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Original Research

Assessment of Soil Quality in Soils of Contrasting Geological Formations in Anambra State, Nigeria

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Abstract

Soil quality deterioration is one of the major limitations of agricultural production in Anambra State. This study assessed soil characteristics and quality across four geological formations: Ameki (AM), Alluvial Plain (AP), Ogwashi-Asaba (OA), and Imo Shale (IS). Soil samples were collected in triplicate from each geology at three depths (0-30, 30-60 and 60-90 cm), giving a total of 72 samples (36 core and 36 bulk). Standard laboratory methods were used for soil analyses, while data were subjected to analysis of variance. Soil texture varied from Sandy loam (AP) to loamy sand (AM and OA) and clay loam (IS). The trend in soil quality indicators was AP>IS>AM >OA, whereas the soil quality index ranged from 28 to 39%, with AP falling into moderate class while others qualified as low class. The major limitations to soil quality in most of the geological formations were low C, N, av. P, K^+, soil respiration, and high bulk density. Hence, this study show that geological formation influenced soil characteristics, and is one of the major determinants of soil quality.

1. Introduction

Soil quality is the soil's capacity to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation (Diack and Stott, 2001). It is related to soil function because of its role as an ecosystem service provider (Drobnik *et al.*, 2018). Soil quality is a prerequisite for better planning and utilization of land resources (Amalu and Isong 2017; Kalambukattu *et al.*, 2018). A decline in soil quality interrupts primary soil functions and may hamper crop production and food security (Isong *et al.*, 2022). Determining the soil quality of land is very important as it plays a major role in land resource management (Zhang *et al.*, 2022). Soil quality does not depend on a single factor but the integration of physical, chemical, and biological factors for its quantification through soil quality index (Shekhovtseva and Mal'tseva, 2015). The SOC is one of the major determinants and indicators of soil quality, fertility and is closely related to soil productivity in an ecosystem. It plays an important role in controlling soil quality and resilience through affecting buffering capacity, microbial biodiversity, water retention, and structural stabilization (Balashov and Buchkina, 2011; Kadlec *et al.*, 2012; Gaida *et al.*, 2013). The SOC is not only a significant contributor to food production, but also helps in moderation and adaptation to changing climatic patterns, thus favoring the attainment of sustainable development goals (Sharma *et al.*, 2023).

Geological materials (which give rise to parent materials of the soils) are one of the factors that have the greatest impact on soil formation and development, and are mainly responsible for the nature, composition and behaviour of the soil (Javadi *et al.*, 2020). Geological materials not only affect soil properties and processes within the soil but its quality (Legaz *et al.*, 2017). Assessing and developing soil quality classes can minimize agricultural management costs and input wastage (Isong *et al.*, 2022). It could increase nutrient use efficiency in commercial farms and decrease the risk of nutrient pollution. Hence, it is necessary to know more accurately the quality of soils in relation to their geological materials. Therefore, this study aims to assess soil quality in soils of contrasting geological formations in Anambra State, Nigeria.

2. Materials and Methods

2.1 Site description

Anambra State lies within latitudes 5° 40′ N and 6° 45′ N and longitudes 6° 35′ E and 7° 21′ E with Delta State to the West, Imo State to the South, Enugu State to the East and Kogi State

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to the North as its boundaries (Fig 1). It is characterized by two seasonal climatic conditions: rainy and dry seasons with most rain falling during the rainy season from March to October with its peaks in July and September; and a short break in either July ending or August known as August break. The dry season extends from November to February with harmattan occurring between the months of December and January.

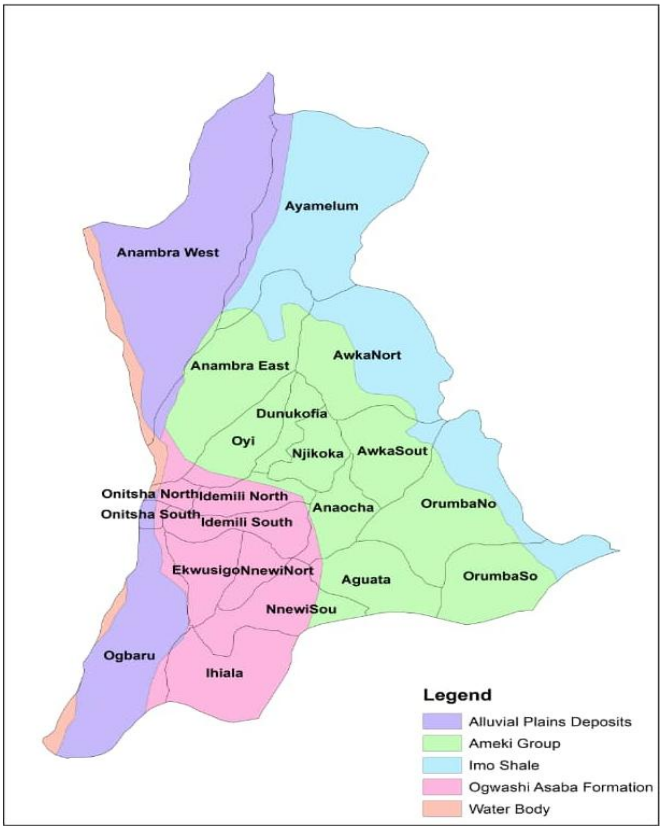


Figure 1. Geological Map of Anambra State
Source: Soil Survey Unit, Department of soil Science, University of Nigeria, Nsukka (2025)

The mean annual rainfall is 2804.55 mm concentrated mainly in eight months of the year (NIMET, 2024). It has an average temperature of 27 °C with mean annual minimum and maximum temperatures in ranges of 22 to 24 °C and 26 to 29 °C respectively (NIMET, 2024). The relative humidity ranges from 75 to 95% (NIMET, 2024). Anambra State falls within the Anambra basin which has about 12,000 m of sedimentary rocks (Akinyemi *et al.*, 2013). It comprises ancient Crateceous Delta, somewhat similar to the Niger Delta, with Nkporo Shale, the Mamu Formations, the Ajali Sandstone, the Nsukka Formations, Ogwashi-Asaba Formation, Imo Formations and Ameki group as the main deposits with outcrops of sandstone occurring at Abagana, Nsugbe and Nanka (Ezeigwe, 2015). These formations gave rise to ferrallitic, hydromorphic and alluvial soils. The native vegetation was originally rainforest characterized by very tall, big trees with thick undergrowth and numerous climbers (Ezeigwe, 2015). However, as a result of human interferences, the vegetation now consists of intermixture of arable crop farms, tree crops and bush regrowth. Agriculture, hunting and cottage industries are predominant means of livelihood in the area (Orji-Uzor and Obasi, 2012). The major plant species in the area include: Oil palm (*Elaeis guineensis*), Cassava (*Manihot* spp), Ogbono (*Irvingia gabonensis*), Maize (*Zea mays)*, Cocoyam (*Colocasia esculentus*), Rice (*Oryzea sativa*), Yam (*Discorea* spp), Mango (*Magnifera indica*), Plantain (*Musa* spp) (Chikere-Njoku, 2015).

2.2 Field studies

Guided by the geological map of Anambra State (Fig 2.), soil samples were collected in triplicate from a cultivate land (under mixed cropping for about 10 years) of four geological formations: Ameki (Abagana, Njikoka), Alluvial Plain (Attani, Ogbaru), Ogwashi-Asaba (Umeze, Ihiala) and Imo Shale (Ifite Ogwari, Anyamelum) at three depths: 0-30, 30-60 and 60-90 cm. A total of 72 samples (36 bulk and 36 core samples) were collected. The soil samples were bagged into different components in polyethylene bags and properly labelled for onward transportation to the laboratories for analyses using standard procedures. (Note: soil sampling was done during rainy season between May 20 and 25th, 2025).

2.3 Laboratory analysis

The soil samples collected, were air-dried (except those for microbial analysis), gently crushed and later sieved with a 2 mm sieve. Particle size distribution was determined using the Bouyoucos hydrometer method (Gee and Or, 2002), with 0.1N NaOH as dispersant. Soil bulk density was determined by core method (Blake and Hartage, 1986). The soil pH was determined using a glass electrode pH meter in water at a soil-liquid ratio of 1:2.5 (McLean, 1982). The SOC content was determined by the wet dichromate acid oxidation method (Nelson and Sommers, 1982). Total nitrogen was determined using the Kjeldahl method (Bremner, 1996). Available P was determined using Bray II method (Bray and Kurtz, 1945). Exchangeable Ca^{2+}, Mg^{2+} and K^{+} were leached from the soil sample using NH_4OAc (pH 7.0) buffer. The K^{+} were measured with a flame photometer (Rhoades, 1982) while Ca^{2+} and Mg^{2+} were determined using Atomic Absorption Spectrophotometer (Thomas, 1982). Soil microbial biomass carbon and nitrogen were determined using chloroform-fumigation-extraction method after incubation for three days at 25 °C as described by Anderson and Ingram (1993).

Microbial biomass C = (Extracted C_{t1} – Extracted C_{t0}) x 2.64 (Vance *et al.*, 1988). (1)

Microbial biomass N was determined by analyzing total N in the extract after digestion.

Microbial biomass N = (Extracted N_{t1} - Extracted N_{t0}) x 1.46 (Brookes *et al.*, 1985). (2)

Soil respiration was evaluated in the laboratory closed chambers by CO_2 concentrations in an alkaline solution saved in a plastic container during the incubation process for 10 days at 25 °C as described by Anderson and Domsch (1989).

2.4 Soil quality assessment

Tropical Soil Quality Index by Arifin *et al.* (2012) was used to determine soil. The minimum data set of indicators for assessing soil quality and the rationale for the assessment were presented in Table 1. The method used a scoring of 0-2, where soil properties with sufficient amounts receive a higher score (2 or 1), while those with low amounts receive zero (0) (Table 2). The soil quality index was ranked using Li *et al.* (2018) soil quality classes. According to Li *et al.* (2018), "Grade I (80-100%) is described as having a very high value, which is the most suitable for crop growth; Grade II (60-79%) showed a high

Table 1. Minimum data set of indicators for assessing soil quality

Indicators	Rational for assessment
Biological	
Microbial biomass C and N	Describe microbial catalytic potential for C and N. Provides an early warning of management effects on organic matter
Soil respiration	Defines a level of microbial activity. Provides an estimate of biomass activity
Chemical	
Soil organic matter	As a proxy for soil fertility and nutrient availability
pH	Biological and chemical activity threshold
Extractable Ca and Mg	Describes plant available nutrients and potential for Ca and Mg loss
Extractable N, P and K	Describes plant available nutrients and potential for N loss. Indicates productivity and environmental quality.
Physical	
Soil bulk density	Describes the potential for leaching, productivity and erosion. Bulk density is used to correct soil analysis to a volumetric basis

Sources: Doran *et al.* (1996); Larson and Pierce (1994)
C= Carbon; N=Nitrogen, Ca= Calcium, Mg= Magnesium; K=Potassium, P=Phosphorus

Table 2. Selected soil properties for tropical soil quality index

SN	Parameters	Level	Interpretations	Index
1	BD (Mg m^{-3})	>1.5	Possible adverse effect	0
		≤1.5	Adverse effect unlikely	1
2	Soil pH	3.01-4.0	Strongly acid-only the most acid tolerant crop can grow	0
		4.01-5.5	Moderate acid- growth of acid tolerant crop is affected	1
		5.51-7.2	Slightly acid to near neutral-optimum or many plant species	2
		7.21-8.5	Slightly to moderately alkaline-optimum expect for those prefer acid soils	1
		>8.5	Strongly alkaline-preferred by plants adapted to this pH range	0
3	Total carbon (g kg^{-1})	>5	High excellent buildup of organic C with all associated benefit	2
		1-5	Moderate adequate level	1
		<1	Low-could indicate a possible loss of C	0
		>0.5	High excellent reserve of N	2
4	Total nitrogen (g kg^{-1})	0.1-5	Moderate-adequate level	1
		<0.1	Low-could indicate a possible loss of N	0
5	K^+ (cmol kg^{-1})	>1.28	High-excellent reserve	2
		0.26-1.28	Moderate-adequate levels for plans	1
		<0.26	Low-possible deficiencies	0
6	Mg^{2+} (cmol kg^{-1})	>4.17	High-excellent reserve	2
		0.42-4.17	Moderate-adequate levels for plans	1
		<0.42	Low-possible deficiencies	0
7	Ca^{2+} (cmol kg^{-1})	>5	High-excellent reserve, probably calcareous plant	2
		0.51-5.00	Moderate-adequate levels for plans	1
		0.05-0.50	Low-possible deficiencies	0
		<0.05	Very low-severe ca depletion, adverse effect unlikely	-
8	Available P (mg kg^{-1})	>30	High-excellent reserve of P in slightly acidic/alkaline soils	2
		15-30	Moderate-adequate levels for plant growth	1
		<15	Low- deficiencies likely	0
9	*MBC (mg C kg^{-1})	>110	High excellent reserve for active nutrient cycling	1
		<110	Low-possible deficiencies	0
10	*MBN (mg N kg^{-1})	>13	High excellent reserve for active nutrient cycling	1
		<13	Low-possible deficiencies	0
11	*SR (mg CO_2 kg^{-1})	>90	High excellent reserve for active microbial activities	1
			Low-possible deficiencies	0
		<90		

Source: Arifin *et al.* (2012); *Lopes *et al.* (2013)
Note: MBC= Microbial Biomass Carbon, MBN= Microbial Biomass Nitrogen, SR= Soil Respiration, BD= Bulk Density, Ca= Calcium, K= Potassium, P= Phosphorus, Mg=Magnesium

value and is suitable for crop growth; Grade III (35-59%) had a moderate value and had some limitation; Grade IV (20-34%) showed a low value and had more limitations than Grade III; grade V (0-19%) was characterized as having a very low value and the most severe limitations".

2.5 Statistical analysis

Data collected were also subjected to a two-way analysis of variation to analyse variation in soil quality indicators across the geological formations and between the depths. The Fisher's Least Significant Differences (F-LSD) was used for mean separation at 95% confidence level.

3. Results and Discussion

3.1 Main effect of geological formation on soil particle size distribution

The results of the particle size distribution across the geological formations are presented in Table 3. The textural classes varied from Sandy loam (Alluvial Plain) to loamy sand (Ameki and Ogwashi-Asaba) and clay loam (Imo Shale). Imo Shale recorded the highest clay and Silt fractions (350 and 260 g kg^{-1} respectively), which is indicative of soils developed from fine-textured formations; and suggests reduced permeability and potentially higher nutrient retention capacity (Nnaji *et al.*, 2023). The highest value of fine sand (570 g kg^{-1}) and coarse sand fractions (400 g kg^{-1}) in Ogwashi-Asaba and Ameki soils, respectively reflects the arenaceous nature of the parent materials (Ugwuoju *et al.*, 2026). The variations of textural classes could be attributed to the nature of their parent materials, similar to the findings of Umeugokwe *et al.* (2023).

Table 3. Main effect of geological formation on soil particle size distribution

Geological Formation	Clay	Silt	Fine Sand	Coarse Sand	Texture
	(g kg^{-1})				
Alluvial Plain	180	170	280	370	Sandy loam
Ameki	130	50	250	570	Loamy sand
Imo Shale	350	260	140	250	Clay loam
Ogwashi-Asaba	120	60	400	420	Loamy sand
F-LSD (0.05)	3.12	1.97	2.61	3.82	

F-LSD (0.05) = Fisher's least significant difference at 5% probability level

3.2 Effect of geological formation and soil depth on selected soil quality indicators

Generally, the soils were slightly acidic in soil reaction and may be attributed to high intensity rainfall in the area that leaches the basic cations (Igwe *et al.*, 1999) in addition to the acidic nature of the parent materials. The soil pH was highest (5.51) and lowest (4.98) pH values at Alluvial Plain and Ameki formation respectively, and this might be attributed to the inherent factors like climatic conditions, mineral content and soil texture (Table 4). Zhang *et al.* (2019) reported that mineral composition of parent material influences the pH value of soils.

The value of C (0.97 g kg^{-1}) was found to be highest on Alluvial Plain and lowest (0.11 g kg^{-1}) on Ogwashi-Asaba formation due to higher organic material in the Alluvial Plain soils and also suggests that the soils are not flooded. This finding contradicts with Rahayu *et al.* (2023) as they found low SOC content in soils of alluvial formation and linked it to frequent flooding in the area. Saint-Laurent *et al.* (2016) also found that alluvial areas that are often flooded have lower SOC content than areas that are not flooded. Alluvial Plain soils also had the highest value of N (0.16 g kg^{-1}) implying that the soils are not prone to runoff. Conversely, Verrina *et al.* (2013) and Wang *et al.* (2015) found low N in alluvial formation due to runoff. The highest (2.16 cmol kg^{-1}) and lowest (1.43 cmol kg^{-1}) values of Ca^{2+} were obtained in Alluvial Plain and Ogwashi-Asaba respectively (Table 4). This suggests that soils developed over depositional or mixed parent materials tend to retain more basic cations and exhibit better nutrient-holding capacity (Ugwuoju *et al.*, 2026).

The highest value of available P (3.42 mg kg^{-1}) was observed on Ameki formation while the lowest (2.48 mg kg^{-1}) was on Imo Shale formation (Table 10). The lower value of available P in soils on Ameki formation could be linked to the strong acidity and the presence of high Fe and Al oxides, which promote phosphorus immobilization (Scherwietes *et al.*, 2024). Soils on Imo Shale had the highest value of K^+ (0.07 cmol kg^{-1}) while the lowest (0.04 cmol kg^{-1}) was found on Alluvial Plain. According to Portela *et al.* (2019), soils with high K content are found in soils whose parent materials are carbonate rock, gabbro, gabbro-diorite, and quartz-diorite. This could explain the relative high K^+ on Imo Shale formation. The values of soil respiration, biomass carbon and nitrogen were highest in Alluvial Plain (19.31 mg CO_2 kg^{-1}, 227.89 mg C kg^{-1} and 52.89 mg N kg^{-1} respectively) and lowest in Imo Shale (14.91 mg CO_2 C kg^{-1}, 186.11 mg C kg^{-1} and 38.78 mg N kg^{-1} respectively) owing to higher organic carbon content of the soil. Higher soil respiration have also been observed in soils with more organic carbon by Baldock (2007) and Schmidt *et al.* (2012). Conversely, Rahayu *et al.* (2023) opined that Alluvial formation have relatively low microbial biomass carbon due to low SOC caused by flooding.

The values of C, Av. P and Mg^{2+} decreased with soil depth (Table 4). This might be attributed to decrease in organic material and fauna activities with depth. Similar observations were made by Nuga *et al.* (2006) and they attributed the process to the decrease in organic materials with depth. Lawal *et al.* (2013) also observed a decrease in C with increasing soil depth and linked it to reduction in faunal activities with depth.

Table 4. Main effect of geological formation and soil depth on selected soil quality indicators

Geological Formation	pH (H_20)	pH (KCl)	C	N	P	K^{+}	Ca^{2+}	Mg^{2+}	BD	SR	MBC	MBN
			g kg^{-1}		mg kg^{-1}	cmol kg^{-1}			Mg m^{-3}	mg CO_2 kg^{-1}	mg C kg^{-1}	mg N kg^{-1}
Alluvial Plain	5.51	4.26	0.97	0.16	2.59	0.04	2.16	1.93	1.52	19.31	227.89	52.89
Ameki	4.98	4.52	0.48	0.11	3.42	0.06	2.02	1.84	1.52	15.68	192.67	39.89
Imo Shale	5.14	4.39	0.79	0.09	2.48	0.07	1.78	1.72	1.52	14.91	186.11	38.78
Ogwashi-Asaba	5.01	4.22	0.23	0.02	2.59	0.05	1.43	1.80	1.59	15.38	192.44	39.33
F-LSD (0.05)	0.41	Ns	0.30	0.09	0.72	0.02	0.53	Ns	Ns	1.75	16.40	7.11
Soil Depth												
0-30 cm	5.38	4.43	0.89	0.13	3.49	0.07	2.07	2.12	1.48	20.00	229.33	53.33
30-60 cm	5.40	4.40	0.50	0.10	2.50	0.10	1.90	1.80	1.50	16.40	201.40	43.10
60-90 cm	5.08	4.23	0.46	0.08	2.34	0.04	1.57	1.53	1.59	12.60	168.58	31.75
F-LSD (0.05)	Ns	Ns	0.26	Ns	0.62	0.02	Ns	0.37	0.06	1.51	14.20	6.16

Note: MBC= microbial biomass carbon, MBN= microbial biomass nitrogen, SR= soil respiration, C= carbon, N= nitrogen, K= potassium, BD= bulk density, Ca= calcium, Mg= magnesium, P= Available phosphorus, NS= not significant; F-LSD (0.05) = Fisher's least significant difference at 5% probability level

The values of bulk density had an increasing trend with depth. This could be attributed to reduction in organic materials and tillage activities with soil depth. The value of K^{+} was highest at 30-60 cm depth (0.10 cmol kg^{-1}) and lowest at 60-90 cm depth (0.04 cmol kg^{-1}). The values of soil respiration, biomass carbon and nitrogen had a decreasing trend with increasing soil depth owing to the reduction in organic materials with increasing soil depth. The interaction of geological formation and soil depth on selected soil quality indicators were not significant for all soil quality indicators at P >0.05 (Table 5).

3.3 Soil quality assessment

Table 6 show that the ideal score was 18 which is 100% quality index. Soils of Alluvial Plain ranked highest in soil quality index (39%) followed by soils of Ameki (33% quality index) and lowest on soils of Imo Shale and Ogwashi-Asaba (28% quality index). The soil quality index of all the geological formations was classified as low except that of Alluvial Plain which qualified as moderate value (Li *et al.*, 2018) owing to higher carbon content of the soils. Isong *et al.* (2022) observed poorer soil quality in soils developed on shale, basalt, and limestone parent materials and richer in soils developed on basement complex and sandstone parent materials. Isong *et al.* (2022) attributed the low soil quality to low percentage of SOC, low soil structural stability and a high bulk density, as well as intensive mismanagement practices in the area. Conversely, Rahayu *et al.* (2023) observed same soil quality across all geological formation studied and conclude that geological formation is not the dominant factor in determining soil quality but management.

Table 5. Interaction effect of geological formation and soil depth on selected soil quality indicators

Geological Formation	Depth Cm	pH (H_20)	pH (KCl)	C	N	P	K^{+}	Ca^{2+}	Mg^{2+}	BD	SR	MBC	MBN
				g kg^{-1}		mg kg^{-1}	cmol kg^{-1}			Mg m^{-3}	mg CO_2 kg^{-1}	mg C kg^{-1}	mg N kg^{-1}
Alluvial Plain	0-30	5.10	4.20	1.20	0.14	3.42	0.05	2.49	2.49	1.44	23.75	268.00	66.33
	30-60	5.00	4.30	0.90	0.10	2.20	0.01	2.20	1.70	1.50	19.60	229.70	55.00
	60-90	4.83	4.23	0.79	0.09	2.18	0.03	1.85	1.59	1.60	14.59	186.00	37.33
Ameki	0-30	5.53	4.67	0.93	0.30	4.35	0.08	2.67	1.73	1.47	20.00	224.67	50.00
	30-60	5.67	4.50	0.13	0.07	3.11	0.06	2.13	2.00	1.53	15.90	194.67	41.33
	60-90	5.33	4.40	0.39	0.12	2.80	0.05	1.27	1.80	1.57	11.14	158.67	20.33
Imo shale	0-30	5.60	4.57	1.29	0.07	3.40	0.09	1.53	2.07	1.43	18.89	218.00	50.00
	30-60	5.67	4.43	0.68	0.11	2.18	0.07	1.87	1.70	1.53	14.67	186.33	38.33
	60-90	5.27	4.17	0.40	0.08	1.87	0.04	1.93	1.40	1.59	11.16	154.00	28.00
Ogwashi-Asaba	0-30	5.30	4.30	0.13	0.02	2.80	0.06	1.59	2.20	1.57	17.36	206.67	47.00
	30-60	5.23	4.27	0.30	0.03	2.49	0.05	1.46	1.85	1.61	15.28	195.00	37.67
	60-90	4.90	4.10	0.26	0.02	2.49	0.04	1.24	1.35	1.58	13.49	175.67	33.33
F-LSD (0.05)		Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Note: MBC= microbial biomass carbon, MBN= microbial biomass nitrogen, SR=microbial respiration, C= carbon, N= nitrogen, K= potassium, BD= bulk density, Ca=calcium, Mg= magnesium, P= Available phosphorus, NS= not significant; F-LSD (0.05) = Fisher's least significant difference at 5% probability level

Table 6: Soil quality assessment across the geological formations

SQI	IV	SC	AP	SC	AM	SC	1S	SC	OA	SC
BD Mg m^{-3}	<1.50	1	1.52	0	1.52	0	1.52	0	1.59	0
pH (H_20)	5.51-7.20	2	5.51	2	4.98	1	5.14	1	5.01	1
Carbon (g kg^{-1})	>5	2	0.97	0	0.48	0	0.79	0	0.23	0
Nitrogen (g kg^{-1})	>0.5	2	0.11	1	0.16	1	0.09	0	0.02	0
K^+ (cmol kg^{-1})	>1.28	2	0.04	0	0.06	0	0.07	0	0.05	0
Mg^{2+} (cmol kg^{-1})	>4.17	2	1.93	1	1.84	1	1.72	1	1.80	1
Ca^{2+} (cmol kg^{-1})	>5	2	2.16	1	2.02	1	1.78	1	1.43	1
Av. P (mg kg^{-1})	>30	2	2.59	0	3.42	0	2.48	0	2.59	0
MBC (mg C kg^{-1})	>110	1	227.89	1	192.67	1	186.11	1	192.44	1
MBN (mg N kg^{-1})	>13	1	52.89	1	39.89	1	38.78	1	39.33	1
SR (mg CO_2 hr^{-1})	>90	1	19.31	0	15.68	0	14.91	0	15.38	0
Total		18		7		6		5		5
Percentage (%)		100		39		33		28		28

Notes: SQI= soil quality indicator; IV=ideal value, AP= Alluvial Plain, AM= Ameki formation, SC= scores; IS: = Imo Shale, OA=Ogwashi-Asaba, MBC: microbial biomass carbon, MBN: microbial biomass nitrogen, SR: microbial respiration, C: carbon, N: nitrogen, K: exchangeable potassium, BD: bulk density

The major limitations to soil quality in most of the geological formations were low C, N, av. P, K^+, soil respiration, and high bulk density. The SOC is important in soil because of its relationship to other properties and lack of SOC in the soil reduces soil productivity (Wiesmeier *et al.*, 2016). The SOC influences almost all soil properties and nutrient cycles (Rice *et al.*, 2021). Nitrogen is important because nitrogen is needed for the growth of plant and soil microbes as well as soil productivity (Simfukwe *et al.*, 2021) which deficit affects plant productivity, soil properties and plant physiology (Sun *et al.*, 2020). Bulk density also determines soil quality and soil fertility (Xu *et al.*, 2016) and is very important because of its ability to determine soil structure, transport of water and dissolved nutrients, and air flow in the soil (Meng *et al.*, 2023).

The low soil respiration reduced soil productivity by limiting microbial activities e.g. decomposition and mineralization of organic materials (Lopes *et al.*, 2013). The high bulk density tend to reduce soil aeration, infiltration, percolation and root proliferation (Brady and Weil, 2014).

4.0 Conclusions

Geological formation influenced soil quality indicators such as pH, C, N, av. P, K^+, soil respiration, microbial biomass C and N. The soil quality index for the various formations were in the range of 28 to 39% with soils on Alluvial Plain falling into moderate class while others qualified as low class. Therefore, soil management approaches such as liming, cover cropping, mulching, crop rotation, organic and inorganic fertilization, integrated nutrient management, agroforestry etc. are recommended for soils developed on Ameki, Imo Shale, and Ogwashi-Asaba for improvement in the soil quality.

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