



Assessing Soil Spatial Variability for Increased Crop Productivity in a Granitic Gneiss Terrain

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Abstract

This study identifies soil spatial variability by examining the various physiochemical properties of soil in the study area. Other properties such as soil texture, pH value, bulk density, climate, precipitation and temperature were considered to map the suitability of the soil for increased cashew production. The cashew plantation in Ladoke Akintola University of Technology, Ogbomoso, Nigeria served as the study area, where pits were dug for soil profiling. A soil spatial interval of 100metres was adopted for analysis and documented through the guidelines by Food and Agriculture Organization of the United Nations (FAO) 1977, and the 1981 Soil Survey Staff classification. The horizon classification was taken from soil samples collected dug pits and tagged to their respective layers in the profile. These samples were air dried and crushed for a 2mm sieving process prior physiochemical analysis. The pH of the soil was between 4.8 – 5.6 values. The soil in the study area revealed low levels of important nutrients, especially organic carbon and nitrogen. The soil seemed moderately suitable for cashew plantation where little soil enhancement is required for increased productivity and conservation. The soil showed poor water holding capacity (WHC) and wilting point (WP). The moisture content turned out low. The result of the differences in the topsoil and the subsoil horizons were factored by the illuvial and eluvial clay transport. Consequently, in order to enhance cashew products, the soil in the area requires the application of organic manure such as dungs, compost to produce more nitrogen and other necessary nutrients required by cashew-producing soil. Also, the moisture content of the soil is low resulting in low WHC and WP. For improvement in the soil's efficiency, the amendments like manure application, nitrogen increment and water holding capacity should be considered.

Keywords: Cashew, FAO, Horizon, Spatial, Soil variability

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Introduction

Sustainable farming methods and efficient land management depend on an understanding of the physiochemical characteristics of soil (Brady & Weil, 2010). Crop production and soil fertility are significantly influenced by soil characteristics as texture, pH, organic carbon, and nutrient concentration (Lal, 2004). A natural phenomenon in soil, spatial variation quantifies the variations in the physical and chemical characteristics of soil from one location to

another. There are two types of soil variation: minor and large. It may also be related to the parent materials used to make the soil, the climate (temperature, rainfall), the relief of the landscape, and biological and human activity (Ojanuga, 1978, Ogunkunle, 1987). The living medium known as soil is extremely diverse in nature, with a wide range of sizes, functions, characteristics, and compositions (Dahiya et al., 1984). Therefore, changes that arise in the soil as a result of daily and occasional reactions inside it are referred to as soil variability (Becket and Webster, 1971). How to best deal with the

spatial distribution of soil qualities and their impact on crop production is the relevant subject that researchers have brought up.

Soil variability can be useful in identifying soil properties related to crop production, irrigation scheduling, land drainage, land reclamation, runoff pollution, water from the ground contamination, pesticide management, liquid waste disposal from municipalities, industries, and nuclear power plants, as well as soil mapping and classification. Soil variety has a detrimental effect on farm owners' livelihood, production, and existence. They use complex farming techniques to deal with or overcome the variability; the more complex the farming methods required to deal with such soils, the smaller the farm and the more diversified the environment (Cassel, 1983, Ford, 1990). farmers employ a variety of technologies and methods to address these issues, including mulching systems, cover crops, legume planting, crop rotation, mixed crops, bush fallows, and more (Brouwner & Bouma, 1995). A

farmer's level of knowledge about the soil he works with determines how precise his farming is for maximum yield. For optimal and sustainable agriculture, it is crucial to understand the regional variability of soil physical and chemical properties (Wilding, 1985).

Crop planting and growth are influenced by numerous factors, but it is not practical to take them all into account. In light of the current state of affairs in Nigeria and the circumstances that favor crop growth, the following criteria were selected in order to assess the appropriateness of land for agricultural goods (Oduwole & Ridwan, 2022). The study was carried out at Ladoke Akintola University of Technology's cashew farm in Ogbomosho, Nigeria. The region has a tropical environment with distinct wet and dry seasons, which have a big impact on the characteristics of the soil. The LAUTECH Teaching and Research Farm is the study area. It is located in the Ogbomosho University campus. The coordinates fall between latitude 8° 05' N and longitude 4° 25' E.

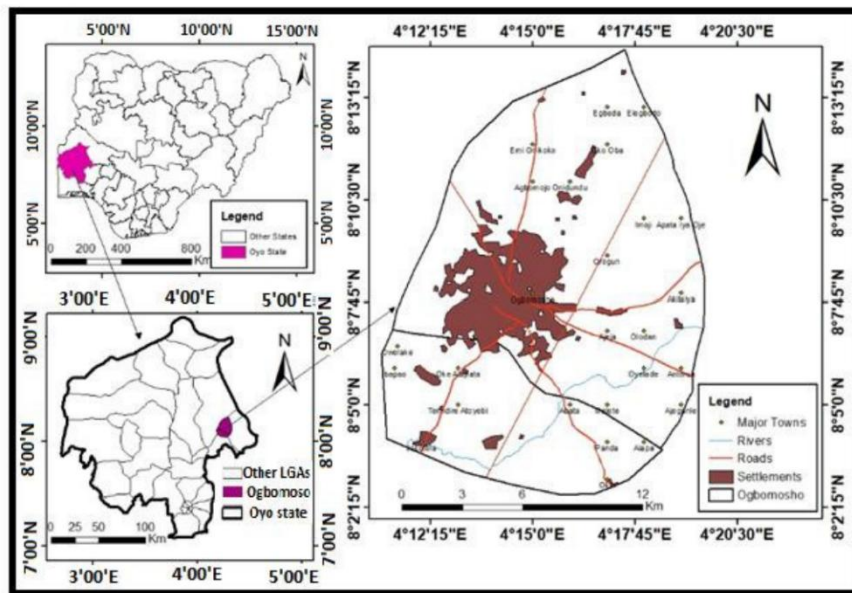


Fig 1. Study Area (Source: Dada, 2023)

The study area has hosted many researches for many years but few details are documented about its soil profile and characteristics. The study therefore took on detailing the nutrient quality of the soil by profiling different characteristics of soil at various location for

proper cashew yield. This study eventually evaluates the spatial variability of the soil at the LAUTECH cashew plantation. The objectives of this study were to: evaluate the soil physiochemical properties of the cashew plantation; and suggest improvement needed for soil

suitability towards increased cashew crop productivity and sustenance.

Methodology

Soil Sampling

At least four (4) soil profile pits were taken a 100meters interval. The analyses carried out were guided by the procedures designed by the Food and Agriculture Organization (FAO) and the horizon designation of the soil survey. The samples were well labelled to distinctively identify each specimen.

Laboratory Analysis

The collected soil samples were air-dried, crushed, and sieved through a 2mm mesh. The following analyses were conducted:

- Soil Texture: Determined using the hydrometer method (Gee & Bauder, 1986).
- Bulk Density: Measured using the core method (Blake & Hartge, 1986).
- pH: Measured in a 1:1 soil-water suspension using a pH meter (McLean, 1982).
- Organic Carbon: Estimated using the Walkley-Black method (Walkley & Black, 1934).
- Total Nitrogen: Determined using the Kjeldahl method (Bremner & Mulvaney, 1982).
- Cation Exchange Capacity (CEC): Measured using the ammonium acetate method (Thomas, 1982).
- Nutrient Analysis: Calcium (Ca), Magnesium (Mg), and Iron (Fe) were analyzed

using atomic absorption spectrophotometry (AAS).

Using the macro Kjeldahl method (Black, 1965), the total Nitrogen content in the samples was determined by mixing auto-phosphoric acid with hydrogen tetraoxosulphate VI (H₂SO₄) digested in three (3) hours at temperature 37 degrees centigrade in a Tecator digester. The Technicon's (AAII) auto-analyzer was employed to analyze the nitrogen content. For the determination free of iron oxide was carried out by applying the dithionite-citrate-bicarbonate method as described by Michra and Jackson (1960). Orthophenanthroline colorimetric procedure was then utilized to determine the amount of iron extracted.

Results and Discussion

According to the results obtained, the soil in the study area was classed mildly acidic, the pH is within 4.8 – 5.6., the nutrient availability and microbial activity are vital for plant growth, which can be impacted by acidity (Havlin et al., 2014). The soil samples taken at regular interval within the study area were found to be lacking major nutrients especially total nitrogen and organic carbon. Nitrogen as an essential soil content for vegetative development and plant health, its low value may impair or restrict cashew tree from growing well and producing good yield. (Fageria et al, 2008).

Although the soil was discovered to be useful for cashew farming but it definitely requires few enhancements to increase productivity. However, the wilting point (WP) and WHC were low due to lack of moisture content in that soil. therefore, in dry periods, the poor moisture retention poses significant threat to agricultural productivity (Mishra et al, 2006). In the eluvial and illuvial clay transport, as it affects soil structure and fertility it can be attributed to the soil heterogeneity from the topsoil to other strata of soil (Baker et al., 2006).

Table 1: Morphological properties of the pedon AAT1

Horizon	Depth (Cm)	Gravel Content (%)	Soil> 2mm (%)	Soil Colour
A1	0-30	60.83	39.17	Reddish brown
A2	30-80	77.39	22.61	Red
B1	80-120	72.63	27.37	Dull yellow orange

B2	120-150	64.20	35.80	Yellow orange
BC	150-180	24.14	75.86	Orange

Table 2: Morphological properties of the soil of pedon AAT2

Horizon	Depth	Gravel Content (%)	Soil <	2mm (%)
A1	0-30cm	29.21	70.79	Dull reddish brown
A2	30-70cm	76.79	23.21	Reddish
B1	70-100cm	69.68	30.32	Orange
B2	100-130cm	71.89	28.11	Yellow orange
BC	130-170cm	57.98	42.02	Dull yellow orange

Table 3: Morphological properties of the soil of pedon AAT3

Horizon	Depth (cm)	Gravel Content (%)	Soil < 2mm (%)	Soil Colour
A1	0-23	38.37	61.63	Reddish brown
A2	23-52	77.06	22.94	Red
B1	52-97	78.17	21.83	Red
B2	97-159	73.20	26.80	Red
BC	159-197	55.02	44.98	Reddish

Table 4: Morphological properties of the soil of pedon AAT4

Horizon	Depth (cm)	Gravel content (%)	Soil < 2mm (%)	Soil colour
A1	0-30	64.82	35.18	Dark red
A2	30-60	71.97	28.03	Red
B1	60-100	80.29	19.71	Orange
B2	100-120	77.45	22.55	Orange
BC	120-140	55.11	44.89	Light gray

Table 5 shows the particle size distribution and texture of the soils in varying grades. Sand concentration was the highest and somehow followed by clay and silt, and others accordingly.

The distribution of sand indicates that it falls between 55% and 74%. Horizons A2 (30–80 cm depth) and B1 (80–120 cm depth) of Pedon AAT1 had the largest and lowest sand contents,

respectively, at 74% and 55%. According to the silt distribution, it falls between 13 and 18 percent. Horizon B2 and BC had the highest silt percentage (18%), while Pedon AAT1's horizon A2 had the lowest silt content. The percentage of clay varies from 13 to 29 percent. Horizon B1 had the most clay content (29%), whereas Pedon AAT1's A2 had the lowest clay amount (13%).

The distribution of sand indicates that it falls between 68 and 80%. Horizon BC (130–170 cm depth) had the maximum sand concentration (80%), while Pedon AAT2's horizon B1 (70–100 cm depth) had the lowest sand content (68%). The distribution of silt indicates that it falls between 10 and 14 percent. Horizon A2 of Pedon AAT2 had the highest silt level (14%), while Horizons B1 and B2 had the lowest silt content. The percentage of clay varies between 13-22%. Horizon B2 had the most clay content (22%), whereas Pedon AAT2's A1 had the lowest clay amount (13%).

The distribution of sand indicates that it falls between 70 and 82 percent. Horizon A1 (0–23 cm depth) had the maximum sand concentration (82%), while Pedon AAT3's horizon B2 (97–159 cm depth) had the lowest sand content (70%). The distribution

of silt indicates that it falls between 8 and 10%. Horizons A1 and A2 of Pedon AAT3 had the lowest silt concentration, while horizons B1, B2, and BC had the greatest silt level (10%). The percentage of clay varies between 9 and 20%. Horizon B2 had the most clay percentage (20%), whereas Pedon AAT3's A2 had the lowest clay amount (9%).

The distribution of sand indicates that it falls between 72 and 80%. Horizon A2 (30–60 cm depth) had the highest sand concentration (80%), while Pedon AAT4's horizon B1 (60–100 cm depth) had the lowest sand content (72%). According to the silt distribution, it falls between 9 and 16 percent. Horizon A1 of Pedon AAT4 had the highest silt content, at 16%, whereas Horizon B2 had the lowest silt percentage. The distribution of clay is between 10 and 16 percent. Horizon B1 had the highest clay percentage (16%), whereas Pedon AAT4's A1 and A2 had the lowest clay contents (10%).

In the surface of the horizons, the texture classes shifted from loamy sand/sandy loam to sandy loam and sandy clay loam in the epipedon. Lesivage and elucidation could be the cause of the more clayey sub –surface horizons (Okusami and Oyediran, 1985).

Table 5: Particle size distribution of the soils

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
Pedon AAT1					
a1	0-30	72	14	14	Loamy Sand
a2	30-80	74	13	13	Sandy Loam
b1	80-120	55	16	29	Sandy Clay Loam
b2	120-150	56	18	26	Sandy Clay Loam
Bc	150-180	57	18	25	Sandy Clay Loam
Pedon AAT2					

a1	0-30	74	13	13	Sandy Loam
a2	30-70	72	14	14	Sandy Loam
b1	70-100	68	10	22	Sandy Loam
b2	100-130	72	10	18	Sandy Loam
Bc	130-170	80	10	10	Loamy Sand

Pedon AAT3

a1	0-23	82	8	8	Loamy Sand
a2	23-52	81	8	11	Loamy Sand
b1	52-97	72	10	18	Sandy Loam
b2	97-159	70	10	20	Sandy Loam
Bc	159-197	72	10	18	Sandy Loam

Pedon AAT4

a1	0-30	74	16	10	Sandy Loam
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A2	30-60	80	10	10	Loamy sand
B1	60-100	72	12	16	Sandy loam
B2	100-120	78	9	13	Sandy loam
BC	120-140	76	10	14	Sandy loam

Some chemical properties of the soil are shown in Table 6. The pH values (pH in H₂O) ranged between 4.8 and 5.4 in Pedon AAT1, 4.9 to 5.6 in Pedon AAT2, 4.9 to 5.5 in Pedon AAT3 and 5.0 to 5.6 in Pedon AAT4. Generally, the Ph. values decreased with increasing soil depth i.e. the top soils have higher values than the sub soil horizons (Table 6). The Ph in KCL was generally lower in all horizons than the PH in H₂O. This indicates the dominance of silicate minerals (Van Raij, 1972). The decrease in PH with increasing depth observed can be attributed to the transfer of bases from deeper horizons and their subsequent accumulation in surface horizon when the ground water table reach

the soil surface. Generally, the effective ECEC values for all the profile studied followed the same trend in which the values decreased with increasing depth. Relatively high ECEC values obtained in the A1 horizons could be attributed to significant contribution of soil organic matter to cation exchange capacity.

The Na content was generally low in all profiles. Exchangeable Ca dominated the exchangeable site in all horizons followed by exchangeable Mg. The exchangeable Al content was greater than H in all horizons of the various profiles.

Table 6 also shows the organic carbon, total

nitrogen, and micronutrient concentrations. The levels of Fe and Cu were higher than those of Zn and Mn. Cu has a value between 10.0 and 31.1 mgk-1, while Fe has a value between 12.8 and 62.1 mgk-1. Mn concentrations range from 5.2 to 18.1 mgk-1, while Zn values range from 10.3 to 24.2 mgk-1. This suggests that iron and copper are important in the formation of soil. The range of organic carbon

was 0.5–3.4 gkg-1. As soil depth increases, the amount of organic carbon in the soil decreases. Plant litter accumulation is the cause of the high level of organic carbon in the soil surface horizon. Low levels of total nitrogen (0.1 to 0.4 gkg-1) were found, and the distribution trended similarly to that of organic carbon.

TABLE 6: CHEMICAL PROPERTIES OF THE SOIL PROFILES.

HORI ZON	DEPTH (cm)	PH in H2O	PH in KCL	Ca 2+	Mg 2+	N a+	K +	Al 3+	H +	EC	EC _e	Organic C (%)	Total N (%)	Fe	C u	Z n	M n
PEDON AAT1																	
A1	0-30	5.4	5.2	0.73	0.22	0.03	0.04	0.02	0.05	1.09		3.4	0.04	6.21	30.0	24.2	18.1
A2	30-80	5.2	4.8	0.56	0.11	0.05	0.55	0.03	0.04	1.34		2.0	0.02	43.2	21.0	16.1	12.4
B1	80-120	5.2	4.9	0.41	0.18	0.05	0.24	0.04	0.22	1.14		1.0	0.01	24.1	18.4	12.3	10.0
B2	120-150	4.8	4.7	0.25	0.08	0.04	0.95	0.02	0.18	1.52		0.8	0.01	28.2	16.8	14.1	9.6
BC	150-180	4.8	4.6	0.14	0.06	0.03	0.03	0.02	0.22	0.5		0.6	0.01	22.0	12.1	13.0	6.4
PEDON AAT2																	
A1	0-30	5.6	5.2	0.80	0.21	0.06	0.11	0.03	0.41	1.62		2.9	0.03	48.2	26.1	18.2	14.0
A2	30-70	5.0	4.9	0.45	0.09	0.04	0.07	0.02	0.40	1.07		2.1	0.02	33.1	24.3	12.4	11.1
B1	70-100	4.9	4.6	0.46	0.12	0.03	0.09	0.01	0.26	0.97		1.2	0.01	30.1	25.0	12.4	9.4
B2	100-130	4.9	4.5	0.23	0.14	0.03	0.07	0.02	0.19	0.68		0.9	0.01	22.0	18.1	10.3	8.0
BC	130-170	4.9	4.6	0.11	0.08	0.02	0.05	0.02	0.14	0.42		0.5	0.01	18.4	12.0	8.4	5.3
PEDON AAT3																	
A1	0-23	5.5	5.3	0.24	0.06	0.08	0.9	0.03	0.40	0.87		2.3	0.02	50.2	31.1	22.3	16.2
A2	23-52	5.5	5.2	0.36	0.20	0.04	0.10	0.03	0.41	1.14		1.9	0.02	48.6	24.2	18.2	13.0
B1	52-97	5.3	4.9	0.64	0.30	0.08	0.12	0.02	0.36	1.52		1.0	0.01	50.1	24.2	16.3	13.0
B2	97-159	5.2	4.8	0.48	0.22	0.05	0.10	0.03	0.39	1.27		0.8	0.01	30.2	16.3	12.4	10.1
BC	159-197	4.9	4.6	0.30	0.10	0.03	0.09	0.02	0.14	0.68		0.6	0.01	22.3	16.8	10.8	9.9
PEDON AAT4																	
A1	0-30	5.6	5.2	0.68	0.24	0.09	0.14	0.03	0.05	1.23		3.2	0.03	48.3	30.0	20.3	16.8
A2	30-60	5.4	5.0	0.52	0.20	0.05	0.10	0.03	0.05	0.95		1.6	0.02	29.0	21.1	16.2	12.3
B1	60-100	5.0	5.0	0.54	0.19	0.05	0.09	0.04	0.14	1.05		1.0	0.01	20.1	18.0	12.0	12.0
B2	100-120	5.0	4.8	0.31	0.12	0.04	0.06	0.02	0.18	0.73		0.8	0.01	18.2	12.3	13.1	11.2
BC	120-140	5.0	4.6	0.18	0.11	0.03	0.08	0.01	0.20	0.61		0.5	0.01	12.8	10.0	11.0	6.3

Conclusion

The study concludes by pointing out the notable soil heterogeneity seen in the Ladoke Akintola University of Technology cashew crop. The results show that while the soil is somewhat adequate for cashew growth, it needs additives such organic manure (cow dung and compost) to increase productivity and boost nutritional content. For the region's cashew production to be sustainable, it is also imperative that the low moisture retention capacity be addressed. Long-term soil management techniques should be the main focus of future research in order to enhance crop productivity and soil health.

The majority of the subsoil is reddish due to improved drainage and clay buildup, whereas the top soil strata were typically darker in color due to the deposition of organic matter in the soil. Clay may be transported to the subsurface horizons via eluvial or illuvial processes, which could account for the soil's vertical variance from topsoil to subsurface horizons. Because of the clay content in the profiles being washed down, there is less gravel in the topsoil. Applying organic or organ mineral fertilizers could improve the soil's adaptability for cashew production.

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