

Hydrological, Chemophysical and Environmental Quality Index of Epipedon Coastal Soils in Bayelsa State

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Abstract: This study evaluated the hydrological, chemo physical, and environmental quality index (EQI) of epipedon coastal soils in Bayelsa State. The objective was to characterize soil physical and chemical properties, assess hydrological behavior, and determine overall soil quality using an integrated index approach. Field sampling was conducted across two Local Government Areas namely Southern Ijaw and Ogbia where thirty (30) soil samples (15 each) were collected at 0–20 cm depth and analyzed using standard laboratory procedures. Environmental quality index was computed using a weighted additive model. Results revealed that soils were predominantly sandy, with a grand mean sand content of 640.60 g kg⁻¹, indicating high permeability but low water and nutrient retention capacity. Bulk density ranged from 1.32 to 1.69 Mg m⁻³, while total porosity averaged 43.68%, suggesting moderate structural conditions. Soil pH ranged from 4.60 to 5.53, indicating strongly to moderately acidic soils. Soil organic matter (19.5 g kg⁻¹) and total nitrogen (1.70 g kg⁻¹) were moderate, whereas available phosphorus (7.20 mg kg⁻¹) was generally low. Hydraulic conductivity varied widely from 2.88 mm h⁻¹ in Otuokpoti (Ogbia) to 73.48 mm h⁻¹ in Otuoba (Ogbia), influencing infiltration and runoff dynamics. Soils in Southern Ijaw generally exhibited moderate permeability, while Ogbia showed wider variability. EQI values ranged from 0.240 in Otuoba to 0.654 in Ogbogoro (Southern Ijaw), indicating spatial variability in soil quality. Higher EQI values were associated with improved organic matter and nutrient status. The study highlights the interactions among hydrological, chemo physical, and chemical properties in coastal soils and underscores the need for integrated soil management. The EQI approach provides a reliable framework for evaluating soil quality and supporting sustainable land-use planning in coastal agroecosystems.

Keywords: Hydrological properties, Chemo physical properties, Environmental Quality Index, Soil degradation, Niger Delta, Coastal Soil, Infiltration, Sustainable agriculture, erosion risk, soil variability.

Introduction

In the humid tropics, particularly within the Niger Delta, soils are predominantly derived from recent coastal plain deposits and are characterized by shallow epipedons, high sand content, and fluctuating water regimes. These attributes strongly influence the hydro-chemo-physical behavior of the soils, with direct implications for soil quality, fertility, structural stability, ecological resilience, and land-use sustainability.

Hydrological properties especially infiltration, hydraulic conductivity, and water retention are fundamental in determining the movement and storage of water within the soil profile. These processes control plant water availability and regulate the transport of nutrients and contaminants (Olorunfemi & Ogunwale, 2021). In coarse-textured soils, rapid drainage and high permeability often lead to low water-holding capacity and increased nutrient leaching. Blanchy et al (2023), and Jarvis et al. (2013), emphasized that soil hydraulic behavior is largely governed by pore size distribution, structure, and organic matter content, which together regulate the partitioning of rainfall into infiltration and runoff.

Closely linked to hydrological behavior are chemophysical properties such as pH, organic carbon, total nitrogen, texture, and bulk density (Abowei et al., 2023). These properties determine the structural framework of soils and influence both water movement and root development. Coastal soils in southern Nigeria are typically sandy, promoting high infiltration but limiting nutrient retention due to low specific surface area and weak aggregation. However, the presence of finer particles and organic matter can enhance aggregation and increase microporosity (Alaoui, 2023; Batista et al., 2024). Additionally, these soils are often acidic due to intense leaching under high rainfall, resulting in the depletion of basic cations and reduced cation exchange capacity. This chemical limitation, combined with high permeability, contributes to poor nutrient availability and reduced agricultural productivity. High hydraulic conductivity may further accelerate nutrient losses and increase the risk of groundwater contamination (Xiao et al., 2025; Usowicz and Lepiec, 2025).

To comprehensively evaluate soil quality, integrated indices such as the Environmental Quality Index (EQI) have been widely adopted. The EQI combines multiple soil indicators into a single metric, facilitating comparison across locations and management systems. In heterogeneous and environmentally sensitive soils, such integrative approaches are particularly valuable. Bargués-Tobella et al. (2024) demonstrated that soil quality indices effectively capture the combined influence of physical, chemical, and hydrological properties, providing a robust tool for sustainable land management.

Despite the ecological and agricultural importance of coastal soils, there is limited information on the interactions among hydrological, chemophysical of epipedon soils in the study area. Most existing studies focus on individual attributes without adequately addressing their combined effects on soil quality and environmental sustainability. This

gap necessitates a comprehensive evaluation using both conventional measurements and integrated indices.

Therefore, this study aims to assess the hydrological, chemophysical, and environmental quality index of epipedon coastal soils in Bayelsa State. Specifically, it seeks to (i) characterize the physical and chemical properties of the soils, (ii) evaluate their hydrological behavior, and (iii) determine overall soil quality using an environmental quality index approach. The findings are expected to provide a scientific basis for improved soil management and enhanced agricultural productivity in coastal environments.

3.0 Materials and Methods

3.1 Study Area

The study was conducted in two Local Government Areas (LGAs) in Bayelsa State, namely Southern Ijaw and Ogbia. Southern Ijaw is located at latitude 4.4693° N and longitude 6.0704° E, while Ogbia lies at latitude 4.6251° N and longitude 6.3176° E. The area is underlain by unconsolidated Quaternary coastal plain sands deposited by the Niger River and its distributaries. These deposits consist of varying proportions of sand, silt, clay, and organic-rich peat materials. The landscape is characterized by low-lying terrain, freshwater swamp forests, meandering river channels, and seasonally inundated floodplains. The dominant parent material is clay shale, typical of wetland geological environments (Reyment, 1965).

The climate of the study area falls within the tropical monsoon zone, with high humidity and a bimodal rainfall pattern. Rainfall occurs mainly between April–July and September–November, with annual totals exceeding 2,500 mm. Mean daily temperatures range from 25°C to 32°C , creating favorable conditions for luxuriant vegetation and continuous agricultural activity (NIMET, 2023).

The inhabitants of the study area are predominantly engaged in subsistence agriculture and fishing. Major crops cultivated include cassava (*Manihotesculenta*), rice (*Oryza sativa*), yam (*Dioscorea spp.*), sugarcane (*Saccharumofficinarum*), and plantain (*Musa spp.*).

3.2 Pre-field Survey and Soil Sampling

A reconnaissance survey was conducted prior to sampling to identify representative sites and prepare a location map (Fig 1). Geographic coordinates of sampling points were recorded using a Global Positioning System (GPS), and site characteristics such as slope, elevation, and altitude were noted.

Soil samples were collected at a depth of 0–20 cm (epipedon layer) using a soil auger. In each LGA, five communities were selected, and samples were collected randomly in

triplicate from each location, resulting in 15 samples per LGA and a total of 30 composite samples for the study.

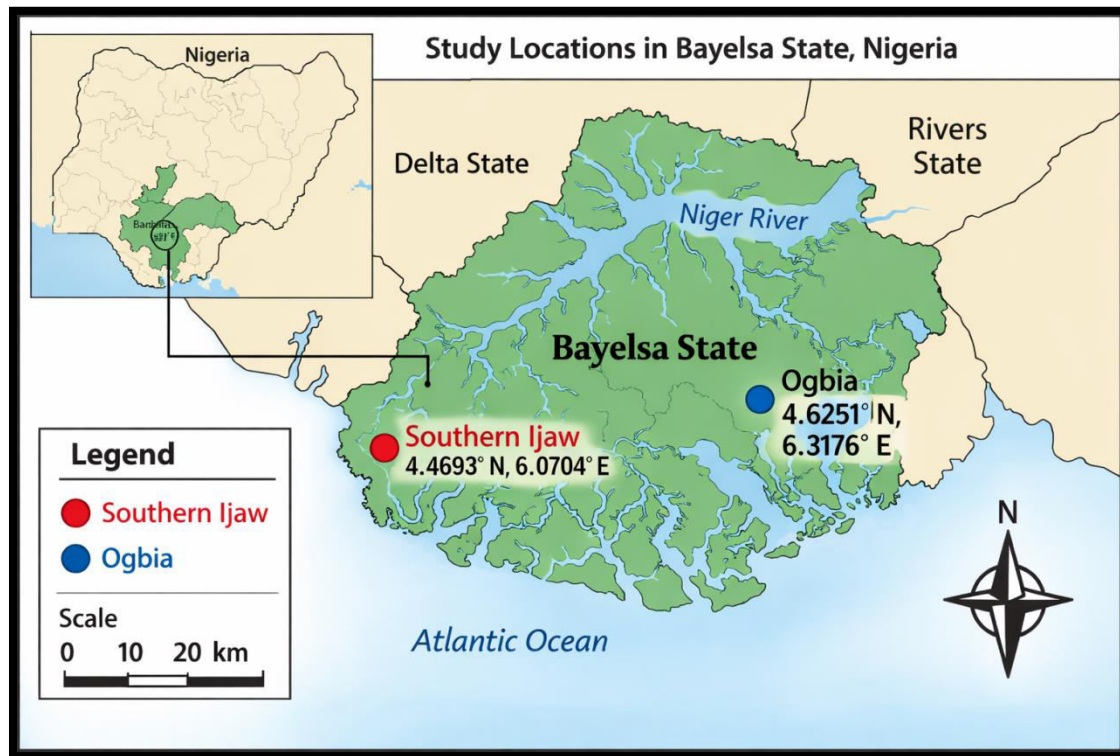


Figure 1. Location map

3.3 Experimental Design

The study was arranged in a randomized complete block design (RCBD) to account for spatial variability across sampling locations.

3.4 Laboratory Analyses

3.4.1 Chemophysical Properties

Particle size distribution was determined using the hydrometer method as described by Gee and Or (2002). Bulk density was measured using the core sampling method following Grossman and Reinsch (2002), and calculated as:

Bulk Density = $\frac{\text{mass of oven dried soil}}{\text{volume of soil}}$ (1), Volume = $\pi r^2 h$: Where: r, radius of the cylinder/core, and h, height of the cylinder/core.

Total Porosity was calculated using the relationship documented by Brady and Weil (2017) as $TP = \left(1 - \frac{Bd}{Pd}\right) \times 100$ (2)

Where: TP = Total Porosity (%), Bd = Bulk density (g/cm^3) Pd= particle density (g/cm^3). **Moisture content**: was determined by gravimetric method (Gardener, 1986). It is calculated as:

$$\%MC = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \dots\dots\dots (3), \text{ Where; } \% MC = \text{moisture content, } W_1 = \text{weight of}$$

moisture can, W_2 weight of air-dried soil plus moisture can, W_3 weight of oven-dried soil plus moisture can.

The soil pH, organic carbon and total nitrogen were determined by the methods of Van Reeuwijk (2002) respectively. **Available Phosphorus** was determined using the molybdenum blue Bray 2 method (Olsen and Sommers, 1990). **Effective cation exchange capacity (ECEC)** was determined by summing up the exchangeable basic cations and exchange acidity (Brady and Weil, 2017, Landon 1991).

3.4.2 Hydrologic properties of soil

Saturated hydrologic conductivity (K_{sat}) was determined using a constant head permeameter method by following Klute (1965). The K_{sat} was calculated using Equation $K_{sat} = \frac{al}{At} \ln\left(\frac{h_0}{h_1}\right) \dots\dots\dots (4)$. Here, K_{sat} represents the hydraulic conductivity (cm/s), a represents the cross-sectional area of the burette (cm^2), A , represents the cross-sectional area of the soil sample (cm^2), L represents the column length of the soil sample (cm), h_0 represents the initial water height (cm), h_1 represents the final water height (cm), and t represents the time between the start and end (s). Soils with hydraulic conductivity (HC) below 13 mmh^{-1} are classified as having low permeability; those between $13\text{--}50 \text{ mmh}^{-1}$ fall within the moderate range, while values above 50 mmh^{-1} are considered highly permeable (USDA-NRCS 2009 and Jabro 1992).

Hydrologic Soil Group (HSG) and the associated runoff potential, class index and structure were determined based on the provided Hydraulic Conductivity (HC in mmh^{-1}) data, by applying the USDA-NRCS classification system (USDA-NRCS 2021). Gravity-Driven Flow described as the flow rate (Q) of water through a porous medium, such as soil or rock, driven by gravity was computed as using the method by Bear (1972) as $Q = -K * A * (dh/dl) \dots\dots 5$, where: Q = Flow rate (volume per unit time), K = Hydraulic conductivity (measure of the ease of water flow through the medium), A = Cross-sectional area of the flow (dh/dl); also known as Hydraulic gradient (change in hydraulic head per unit distance). The Cumulative Infiltration under Constant Head (Steady-State) approach was applied based on Darcy's Law, which states that under saturated, steady-state conditions with a constant hydraulic gradient, cumulative infiltration can be described by a linear relationship: $I = K \cdot t$, where I = represents the cumulative infiltration (e.g., cm or mm), K = is the saturated hydraulic conductivity (cm/hr or mm/hr), and t = is time (e.g., hr, min,) (Klute, 1986; Hillel, 2008). Flow Rate which estimates the flow rate (Q) of water based on the cross-

sectional area (A) and flow velocity (v) was computed by the method of Freeze & Cherry (1979), $Q = A * v$ (6), Where: Q = Flow rate (volume per unit time) A = Cross-sectional area of the flow, V = Flow velocity (distance per unit time)

Hydraulic Gradient was calculated using the relationship ($I = dh/dl$) .(7) Where; I = represents the change in hydraulic head , dh = per unit distance , dl = length of the column/ hydraulic heads

Transmissivity was determined using Darcy-based relationships linking hydraulic conductivity to flow through saturated soil media (Alaoui, 2023; Blanchy et al., 2023) ($T = K * b$) (8), where T = Transmissivity, , K = Hydraulic conductivity, b =Aquifer thickness/Equivalent to the depth of soil sampling scale

3.4.3. Soil Environmental Quality Index (EQI) was computed using a weighted additive model following Fariba et al. (2022), Cherubinetal (2016) documentation. The composite score was computed as: $WQI = \sum(W_i \times S_i)$,(9), where W_i is the weight and S_i the standardized score.

3.5. Data presentation and statistical analysis

The data ascertained from the field experiments were analyzed statistically using the analysis of variance (ANOVA), and significant means were separated using FLSD. Various laboratory analysis data were presented in Tables.

4.0 Results and Discussions

4.1. Chemophysical properties

The chemophysical properties of the soils across the study locations are presented in Tables 1 and 2 respectively. Sand fraction dominated the soils in both Ogbia and Southern Ijaw, with grand mean values of 640.60 g kg^{-1} , reflecting the predominance of sandy loam (SL), loamy sand (LS), and sandy clay loam (SCL) textural classes (Table 1). The high sand content suggests low water retention but enhanced permeability, which is typical of coastal plain soils in the Niger Delta region. The clay content was relatively low in Ogbia (120.50 g kg^{-1}) compared to Southern Ijaw (171.77 g kg^{-1}). This variation likely influenced the observed differences in soil moisture content and hydraulic behavior. Similar findings were reported by Usowicz and Lepiec, (2025), who observed that clay-rich soils exhibit reduced hydrolic conductivity due to increased microporosity. The higher clay fraction values at Agbura and Igeibiri though enhance moisture and nutrient retention may lead to complications such as shrink-swell behavior and reduced permeability factors critical to both agricultural productivity and civil engineering applications, as emphasized by Hazelton and Murphy (2007). Osinubi and Eberemu (2005), reported that soils with clay content above 200 g kg^{-1} typically exhibit increased plasticity and reduced permeability, influencing their mechanical performance.

Bulk density (BD) ranged from 1.32 to 1.52 Mg m⁻³ in Otokpoti and Agbura (Ogbia) and from 1.40 -1.69 Mg m⁻³ in Igeibiri and Taliladei (Southern Ijaw) respectively (Table 1). These results are consistent with Hillel (2008), reported bulk density values ranging from 1.3 to 1.6 Mg m⁻³ as ideal for mineral soils. The lower bulk densities observed in Ogbia suggest improved soil structure, increased porosity, healthy root development and a higher potential for moisture retention and minimizes surface runoff, thereby helping to mitigate flooding and erosion risks. The inverse relationship between bulk density and total porosity was evident, as soils with lower bulk density (e.g., Otuogori) recorded higher porosity values. Total porosity differed significantly ($P < 0.05$) and ranged from 36.29 to 50.09%. Hillel (2008) noted that total porosity above 40 % is optimal for mineral soils, promoting a healthy balance between air and water movement and supporting essential biological processes.

Moisture content varied significantly, spanning from 157.00 g kg⁻¹ in Agbura to 237.50 g kg⁻¹ in Otuokpoti (Ogbia), and from 147.10 g kg⁻¹ in Tariladei to 244.10 g kg⁻¹ in Amassoma, (Southern Ijaw). This suggests that, despite high sand content, the presence of silt and organic matter may enhance water retention. According to Mujdeci et al. (2017), soil moisture dynamics in sandy soils are strongly influenced by aggregation and organic matter content, which improve water-holding capacity. These moisture levels suggest the presence of soils with favourable water-holding capacity for seed germination and microbial processes (Hillel 2008 and Lal & Shukla 2004).

Table 1. Physical properties of soils of the study area

Locations	Sand	Silt	Clay	TC	DBD	TP	MC
	g kg ⁻¹				Mgm ⁻³	%	g kg ⁻¹
Ogbia							
Otuoba	776.8	184.69	38.51	LS	1.46	44.81	214.30
Otuogori	583.47	231.36	145.17	SL	1.32	50.09	199.30
Oneubum	580.13	244.69	175.17	SL	1.41	46.58	230.50
Agbura	558.93	229.24	211.83	SCL	1.52	42.51	157.00
Otuokpoti	743.47	194.69	31.84	LS	1.32	50.01	237.50
Mean	648.56	216.94	120.50	–	1.41	46.80	207.70
Southern-Ijaw							
Aguobiri	563.47	318.03	118.51	SL	1.46	45.06	174.40
Angi-Ama	643.47	288.03	68.51	SL	1.51	43.13	211.50
Tariladei	643.47	206.69	149.84	SL	1.69	36.29	147.10
Igeibiri	584.8	264.69	352.84	SC	1.40	47.13	200.99
Amassoma	746.93	60.56	169.17	SL	1.61	39.19	244.10
Mean	636.43	227.60	171.77	–	1.53	42.16	195.61
Grand Mean	640.60	235.08	136.70	–	1.51	43.68	199.61
Lsd _{0.05}	6.22 *	6.24 *	2.79 *	–	0.09ns	0.04*	3.18*

TC = Textural class, SL = Sandy loam, SCL = Sandy clay loam, SC = Sandy clay, LS = Loamy sand, DBD = Dry bulk density, TP = Total porosity, MC = Moisture content, * = significant, NS = not significant, p= probability level at 5%

Soil pH varied between 4.60 and 5.53 (Table 2) indicating strongly to moderately acidic conditions reflecting the typical characteristics of highly leached tropical soils. In Ogbia LGA, pH values were slightly elevated, ranging between 5.01 and 5.50, with a mean of 5.23, though they remained within the acidic spectrum. This is likely the result of extensive weathering and the build-up of exchangeable aluminum, supporting Lal's (2004) observations on the adverse effects of soil acidity on legume nodulation in tropical settings. Southern Ijaw LGA recorded pH values between 5.02 and 5.53, averaging 5.22.

Soil Organic Matter (SOM)

In Ogbia LGA, SOM levels showed moderate variability, ranging from 15.70 g kg⁻¹ in Otuoba to 23.8 g kg⁻¹ in Otuokpoti, with a mean of 19.7 g kg⁻¹ (Table 2). These values fall within the moderate fertility range but also indicate fluctuating organic matter dynamics, potentially resulting from varied land use practices, drainage conditions, or inconsistent

organic input. The lower SOM value in Otuoba could be a sign of land degradation or insufficient organic matter replenishment. Southern Ijaw LGA recorded the highest SOM range, from a low of 6.0 g kg⁻¹ in Tariladei to a high of 26.9 g kg⁻¹ in Angi-Ama, averaging 16.8 g kg⁻¹ the lowest mean among the three LGAs. The very low SOM at Tariladei may be attributed to factors such as erosion, prolonged water saturation, or land clearing, indicating severe organic matter loss. In contrast, Angi-Ama's higher SOM suggests localized organic enrichment, likely from sediment buildup or dense vegetation input. The wide variability across Southern Ijaw underscores the heterogeneity of its landscape and the need for site-specific soil fertility interventions. The overall average SOM across all locations was 19.5 g kg⁻¹, placing the soils within the moderate organic matter category (15–25 g kg⁻¹) according to Landon (1991).

Total nitrogen (TN)

In Ogbia, TN values ranged from 1.50 g kg⁻¹ (Otuoba) to 1.90 g kg⁻¹ (Otuokpoti), averaging 1.70 g kg⁻¹ adequate for moderate productivity. Southern Ijaw LGA exhibited the broadest TN range (1.00–2.10 g kg⁻¹), with a mean of 1.50 g kg⁻¹, suggesting lower nitrogen availability in some areas, particularly where flooding, leaching, or biomass removal are common. The relatively low nitrogen values in some locations may be due to leaching losses, especially in soils with high hydraulic conductivity. This is consistent with findings that nitrogen is highly mobile and easily lost in permeable soils (Li et al., 2025).

Available phosphorus (Av. P) displayed marked differences, ranging from a critically low 1.36 mg kg⁻¹ at Oneubum (Ogbia) to 14.72 mg kg⁻¹ at Aguobiri (Southern Ijaw), with a grand mean of 7.20 mg kg⁻¹ (Table 2). Soil under Ogbia recorded lower available phosphorus levels with an overall of 5.47 mg kg⁻¹. The low values recorded at Oneubum, could be attributed to phosphorus fixation by iron and aluminum oxides of acidic, low-activity clay soils (Brady & Weil, 2017). Conversely, Southern Ijaw soils exhibited relatively high phosphorus availability (6.11–14.72 mg kg⁻¹ and grand mean of 9.80 mg kg⁻¹), likely due to better organic input and less fixation, potentially associated with estuarine sediment influences.

Effective Cation Exchange Capacity (ECEC),

Soils from Ogbia LGA recorded slightly lower ECEC values, spanning 11.50 cmol kg⁻¹ (Otuoba) to 14.10 cmol kg⁻¹ (Otuoguri), with a mean of 12.62 cmol kg⁻¹, indicative of moderate to high fertility status, albeit slightly less than that of Yenagoa. Conversely, Southern Ijaw LGA recorded the lowest ECEC values, ranging from 5.65 cmol kg⁻¹ (Tariladei) to 12.30 cmol kg⁻¹ (Aguobiri), with a mean of 10.18 cmol kg⁻¹. This suggests moderate to low nutrient-holding capacity, particularly in sites with ECEC below the critical threshold of 10 cmol kg⁻¹.

Table 2. Chemical properties of soils

LOCATION	pH H ₂ O	SOC	SOM	TN	Av. P	ECEC
		g kg ⁻¹			mg kg ⁻¹	cmol kg ⁻¹
Ogbia						
Otuoba	5.01	9.10	15.7	1.51	4.147	11.5
Otuoguri	5.30	12.40	21.3	1.62	1.363	14.1
Oneubum	5.23	10.60	20.0	1.73	7.63	12.1
Agbura	5.11	10.30	17.8	1.60	9.78	13.3
Otuokpoti	5.50	13.80	23.8	1.90	4.403	12.1
Mean	5.23	11.30	19.7	1.71	5.47	12.62
Southeren Ijaw						
Aguobiri	5.12	11.40	19.6	1.61	14.72	40.29
Angi-Ama	5.09	15.62	26.9	2.10	9.59	25.08
Tariladei	5.53	3.50	6.0	1.00	6.11	23.20
Igeibiri	5.02	9.01	15.5	1.30	9.78	17.96
Amassoma	5.33	10.00	17.2	1.61	8.81	24.59
Mean	5.22	9.71	16.8	1.50	9.80	7.75*
Grand Mean	5.16	11.31	19.5	1.70	7.20	15.85
LSD 0.05	0.2NS		0.299*	0.533*	0.03*	16.10

pH H₂O= pH in water, SOC= Soil organic carbon, SOM= Soil organic matter, TN= Total Nitrogen, Av.P = Available Phosphorus, ECEC = Effective cation exchange capacity, *Significant, NS = Not significant, p=probability level 5 %.

4.2 Hydrologic properties of studied soils.

Saturated hydraulic conductivity.

The distribution of hydraulic properties across the study areas is shown in Table 3. Saturated hydraulic conductivity (SHC) which differed significantly ($P < 0.05$) with values spanning from 2.88 mmh⁻¹ in Otuogori to a peak of 73.48 mmh⁻¹ in Otuoba, with a resultant grand mean of 19.28 mmh⁻¹ (Table 3). Soils in Southern Ijaw Local Government Areas (LGAs) generally exhibited moderate permeability where as soils in Ogbia Local government displayed a wide range from extremely low in Otuokpoti and Otuogori to very high values in Otuoba (USDA-NRCS 2009 and Jabro, 1992). The significantly higher saturated hydraulic conductivity recorded in Otuoba can be attributed to itsloamy sand texture (Vieira et al., 2025), granular structure which favor the development of macropores, Marzini et al. (2025) and enhance water transmission. In addition, high saturated hydraulic conductivity (Ksat) of the soils can be attributed to a combination of inherent soil factors, biological influences Marzini et al.(2025), and land management practices that

collectively create a soil environment with enhanced pore connectivity and macro-porosity, facilitating efficient water infiltration, good drainage, and aeration. On the other hand, high SHC promotes nutrient leaching, reduces water retention, and may lead to groundwater contamination. In contrast, the very low conductivity observed in Otuokpoti is likely due to its blocky/subangular structure and classification under hydraulic soil group (HSG) D, which is typically associated with high runoff potential and restricted infiltration.

Runoff potential, Hydrologic soil group (HSG) and infiltration

Surface runoff potential closely followed a reverse trend with saturated hydraulic conductivity. Very low SHC soils such as Otuokpoti (2.88 mmh^{-1}) and Agbura (6.52 mmh^{-1}), demonstrated high and moderate surface runoff potentials, respectively aligning with their placement within Hydraulic Soil Groups (HSG) D and C. This supports the established understanding that soils with low permeability hinder water infiltration, leading to greater surface runoff. The findings align with Essoka et al. (2020), who found that soils particularly in coastal environments display a wide range of infiltration and runoff responses due to differences in sediment deposition, clay content, and human-induced modifications.

Hydrologic soil group (HSG) classification further explains the infiltration and runoff characteristics of the soils. Most soils fell under group C, indicating moderate infiltration rates and moderate runoff potential, while Otuokpoti (group D) exhibited high runoff potential. The inverse relationship between infiltration and runoff potential observed in this study is consistent with hydrological theory and recent findings by Michaud and Gan (2025).

The descending order of infiltration rate magnitude across the studied soils were: Otuoba>Angi-Ama>Aguobiri>Otuogori>Tariladei>Oneubum>Igeibiri>Amassoma>Agbura>Otuokpoti. This infiltration pattern strengthens the previously noted runoff and permeability behaviors. High infiltration capacity enhances groundwater recharge and irrigation efficiency, while low infiltration increases risks of surface ponding and erosion, a concern documented by Lal and Shukla (2004).

Flow rate

Gravity-driven flow and transmissivity also varied significantly ($p \leq 0.05$), reflecting differences in soil pore structure and continuity. Higher transmissivity values, such as in Angi-Ama ($287.24 \times 10^{-3} \text{ cm}^2 \text{ s}^{-1}$), indicate enhanced lateral water movement, which may increase the risk of nutrient leaching. According to **Usovicz and Lepiec (2025)**, soils with high transmissivity and hydraulic conductivity are more prone to rapid solute transport, which has implications for soil fertility management

Table 2. Hydrologic properties of the soil

Location	HC mm/h	Soil Permeability Indices				Runoff potential	Gravity driven flow (cm ² /s) (10 ⁻³)	Hydrau lic Gradie nt (i)	infiltrati on (f) mm/s	Flow rate(cm ³ /se c) (10 ⁻³)	Transmissivity (cm ² /s) (10 ⁻³)
		Classification	Structure	HSG	Class index						
Ogbia											
Otuoba	73.477	High	Granular	A	5	Very low	204.082	1	1.2246	7.9218	40.82
Otuoguori	14.476	Low	Granular	C	5	Moderate	202.774	1	0.2412	22.7114	16.0
Oneubum	9.844	Low	Blocky	C	4	Moderate	207.820	1	0.1638	14.3481	54.6
Agbura	6.519	Very low	Blocky	C	5	Moderate	204.783	1	0.1086	9.9862	36.2
Otuokpoti	2.88	Very low	Blocky/ subangular	D	4	High	204.082	1	0.048	23.0781	80.4
Mean	21.439	-		B	5	Low	204.7	1.00	0.357	16.00	45.6
Southern-ijaw											
Aguobiri	20.670	Moderate	Granular	B	5	Low	204.082	1	0.3444	57.240	11.48
Angi-ama	14.392	Low	Granular	C	5	Moderate	204.082	1	0.240	287.236	8
Tariladei	13.346	Low	Granular	C	5	Moderate	204.082	1	0.2226	88.041	74.2
Igeibiri	13.089	Low	Granular	C	5	Moderate	204.082	1	0.2184	29.673	72.8
Amassom	10.032	Low	Granular	C	5	Moderate	204.082	1	0.167	104.264	55.8

a			r								
Mean	14.306	-	Granular	C	5	Moderate	204.0	1.00	0.238	110	44.5
Grand mean	19.28	-	-	C	5	Moderate	204.2	1.00	0.321	0.11	38.0
Lsd 0.05	0.066*						0.019*		0.2609*	0.0779*	0.03*

SHC = Saturated Hydraulic Conductivity, HSG = Hydrological soil group, *Significant, NS = Not significant, p=probability level 5 %

4.0. Environmental quality Index Ranking

The environmental quality Index scores ranged from 0.24 to 0.65 in Otuoba and Ogbogoro respectively (Table 4). The variation in EQI reflects differences in soil chemical properties, organic matter content, and nutrient availability. Higher EQI values are generally associated with better nutrient status, improved soil structure, and enhanced biological activity. Where as low EQI values in sandy soils may be attributed to nutrient leaching and low cation exchange capacity.

The low EQI observed in some locations is consistent with the high hydraulic conductivity reported in Table 3, which promotes nutrient loss through leaching. Soils with high permeability often exhibit low nutrient retention and reduced fertility status due to rapid leaching of mobile nutrients such as nitrate and potassium (Li et al., 2025; Bargués-Tobella et al., 2024).. Furthermore, the relationship between fertility and physical properties is evident, as soils with better structure and higher organic matter tend to have higher fertility indices. Soil organic carbon plays a critical role in improving both nutrient availability and soil chemical conditions (Bargués -Tobella et al. 2024).

Table 4 . Environmental quality Index

Location	LGA	CEQI Score	Ranking
Ogbogoro	Southern Ijaw	0.654	1
Angi-ama	Ogbia	0.607	2
Aguobiri	Southern Ijaw	0.592	3
Amassoma	Southern Ijaw	0.582	4
Otuogori	Ogbia	0.531	5
Agbura	Ogbia	0.528	6
Tarilade	Ogbia	0.519	7
Igeibiri	Southern Ijaw	0.460	8
Oneubum	Ogbia	0.291	9
Otuoba	Southern Ijaw	0.240	10

Conclusion

This study demonstrated that epipedon coastal soils in Bayelsa State exhibit significant spatial variability in their hydrological, chemophysical, properties with important implications for soil quality, agricultural productivity, and environmental sustainability. The dominance of sandy textures across the study locations contributed to high permeability and moderate to high infiltration rates, but also resulted in low water-holding capacity and increased susceptibility to nutrient leaching. The acidic nature of the soils reflects intense leaching under high rainfall conditions typical of the area. Although soil organic matter and total nitrogen levels were generally moderate, effective cation exchange

capacity suggests differences in nutrient retention capacity and fertility status across sites. A high saturated hydraulic conductivity values were noted. The Environmental Quality Index (EQI) effectively integrated these parameters, revealing variability in soil quality from low to relatively high fertility levels across locations. Overall, the findings emphasize that soil quality in coastal environments is controlled by the interaction of physical, chemical, and hydrological factors. Sustainable management of these soils requires some agronomic interventions, including the application of organic amendments to improve soil structure and nutrient status, liming to correct soil acidity, and the adoption of water and erosion control practices. The use of EQI is recommended for informed decision-making aimed at enhancing soil health, agricultural productivity, and environmental resilience in coastal agroecosystems.

References:

1. Abowei, F. N., Akparobi, S. O., &Ovie, S. I. (2023). Assessment of soil fertility and land capability classification of selected soils in coastal agro-ecologies of southern Nigeria. *Nigerian Journal of Soil and Environmental Research*, 21(2), 34-45.
2. Batista, A. M., Pessoa, T. N., Putti, F. F., Andreote, F. D., &Libardi, P. L. (2024). Root influences rhizosphere hydraulic properties through soil organic carbon and microbial activity. *Plants*, 13(14), 1981.
3. Blanchy, G., Albrecht, L., Bragato, G., Garre, S., Jarvis, N., &Koestel, J. (2023). Impacts of soil management and climate on hydraulic conductivity. *Hydrology and Earth System Sciences*, 27, 2703-2723.
4. Brady, N. C., & Weil, R. R. (2017). *The nature and properties of soils* (15th ed.). Pearson.
5. Bargués-Tobella, A., Winowiecki, L. A., Sheil, D., &Vågen, T. (2024). Determinants of soil field saturated hydraulic conductivity across Sub-Saharan Africa: Texture and beyond. *Water Resources Research*, 1-25.
6. Cherubin, M. R., Karlen, D. L., Cerri, C. E. P., Franco, A. L. C., Tormena, C. A., Davis, C. A., Cerri, C. C., & Liang, W. (2016). Soil quality index strategies for evaluating sugarcane expansion in Brazil. *PLoS ONE*, 11(3), e0150860.
7. Essoka, P. A., Ogbaji, M. I., &Essoka, B. A. (2020). Assessment of physicochemical properties and soil quality index of Obudu agricultural zone, southeastern Nigeria. *African Journal of Environmental Science and Technology*, 14(1), 1-9.
8. Fariba, S., Hojat, E., & Amir, L. (2022). Assessing soil quality of pasture and agricultural land uses in Shadiz County, Northwestern Iran. *Ecological Indicators*, 139, 108974.
9. Freeze, R. A., & Cherry, J. A. (1979). *Groundwater*. Prentice-Hall.

10. Gardner, W. H. (1986). Water content. In A. Klute (Ed.), *Methods of soil analysis: Part 1—Physical and mineralogical methods* (2nd ed., pp. 493–544). ASA-SSSA.
11. Gee, G. W., & Or, D. (2002). Particle-size analysis. In J. H. Dane & G. C. Topp (Eds.), *Methods of soil analysis: Part 4—Physical methods* (pp. 255–293). Soil Science Society of America.
12. Grossman, R. B., & Reinsch, T. G. (2002). Bulk density and linear extensibility. In J. H. Dane & G. C. Topp (Eds.), *Methods of soil analysis: Part 4—Physical methods* (pp. 201–228). Soil Science Society of America.
13. Hazelton, P., & Murphy, B. (2007). *Interpreting soil test results: What do all the numbers mean?* (2nd ed.). CSIRO Publishing.
14. Hillel, D. (2008). Soil physical attributes. In D. Hillel (Ed.), *Soil in the environment* (pp. 55–77). Academic Press.
15. Jabro, J. D. (1992). Estimating saturated hydraulic conductivity from soil physical properties. *Soil Science*, 154(1), 1–5.
16. Jarvis, N., Koestel, J., Messing, I., Moeys, J., & Lindahl, A. (2013). Influence of soil, land use, and climatic factors on hydraulic conductivity. *Hydrology and Earth System Sciences*, 17, 5185–5195.
17. Klute, A. (1986). Laboratory measurements of hydraulic conductivity of saturated soil. In C. A. Black et al. (Eds.), *Methods of soil analysis: Part 1* (pp. 210–221). American Society of Agronomy.
18. Lal, R., & Shukla, M. K. (2004). *Principles of soil physics*. CRC Press.
19. Landon, J. R. (Ed.). (1991). *Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics*. Longman.
20. Lin, H., Bouma, J., Wilding, L. P., Richardson, J. L., Kutílek, M., & Nielsen, D. R. (2020). Advances in hydropedology: Bridging disciplines to understand soil-water processes. *Geoderma*, 397, 115106.
21. Nigerian Meteorological Agency (NIMET). (2023). *Seasonal climatic prediction*.
22. Marzini, L., Papisidero, M. P., D'Addario, E., Schwarz, M., & Disperati, L. (2025). Exploring the relationship between saturated hydraulic conductivity and root distribution. *Frontiers in Sustainability*, 6, 163182.
23. Michaud, M. E., & Gan, H. (2025). Comparison of common methods to quantify field saturated hydraulic conductivity. *Soil Science Society of America Journal*.
24. Mujdeci, M., Simsek, S., & Uygur, V. (2017). The effects of organic amendments on soil water retention characteristics under conventional tillage system. *Fresenius Environmental Bulletin*, 26(6), 4075–4081.
25. Natural Resources Conservation Service (NRCS). (2021). *National engineering handbook: Hydrology—Hydrologic soil groups*. U.S. Department of Agriculture.

26. Olorunfemi, A. A., & Ogunwale, J. A. (2021). Effects of hydrological variability on soil properties and land degradation in southern Nigeria. *African Journal of Environmental Science and Technology*, 15(6), 210–222.
27. Olsen, S. R., & Sommers, L. E. (1990). Phosphorus. In A. L. Page (Ed.), *Methods of soil analysis: Part 2—Chemical and microbiological properties* (pp. 403–430). ASA and SSSA.
28. Osinubi, K. J., & Eberemu, A. O. (2005). Compressibility characteristics of lateritic soil mixed with fly ash. *Nigerian Journal of Soil and Environmental Research*, 5, 96–103.
29. Reyment, R. A. (1965). *Aspects of the geology of Nigeria*. University of Ibadan Press.
30. Reynolds, W. D., Bowman, B. T., Drury, C. F., Tan, C. S., & Lu, X. (2009). Indicators of good soil physical quality: Density and storage parameters. *Geoderma*, 152(3–4), 252–263.
31. USDA-NRCS. (2009). *Soil survey field and laboratory methods manual (Soil Survey Investigations Report No. 51)*. U.S. Department of Agriculture.
32. USDA-NRCS. (2021). *National soil survey handbook*. U.S. Department of Agriculture.
33. Usowicz, B., & Lepiec, J. (2025). Predicting unsaturated soil hydraulic conductivity during drying and wetting processes with a statistical physical model. *Scientific Reports*, 15, 41942.
34. Van Reeuwijk, L. P. (2002). *Procedures for soil analysis (6th ed.)*. ISRIC.
35. Xiao, T., Li, P., Sun, L., Zhang, F., Yang, J., Qi, G., & Wang, J. (2025). Investigating saturated hydraulic conductivity and its variation in fine-grained soil with root exudates of *Robinia pseudoacacia* L. *Journal of Rock Mechanics and Geotechnical Engineering*, 17, 7447–7459.
36. Vieira, C. B., Silva, G. H. M. C., Almeida, B. G., Pessoa, L. G., Freire, F. J., de Souza Júnior, V. S., Melo, H. F., Lima, L. G., Paiva, R. F., Ferreira, J. F., & Freire, M. B. (2025). Saturated hydraulic conductivity of nine soils according to water quality, soil texture, and clay mineralogy. *Agronomy*, 15(4), 864.