International Journal of Organic agricultural Research & Development
Volume 20 (3) (2025)

ASSESSMENT OF SPATIAL VARIABILITY IN SOILS DEVELOPED ON THE BASEMENT COMPLEX OF ORILE-IGBON/GAMBARI, OGBOMOSO, SOUTHWESTERN NIGERIA

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ABSTRACT

Understanding the relationship between parent materials and soil properties is crucial for effective land use planning and management. This study aims to determine parent materials effect on the physical and chemical characteristics of a selected toposequence in the Orile-Igbon/Gambari area of Ogbomoso, Oyo State, Nigeria. Four soil profile pits were dug at identified topographic positions (summit, upper slope, middle slope and the valley bottom) on a selected toposequence. Soil profile pits were studied and morphological attributes were described using USDA soil taxonomy guideline 2007 (color, stoniness, consistence, texture and structure). Soil samples collected from identified horizons were air dried, sieved and processed for laboratory analysis as pH, exchangeable cations, organic matters. Data collected were subjected to descriptive statistics and Coefficient of variation. The results of the analysis showed that, there was moderate variability of some soil morphological properties across the four positions on the toposequence. The textural class of the soil ranged from loamy sand to sandy loam, Available phosphorus was low in all the locations (2.5-28.6mg/kg), total nitrogen was predominantly low (0.5-3.9%). The topographic position also influenced soil properties, with valley bottom soils tending to have higher clay content and lower permeability due to the accumulation of finer particles. The results of this study can help guide sustainable land management techniques and offer insightful information about the spatial diversity of soil qualities in the area.

Keywords: *Toposequence, soil characteristics, parent materials, land management*

INTRODUCTION

Soil, a fundamental component of agricultural systems strongly determines the suitability, sustainability, and productivity of those systems (FAO and ITPS, 2015; Brady and Weil, 2016). The ability of soils to support crop productions. However, the soil within a given area with an identical climate may differ greatly due to differences in parent materials, slope and or vegetation (Olatunji *et al*., 2017). Its formation is a complex process shaped by climate, parent material, relief, and organisms over time. Parent material, the foundation of soil, consists of consolidated or unconsolidated mineral particles and organic matter that have undergone varying degrees of chemical weathering (Weinheim, 2012). The variations of soil characteristics are dependent on the changes in the factors of soil formation and most influenced by the predominant factor(s) and subsequently the distribution of soils. These could be captured for crop production and management with the aid of soil survey. An Assessment of Spatial Variations of Some Soil Properties under Different Land Uses in SouthWestern Nigeria (Senjobi *et al*., 2013) found that different land use types on the same soil class had varying high coefficients of variation (CV > 35%) for many soil properties, indicating significant variability within fairly small areas. Potentials and limitations of soil physical conditions are very important for crop production as they control the environment and hence moisture and nutrient uptakes. In light of the above, it is of paramount importance to have an in-depth knowledge on the characteristics of soils of any area, in order to manage and use the resources, thereby maximize crop production to the allowable genetical potential limits and conserve the soils for future use (Olatunji *et al*., 2017).

A major motivation for research in soil variability is the need to make the best use of the land, available water and energy resources. Thus, this study focused on assessing soil variability as a key factor in identifying soil properties related to crop production, particularly in the Orile-Igbon/Gambari area of Ogbomoso, which has been under a mixed cropping system for several years. This work aimed at identifying where variations occur on the various part of the landscape. Thus, the objectives of the study were. (i) To characterize the morphological, physical and chemical properties of the soil profiles along the selected landscape; and (ii) Provide information of the properties of soils on the landscape that could be limiting the productivity of these farms in relation to topographical effects for sustainable crop productions.

Materials and method

Description of the study area

The study was conducted on a major toposequence situated within the Southern Guinea savanna region of Ogbomoso, Oyo State, Nigeria. This area is characterized by a distinct dry and wet season cycle with relatively high humidity. Specifically, Orile Igbon-Gambari is located at the northwestern part of Surulere Local Government Area, Oyo State. The region has an elevation of approximately 100 meters above sea level latitude 8° 16' 0" N and longitude 4° 19' 59" E. The average annual temperature in this area is 28°C, while the mean annual rainfall is around 1200 mm, with a recorded range of 786.2 to 1513 mm. The high relative humidity favours the cultivation of crops such as cowpea, maize, millet, cassava and yam (Akande *et al.,* 2024).

Soil sampling and laboratory analysis

The selected toposequence was divided into four topographic positions for the purpose of this work. The positions included the summit or crest, upper slope, middle slope, and the valley bottom. Four standard profile pits were dug on each of the topographic positions, described and according to numbers of identified horizons using FAO (2006) guideline for soil profile pit description. The samples were air dried, crushed and made to pass through 2.0 mm mesh sieve. Percentage gravel in the soils was determined by sieving and calculated as a percentage of the whole soil mass that passed through the 2.0 mm sieve. Particle size analysis was performed using the Bouyoucous hydrometer method as outlined by Gee and Or, (2002). Exchangeable bases (Ca, Mg, K, and Na) were extracted with 1 N NH_4OAc (pH 7) (Thomas, 1982). Exchangeable calcium and magnesium were determined by EDTA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). Cation Exchange Capacity (CEC) was determined by ammonium acetate solution (NH_4OAc) displacement method conducted at pH 7.0 as explained in the Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology, University of Ibadan (Odu *et al.*, 1986). Soil organic carbon was analyzed by Walkley and Black wet digestion method as modified by Nelson and Sommers, (1982). Soil pH was measured in both water and 1 N KCl at the soil- liquid ratio of 1:2.

Statistical analysis

The data generated were analyzed using classical statistical methods to obtain the minimum, maximum, mean, median and standard deviation. Coefficient of variation was determined to find out how variables vary in the study sites. All statistical analysis was carried out with the aid of SAS (SAS Institute, 2009).

RESULTS AND DISCUSSIONS

Variation in morphological properties

The morphological features of the soils on the four profile pits at the study area are presented in Table 1. The soils were generally deep (ranging from 170 – 200 cm) and between 4 to 6 horizons could be identified in all the profile pits. All the four pedons were grayish brown (10YR 5/4) at top soil. The other physical properties observed in study area were mottle, stoniness, structure, cutan, boundary form. Pedon 1 had a total of 6 horizons. The result shows that the soil at pedon 1 is basically loam. Pedon 2 had a total of 5 horizons and the soil at pedon has a textural class of sandy clay. Pedon 3 had 6 total sampling point with textual class of sandy clay. While pedon 4 had a total of 4 horizons with a textural class of silt loam. The black and dark brown colour (7.5YR 3/1) observed at the topsoil can generally be attributed to a high organic matter content or the presence of expanding clay minerals such as smectite. Organic matter imparts a dark coloration to soils because decomposed plant and microbial residues form humic substances that strongly absorb light (Brady and Weil, 2017). In addition, soils containing 2:1 expanding clays tend to appear darker when moist due to their fine particle size, high surface area, and strong ability to retain water and adsorb organic coatings (Essington, 2004).

Furthermore, the accumulation of eroded materials from higher topographic positions to the lower points can led to accumulations of organic matter and finer soil particles in lower areas. These depositional processes contributed to the dark coloration and higher fertility observed in the pedons at the lower positions (Jenny, 1994; Foth, 1990).

Thus, the observed dark colour of the topsoil likely reflects a combination of organic matter content enrichment and clay materials accumulation resulting from both biological activities and topographic redistribution of materials. pH is consistently the least variable chemical properties in the study area. The pH values range between 4.8 to 5.7 for H_2O and 4.8 to 5.2 for KCl across the different pedons and depths. These values indicate slightly acidic to neutral soils, which is typical for many agricultural soils, as such pH ranges generally favor nutrient availability and microbial activity (Brady and Weil, 2017). The presence of Ca^{2+} and Mg^{2+} as dominant exchangeable cations is also characteristic of fertile soils, since these basic cations help buffer soil acidity and contribute to improved soil structure and plant nutrition (Foth, 1990; Havlin *et al.,* 2014).

These are essential nutrients, with Ca^{2+} being higher than Mg^{2+} in all pedons and depths, contributing to soil structure and plant nutrition. Na^+ and K^+: These are relatively low, indicating low salinity and potentially low exchangeable K^+. Hydrogen (H^+), Aluminum (Al^{3+}), and ECEC. H^+ and Al^{3+}: These are indicators of soil acidity and potential toxicity. The values are generally low, indicating low acidity and low potential for aluminum toxicity. ECEC (Effective Cation Exchange Capacity). This is a measure of the soil's ability to hold and exchange cations. Values range between 0.5 to 1.66 cmol/kg, indicating moderate to high cation exchange capacity, which is favorable for nutrient retention. Organic Carbon (Org. C) and Total Nitrogen (Total N). These are important indicators of soil fertility and health. Org. C ranges from 0.04% to 0.06%, while Total N ranges from 0.90% to 3.90%, which are moderate levels for agricultural soils. Iron (Fe), Copper (Cu), Zinc (Zn), and Manganese (Mn) Fe, Cu, Zn, and Mn. These micronutrients are essential for plant growth and metabolism. The levels are generally sufficient for plant growth, with Fe being the highest. The soils described are moderately acidic, with good levels of organic matter and essential nutrients for plant growth. They show moderate to high cation exchange capacity and low acidity, which is generally favorable for agricultural productivity.

RESULTS AND DISCUSSION

Table 1: Morphological properties of soils of Orile Igbon/Gambari area toposequence

Horizon	Depth (cm)	Colour	Structure	Consistence (moist)	Boundary
			pedon 001 GB summit		
A_1	0-30	10YR 5/6	Granular	non-sticky and loose	Smooth and clear
AB	30-55	10YR 5/6	Granular	non-sticky and loose	smooth and clear
B_1	55-90	2.5YR 5/4	very fine granular	non-sticky and dry loose	Smooth and clear
B_2	90-140	10YR 4/6	coarse sub-angular blocky	non-sticky and dry loose	broken and gradual
BC	140-170	10YR 7/8	medium sub-angular blocky	sticky, firm and very hard	broken and gradual
C_1	170-200	10YR 7/8	medium sub-angular blocky	sticky, firm and very hard	
pedon 002 GB upper slope					
A_1	0-29	10YR 4/3	single grain	non-sticky and dry loose	clear and smooth
AB	29-66	10YR 5/3	single grain	non-sticky and dry loose	clear and smooth
B_1	66-115	10YR 6/6	single grain	non sticky, loose and dry loose	Smooth and clear
B_2	115-161	10YR 7/8	very fine granular	non sticky, loose and dry loose	smooth and diffuse
BC	161-200	10YR 8/8	coarse angular blocky	non-sticky, loose and very hard	
pedon 003 GB middle slope					
A_1	0-22	10 YR 3/2	very fine crumb	non-sticky, firm and dry loose	irregular and diffuse
AB	22-56	10YR 3/1	single grain	non-sticky and dry loose	clear and smooth
B_1	56-88	10YR 6/6	fine or thin granular	non-sticky, loose and dry loose	irregular and diffuse
					wavy and gradual
BC	133-170	7.5YR 6/6	medium and granular	non-sticky, loose and dry loose	broken and gradual
C_1	170-200	10YR 7/3	coarse angular blocky	sticky, firm and hard	
pedon 004 GB lower slope					
A_1	0-35	7.5YR 3/1	very fine crumb	non-sticky loose and dry	smooth and clear
AB	35-51	7.5 YR 8/1	very fine crumb	non-sticky, loose and dry loose	smooth and clear
B_1	51-100	10YR 7/1	very fine crumb	very sticky, very firm and hard	Gradual
BC	100-170	10YR 7/2	Very fine crumb	Waterlogged	

Table 2: Physical properties of soils of Orile Igbon toposequence

Horizon	Depth (cm)	Very coarse sand (2-1mm)	Coarse sand (1-.45)	Medium sand (.45-.225)	Fine sand (.225-.05)	Very fine sand (.075-.75)	Total sand	Silt (.05-.002)	Clay (<.002mm)
pedon 001 GB summit									
A_1	0-30	4.3	7.5	14.2	18.7	21.0	65.7	22.5	**11.8**
AB	30-55	4.4	6.8	14.5	22.4	26.4	74.5	5.9	**19.6**
B_1	55-90	3.3	5.6	8.9	15.3	19.8	52.9	34.3	**12.8**
B_2	90-140	3.9	8.1	13	16.9	26.7	68.6	23.5	**7.9**
BC	140-170	3.9	8.9	16.7	23.5	21.5	74.5	17.7	**7.8**
C_1	170-200	3.7	8.9	15.3	18.5	21.5	66.5	17.2	**7.8**
pedon 002 GB upper slope									
A_1	0-29	5.0	9.2	15.0	19.7	25.6	74.5	15.7	**9.8**
AB	29-66	13.8	9.5	17.0	22.6	27.6	90.2	3.9	**5.9**
B_1	66-115	6.9	10.9	22.8	28.0	25.5	94.1	2.0	**3.9**
B_2	115-161	4.0	14.8	12.3	18.1	21.4	70.6	15.7	**13.7**
BC	161-200	15.7	15	14.7	22.7	23.1	91.2	2.0	**6.8**
pedon 003 GB middle slope									
A_1	0-22	6.5	16.5	16.0	23.3	24.0	85.3	5.9	**7.8**
AB	22-56	5.3	11	18.6	21.7	27.7	84.3	6.9	**8.8**
B_1	56-88	6.2	11.9	18.6	21.5	18.3	76.5	15.7	**7.8**
B_2	88-133	10.5	14.3	13.8	20.3	23.5	82.4	4.9	**12.7**
BC	133-170	5.2	11.0	18.6	26.5	26.9	88.2	4.9	**6.9**
C_1	170-2--	6.1	13.7	16.4	18.0	30.1	84.3	3.9	**11.8**
pedon 004 GB lower slope									
A_1	0-35	9.6	17.9	21.0	17.4	20.4	86.3	4.9	**8.8**
AB	35-51	6.2	18.4	16.3	23.6	20.8	85.3	5.9	**8.8**
B_1	51-100	5.7	24.8	16.7	19.2	17.9	84.3	6.9	**8.8**
BC	100-170	6.2	19.7	15.2	20.0	17.6	84.7	6.9	**8.8**

Table 3: Chemical properties of soils of Orile Igbon toposequence

Horizon	Depth (cm)	pH (H_2O)	K^+ (C mol kg^{-1})	Al^{3+} (C mol kg^{-1})	ECEC	Org. C	Total N	P (mgkg^{-1})	Fe (mgkg^{-1})
						%	%		
				pedon 001GB summit					
A_1	0-30	5.7	0.09	0.02	1.42	3.9	0.04	28.6	36.22
.00AB	30-55	5.5	0.1	0.02	0.64	2	0.02	21.2	39.01
B_1	55-90	5.4	0.2	0.03	1.15	1.17	0.02	16.2	27.11
B_2	90-140	5.4	0.24	0.04	1.29	1.04	0.01	12	28
BC	140-170	5.4	0.18	0.02	0.96	0.68	0.01	10.3	24.16
C_1	170-200	5.3	0.11	0.02	0.62	0.6	0.01	2.5	20.1
				Pedon 002GB upper slope					
A_1	0-29	5.7	0.14	0.03	1.66	3.5	0.03	28.2	40
AB	29-66	5.4	0.11	0.02	0.75	2	0.02	21.2	38.11
B_1	66-115	5.3	0.13	0.02	0.78	0.9	0.01	16.2	31
B_2	115-161	5.2	0.12	0.02	0.72	0.7	0.01	12	26
BC	161-200	5	0.11	0.02	0.57	0.5	0.01	10.3	20
				Pedon 003GB middle slope					
A_1	0-22	5.6	0.12	0.02	1.4	3.7	0.03	26.4	34
AB	22-56	5.5	0.11	0.03	0.91	1.9	0.02	23.4	29
B_1	56-88	5.4	0.2	0.02	0.97	1.9	0.01	19.2	31
B_2	88-133	5.4	0.18	0.02	0.83	0.8	0.01	10.3	24
BC	133-170	5.2	0.11	0.02	0.68	0.8	0.01	8	21
C_1	170-200	5	0.1	0.02	0.69	0.06	0.01	6.5	22
				Pedon 004GB lower slope					
A_1	0-35	5.6	0.12	0.03	1.46	3.6	0.03	21.4	38
AB	35-51	5.5	0.1	0.02	0.86	1.4	0.01	13.2	20.6
B_1	51-100	5.3	0.18	0.03	1.04	1	0.01	8	21
BC	100-170	5.3	0.12	0.02	0.73	0.8	0.01	5.1	20.1

CONCLUSION

According to the study, Orile Igbon soils have beneficial traits like as low amounts of organic matter and exchangeable cations, which are signs of good soil fertility and nutrient availability. On the other hand, high sand concentration in some profiles can reduce the capacity to hold nutrients and retain water, which could reduce crop output and cause nutrient leaching. To improve these properties, it is essential to implement practices that enhance nutrient and water retention. This can be achieved through amendments such as organic matter or mulch. Organic matter, which includes compost, manure, and plant residues, helps to increase soil porosity, improve water infiltration, and enhance nutrient cycling. Mulching, the application of a protective layer of organic material on the soil surface, can help to reduce water loss through evaporation, conserve moisture, and suppress weed growth (Havlin *et al*, (2013). Orile-Igbon / Gambari area toposequence seems to have a better soil because of the presence of Low Na^+ and K^+ levels indicate low soil salinity and suggest that potassium fertilization may be necessary to improve soil fertility.

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