PEDOMETRIC MORPHOLOGICAL CHARACTERIZATION OF SOILS OF KONA DISTRICT, TARABA STATE, NIGERIA.

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ABSTRACT
A soil morphological study of two landuse types on cultivated and uncultivated sites at Kona district of Taraba State employing pedometrics was done to evaluate and transform soil morphological data for a reliable pedogenic prediction, simulation and visualization. A pedon was sunk on the upper, middle and lower slopes of each landuse type to also discern the trend of pedogenic progresses. Emphasis was put on the morphological attributes of these soils and an evaluation of the soils' particle distribution in order to appreciate the textural influence on the soil pedogenic processes. Similarity in soil depth was observed under cultivated upper slope (CUS), cultivated middle slope (CMS) and cultivated lower slope (CLS) of the same landuse type. The CLS had the lowest observable depth (102 cm) contrary to the assumption that lower slope soils are zone of deposition (enrichment) of materials. Soils formed within the uncultivated sites i.e., the uncultivated upper slope soils (UCUS) and uncultivated lower slope soils (UCLS) were deep to very deep (> 100cm). Colour development and its distribution within the soil profiles were evaluated to make scientific comparison of visualization. Transformed Munsell colour notation contrasted the soil colours across their corresponding horizon levels to visualize their differences and was found that 45.46 % contrasted prominently, 27.27 % contrasted distinctly and 27.27 % contrasted faintly. Organic carbon content was evaluated and its distribution with the soil texture data determined and transformed together with the soil texture data and correlated pedometrically.

Key word: Pedometrics, soil characterization, soil morphology, soil colour, soil structure, soil texture.

INTRODUCTION

Sources of information in use to revealing and predicting the properties of soil have been through morphological (Esu, 1985; McKenzie and MacLeod, 1989; Calhoun *et al*., 2001; Pajor *et al*., 2010; Kefas *et al*., 2020), physical (Lin *et al*., 1999; Maniyunda *et al*., 2013; Shobayo *et al*., 2019a), chemical (Ogezi, 1977; Agbenin and Tiessen, 1995; Raji *et al*., 2000; Adiele *et al*., 2015; Shobayo and Ya'u, 2020), mineralogical (Gold *et al*., 1983; Hseu *et al*., 2007; Kamau, 2013; Shobayo *et al*., 2019b) and climatological (Mosugu, 1989; Oluwasemire and Alabi, 2004) studies. However, the use of pedometrics which has been termed the application of mathematical and statistical methods for the study of soil that addresses its problems from the perspective of emerging quantitative approaches (McBratney and Lark, 2018) is an emerging trend for soil data simulation and prediction sourced from both laboratory and field description (soil morphology). This work collected soil morphological data from two different landuse types across three physiographic units in order to understand partly, the soil morphological dynamics. In real instance, soil morphology comprises of the field observable attributes of the soil within the various soil horizons and the description of the kind and arrangement of the horizons as featured in the profile. For the proper assessment of the soil particles and aggregates, organic carbon of the soil was also evaluated. Study on the soil morphology is very important to get a picture of changes that occur in the soil body through the description and interpretation of soil profile properties in the form of diagnostic epipedon and endopedon, which will be the initial information in soil classification especially at the textural level. Most research has been focused on correlating laboratory-determined soil properties with more difficult-to-measure properties, mainly because of the availability of comprehensive soil data and the presumption that these properties are most appropriate for predictive purposes (Padarian *et al*., 2018). However, this study aimed at establishing that soil morphological studies employing pedometrics could be used as reliable predictors of transformed morphological data for empirical evaluations and visualization.

MATERIALS AND METHODS

Description of the study area

The study was conducted in three physiographic units in Kona District, Taraba State, Nigeria. The area is underlain by Basement Complex (Kefas *et al*., 2021) and located between Latitudes 9.012288°N and 8.963277°N and Longitudes 11.344359°E and 11.346971°E occupying a land area of 20 ha. Kona district lies within the Northern Guinea Savanna agro-ecological zone of Nigeria. The region is characterized by double maxima rainfall pattern and has about four to five months of dry season. The relative humidity is generally over 80 % in the morning and falls to between 50 and 79 % in the afternoon (NIMET, 2021). The wet season sets in by April and lasts till October; it has a mean annual rainfall ranging between 1000 – 1200 mm, peaking between July and August. The mean annual temperature is about 34 °C, but the mean monthly values vary between 28.4 °C in the coolest month of December and 37 °C in the hottest month of March (NIMET, 2021).

Field work and sampling

Two landuse types of adjacent fields were selected (cultivated and uncultivated), and on each landuse type, three physiographic units (upper slope, middle slope and lower slope) were identified. A total of six profile pits were dug (georeferenced), each sited at a physiographic unit. Standard dimension (Soil Survey Staff, 2014) was observed during the profile pits sinking. Soil samples were collected from pedogenic horizons identified and soil morphological properties were described *in situ* (Soil Survey Staff, 2014). Soil samples were collected and well labeled for laboratory particle size distribution analysis (Bouyoucos, 1962) as described by Jaiswal (2003) and organic carbon was determined using the method of Walkley and Black as described by Juo (1979).

Pedometrical analysis

The data generated was analysed using compatible packages ("readr", "psych" "Hmisc", "RColorBrewer", "aqp", "colorspace", "sharpshootR", "soiltexture", "scales") on R (R Core Team, 2019); a software for statistical computing.

RESULTS AND DISCUSSION

On depth basis, cultivated upper slope (CUS), cultivated middle slope (CMS) and cultivated lower slope (CLS) soils had similar depth characteristic (Table 1) as observed on the local reliefs. The depth distribution at both horizonal and pedal level was analyzed and simulated to produce a visual presentation (Fig. 1). The soil pedal depths were greater than 100 cm and less than 150 cm, hence classified as deep soils. However, CLS had the lowest observable depth (102 cm) contrary to the assumption that lower slope soils are zone of deposition (enrichment) of materials. This occurrence

Table 1: Soil morphological properties

Id	top	bottom	Hzname	group	Hue	value	chroma	sand	silt	clay	Hztexcl
Cultivated Soils of Kona											
Upper slope soil			**Elevation: 230 m**				**Coord. 8.713105°N, 11.719898°E**				
CUS	0	20	Ap	1	7.5YR	2.5	2	740	180	80	Sandy loam
CUS	20	46	AB	1	7.5YR	3	3	660	220	120	Sandy loam
CUS	46	77	Bt1	1	2.5YR	3	4	660	140	200	Sandy loam
CUS	77	120	Bt2	1	5YR	4	6	320	280	400	Clay
Middle slope soil				**Elevation: 205 m**			**Coord. 8.97205°N, 11.348863°E**				
CMS	0	20	Ap	2	7.5YR	5	3	760	160	80	Sandy loam
CMS	20	43	AB	2	7.5YR	2.5	3	680	160	160	Sandy loam
CMS	43	90	B1	2	5YR	4	6	700	120	180	Sandy loam
CMS	90	120	B2	2	5YR	4	6	660	160	180	Sandy loam
Lower slope soil				**Elevation: 185 m**			**Coord. 8.966308°N, 11.350653°E**				
CLS	0	30	Ap	3	7.5YR	2.5	2	700	200	100	Sandy loam
CLS	30	58	AB	3	5YR	7	2	660	240	100	Sandy loam
CLS	58	102	B	3	5YR	8	3	680	240	80	Sandy loam
Uncultivated Soils Kona											
Upper slope soil				**Elevation: 243 m**			**Coord. 8.976138°N, 11.344126°E**				
UCUS	0	20	A1	4	10YR	4	3	760	160	80	Sandy loam
UCUS	20	80	AB	4	10YR	4	3	760	160	80	Sandy loam
UCUS	80	123	B1	4	10YR	6	4	660	220	120	Sandy loam

UCUS	123	165	B2	4	10YR	5	4	700	180	120	Sandy loam
Middle slope soil				**Elevation: 203 m**			**Coord. 8.971541°N, 11.346369°E**				
UCMS	0	23	A	5	7.5YR	5	3	760	160	80	Sandy loam
UCMS	23	45	AB	5	7.5YR	3	4	740	160	100	Sandy loam
UCMS	45	64	Bt	5	7.5YR	3	3	720	100	180	Sandy loam
UCMS	64	116	B	5	5YR	4	3	760	140	100	Sandy loam
Lower slope soil				**Elevation: 180 m**			**Coord. 8.963277°N, 11.346971°E**				
UCLS	0	18	A	6	10YR	4	4	760	160	80	Sandy loam
UCLS	18	53	AB	6	10YR	4	3	660	260	80	Sandy loam
UCLS	53	105	Bt1	6	10YR	5	4	660	180	160	Sandy loam
UCLS	105	155	Bt2	6	10YR	6	4	600	160	240	Sandy clay loam

shows that pedogenesis was truncated and loss of soils at this local relief may be unconnected to the surface slope class (C) which is moderately to strongly sloping (4 - 7 %). The elevation differentials (230 m - 205 m - 185 m), 45 m and 20 m as against CUS and CMS respectively may have affected pedogenetic activity in CLS due to higher temperature effects on weathering and pedogenic processes (e.g., leaching) with the attendant erosional effect contributed by precipitation on the CLS soil slope gradient (Kefas, 2021). This deduction however, did not affect the soil textural classes from the three physiographic units. Sandy loam dominated all the pedogenetic soil horizons thereby implying that climate supererogatory influence on CLS was more or less counterproductive resulting on soil loss. This assertion was further buttressed by the number of horizons observed at each physiographic unit. The CUS and CMS had four (4) horizons each (Table 1) while three (3) horizons were observed for CLS; again, soil development was truncated.

Table 1 cont.: Soil morphological properties

Id	top	bottom	hzname	strxgrd	strxcl	strxshp	OC
Cultivated Soils Kona							
Upper slope soil			**Elevation: 230 m**		**Coord. 8.713105°N, 11.719898°E**		
CUS	0	20	Ap	moderate	coarse	crumb	0.80
CUS	20	46	AB	moderate	coarse	subangular blocky	3.10
CUS	46	77	Bt1	moderate	coarse	subangular blocky	2.30
CUS	77	120	Bt2	strong	fine	subangular blocky	0.60
Middle slope soil			**Elevation: 205 m**		**Coord. 8.97205°N, 11.348863°E**		
CMS	0	20	Ap	moderate	medium	crumb	1.00
CMS	20	43	AB	moderate	coarse	subangular blocky	0.30
CMS	43	90	B1	moderate	coarse	subangular blocky	0.08
CMS	90	120	B2	moderate	coarse	subangular blocky	0.70
Lower slope soil			**Elevation: 185 m**		**Coord. 8.966308°N, 11.350653°E**		
CLS	0	30	Ap	moderate	medium	crumb	3.50
CLS	30	58	AB	moderate	coarse	subangular blocky	0.80
CLS	58	102	B	moderate	coarse	subangular blocky	1.90
Uncultivated Soils Kona							
Upper slope soil			**Elevation: 243 m**		**Coord. 8.976138°N, 11.344126°E**		
UCUS	0	20	A1	moderate	fine	subangular blocky	1.00
UCUS	20	80	AB	moderate	fine	subangular blocky	3.50
UCUS	80	123	B1	moderate	fine	subangular blocky	3.50
UCUS	123	165	B2	moderate	fine	subangular blocky	3.80
Middle slope soil			**Elevation: 203 m**		**Coord. 8.971541°N, 11.346369°E**		

UCMS	0	23	A	moderate	fine	subangular blocky	2.40
UCMS	23	45	AB	moderate	fine	subangular blocky	2.50
UCMS	45	64	Bt	moderate	fine	subangular blocky	2.40
UCMS	64	116	B	moderate	coarse	subangular blocky	1.20
Lower slope soil			**Elevation: 180 m**		**Coord. 8.963277°N, 11.346971°E**		
UCLS	0	18	A	moderate	medium	subangular blocky	1.30
UCLS	18	53	AB	moderate	medium	subangular blocky	1.20
UCLS	53	105	Bt1	moderate	coarse	subangular blocky	1.00
UCLS	105	155	Bt2	strong	coarse	subangular blocky	0.60

Soils formed within the uncultivated sites were deep to very deep. The uncultivated upper slope soils (UCUS) and uncultivated lower slope soils (UCLS) had very deep pedal depth (165 cm and 155 cm respectively) while the uncultivated middle slope soils (UCMS) had deep depth (116 cm). The highest depth recorded in UCUS may be attributed to its contiguous stretch into the crest on one hand and its nearly flat level on the other hand which promotes the retention of weathering products and consequent accumulation of the products over time. Its sandy loam texture across the horizons facilitated co-translocation of weathering products from the surface to lower depths, thereby forming very deep soils. Similar observation was attributed to UCLS. Climate as an active factor of soil formation could not be said to have affected radically and distinctively any of physiographic units but rather similarly. The depth (116 cm) as observed in the UCMS may be attributed to pedogenic equilibrium characterizing the middle slope local relief.

Edaphologically, both the cultivated and uncultivated soils across the three physiographic units have the capacity to support both shallow and deep-rooted crops. Coupled with the sandy loam nature of the soils and good drainage (well drained and non-mottled), they will support both light and heavy mechanization. Fig. 1 shows the horizon thickness and depth distributions of the soils.

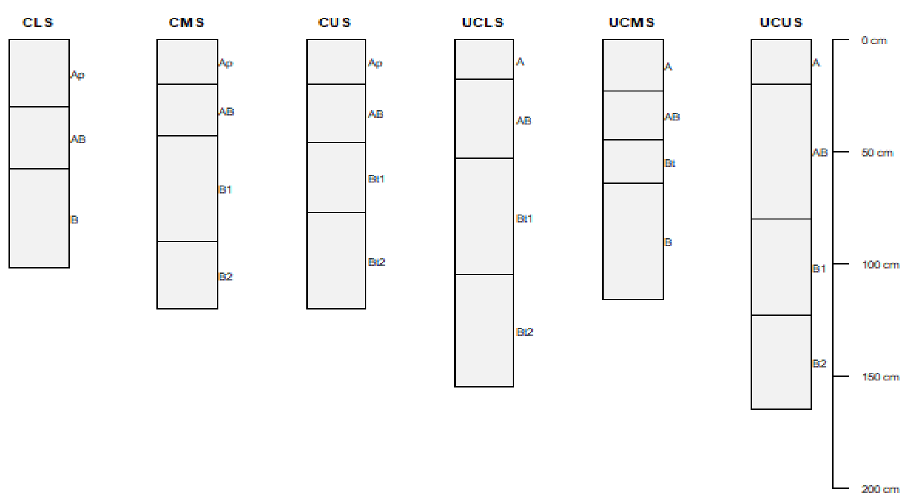


Fig. 1: Horizon thickness and depth distribution visualization of the pedons across physiographic unit and landuse.

In order to estimate the subsurface diagnostic characteristics of the soils, the soil data (Table 1) was subjected to algorithm for quantitative pedology which gives a numeric vector containing top depth of argillic horizon if present but returned NA implying that no argillic horizon was formed within any of the physiographic units.

Colour development and its distribution within the soil profiles was used as a major guide during the identification and delineation of soil horizons and horizon boundaries. Because of its predictive tendencies that give direction of pedogenic processes, we have reliably used it to discuss our data. Firstly, we aggregate the horizon soil for each physiographic unit (Fig. 2a and 2b), then make scientific comparison of visualization.

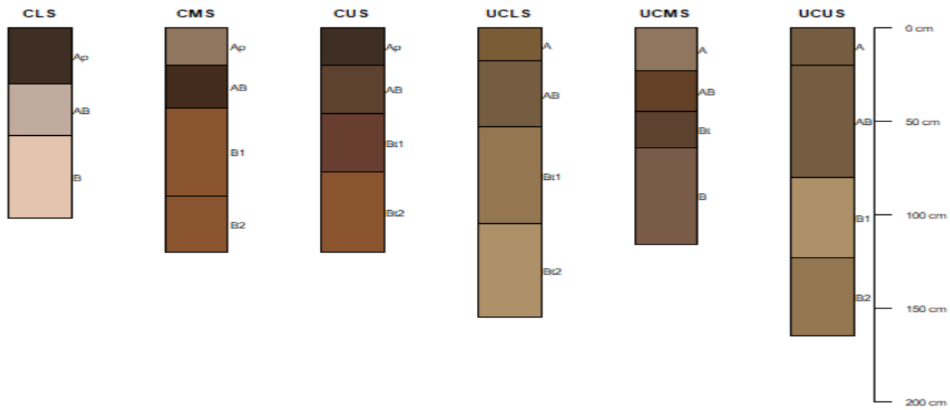


Fig.2a: Horizon colour distribution at pedal depth of study areas

Figure 2a shows that CLS and CUS had a characteristic darkened surface horizon, a very dark brown soil colour (Fig. 2b) implying that the Ap had been humified and meets the submissions that surface soils are the enrichment zones for organic matter at its different stages of composition. Both physiographic units exhibited a systematic organic material transformation and translocation with pedal depth. Similarly, CMS of the same landuse type (cultivated) exhibited horizon colour sequence that was however remodified by leaching. The soil colour distribution was associated mainly to three pedogenic processes; humification at the surface soils and extending into the transitional horizons on one hand and braunification and ferritization at the solum on the other. Figure 2b validates the dominance of two soil colour matrices of brown and red and their variant shades in the study areas.

On soils formed in the uncultivated study area, the physiographic units (i.e., UCLS, UCMS and UCUS) exhibited a fairly systematic soil colour distribution with pedal depth (figs. 2a and 2b). The colour sequence is as thus: Dark yellowish brown-Brown-Yellowish brown-Light yellowish brown, Brown-Dark brown-Dark brown-Reddish brown and Brown-Brown-Light yellowish brown-yellowish brown respectively for UCLS, UCMS and UCUS. Braunification and humification are the dominant co-pedogenic processes influencing the soil colour matrix in the soil profiles and was attributed to the landuse type being undisturbed which allowed for organic matter accumulation, transformation and translocation with pedal depth.

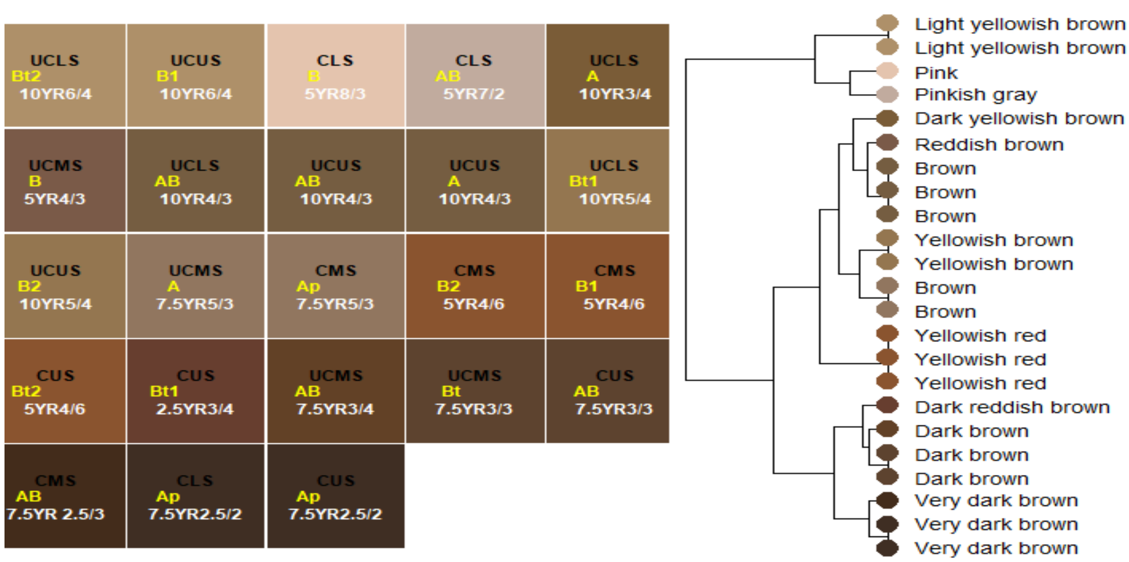


Fig.2b: Soil colour aggregation within soil matrices of study areas

The study areas soil colour data were transformed and contrasted pedometrically to visualize their significant differences as thus (2c):

Cultivated surface soils

Uncultivated surface soils

Fig. 2c: Colour contrasts between surface soils of CUS, CMS, CLS and UCUS, UCMS, UCLS

The observed distinct soil colour (darker) at surface soils of the cultivated (landuse) soils over uncultivated (landuse) soils was attributed to the management practice of the farmers in the study area such as organic manuring, use of organic materials for mulching and crop residue leftovers after harvest. However, it is surmised that the uncultivated soil colours gave the true scenario of the organic matter decomposition of the agro-ecological zone. We transformed the Munsell colour notation (a semi qualitative data) into a quantitative data then, contrasted the soil colours across their corresponding horizon levels to visualize their differences and found that 45.46 % contrasted prominently, 27.27 % contrasted distinctly and 27.27 % contrasted faintly (Fig. 2d). This implies that only 27.27 % of the soil colours share similarity while 72.73 % are dissimilar. This soil colour dissimilarity is attributed solely the landuse types.

Cultivated soils (m1)

Uncultivated soils (m2)

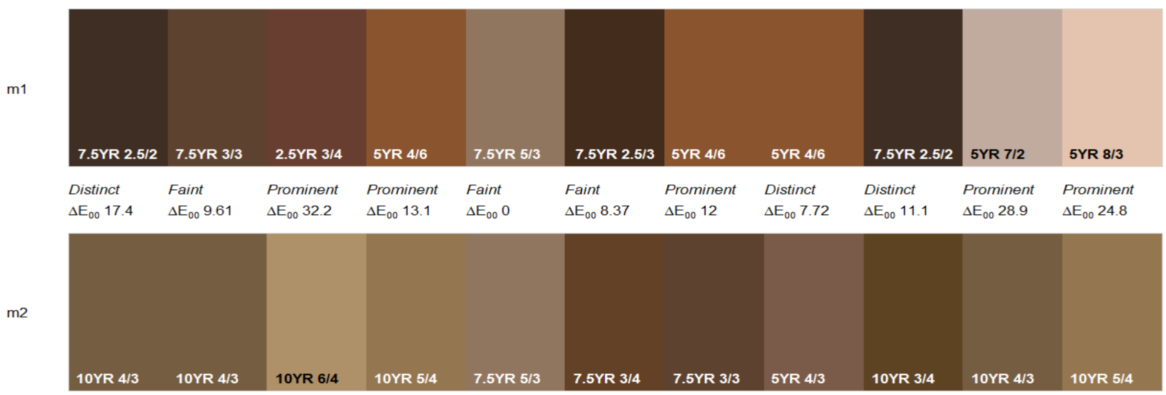


Fig. 2d:

Texturally, sandy loam (Fig. 3a), a coarse texture (Fig. 3b), dominated the soils across horizonal space (Table 1). This observation was attributed to the parent material make-up of the soils being granitic. Kefas *et al*. (2021) reported that soils of the study area were formed over the basement complex formation. The sandy loam texture will influence the soils' porosity with a resultant low water holding capacity and improved gaseous diffusion with pedal depth. Because, from the two landuse types, in most cases, the same textural class was observed to be concentrated within the textural class (Fig. 3a&b). Hossain *et al*. (2018) submitted that soil properties such as organic carbon (OC) content, electrical conductivity (EC) and cation exchange capacity (CEC) are mostly dependent on soil texture. On this submission, we look at the influence of OC as a component of soils' make-up, aside the mineral fractions determining the textural attributes. Organic carbon content was evaluated and its distribution with the soil texture data determined (Fig. 4a and 4b) and then, transformed together with the soil texture data and correlated pedometrically.

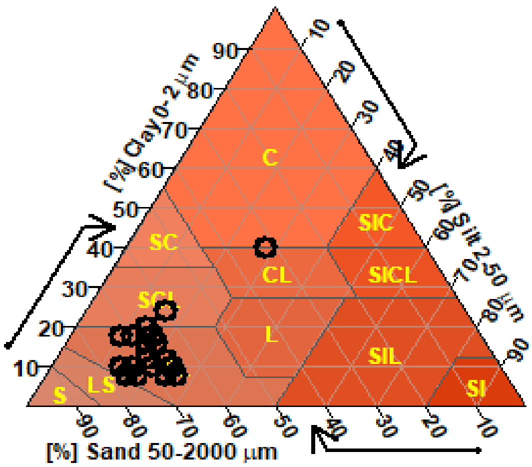


Fig. 3a: Soil texture data textural class distr.

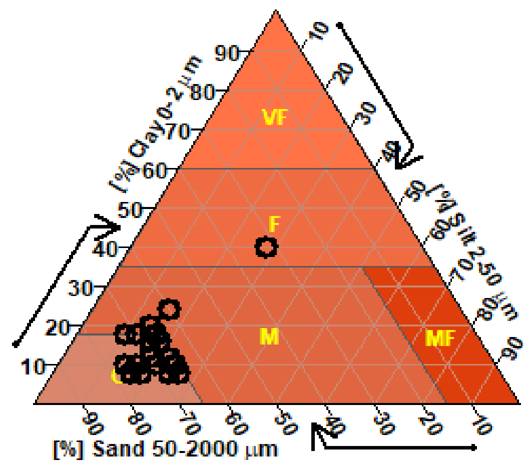


Fig. 3b: Soil texture data coarseness degree

Fig. 4c shows the visual representation of the statistic (Z), however, as exploratory data analysis, because it may be difficult to know the real OC value of a point (Moeys, 2018).

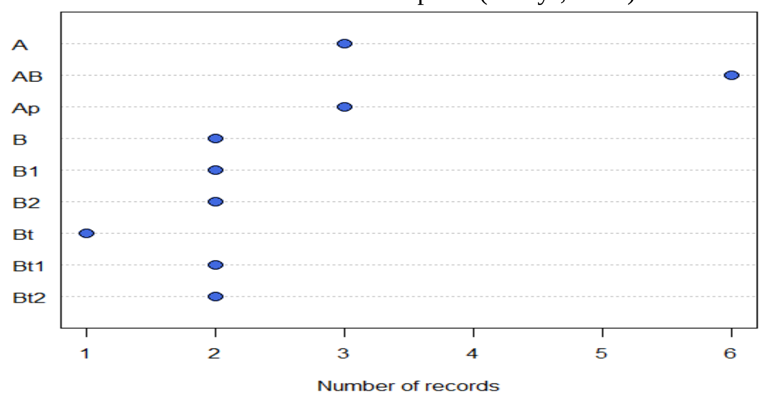
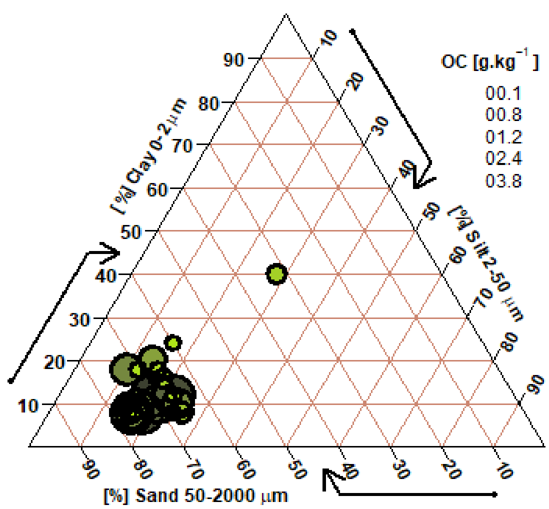


Fig. 4a: Texture data records per generalized horizon labels



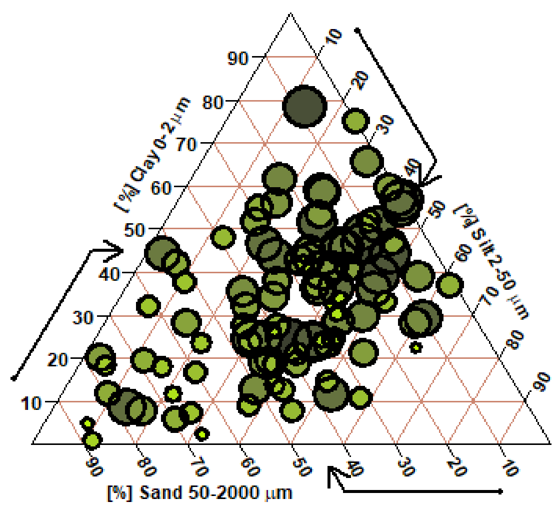


Fig. 4b: Soil texture data and OC bubble plot **Fig. 4c: Soil texture data and Z bubble plot**

NB: Low values have a small diameter and high values have a big diameter

The soil structural data was not analyzed pedometrically, because no compatible package on R was found as at when this research was done. The soils' structural form was generally described as subangular blocky in the study areas with mostly moderate structural grades and variant structural sizes across pedal depth. The observed uniform structural form between landuse types and physiographic units was attributed to the interplay of similar pedogenetic processes that have acted on the same parent material (Kefas, 2021) which formed the soils under the same climate. However, the crumb structural form observed at the surface soils of the cultivated soils (CLS, CMS and CUS) was associated with the soil aggregates broken into shapes by the artificial actions of tillage. The ability of soils to deliver benefits has been linked to its structure (The Royal Society, 2021). The sandy loam textural class across pedal depth in association with the blocky soil structure is an indication that the soils will have a continuous network of pore spaces that will improve its drainage capacity, air diffusion and translocatable materials vertically and laterally within the soils. Hence the soils can be said to be well structured and good for agricultural purposes as root propagation will be unhindered.

The moderate structural grades of the soils can otherwise be connected to the loamy attributes of the soils. In the cultivated soils as observed, coarse structural class dominated; and was attributed to the granitic origin of the soils (Kefas, 2021). However, on soils of the uncultivated study area (i.e., UCLS, UCMS and UCUS), fine-medium structural class dominated, implying that pedogenetic translocation of weathered materials with pedal depth have been promoted unabated.

CONCLUSION

Soil morphological data manipulation and analysis of depth distribution, colour and texture that were hitherto addressed using narrative or tabular form were further characterized using pedometrics to make the generated data possible for aggregation, transformation, summarization, simulation and visualization.

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