP ( $r = 0.61$ ) and weakly with TN ( $r = 0.49$ ). Sand under the Forested area had a strong positive correlation with TN ( $r = 0.57$ ) and pHc ( $r = 0.94$ ), positive weak with pHw ( $r = 0.29$ ) and negative weak with SCR ( $r = -0.49$ ). SCR related to all the studied soil chemical properties under Cultivated, with OC, OM, pHc and TN under Deforested and non-under Forested land use. Soil organic carbon interacted perfectly with OM and considerably interacted with other soil variables in like manner across the land-use types (Tables 2, 3 and 4). Total nitrogen correlated weakly with pHc ( $r = 0.36$ ) and AP ( $r = -0.42$ ) under Cultivated areas, strongly under Deforested (pHc:  $r = -0.74$ , AP:  $r = 0.57$ ) and Forested (pHc:  $r = 0.65$ , AP:  $r = 0.57$ ) and weakly with pHw ( $r = -0.33$ ). There is no significant correlation between soil pH in water and  $\text{CaCl}_2$  in Cultivated and Forested areas, while there is a weak negative correlation ( $r = -0.37$ ) under Deforested areas. Soil pH in water interacted negatively with AP across the three land uses, while pHc interacted with AP ( $r = -0.67$ ) under Deforested areas only.

Generally, the correlation coefficients revealed that the way and manner of interaction between studied soil variables are greatly influenced by land-use changes and management patterns. Similar results were observed by several authors (Amanuel et al., 2018; El Mazi et al., 2022; Ghouloubi et al., 2019).



**Table 2** Pearson correlation coefficients between various soil quality indicators under the Cultivated land-use management

Cultivated	Clay (%)	Silt (%)	Sand (%)	SCR	OC (%)	OM (%)	TN (%)	pHw	pHc	AP (ppm)
Clay (%)	1.00									
Silt (%)	0.80**	1.00								
Sand (%)	-0.91**	-0.98**	1.00							
SCR	-0.09	0.52*	-0.33*	1.00						
OC (%)	0.43*	0.68**	-0.62**	0.51*	1.00					
OM (%)	0.42*	0.67**	-0.61**	0.51*	1.00	1.00				
TN (%)	0.16	-0.22	0.09	-0.58**	-0.41*	-0.41*	1.00			
pHw	0.58**	0.13	-0.30*	-0.61**	0.36*	0.36*	0.20	1.00		
pHc	0.61**	0.22	-0.37*	-0.51*	-0.43*	-0.44*	0.36*	0.27	1.00	
AP (ppm)	0.00	0.55*	-0.37*	0.91**	0.74**	0.74**	-0.42*	-0.34*	-0.67**	1.00

**Table 3** Pearson correlation coefficients between various soil quality indicators under the Deforested land-use management

Deforested	Clay (%)	Silt (%)	Sand (%)	SCR	OC (%)	OM (%)	TN (%)	pHw	pHc	AP (ppm)
Clay (%)	1.00									
Silt (%)	0.00	1.00								
Sand (%)	-0.54*	-0.84**	1.00							
SCR	-0.69**	0.72**	-0.23	1.00						
OC (%)	0.09	-0.98**	0.78**	-0.78**	1.00					
OM (%)	0.08	-0.98**	0.79**	-0.77**	1.00	1.00				
TN (%)	0.05	-0.61**	0.49*	-0.51*	0.64**	0.64**	1.00			
pHw	-0.17	0.10	0.01	0.22	-0.23	-0.24	0.24	1.00		
pHc	-0.60**	0.49*	-0.08	0.77**	-0.50*	-0.49*	-0.74**	-0.37*	1.00	
AP (ppm)	-0.30*	-0.53*	0.61**	-0.23	0.62**	0.63**	0.57**	-0.52*	0.00	1.00

**Table 4** Pearson correlation coefficients between various soil quality indicators under the Forested land-use management

Forested	Clay (%)	Silt (%)	Sand (%)	SCR	OC (%)	OM (%)	TN (%)	pHw	pHc	AP (ppm)
Clay (%)	1.00									
Silt (%)	0.27*	1.00								
Sand (%)	-0.58***	-0.94***	1.00							
SCR	-0.43*	0.75***	-0.49*	1.00						
OC (%)	-0.51*	-0.10	0.26*	0.22	1.00					
OM (%)	-0.53*	-0.13	0.29*	0.20	1.00	1.00				
TN (%)	-0.76***	-0.37*	0.57***	0.15	0.92***	0.93***	1.00			
pHw	-0.17	-0.27*	0.29*	-0.08	-0.57***	-0.58***	-0.33*	1.00		
pHc	-0.76***	-0.80***	0.94***	-0.24	0.31*	0.34*	0.65***	0.22	1.00	
AP (ppm)	-0.21	-0.04	0.11	0.04	0.63***	0.65***	0.57***	-0.88***	0.24	1.00

## 4 Conclusion

Changes in soil quality indicators with respect to land-use changes and management patterns (Cultivated, Deforested and Forested areas) were investigated in Kyayya, Jema'a Local Government Area of Kaduna State, Nigeria. Analysis carried out is suggestive of the homogeneity in the soil types, an indication that changes observed in the soil qualities are largely connected to the land-use management types. The transition from Forested to Cultivated land-use management types had a detrimental impact on soil quality indicators. Forest provided good soil cover, enriching soil OM as well as carbon stock levels and excellent protection against erosion. The cultivated area, on the other hand, was mainly affected by successive tillage operations which modified the soil quality exposing it to harsh weather conditions. This is true, especially with an SCR of above 0.2. However, variation in the soil quality indicators was minimal under the Deforested land-use management type when compared to the Forested area. Thus, the result of the study revealed the need for urgent national policies to prevent the remaining forested areas from being converted into cultivated areas: agroforestry practices to ensure food security and development of sustainable cultivation practices to improve carbon storage and implementation of extension programmes to ensure the conservation of crop residues to compensate for the large mineralization of organic matter to reduce drastic effects on soil quality.

**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by EOOU, BB, OEN and JOA. The first draft of the manuscript was written by EOOU, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Data availability** The data that support the findings of this study are available on request from the corresponding author [Obidike-Ugwu, E.O].

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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