LAND-USE VARIATIONS ON SOIL PROPERTIES ALONG THE RIVER KATSINA-ALA IN BENUE STATE NORTH CENTRAL, NIGERIA

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Abstract
Land use is a major driver of global environmental changes especially agricultural land clearing and urbanization; these changes influence the basic reserve of land and a variety of soil natural processes. A study of the impact of land use on intrinsic soil properties were studied in the two locations along Katsina- Ala River in Benue state Nigeria. The key land quality indicators were, soil organic matter (SOM), bulk density, total nitrogen (TN), carbon- nitrogen (CN) ratio, soil pH, soil depth, Porosity, and textural diversity. The soil morphological properties indicated an Ap (10YR 3/3) horizons colour under moist condition at both locations in the top soil with Bt sub soil conditions. The structures were rated weak medium sub angular blocky, this conformed to a favourable bulk density (0.87 – 1.90 g/cm^3) and porosity (61 -67.4 %) values obtained. The soil depth were classified as deep (>100 cm). Calcium and magnesium were dominant in the total exchangeable bases (TEB) and CN ratio which accounted for high rating of microbial biomass carbon (MBC) levels. The high %BS are suggestive of alfisol order but because Bt (argillic) horizon and the colluival/ fluvial additions, soils along Katsina-Ala River tends to have entic properties and the dominant clay was the 2:1 lattice clay minerals. It was observed that many indigenous land practices are both conservation and conventional. Therefore, soil quality indicators were within threshold limits while the major threat to sustainable land use was the mining of top-soil for burn bricks making.
Keywords: Land-use, soil properties, soil organic matter, sustainable agriculture, River Katsina-ala.

Introduction

Land-use (LU) significantly influence soil physical especially structure parameters (Oguike and Mbagwu, 2009). Changes in land-use such as conversion of natural to cropland has contributed to land degradation that manifested in losses of soil organic matter (SOM) and reduced stability of the soil aggregates. Mbagwu and Auerswald (1999) have also demonstrated that LU influences structural stability than intrinsic soil properties and that percolation stability of the soil increased with increase in SOM content. Influences or variation that may occur in soil arising from LU are low aggregate stability and soil water characteristics (water holding capacity, available water, field capacity and permanent wilting point. Physical characteristics such as bulk density, porosity and hydraulic saturation may be altered. In characterizing SOM variation in land utilization type (LUT), Oguike and Mbagwu (2009) observed that SOM accumulation in five LUT they studied in southeastern Nigeria; the order of decrease was forest > four year fallow > grassland >cassava farm and soils under continuous cultivation had the SOM. Their finding agreed with that of Lal (1985) while Kutilek (2004) used heavy machinery in tillage operation that negatively impacted soil pore space via compaction. Changes in LU are the main drivers of environmental changes and the changes influences the basic resources of land and a variety of natural processes including soils which are dynamic and hence susceptible to change in their properties (morphological, physical and chemical). LU influences soil aggregation and overall soil health. Castro *et al*., (2019) agreed that LU changes are the drivers in soil redistribution; by influencing infiltration and runoff, erosion while other authors are in agreement (Conant, *et al* 2001, Saraswathy, *et al* 2007)

Information about the impact of LU on the arable lands on the proximal soils of River Katsina-Ala for sustainable agriculture would be of immense contribution to soil conservation and management practices adaptable. Therefore, the aim of this study was to investigate the effect of LU on soils properties along the river Katsina- ala.

Materials and Method

Study Area

Two locations along the toposequence of River Katsina-Ala were used for the study location. The areas of interest were Katsina-Ala (7°10'25.5'' N and 9°16'0.85''E) and Buruku (7°27'24.8''N and 9°12'41.1''E) at 25 km apart and both are along the river Katsina-Ala in Benue state. River Katsina-Ala is an international (transboundary) water body in the northcentral state of Benue, it originated from the republic of Cameroon in the Bamenda highlands (northwest) and a major tributary of river Benue. The study area is characterized by tropical climate with two distinct seasons, wet and dry season, the wet season lasts from March to October whereas the dry seasons last from November to February, with mean annual rainfall of 1299 – l641 mm distribution is bimodal with peaks in August and September (NIMET, 2021). The relative humidity varies as the season (about 40 % in January and 90 % in July) with mean annual temperature of about 29°C and the dry and wet seasons are controlled by the annual migration of the inter-tropical zone of convergence (ITZC). The area lies in the southern guinea savannah with green vegetation and scanty tall trees (Ukpai, 2021). The vegetation is secondary regrowth due to the influence of man, through bush burning, land clearing and land cultivation. The vegetation is woody savannah characterize by mango (*mangifera indica*), wide palm, *Daniella olivera*, Shea tree (*Vitellaria paradoxa*). The hydrology and drainage is governed by river Katsina-Ala. The soils are derived from alluvium of either basement complexes or false bedded sandstone giving rise to sandy loamy soil (figure 1). The major farm produce are Yam (*Dioscora spp*), Soy Bean (*Glycine max*), Maize (*Zea mays*), Cassava (*Manihot spp*), Rice (*Oryza sativa*), Sugarcane others are Amaranths, Eggplant, Tomatoes and Pepper. Other socioeconomic activities are fishing, river sand mining and burn bricks making from top soil mining along the floodplains. Indigenous grasses identified in the fields were *Andropogon gayanus* (Gamba grass), Brachiaria *decumbens* (Signal grass), *Cenchrus ciliaris* (Buffel grass), *Digitaria smutsii* (Finger grass), *Panicum maximum* (Guinea grass), *Hyparrhenia rufa* (Shuchi grass). The abundance of these pasture acts as attractants to cattle herders (Fulani pastoralist).

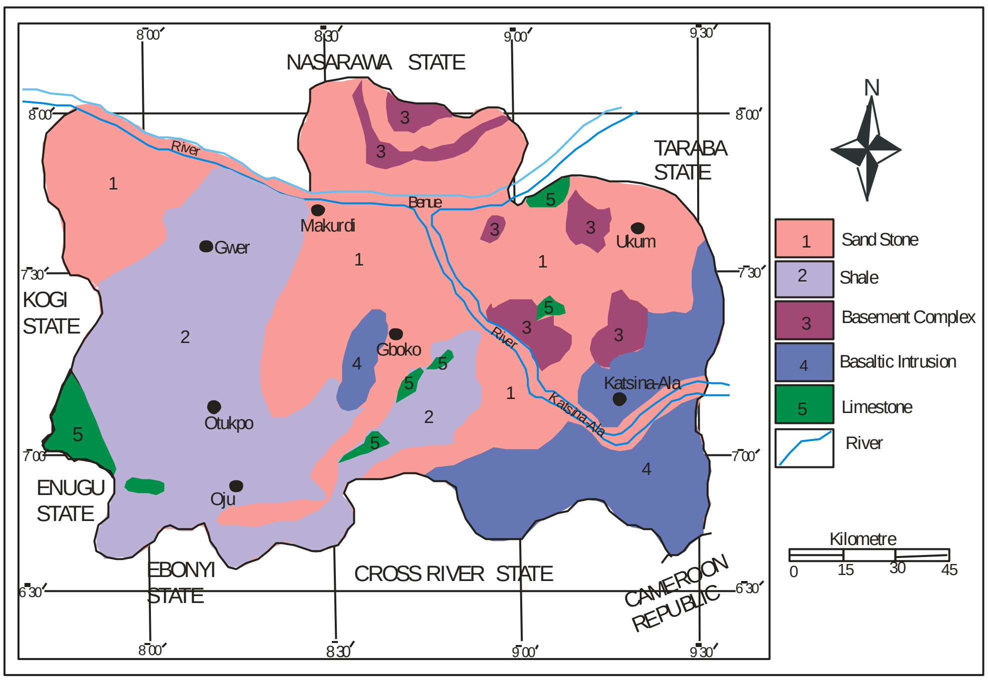

Figure 1: Geology Map of Benue State
Source: Benue State Ministry of Lands, Survey and Solid Minerals, Makurdi

Field Work

Three mapping units were identified and classified based on physiographic position along the toposequence and associated land-use types in the two study sites. A purposive sampling technique was adopted in the study. A transect was used to delineate the slope. Reconnaissance survey was carried out in order to obtain general information about the study area. The toposequence were delineated into mapping units based on their physiographic positions (upper slope, mid-slope and valley bottom) along transect spaced at 200 m across the slope. These slope positions also corresponded to different landuse upon which three profile pits were sunk according to the procedures outlined by Schoeneberger *et al* (2012). Sampling was based on genetic horizon differentiation. All profile pits were geo-referenced with hand held GPS receiver. The profiles were described based on genetic horizons differentiation in-situ. A total of twenty eight (28) soil samples were taken for routine physical and chemical analysis.

Laboratory Analysis

The pH was determined by glass electrode pH meter, particle size analysis was by hydrometer method. Organic carbon was determined by wet dichromate method. Total nitrogen was determined by micro-Kjeldahl digestion method. Extraction of available phosphorus was done using Bray 1 method. Exchangeable cation (K, Ca, Mg, and N) were extracted by neutral normal ammonium acetate, K and Na in the extraction were determined by flame photometer while Ca and Mg were by atomic absorption spectrophotometer. Cation exchange capacity was by summation method. The exchangeable acidic cations:

hydrogen and aluminium were estimated titrimetrically. Bulk density was measured by core method (Grossman and Reinsch, 2002). Total porosity (P_o) was obtained from bulk density (ℓp) values with assumed particle density (ℓs) 2.65 g cm^{-3} as follows, Porosity (Po) =100 – (ℓp/ℓs) ×100/1. The following micro nutrients Fe, Zn, Mn and Cu were analyzed with atomic absorption spectrophotometer after wet digestion with concentrated HCl and HNO_3. The data collected were analyzed using descriptive statistics and coefficient of variability among soil properties were measured using coefficient of variation (CV) and rank according to the procedure of Wilding *et al*., (1994).

Results and Discussion

The morphological properties of Katina- Ala and Buruku soils are presented in tables 1a and 1b. The soil are moderately deep (≥ 100 cm) and porous, the entire horizon were well drained. The soil structure all physiographic positions in both locations had crumby structure in the top soil to weak sub-angular and granular in the sub soil. The soil had different color metrix range, with yellowish red dominating. The top soil in Katsina-Ala had dark reddish brown (2.5YR3/4) in Ap horizons to dark (7.5YR4/6) or strong brown (7.5YR3/3) while sub soil colour indicates yellowish red to pink (5YR7/3) to dark brown (2.5YR5/8) in the Bt argillic horizons. The structure were generally crumby/granular in top soils while they had weak medium sub angular to angular blocky in the sub soils along the toposequence. Mottle development was regarded as few to nil this may be due to the textural class of the soil where sand fraction dominated giving a sandy loam texture which in turn enhances drainage. In the Buruku profiles where in pedon 1, it was observed that across the horizons the colours ranges from dark reddish brown (2.5 YR 314) at Ap horizon, sub soil had pinkish colouration (5 YR 7/3) in the Bt horizon. Pedon 2, had colour range of Strong brown (7.5 YR 5/6) in the Ap horizon to red (2.5 YR 3/8) in the Bt horizon. pedon 3, recorded a colour range from dark in the Ap horizon to red (2.5 YR 5/8) in the sub soil. There were more distinct and observable pedogenic horizons in the Buruku study area than in Katsina-Ala soils. However, the textual classes of the soil were sandy loam in the AP, loamy sand in the Bt1, silty loam in the Bt2 and Loamy sand in the Bt3 horizons. Pedon 2, showed a textual range of sandy loam (SL) in the Ap and AB horizons, loamy sand (LS) in the Bt1, horizons and Sandy Loam (SL) in the Bt2 and Bt3 horizons. Pedon 3, was observed to have a textual range of Loamy sand (LS) in the AP horizons, Silty loam in AB horizon, Sandy Loam (SL) in the Bt1, horizons and loamy sand (LS) at the Bt2 and Bt3 horizons. It could be observed that there was more textural diversity in Buruku than in Katsina-Ala. This is an indication that soil on the lower course of the river tends to have more colluvial and alluvial material sediments and in agreement with the finding of Tomer and Anderson (1995) who attributed differences in soil texture to the variation in parent materials and topography. The colour matrix of dark yellowish brown, strong brown and reddish yellow are associated with minerals such as Goethite (FeOOH) and Haematite (Fe_2O_3) and redoximorphic features associated with flooding/wetness resulted from alternating periods of reduction and oxidation of iron and manganese compounds in the soils (Stoops and Eswaran, 1985; Hossain et al., 2011). These are in agreement with Imadojemu et al (2022). The sub angular and angular structures found in the Bt horizons are indicative of illuviation processes (Imadojemu, 2021). Soil depth are critical to land use, it is a characteristic that defines the agricultural usefulness of the land. The soils in Buruku were deeper than Katsina-Ala. Their depths were averaged 108 cm and 130 cm for Katsina-Ala and Buruku respectively. Soils in these areas are deep even though plinthitic restriction zone

Table 1b: Morphological Properties of the Soils Along the Toposequence of River Katsina- Ala at Buruku

Horizon	Depth (cm)	Color (moist)	Structure	Mottle	Horizon Boundary	Text.	Consistence	Veg.	Root Presence
Profile 1				**Coordinates: 7°27'24.8''N and 9°12'41.1''E 85 MASL**					
AP	0.30	2.5YR3/4 Dark reddish brown	Granular/ crummy	No Mottles	CS	Sandy Loam	Loose	Woody Savannah and tall grasses	Vf- F (Very few)
AB	30-40	7.5YR4/6 Strong brown	Granular/ crummy	None	DW	Silty loam	Friable		Vf- F (Very few)
Bt1	40-67	7.5YR5/8 Strong Brown	Wmsabk	Few mottles (7.5YR2.5/3	CS	Loamy sand	Firm		Vf (Very few)
Bt2	67-92	5YR 5/6 Yellowish red	Wmsabk	Common (2.5YR 6/8)	DW	Loamy sand	Very firm		Vf (Very few)
Bt3	92-120	5YR7/3 Pink	Sabk	2.5YR6/8 and 7.5YR2.5/3	DW	Loamy sand	Very firm		No root
Profile 2				**Coordinates: 7°26'34'9'N and 9°13' 6.6''E 104masl**					
AP	0-10	7.5YR4/6 Strong Brown	Loose	No mottles	CS	Sandy Loam	Coarse friable gritty	Woody Savannah and tall grasses	Vf- C (common)
AB	10-20	7.5YR6/6 Reddish Yellow	Loose	2.5 RY4/1	CS	Sandy Loam	Coarse friable gritty		Vf- M (many)
Bt1	20-70	7.5YR5/6 Strong Brown	Crumby granular	2.5YR4/1	CS	Loamy sand	Firm or moderately		Vf- C (many)
Bt2	70-90	5YR5/6Yellowish Red	Wmsabk	2.5YR4/1	CS	Sandy Loam	Friable		Vf (Very few)
Bt3	90-140	2.5YR5/8 Dark Brown	Wmsabk	2.5YR6/8	CS	Sandy loam	Firm		Vf (Very few)
Profile 3				**Coordinates: 7°26'34.9'N and 9°13' 6.6''E 104masl**					
AP	0-20	7.5YR3/3 Dark Brown	Loose	No mottles	CS	Loamy Sand	Friable	Woody Savannah and tall grasses	Vf- C (many)
AB	20-48	7.5YR3/6 Strong Brown	Loose	No mottles	CS	Silty loam	Friable		Vf- C (many)
Bt1	48-60	7.5YR6/6 Reddish Brown	Loose	No Mottles	CS	Sandy loam	Friable		Vf - F (many)
Bt2	60-90	5YR5/8 Yellowish Red	Wmsabk	No mottles	CS	Loamy Sand	Firm		Vf (Very few)
Bt3	90-130	2.5YR3/8 Red	Wmsabk	No mottles	CS	Loamy Sand	Firm		Vf (Very few)

Table 1a: Morphological Properties of the Soils Along the Toposequence of River Katsina- Ala at Katsina-Ala

Horizon	Depth	Colour	Mottles	Str	HB	Text	Consist	Veg	Root Presence
Pedon 1		Coordinates: 7°10'25.5'' N and 9°16'0.85''E 180 masl							
Ap	0-15	Dark brown 10YR3/3	Nil	Crumby	SC	SL	firm and slightly sticky		Vf-M (common)
AB	15-30	dark reddish brown 2.5YR3/4	Nil	Wmsabk	SC	SL	very sticky and plastic		Vf-M (common)
Bt1	30-55	Very dark brown 7.5YR2.5/3	Nil	Wmsabk	SC	SL	slightly sticky and plastic		Vf-F(few)
Bt2	55-80	pinkish gray 5YR 6/2	present	Sabk	SC	SL	sticky and plastic		vf (very few)
Bt3	80-110	reddish yellow 7.5YR 6/2	reddish	Abk	SC	SL	very sticky and plastic	secondary regrowth and tall grasses	Nil
Pedon 2		Coordinates: 7°10'24.0''N and 9° 16' 15.2''E 183 masl							
Ap	0-25	reddish gray 5YR 5/2	Nil	Crumby	SC	SL	firm and slightly sticky		Vf-M (common)
AB	25-45	Very pale brown 10YR8/4	Black	Wmsabk	SC	SL	very sticky and plastic		Vf-F(few)
Bt1	45-75	pinkish white 7.5YR 8/2	black and red	Wmsabk	SC	SL	slightly sticky and plastic		Vf-F(very few)
Bt2	75-105	pink 7.5 YR8/4	reddish	Sabk	SC	SL	sticky and plastic	secondary regrowth and tall grasses	Vf- F (Very few)
Pedon 3		Coordinates: 7°10'23.7'' N and 9°16' 15.0'' E 190 masl							
Ap	0-15	Light brownish gray 10YR 6/2	Nil	Crumby	SC	SL	friable and non- sticky		Vf-M (common)
AB	15-35	brown 7.5YR4/4	Nil	Wmsabk	SC	SL	friable and non –sticky		Nil
Bt1	35-75	reddish yellow 10YR8/4	Nil	Wmsabk	D W	SL	friable and non- sticky		Nil
Bt2	75-110	reddish yellow 7.5YR 8/6	Nil	Sabk	SC	SL	slightly sticky and plastic	secondary regrowth and tall grasses	Nil

Structure: Wmsabk=weak medium sub angular blocky, sabk= sub angular blocky, HB=**Horizon Boundary**: cs =clear and smooth, **Root Presence**: vf-m= very fine-fine-medium, vf-c= very fine-fine-medium-coarse, **Texture**: SL= sandy

Table 2 presents some physical and chemical properties of the studied soil along the toposequence of River Katsina- Ala. It was observed generally that the contents of sand and silt fractions dominated the soil peds. The preponderance of sandy loam (83%) indicates good drainage and the chemical processes in the soil are oxidized leading to haematite flourishing. The pool size of microbial biomass carbon (MBC) provides a basic tool to generally assess the soil microbes related to soil health, according to Liu, et al (2023) MBC pool was affected significantly by edaphic factors related to organic matter status such as SOC/SOM, total N, C/N ratio and bulk density. The MBC is directly related to how crop residues are managed on the farm to serve as substrate for soil biomass population. The mean silt content was higher in Buruku than in Katsina-Ala while clay was higher in Katsina-Ala than in Buruku. This implied that Buruku has more weatherable minerals. Bulk density mean values were generally non - restrictive to root penetration in both locations however clay content increased down the profile while the porosity had inverse relationship with bulk density. The similarities observed in the two study sites are attributable to similar land utilization types. It was observed that Katsina-Ala soils had moderate SOM compared to Buruku with lower values. C/N ration and TN were rate very high (2.91-1.41 CN, 5.75 -2.31 g/kg TN), which implies that mineralization is favoured because MBC was available in usable form to microbe without resulting to competition and indicating a higher active biological carbon pool (Liu, et al., 2023). The TN recorded in this study was higher (2.01 – 0.91 g/kg) than those obtained by Yitayh et al (2023) for soils under five different LU in western Ethiopia. Soil pH in both locations rated from slightly acid (Katsina-Ala) to slightly alkaline (Buruku), a pH range the favours the prokaryotic domain of the soil microbial population. Percentage base saturation obtained were largely very high and ranged 85.58% and 97.97% for Katsina-Ala and Buruku respectively. The high %BS are suggestive of alfisol order but because Bt (argillic) horizon and the colluival/ fluvial additions, soils along river Katsina-Ala tends to have entic properties and the dominant clay was the 2:1 lattice clay minerals (Okusami, 2018). Okusami (2018), reported different clay mineral found in similar soil on a toposequences in a degrade savanna-forest ecotone of southwest Nigeria. The findings of this research also aligned with the findings reported by Odofin et al (2011), where they observed that many indigenous land practices are both conservation and conventional. Therefore from soil quality indicators, these studied soils have yet attributes of healthy soil because many farm operations are manual and at small scale level of production. The task now is to ensure that the soil is utilized on sustainable basis.

Table 2: Some Physical and Chemical Properties of the Soil Along the Toposequence of River Katsina-Ala

Pedons with their weighted mean values								
Soil properties	Units	K1	B1	K2	B2	K3	B3	CV (%)
Sand	g/kg	751.8	606.6	752.6	675.6	748.8	673.3	LV
Silt	g/kg	109.8	374.4	117.3	261.8	113	266.8	MV
Clay	g/kg	138.4	19	130.1	62.6	138.2	39.6	HV
SCR		0.79	19.71	0.91	4.18	0.82	6.74	HV
TC		SL	SL	SL	SL	SL	LS	
BD	g/cm^3	1.02	1.9	0.87	2.00	2.00	2.00	LV
Po	%	61.8	63	67.4	65	67.4	61	LV
pH	H_2O	6.48	8.66	6.29	7.29	6.35	7.07	MV
SOC	g/kg	14.3	4.5	13.57	9.3	16.7	13	HV
TN	g/kg	5.3	3.2	5.13	3.5	5.75	2.31	HV
C/N		2.69	1.41	2.65	2.66	2.91	5.63	HV
av.P	mg/kg	5.52	11.06	5.53	11.11	5.8	10.4	MV
Ca	cmol/kg	3.06	4.66	3.18	4.62	3.33	4.72	LV
Mg	cmol/kg	2.82	0.81	3.05	0.82	2.9	0.82	LV
K	cmol/kg	0.29	0.28	0.28	0.23	0.28	0.3	MV
Na	cmol/kg	0.3	0.33	0.23	0.34	0.26	0.34	LV
TEB	cmol/kg	6.42	6.08	6.77	6.06	6.52	6.15	MV
TEA	cmol/kg	1.08	0.2	1.04	0.14	1.05	0.12	HV
CEC	cmol/kg	7.5	6.29	7.82	6.19	7.57	6.28	MV
%BS	%	85.58	96.77	86.75	97.74	68.1	97.91	LV
Fe	mg/kg	16.74	17.86	16.47	80.02	16.74	16.63	HV
Zn	mg/kg	1.62	2.95	1.08	1.54	1.08	1.62	HV
Cu	mg/kg	0.12	0.68	1.72	0.68	1.08	0.43	HV
Mn	mg/kg	1.53	1.33	2.78	1.84	2.15	2.35	HV

Pedon K1,B1 are Katsina-Ala and Buruku toe slope respectively
Pedon K2,B2 are Katsina-Ala and Buruku mid slope respectively
Pedon K3,B3 are Katsina-Ala and Buruku top slope respectively
SL: sandy loam, LS: loamy sand
TC: textural class, BD: bulk density. Po: porosity
SOC: soil organic carbon, TN: total Nitrogen, av.P: available Phosphorus,
HV= high variation, MV= medium variation, LV= low variation (Wilding, et al., 1994).

Land Use Change

The land use changes are the manifest of the anthropogenic influence on the earth's surface, without human intervention the geomorphology vis-a-vis the landform will remain more relatively stable. Consequently, the human interference in the study area was rather conservational and conventional which agreed with Odofin et al (2011) in the same vein Yitayh et al (2023) concluded clearing natural vegetation for large scale agriculture resulted in significant SOC losses while Sanchez (2019) asserted to the contrary that the long term relationship between land degradation and population growth was not necessarily negative or linear. Maniyunda and Malgwi (2019) reported that the best land use was a function of crop requirements and qualities of land. The proximal soils are used for a variety of arable crops such as cassava, sugarcane, melon, vegetable (tomato, fluted-pumpkin, amaranth etc.), yam etc while the major threat to sustainable land use was the mining of top-soil for burn bricks making.

Conclusion

Land use changes have larger impact on soil functions in an ecosystem and may lead to large environmental and biodiversity loss. Soil pH in both locations rated from slightly acid (Katsina-Ala) to slightly alkaline (Buruku), a pH range the favours the prokaryotic domain of the soil microbial population. Textual classes of the soil were sandy loam in the AP, loamy sand in the Bt1, silty loam in the Bt2 and Loamy sand in the Bt3 horizons. The high %BS are suggestive of Alfisol order with Bt (argillic) horizon and the colluival/ fluvial additions, soils along river Katsina-Ala tends to have entic properties and the dominant clay was the 2:1 lattice clay minerals. The major reason the soil is in good standing may be due to colluival/ fluvial enrichment occasioned by it physiographic position on the lower course of the transboundary river and the conservational and conventional approach to land use in the study area. At present the land-use do no seemed to have any negative impact(s). However, problems lie in the efforts to utilize the soil on a sustainable basis.

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