

# Assessment of the Variations in Soil Physicochemical Parameters of the Natural Forest and Plantations in Orumba North Local Government Area, Anambra State, Nigeria

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## Abstract

Soil physicochemical parameters are the physical and chemical characteristics of soil such as pH, bulk density, organic carbon, nitrogen content, and nutrient levels at different soil depths. These parameters vary from one vegetation to the other and from one soil to the other. The study assessed the variations in soil physicochemical parameters of the natural forest and plantations in Agu Eke (Eke bush) in Etti village, Nanka and Umunnebo village, Ufuma both located in Orumba North Local Government Area, Anambra State. The experimental research design and stratified random sampling methods were used for the study and a total of 12 soil samples were collected at 30 cm depth from the selected locations of natural forest, cashew and palm plantations. The samples were analyzed using laboratory Varian AA240 Atomic Absorption Spectrophotometer, after which the result was subjected to statistical analysis—Analysis of Variance (ANOVA). The study found that there was no significant difference (variation) between the moisture contents of natural forests and the plantations; that is, the moisture contents were the same. It was also found that there was no significant variation between the bulk densities of the natural forest, oil plantation, and cashew plantation, meaning that the bulk densities were significantly the same. However, there were significant variations in nitrogen, potassium and phosphates, with  $p$ -values:  $\text{sig} = .000 < .05$ ,  $\text{sig} = .010 < .05$  and  $\text{sig} = .000 < .05$ , respectively. That is, the nitrogen and phosphate contents of the natural forest significantly vary more than those of the oil palm and cashew plantations, which probably means that by reducing natural forest to plantation, the nitrogen and phosphate contents of the natural forest reduced from what it used to be when the lands were mere forests. This shows that plantations do not have the same function of maintaining or improving soil quality

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as natural forests. The study recommended adopting a sustainable plantation agricultural system, such as using diverse nutrient sources (manure and compost), in order to maintain the desired soil quality.

### Keywords

Ecosystem, Land Use Change, Soil Quality, Physical and Chemical Characteristics

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## 1. Introduction

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical and biological properties (Manimegalai & Sukanya, 2014; Trivedi, 2018). Soil provides a lot of functions that are beneficial to both human and other living organisms (The Royal Society, 2020). It acts as a filter, buffer storage, transformation system and thus protects the global ecosystem against the adverse effects of environmental pollutants (Sumithra et al., 2013). Soil is one of the most significant ecological factors, on which plants depend for their nutrients, water and mineral supply (Shaikh & Bhosle, 2013). Promoting soil quality (which includes various soil physical and chemical properties) is then deemed major important for any soil management system (Gorems & Goshal, 2020). Such study which involves elucidating the soil physicochemical parameters is necessary for promoting plant growth and soil management (Kanimozhi & Panneerselvam, 2011; Maphuhla et al., 2021).

According to research by Pérez-Sato et al. (2022), the soil physicochemical characteristics alter as oil palm trees get older. In a random sampling, soil samples were taken from the area surrounding the oil palm (at ages 3, 5, and 15) at intervals of 1, 2, and 3 metres from the trunk plant. The following soil characteristics were assessed: soil pH, cation exchange capacity, bulk density, organic matter, total nitrogen, and total mineral composition, including measurements of sulfur, phosphorus, calcium, magnesium, potassium, iron, copper, manganese, zinc, and boron. According to the findings, 15-year-old plants exhibited an increase in fresh and dried root biomass as well as diameter compared to 3- and 5-year-old plantations. Additionally, correlation analysis and principal component analysis show that the examined characteristics are connected to the oil palm's mature age.

Akinde et al. (2020) examine changes in soil properties under different types of agricultural land-use in Ile-Ife, Nigeria, with a view to extending knowledge on the nature of soil properties under long-term land-use practices. The study investigated six types of land-use: paddock, continuously cropped, secondary forest, teak, oil palm, and cacao plantations. The results implied that continuous cultivation led to depletion in soil physical and chemical properties, whereas, afforestation and cultivation of tree crops conserved soil properties better. Therefore, the

establishment of tree crop plantations and conservative soil management practices, such as manuring, mulching, liming, and conservation tillage, were suggested to prevent agricultural lands from degrading in areas with soils under similar conditions.

In 2019, at Ifite-Nanka longtime gully erosion site, Orumba North L.G.A. in Anambra State, Nigeria, Uzoh et al. (2020) evaluated the effects of three land use types on soil organic carbon (SOC) and physical properties and to determine the factors that contributed to the stability of the eroded sites. Horizon variability of these soil parameters was also determined. During the reconnaissance survey, three major land use types were observed: Arable farmland, cashew and oil palm plantation adjacent to the gully. The result showed that Oil palm plantation had significantly ( $p < .05$ ) highest SOC value (.51%) followed by arable cropping (.46%) and least in cashew plantation (.28%). Oil palm plantation had the highest value of water stable aggregate (WSA) (15.35) followed by arable farm land (11.67) and least was cashew plantation but aggregate stability (AS) was highest in arable cropping. Along the profile, SOC was highest in A horizon and so was the WSA and AS. Among SOC, clay and sand content used in determining the stability of the soil, SOC explained 64.9% and 45.5% variations in AS and WSA respectively. Collapsing the structural and stability indices, more of the structural indices were improved in arable land use while more of the stability indices were improved oil palm plantation plots. The authors also showed that arable crop land and oil palm plantation are more suitable for controlling erosion in the research area because the aggregate stability and water stable aggregates were high in these two crop land use types whereas cashew plantation had high bulk density and low aggregate stability. In conclusion the authors recommended that cashew plantations should not be established in such location if erosion is to be controlled. More so, there is need to increase organic matter in such area since organic matter controlled over 60% variation in aggregate stability and has positive correlation with it. This means the more organic matter there is, the better the stability of the studied soil will be.

Jemal (2020) assessed the impact of land use/land cover on the physicochemical parameters of soils in the Wudma Area of Southern Ethiopia. The land use systems studied included grazing land, cultivated land, eucalyptus plantation and natural forest. Jemal's study was superimposed on land use systems that were located nearby on similar soil. Undisturbed core and disturbed composite soil samples were collected randomly with four replications for each land use system. The influence of land use systems on soil properties were analyzed using the analysis of variance general linear model procedure of SAS software. Mean differences due to land use, were identified using the Least Significant Difference (LSD) test after differences were found statistically significant. The results of study showed that forest clearing and subsequently cultivation and tillage practices resulted in the decline of the soil quality and these changes effects on soil sensitivity to degradation and erosion i.e. land usage has a substantial impact on soil texture. The author therefore recommended that, reducing the intensity of cultivation and adopting

integrated soil fertility management could maintain the existing soil condition and replenish the degraded soil properties of the area.

According to Gorems and Goshal (2020) study on effects of land use on soil physiochemical properties at Barkachha, Mirzapur District, Varanasi, India, the different land use practices have a significant impact on soil physicochemical properties; among the land use patterns they studied - natural forest, bamboo plantation, degraded forest, and agricultural land. Natural forest had the highest water holding capacity ( $40.06 \pm 0.74\%$ ), porosity ( $0.539 \pm 0.011\%$ ), soil macro-aggregates ( $64.16 \pm 2.64\%$ ), soil organic carbon ( $0.84 \pm 0.054\%$ ), soil total nitrogen ( $0.123 \pm 0.013\%$ ). Unlikely, bamboo plantation had a higher moisture content ( $2.78 \pm 0.23\%$ ), whereas agricultural land had a lower moisture content ( $2.14 \pm 0.5\%$ ), though there were no significant variations between land use categories. Agricultural land, on the other hand, had a greater bulk density ( $1.37 \pm 0.0193 \text{ g/cm}^3$ ), but natural forest had a lower bulk density ( $1.220 \pm 0.0288 \text{ g/cm}^3$ ). Land use changes, on the other hand, had a considerable impact on bulk density, soil organic carbon, soil total nitrogen, water holding capacity, and porosity. Furthermore, at  $p < .05$ , the correlation analysis revealed that soil organic carbon, soil total nitrogen, moisture content, porosity, water holding capacity, and soil macro aggregates were positively correlated and negatively linked with bulk density, meso, and micro soil aggregates. Soil organic carbon and total nitrogen, in particular, varied significantly across land use types. Natural forest (.84%) produced the most soil organic carbon, followed by bamboo plantations (.72%), degraded forest (.448%), and agricultural land (.435%). There were substantial differences in soil organic carbon in natural forest and bamboo plantation compared to agricultural land and degraded forest, but no significant differences were found between natural forest and bamboo plantation, or degraded forest and agricultural land.

Similarly, variance in soil total nitrogen content was found to be highest in natural forest (.123%), followed by bamboo plantation (.033%), degraded forest (.027%), and agro-ecosystem (.027%) in decreasing order (.014%). The analysis of variance revealed a significant difference in soil total nitrogen between natural forest and other land use types at  $p < .05$ . Degraded forest, bamboo plantations, and agricultural land, on the other hand, showed no significant differences. SOC, STN, and soil macro aggregates were substantially positively connected, while bulk density, meso, and micro soil aggregates were adversely correlated, according to Pearson's correlation coefficients. Furthermore, porosity ( $r = .703$  and  $.555$ ), water holding capacity ( $r = .76$  and  $.66$ ) and macro soil aggregates ( $r = .929$  and  $.970$ ) were strongly correlated with soil organic carbon and total nitrogen, but moisture content ( $r = .548$  and  $.01$ ) was poorly correlated. Soil organic carbon and nitrogen, on the other hand, were inversely linked with bulk density ( $r = -.722$  and  $-.568$ ,  $p < .05$ ), soil meso ( $r = -.901$  and  $-.989$ , respectively), and micro aggregates ( $r = -.946$  and  $-.936$ ,  $p < .05$ ). The total nitrogen content of soil was shown to be substantially linked with macro soil aggregates ( $r = .97$ ,  $p < .05$ ). The authors further posit that the results of the study will help to develop future plan

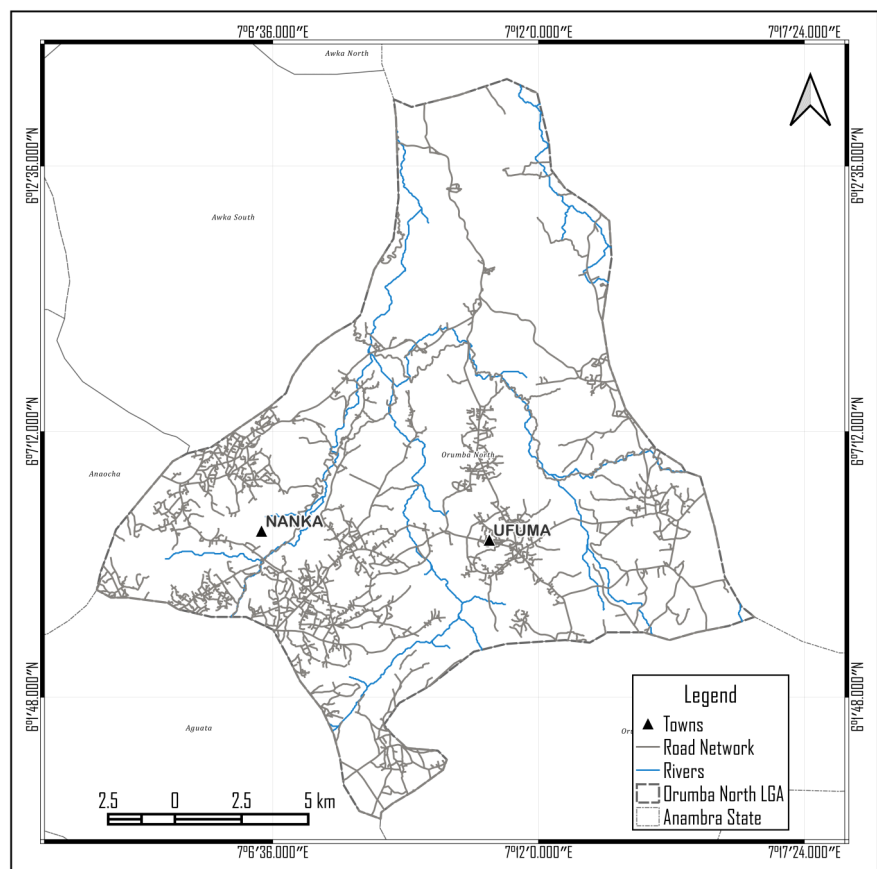
about land use and soil management regarding soil carbon dynamics and climate change mitigation.

Changes in land use from natural to controlled ecosystems may have negative consequences for soil structure and quality (Tellen & Yerima, 2018). Changes in land use/land cover (LULC) have an impact on the earth's biogeochemistry, hydrology, and climate (Tellen & Yerima, 2018; Nedd et al., 2021). To the researcher's knowledge, few, if any, published studies have assessed the variations in soil physicochemical parameters of the natural forest and plantations in Orumba North Local Government Area, Anambra State. As a result, the findings of this study can serve as references and helpful information for other researchers who are trying to comprehend the variations in soil physicochemical parameters of the natural forests and plantations.

## 2. Materials and Methods

### 2.1. The Study Area

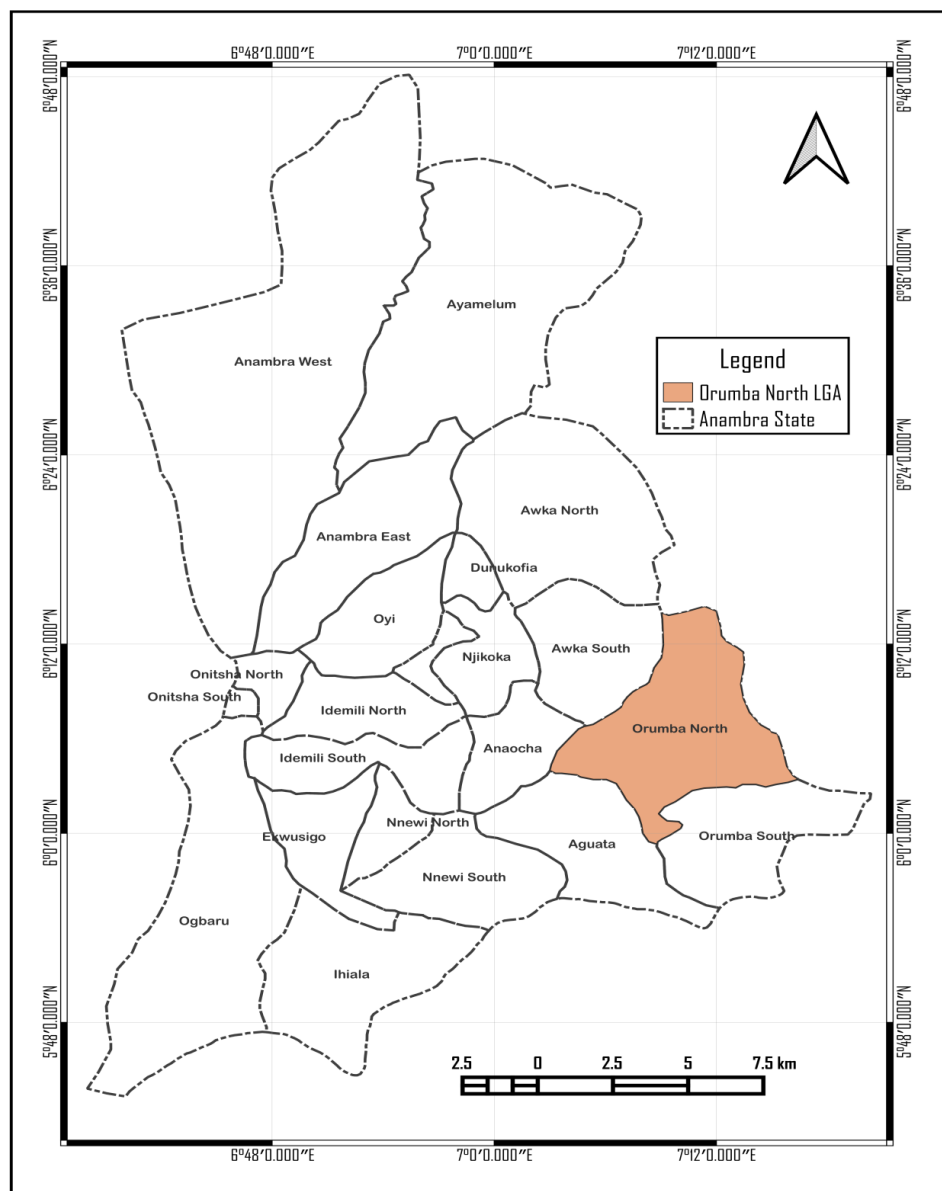
The natural forest and cashew plantation are located in Agu Eke (Eke bush) in Etti village, Nanka, while the oil palm plantation is located at Umunnebo village, Ufuma, both in Orumba North Local Government Area, Anambra State.



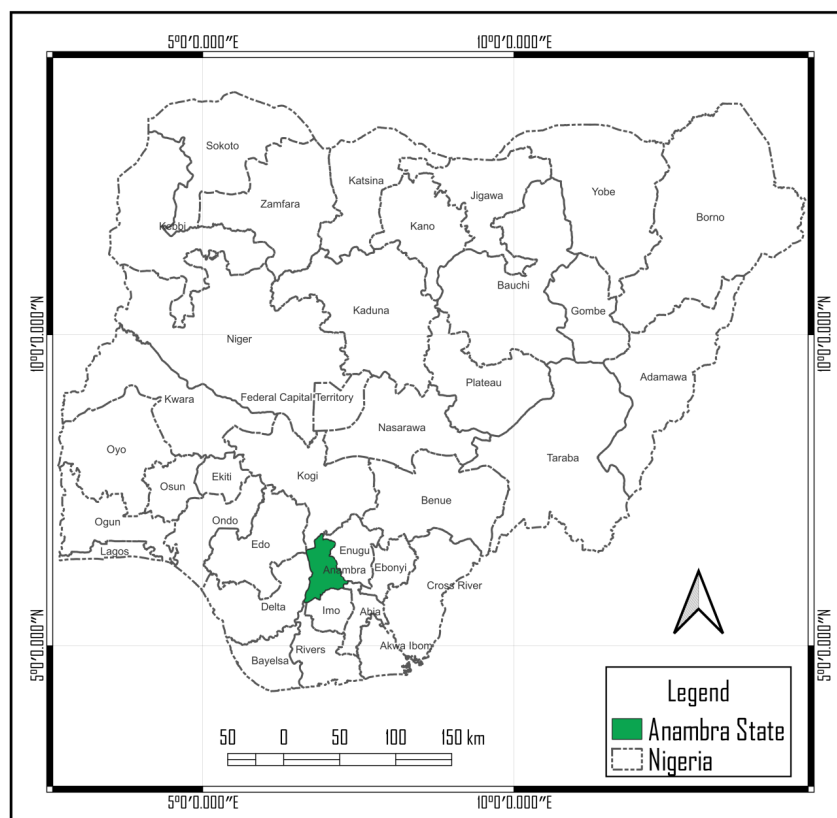
**Figure 1.** Map of Orumba North LGA showing the study areas. Source: Researcher's work, 2024.

## 2.2. Location of Natural Forest and Cashew Plantation in Etti Village, Nanka

The natural forest and cashew plantation are located in Agu Eke (Eke bush) in Etti village, Nanka (**Figure 1**), Orumba North Local Government Area, Anambra State. The study area is situated in Orumba North LGA (**Figure 2**), in Anambra State, Nigeria. **Figure 3** shows the location of Anambra State in Nigeria. The geographic coordinates of Nanka are  $6^{\circ}3'26.64''$  North,  $7^{\circ}2'53.40''$  East and  $6^{\circ}2'5.35''$  N  $7^{\circ}5'1.84''$  E (Ukatu, 2019). Its neighbours are Oko, Agulų, Ekwulọbia, Aguluzoigbo, Isuofia, Umuona, and Awgbu. Nanka comprises of seven villages including Agbiligba, Enugwu, Ifite, Amakor, Umudala, Ubahu, and Etti, in that order (Ukatu, 2019).



**Figure 2.** Map of Anambra State showing Orumba North LGA. Source: Researcher's work, 2024.



**Figure 3.** Map of Nigeria showing Anambra State. Source: Researcher's work, 2024.

The geological setting in the study area is that of layered sequences in which a predominantly sandstone formation is underlain by a predominantly shale formation (Obiadi et al., 2011). The area lies between the tropical rain forests which dominate nearly half of southern Nigeria and is characterized by luxuriant vegetation and abundant plant species but many parts have been subjected to severe deforestation due to anthropogenic activities thereby reducing the area to savannah vegetation in many parts (Obi & Okekeogbu, 2017). It is bounded by fresh water swamp forest in the south and Guinea Savanna in the North, although the area is marked by continuous growth of trees, shrubs and climbing plants, the land is almost bare during the dry season exposing critical areas of the slopes to the impacts of rains at the commencement of wet season (Igwe, 2018). The vegetation in the study area is influenced by hydrogeological factors including relief and lithology as well as other anthropogenic factors (Obiadi et al., 2011). Although Anambra State has a high yearly rainfall, ranging from 1400 mm in the north to 2700 mm in the south, it is concentrated in one season, November to February, with nearly four months of dryness.

### 3. Results

#### 3.1. Result for the Variation in Soil Physical Parameters of the Natural Forest and Plantations

This objective was met by comparing soil physical parameter of natural forest with

oil palm and cashew plantations, using one-way analysis of variance (ANOVA). The aim was to find out if there is significant difference in mean physical effects of natural forest, oil palm and cashew plantations respectively. The physical effects measured here are moisture content (in percentage), bulk density (g/ml), and particle density (g/ml). Each test is significant when the  $p$ -value is less than .05, otherwise the test is not significant. Significance implies that there is significant variation in soil physical parameters of the natural forest and plantations. Post hoc tests were used to determine which of the land use, natural forest, oil palm, and cashew plantations were significant.

From the ANOVA table, the  $p$ -value for the comparison of moisture contents of the natural forest and plantations is .211, which is greater than .05. This implied that there is no significant difference (variation) between the moisture contents of natural forest and the plantations; that is, the moisture contents were the same.

The table also showed that the  $p$ -value of the comparison of bulk densities of natural forest and the plantations is .000. It implied that there were significant difference (variation) in the bulk densities of the natural forest and plantations. The  $p$ -value for the test of variation between particle densities of natural forest and plantations is .548, which is greater than .05. It implied that there were no significant variation between the bulk densities of the natural forest, oil plantation and cashew plantation, meaning that the bulk densities were significantly the same.

The post hoc table showed that the bulk density of the natural forest is higher than that of the oil palm and cashew plantations.

### 3.2. Result for the Variation in Soil Chemical Parameters of the Natural Forest and Plantations

To meet this objective, one way ANOVA was used to assess variations in loss of organic carbon, nitrogen, sodium, calcium, phosphate, pH and calcium, which all constituted the soil chemical parameters. The variations were between natural forest, oil palm and cashew plantations. Like stated earlier, each test is significant if the  $p$ -value is less than .05, otherwise, the test is not significant. Significance implies that there is variation, while non-significant means that there is no variation.

Post hoc tests were also done for significant tests, in order to ascertain which of natural forest, oil palm and cashew plantations is significant.

Result of the ANOVA showed that the  $p$ -values of variations in loss of organic carbon (sig = .000), nitrogen (sig = .000), phosphate (sig = .000), pH (sig = .022) and potassium (sig = .010) are all less than .05. This implied that there were significant variations in these parameters in natural forest, oil palm and cashew plantations.

The  $p$ -values of sodium and calcium are .470 and .249 respectively. The values are greater than .05, implying that there were no significant variations in sodium and calcium in the natural forest and plantations.

For the post hoc results, **Table 4** showed that the loss of organic carbon of the cashew plantation varied significantly more than the others with  $p$ -value = .000, whereas for the variation in nitrogen of the natural forest varied significantly more

than the others with  $p$ -value = .000.

Further comparison of the phosphate, pH and potassium, revealed that phosphate and pH of the natural forest varied more significantly than those of oil palm and cashew plantations, while the potassium of the cashew plantation varied most significantly than others.

## 4. Discussion

By utilizing data obtained from a comprehensive analysis of 12 soil samples from two land uses (natural forest and plantations), this research study represents a pioneering effort in assessing the impacts of plantation agriculture on soil quality.

### 4.1. The Variation in Soil Physical Parameters of the Natural Forest and Plantations

The result of this research on moisture revealed that the  $p$ -value for the comparison of moisture contents of the natural forest and plantations is .211, which is greater than .05 (Table 1). This implies that there were no significant difference (variation) between the moisture contents of natural forest and the plantations; that is, the moisture contents were the same. This is in contrast with reviews from Gorems and Goshal (2020), Jackson et al. (2005) and van Dijk and Keenan (2007), where moisture content had significant relationship between natural forest and plantations. The reason for this variation in soil moisture might be due to the net deficiency between evapotranspiration and precipitation which are two major processes in ecosystem water cycles. The amount of water lost through evapotranspiration is greater than the amount of water gained through precipitation in plantations (Benyon et al., 2006; Stape et al., 2008). According to Jackson et al. (2005), plantations afforested in croplands, grasslands and shrub lands decreased stream flow by 180 mm year<sup>-1</sup> and 38% on average globally, and the climate feedbacks were unlikely to offset the soil water loss. It is important to note that a decrease in soil moisture content may limit root growth and the increment of stand biomass in plantations.

**Table 1.** ANOVA for variations in moisture content, bulk density and particle density.

		Sum of Squares	Df	Mean Square	F	Sig.
Moisture content	Between Groups	280.857	2	140.429	1.860	.211
	Within Groups	679.562	9	75.507		
	Total	960.419	11			
Bulk densities	Between Groups	.043	2	.021	107.459	.000
	Within Groups	.002	9	.000		
	Total	.044	11			
Particle density (g/ml)	Between Groups	.004	2	.002	.644	.548
	Within Groups	.029	9	.003		
	Total	.034	11			

Bulk density tends to be lower in organic soil (loamy soil) and higher in sandy soil (Cresswell & Hamilton, 2002). In contrast, the result of this research showed that natural forest has higher bulk density than plantations because the  $p$ -value of the comparison of bulk densities of natural forests and plantations were significantly different ( $p$ -value  $.000 < .05$ ) (Table 1). This was so because from the Post hoc (multiple comparisons) test, oil palm plantation has lower bulk density, which resulted to the decrease in cashew plantation when computed together (Table 2). The reason for the high bulk density in natural forest may be due to; vegetations, economic activities, geology and soil settings of the research area. The main geologic units (soils) of the Etti village Nnaka are derived from the Nanka Sand (Eocene), overlain by Ogwashi-Asaba, formation (Oligocene) and underlain by Imo Shale and as such comprised mainly of porous, red and brown sandy soils, and brown and pale clay soils (Obiadi et al., 2011). Also the economic activities in the Etti village Nnaka emanating from population pressure and need to provide energy and sustenance for a vast majority, the ecosystems are being altered through: industrialization, built up areas, grazing, slash-burn, firewood gathering etc. This may expose the soil to solar radiation and soil compaction thus leading to higher bulk density in natural forest. Increase in soil bulk density, i.e. soil compaction, is a global concern due to adverse effects on soil environments and productivity (FAO, 2005). Soil compaction may limit the access of roots to water and nutrients, destroy soil structural units, slow gaseous diffusion and reduce rates of root respiration and litter decomposition (Tokunaga, 2006), thereby reducing soil quality.

**Table 2.** Multiple comparisons of the variations of bulk densities of natural forest and plantations.

Dependent Variable: Bulk densities						
LSD						
(I) Land Use Category	(J) Natural forest/ plantation type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1. Natural Forest	Oil palm	.09737500*	.00996766	.000	.0748266	.1199234
	Cashew	-.04567000*	.00996766	.001	-.0682184	-.0231216
2. Agriculture (Oil palm)	Natural forest	-.09737500*	.00996766	.000	-.1199234	-.0748266
	Cashew	-.14304500*	.00996766	.000	-.1655934	-.1204966
3. Agriculture (Cashew)	Natural forest	.04567000*	.00996766	.001	.0231216	.0682184
	Oil palm	.14304500*	.00996766	.000	.1204966	.1655934

\*. The mean difference is significant at the .05 level.

For particle density, the result showed that there were no significant relationship between the natural forest and plantations because the  $p$ -value for the test of variation between particle densities of natural forest and plantations was .548, which is greater than .05 (**Table 1**). This is in contrast with [Selassie and Ayanna \(2013\)](#) where there was a significant relationship between particle density of natural forest and plantation, the reason for this contradiction maybe due to the geographical area of study which is Ethiopia. Particle density shows the chemical composition and structure of minerals in the soil. Therefore any increase in particle density will lead to increase in soil quality vice versa.

#### 4.2. The Variation in Soil Chemical Parameters of the Natural Forest and Plantations

There were significant relationship between loss of organic carbon (sig = .000), nitrogen (sig = .000), phosphate (sig = .000), pH (sig = .022) and potassium (sig = .010) on natural forest and plantations (**Table 3**). However, the post hoc result showed that the loss of organic carbon of the cashew plantation varied significantly more than the others (**Table 4**). This means that introducing cashew plantation to natural forest may reduce the soil organic carbon. This affirms with the studies of [Igu et al. \(2023\)](#); [Hartemink \(2005\)](#) and [Kopittke et al. \(2019\)](#). [Hartemink \(2005\)](#) posits that the main impacts of plantation agriculture using perennials crops like palm oil, cashew, rubber and cocoa include: soil erosion, soil fertility decline and pollution. In contradiction, natural forest landscapes are expected to sequester more carbon since they have sufficient amounts of litter falls and biogeochemical processes from trees, herbs and grasses, as well as a relatively undisturbed carbon cycle and processes ([Igu et al., 2023](#)). Equally, the soil in forest ecosystems is relatively less disturbed and exposed than would be the case in the other land use category and so, has a higher tendency to retain and conserve carbon in the soil ([Igu et al., 2023](#)). Anthropogenic activities such as agriculture generally degrade the soil and affect its ability to provide ecosystem services such as carbon storage ([Kopittke et al., 2019](#)). Though plantation agriculture of tree crops (such as palm or cashew) could protect the soil against direct impacts of sunshine and carbon loss, natural forests have higher capacities for such and have more under-canopy covers ([Igu et al., 2023](#)).

However, it is important to note that certain factors may also contribute to lower soil organic carbon content in plantations such as plantation site preparation, climate, soil texture, land use, drainage, vegetation ([European Community, 2009](#)). The reason for the loss of organic carbon in cashew plantation might be due to high bulk density of cashew plantation in the research area. This is consistent with many previous field studies, in which soil bulk density increase leads to soil Carbon and Nitrogen concentrations decrease in plantations relative to natural forests ([Aborisade & Aweto, 1990](#); [Solomon et al., 2002](#); [Nsabimana et al., 2008](#)).

**Table 3.** ANOVA for variations in the soil chemical parameters.

		Sum of Squares	Df	Mean Square	F	Sig.
Loss of Organic Carbon (Percentage %)	Between Groups	460.073	2	230.036	30.610	.000
	Within Groups	67.637	9	7.515		
	Total	527.709	11			
Nitrogen (Percentage %)	Between Groups	32.815	2	16.408	26.762	.000
	Within Groups	5.518	9	.613		
	Total	38.333	11			
Sodium (PPM)	Between Groups	2.897	2	1.448	.821	.470
	Within Groups	15.871	9	1.763		
	Total	18.768	11			
Calcium (PPM)	Between Groups	6.555	2	3.278	1.627	.249
	Within Groups	18.136	9	2.015		
	Total	24.692	11			
Phosphate	Between Groups	1691.101	2	845.550	26.560	.000
	Within Groups	286.522	9	31.836		
	Total	1977.623	11			
PH	Between Groups	23.424	2	11.712	6.057	.022
	Within Groups	17.401	9	1.933		
	Total	40.825	11			
Potassium	Between Groups	59.400	2	29.700	7.920	.010
	Within Groups	33.748	9	3.750		
	Total	93.148	11			

**Table 4.** Multiple comparisons of variations in the soil chemical parameters.

		LSD					95% Confidence Interval	
Dependent Variable	(I) Land use category	(J) Natural forest/ plantation type	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound	
Loss of Organic Carbon (Percentage %)	1. Natural forest	Oil palm	1.777000	1.938451	.383	-2.60808	6.16208	
		Cashew	<b>-12.156000*</b>	<b>1.938451</b>	<b>.000</b>	-16.54108	-7.77092	
	2. Agriculture (Oil palm)	Natural forest	-1.777000	1.938451	.383	-6.16208	2.60808	
		Cashew	<b>-13.933000*</b>	<b>1.938451</b>	<b>.000</b>	-18.31808	-9.54792	
	3. Agriculture (Cashew)	Natural forest	<b>12.156000*</b>	<b>1.938451</b>	<b>.000</b>	7.77092	16.54108	
		Oil palm	13.933000*	1.938451	.000	9.54792	18.31808	

## Continued

Nitrogen (Percentage %)	1. Natural forest	Oil palm	3.815000*	.553669	.000	2.56251	5.06749
		Cashew	<b>3.086500*</b>	<b>.553669</b>	<b>.000</b>	1.83401	4.33899
	2. Agriculture (Oil palm)	Natural forest	<b>-3.815000*</b>	<b>.553669</b>	<b>.000</b>	-5.06749	-2.56251
		Cashew	-.728500	.553669	.221	-1.98099	.52399
	3. Agriculture (Cashew)	Natural forest	<b>-3.086500*</b>	<b>.553669</b>	<b>.000</b>	-4.33899	-1.83401
		Oil palm	.728500	.553669	.221	-.52399	1.98099
Phosphate	1. Natural forest	Oil palm	28.564750*	3.989723	.000	19.53937	37.59013
		Cashew	<b>18.994500*</b>	<b>3.989723</b>	<b>.001</b>	9.96912	28.01988
	2. Agriculture (Oil palm)	Natural forest	-28.564750*	3.989723	.000	-37.59013	-19.53937
		Cashew	<b>-9.570250*</b>	<b>3.989723</b>	<b>.040</b>	-18.59563	-.54487
	3. Agriculture (Cashew)	Natural forest	-18.994500*	3.989723	.001	-28.01988	-9.96912
		Oil palm	<b>9.570250*</b>	<b>3.989723</b>	<b>.040</b>	.54487	18.59563
Ph	1. Natural forest	Oil palm	<b>2.967500*</b>	<b>.983222</b>	<b>.015</b>	.74330	5.19170
		Cashew	.007500	.983222	.994	-2.21670	2.23170
	2. Agriculture (Oil palm)	Natural forest	-2.967500*	.983222	.015	-5.19170	-.74330
		Cashew	<b>-2.960000*</b>	<b>.983222</b>	<b>.015</b>	-5.18420	-.73580
	3. Agriculture (Cashew)	Natural forest	-.007500	.983222	.994	-2.23170	2.21670
		Oil palm	<b>2.960000*</b>	<b>.983222</b>	<b>.015</b>	.73580	5.18420
Potassium	1. Natural forest	Oil palm	.477500	1.369270	.735	-2.62000	3.57500
		Cashew	<b>-4.462750*</b>	<b>1.369270</b>	<b>.010</b>	-7.56025	-1.36525
	2. Agriculture (Oil palm)	Natural forest	-.477500	1.369270	.735	-3.57500	2.62000
		Cashew	<b>-4.940250*</b>	<b>1.369270</b>	<b>.006</b>	-8.03775	-1.84275
	3. Agriculture (Cashew)	Natural forest	<b>4.462750*</b>	<b>1.369270</b>	<b>.010</b>	1.36525	7.56025
		Oil palm	4.940250*	1.369270	.006	1.84275	8.03775

\*. The mean difference is significant at the .05 level.

Another reason for loss of organic carbon in cashew plantation might be due to the soil formation in Etti village Nnaka which is predominantly sandy with thin clay stone and silt stone bands/laminations. The sand is poorly sorted. These units, separated by shale-siltstone-fine sand layers, may be as thick as 30 m in some places. The deposits also exhibit well-developed patterns of alternating cross-bedded sands and layers of dark-grey shales. The shale units generally occur in beds 40 - 50 cm thick alternating with fine sand and siltstone. The units generally have a low dip ranging between 70 and 90 wests (Egboka & Okpoko, 1984). Therefore, the soil types are recognized as hydromorphic ferrallic soils. This shows why

Nanka soil formation appears the most prone to severe erosion gulling and land sliding because it consists of a thick succession of very loose, friable and barely cemented sands (Ofomata, 1975; Egboka & Nwankwo, 1983; Obiadi et al., 2011; Igwe, 2015; Obi & Okekeogbu, 2017). According to European Community (2009), loss of organic carbon also occurs because erosion washes away top soil and humus. Overall, plantation returns less organic matter to the soil than natural forest (European Community, 2009). Fine texture soils tends to have more organic matter than coarse soils because they hold nutrients and water better thus providing good conditions for plant growth (European Community, 2009). Loss of soil organic carbon content can limit the soil's ability to provide nutrient for sustainable plant production. This may lead to lower yield and affect food security. Loss of organic carbon also means less food for the living organisms present in the soil, thus reducing soil biodiversity (European Communities, 2009).

Looking further at the comparisons of the nitrogen and phosphate, the result showed that the nitrogen and phosphate of the natural forest varied more significantly than those of oil palm and cashew plantations. The decrease in plantation soil Nitrogen, Carbon and Phosphate concentrations could be attributable to the differences in ecosystem properties between plantations and natural forests. Plantations had significantly lower net primary production (percentage change  $\pm 95\%$  CI =  $-10.6 \pm 3.1$ , n = 9), aboveground biomass ( $-21.5 \pm 4.1$ , n = 16), litterfall ( $-36.3 \pm 1.8$ , n = 27), aboveground litter mass ( $-29.1 \pm 3.5$ , n = 29) and fine root biomass ( $-75.8 \pm 10.5$ , n = 19) than natural forests (Liao et al., 2010). These differences may result in lower Carbon input into soils under plantations than under natural forests. The decrease in soil Carbon can lead to a reduction of soil Nitrogen due to the tight coupling between ecosystem Carbon and Nitrogen cycles (Luo et al., 2006). Additionally, site preparations involving burning for establishing plantations might also lead to Phosphate and Nitrogen losses in plantation. This shows why nitrogen and phosphate of natural forest is more significant than plantations.

Our results showed that soil pH differ significantly between plantations and natural forests, with natural forest having the highest value (Table 4). It was also shown that the oil palm plantations reduces the pH deposit of natural forest while there is no significant variation between the pH value of natural forest and cashew plantation. This implies that oil palm plantation when introduced to natural forest has the tendency of reducing the soil pH of natural forest. The high increase in soil pH of natural forest is in line with results from previous reviews by Jackson et al. (2005) and Berthrong et al. (2009). They showed that mean soil pH significantly decreased by .3 units below plantations compared with non-forested lands. They also found that soil sodium (Na) concentration was 71% higher below plantations than below non-forested lands. The increase in soil Na concentration might be responsible for the reduction in soil pH. However, the soils from regions with the same climate tend to be more acidic on natural forests than non-forested lands such as grasslands (Chapin et al., 2002; Berthrong et al., 2009). As the strongest

predictor of pH soil, soil Na concentration did not differ between plantations and natural forests in this research (**Table 3**). Therefore, we conclude that other factors might have contributed to the acidity of natural forests. Soil acidity can occur naturally in higher rainfall areas and can vary according to the landscape geology, clay mineralogy, soil texture, buffering capacity ([Plant and Soil Sciences eLibrary, 2024](#)). The study area of the natural forest is characterized by heavy rainfall, which usually start by April and ends around October ([Igwe, 2018](#)). Soil acidity can also occur by the removal of plant and animal products, leaching of excess nitrate, addition of some nitrogen based fertilizers, build-up in mostly plant-based organic matter ([Plant and Soil Sciences eLibrary, 2024](#)). Animal grazing in the research area could be associated with the loss of vegetation cover, which causes soil degradation and leaching. Soil acidity is a potentially serious land degradation issue. When soil becomes too acidic it can: decrease the availability of essential nutrients, increase the impact of toxic elements, decrease plant production and water use, affect essential soil biological functions like nitrogen fixation and make soil more vulnerable to soil structure decline and erosion ([Plant and Soil Sciences eLibrary, 2024](#)). Without treatment, soil acidification can impact agricultural productivity and sustainable farming systems. Acidification can also extend into subsoil layers, posing serious problems for plant root development ([Plant and Soil Sciences eLibrary, 2024](#)).

Potassium is essential for plant growth because it plays a crucial role in absorption, stomatal movement, enzyme activation and protein synthesis ([Li et al., 2023](#)). Plant growth is inseparable from nutrient elements in nature because plants commonly experience stress from the lack of many of these nutrient elements especially potassium ([Li et al., 2023](#)). The potassium concentration of the cashew plantation varied more significantly among others in this research (**Table 3** and **Table 4**). This is in contrast with review from [Tellen and Yerima \(2018\)](#), where potassium concentration did not significantly vary among the land use types (natural forest, farmland and plantation) although soils from natural forest had the highest potassium concentrations (4.00 cmol (+)/kg soil) at ( $p < .01$ ) followed by farmland (2.94 cmol (+)/kg soil) while those under plantation had the lowest concentrations (1.05 cmol (+)/kg soil). This variation from the two studies showed that land use change alone cannot determine the potassium concentration present in the soil. Other factors such as ecosystem differences will also have to be put into consideration. However, an increase in the potassium concentration of cashew plantation in this research may be due to the observed frequent application of household wastes, particularly wood ash. This is consistent with the findings of [Bohn et al. \(2001\)](#).

Furthermore, the result showed that there were no significant variations in sodium (.470), calcium (.249) and magnesium (.713) (**Table 3** and **Table 4**) of the natural forest and plantations. This affirms the findings of [Tellen and Yerima \(2018\)](#). Magnesium and calcium are among the secondary nutrients required by plants for normal and healthy growth, that is, all plants need calcium and

magnesium rich soil to grow. Calcium is a non-leaching mineral that helps improve water penetrability and reduce soil salinity. It is used by the plant to develop cell walls and membranes (Tellen & Yerima, 2018). This insignificant variation in the calcium of soil of natural forest and plantations indicates the reason for the insignificant sodium concentration in natural forest and plantations because calcium reduces soil salinity. That is, the higher the calcium the lower the sodium and vice versa.

From the above discussions this research was able to establish the variations in the chemical parameters of natural forest and plantations and the possible reasons for such variations.

## 5. Conclusion

Soil quality as assessed in this research is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plants and animal. It also refers to the physical, chemical and biological properties of soil. The numerous physicochemical parameters of soil in this research including; moisture content, soil bulk density, particle density, soil pH, phosphate, potassium, sodium, carbon, magnesium, calcium and nitrogen concentrations, were all important indicators of soil quality because changes in these characteristics had significant effects on plant growth. From the study, it is believed that natural forests are important for preserving or enhancing soil quality. However, with the reality of land use change emanating from population pressure and need to provide nutrition, energy and sustenance for a vast majority, ecosystems are being altered significantly through agricultural and non-agricultural (building of residential areas, industrialization, cutting of plants for wood purposes, etc) practices. Moreover, this research also observed that the variation in soil physicochemical parameters are not only determined by land use change as various factors such as climate change, geology and soil settings, vegetation also affect soil quality.

Furthermore, some limitations were met during the period of this study. One of the limitations was the paucity of fund. The study could have cut across so many towns and villages within Orumba North Local Government Area, but doing that would have demanded a whole lot of fund which the researchers did not have. More so, at the locations studied, more variables would have been studied for further comparisons and comprehension, but the researchers had a limit of what they could fund.

While this study has given a comprehensive assessment of the variations in soil physicochemical parameters of the natural forest and plantations, it is important that suggestions are directed for future research on sustainable plantation agriculture, land use type, soil physicochemical parameters involving topography, microclimate, past land management practices, specific crop varieties, and research involving plantations and cation exchange capacity, base saturation, aluminum toxicity, amongst others.

## 6. Recommendations

From the findings of this research study and the need to improve soil quality, it is recommended that:

1) There is a need to adopt a sustainable plantation agricultural system by using diverse nutrient sources (manure and compost) that adds organic matter as well as an array of nutrients that can maintain soil health. Adding new organic matter every year is perhaps the most important way to improve and maintain soil quality, because regular addition of organic matter improves soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction and support a healthy community of soil organisms.

2) Another method of maintaining soil quality is by nutrient cycling through which nutrients are added to, removed from and changed within the soil. However, a careful balance between simplicity of use and clarity and efficiency of the selected sustainability system is required.

3) Since the major cause of higher bulk density and pH is attributed soil settings and Nanka soil having high sandy siltstones, it is recommended that Nanka soils be aerated because the presence of oxygen results in a more rapid decay of organic matter thus boosting the soil organic carbon content

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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