



Research Article

Palynological Analysis of Surface Sediments from Ngada, Taraba State, Nigeria

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ABSTRACT

Palynomorph assemblages preserved in sediments provide valuable proxies for reconstructing vegetation dynamics and inferring environmental conditions. This study presents the first preliminary palynological investigation of the Ngada area in Taraba State, Nigeria, aimed at characterizing the vertical distribution of palynomorphs and associated sedimentary properties within a shallow sediment profile. A single sediment core was retrieved using a universal peat corer, and four sub-samples were collected at depths of 0, 15, 30, and 45 cm. Each sub-sample was analyzed for palynological content, lithology, pH, and salinity. A total of 33 palynomorph types were recovered, comprising pollen grains attributed to 27 plant taxa together with several fungal spore morphotypes. The dominant pollen taxa included *Ficus* sp., *Dalbergia* cf. *hostilis*, *Uapaca* sp., *Diospyros* cf. *abyssinica*, *Medicago* sp., and *Olea* cf. *capensis*, while frequently encountered non-pollen palynomorphs (NPPs) included *Sporidesmium*-type, *Puccinia*-type teliospores, *Torula*-type, *Sordaria*-type, *Brachysporium*-type, and *Nigrospora*-type spores. Lithological observations revealed alternating mudstone and well-sorted sand units, consistent with fluctuations between low- and higher-energy depositional regimes. Variations in pH and salinity across depths further suggest changes in the physicochemical conditions of the depositional environment. The recovered assemblages are tentatively consistent with a vegetation mosaic transitioning between woodland and open savanna elements, possibly reflecting a combination of natural environmental variability and anthropogenic influence, particularly from agricultural activity. Given the limited number of samples and the absence of chronological control, these results are presented as a baseline exploratory dataset intended to guide future high-resolution, chronologically constrained paleoenvironmental studies in the Ngada Region.

Keywords: Ngada; Nigeria; Non-Palynomorphs; Palynology; Surface Sediments; Taraba

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INTRODUCTION

Palynology, the study of pollen grains and spores, is widely applied across disciplines ranging from allergy and forensic science to paleoecology and

paleoclimatology (Mercuri *et al.*, 2025). In environmental research, both modern and fossil palynomorphs serve as durable biological proxies for reconstructing vegetation patterns, inferring climatic

conditions, and detecting human impacts on ecosystems (Chevalier *et al.*, 2020; Adekanmbi *et al.*, 2019). Pollen and spores are abundantly produced, dispersed across landscapes, and well preserved in many sedimentary contexts, they remain among the most informative tools for tracking ecological change at local to regional scales (Kiage, 2025; Singh and Barinova, 2022). When combined with lithological and physicochemical sediment data, palynological records can yield integrated insights into past depositional environments and vegetation dynamics (Edvardsson *et al.*, 2022).

In West Africa, palynological investigations from the Niger Delta and parts of Central Africa have produced informative records of vegetation and environmental change (Kiage, 2025; Zargar, 2025). However, large areas of Nigeria particularly the ecologically diverse highland and sub-montane zones of the eastern part of the country remain substantially under-represented in the regional paleoecological literature. This data gap limits our ability to interpret regional patterns of vegetation response to climatic and anthropogenic drivers, and to develop locally informed conservation and land-use frameworks.

The Ngada area of Taraba State, situated in close proximity to the Mambilla Plateau and the Cameroonian Highlands both internationally recognized biodiversity hotspots represent one such under-studied area. Its varied topography, climatic gradients, and soil mosaics are likely to support considerable floral diversity (Al-Namazi *et al.*, 2022; Wani *et al.*, 2023). At the same time, the region is subject to increasing pressures from agricultural expansion, transhumance, population growth, and land-use change. To date, no published palynological, floristic, or pedological studies are available for Ngada, making even basic baseline data on local vegetation–environment relationships scarce.

Given the absence of prior work, the present study is conceived as a preliminary, exploratory investigation rather than a long-term paleoclimatic reconstruction. Specifically, this study aims to: (i) document the palynomorph assemblages preserved in a shallow sediment profile from Ngada; (ii) characterize associated lithological and physicochemical (pH, salinity) properties of the sampled depths; and (iii) provide a baseline dataset that can guide the design of future high-resolution, replicated, and chronologically constrained paleoenvironmental investigations in the region.

MATERIALS AND METHODS

The study area

The study was conducted in the Ngada area of Taraba State, north-eastern Nigeria (7°29' N, 10°56' E; Figure 1). The area is characterized by steep-sided hills rising 610–910 m above the surrounding base, and it spans portions of five local government areas Bali, Donga, Gashaka, Kurmi, and Sardauna collectively encompassing more than 116 villages and a combined population exceeding 34,000 inhabitants (Nagombe, 2025).

The terrain is gently undulating, dominated by open savanna with tall grasses and scattered fire-tolerant trees. Soils are shallow, with strongly developed lateritic concretions on the interfluvies. High-forest patches occur as fragments, mainly along streams or as isolated stands within the savanna matrix. Extensive forest clearance has occurred for oil-palm and cocoa cultivation, while the remaining vegetation comprises savanna woodland with common taxa including *Crossopteryx febrifuga*, *Uapaca togoensis*, and *Anogeissus leiocarpus*, the latter typically associated with transitional woodland or regrowth on fallowed farmland. Slash-and-burn cultivation and bush-fallow rotation are the principal agricultural practices among the local Ndola people. Ngada lies in proximity to the Mambilla Plain and the Baissa forest, both of which are recognized for their botanical significance and conservation value.

Palynological Analysis

A single sediment core was retrieved from the study site using a universal peat corer, and four sub-samples were extracted at depths of 0 cm (LC-01), 15 cm (LC-02), 30 cm (LC-03), and 45 cm (LC-04). The sampled interval (0–45 cm) was selected to capture palynomorph signals reflecting recent vegetation cover, surface disturbance, and contemporary anthropogenic influences, rather than long-term paleoclimatic change. The authors acknowledge that the low number of sampling points ($n = 4$), the absence of replicate cores, and the lack of radiometric age control limit the temporal resolution of the dataset. Accordingly, the data are presented as a preliminary, exploratory baseline intended to inform the design of future higher-resolution, chronologically constrained studies in the Ngada region.

Ten grams of each sediment sub-sample were measured and processed using standard palynological preparation protocols, following the procedures outlined by Faegri and Iversen (1966) and Erdtman (1969). All laboratory work was carried out in the Laboratory of Palynology and Palaeobotany, Department of Botany, University of Lagos. Each sample was subjected to a three-step preparation

process. The first stage involved demineralization: siliceous components were removed using 40% hydrofluoric acid (HF) left overnight, followed by treatment with concentrated hydrochloric acid (HCl) to eliminate calcareous materials. In the second stage, heavy liquid separation was performed using a solution of zinc chloride and hydrochloric acid with a specific gravity of 2.0 to concentrate organic residues. The final stage involved acetolysis, which breaks down cellulosic matter to enhance the visibility and identification of palynomorphs. After preparation, the residues were preserved in 100% glycerin to prevent desiccation. From these stock mixtures, aliquots were mounted onto microscope slides and examined under 40x magnification using an Olympus CH2 light microscope. Identification of the palynomorphs was conducted with the aid of published pollen atlases and relevant literature, including Gosling *et al.* (2013), Chevalier (2021) and Gu *et al.* (2025), as well as the pollen reference slide collection housed in the same laboratory. Selected

palynomorphs were photographed using a Motic 2300 digital camera for documentation. Specifically, the pollen sum refers to the total number of counted pollen grains per sample, which was used to calculate the relative percentages of each pollen type. In interpreting the palynological data, a pollen diagram was constructed using Tilia software, by calculating the percentage representation of each phytoecological group. This involved deriving the relative abundance of pollen types corresponding to specific plant groups at each sampled depth, following the methodologies described by Pardoe (2021) and Senn *et al.* (2022).

A pollen diagram was generated by calculating the percentage representation of each phytoecological group, based on the relative abundance of pollen types associated with specific plant groups at each sampled depth, using Pattern Analysis Software Tools (PAST). Tilia software was then employed to map and visualize the pollen and spore data, producing both a pollen profile and a pollen calendar (Grimm, 2013).

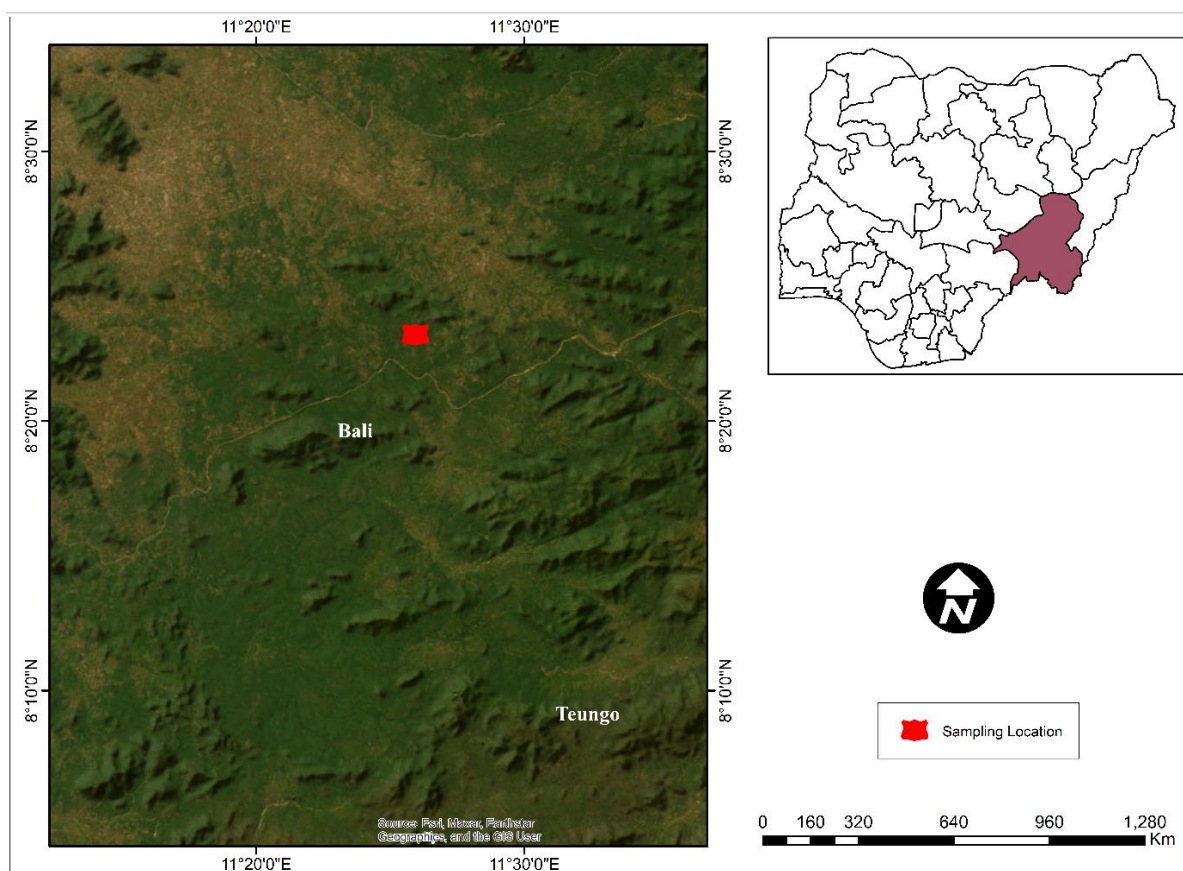


Figure 1. The map of the study area

Lithological analysis

Each sediment sample was subjected to lithological analysis to determine its physical characteristics. Textural features including grain size, shape, and sorting were assessed using the standard grain size scale specified by the American/Canadian Stratigraphic Code.

Soil Salinity or pH test

Five grams of each soil sample were measured and mixed with 50 ml of distilled (deionized) water to create a suspension. The mixtures were thoroughly stirred using a glass rod and left to stand for three hours to facilitate the dissolution of salts and ions from the sediments into the water. Following this, a La Motte pH/Conductivity/TDS/Salinity Meter Tracer Pocketester (Code 1766) was used to measure the salinity (in ppm) and pH levels of each sample.

RESULTS

Palynology

The distribution and preservation of palynomorphs varied significantly across different depths within the 45 cm sediment core analyzed in this study. A total of 33 distinct palynomorph types belonging to 27 different plant taxa were identified. The palynological

investigation revealed a diverse assemblage of pollen types and fungal spores (Table 1, Plate 1). Dominant palynomorphs included: *Ficus* sp. (7.65%), *Dalbergia hostilis* (6.47%), *Nigrospora* sp. (5.88%), and *Uapaca* sp. (4.71%).

Lithology and Salinity

The lithological characteristics of each unit are described as follows: LC-01: Brown, moderately hard, and non-fissile mudstone; LC-02: Light grey, coarse to fine-grained sand that is sub-angular and poorly sorted; LC-03: Light grey, fine-grained sand that is angular and very well sorted, with interbedded dark grey, hard, and non-fissile mudstone, and LC-04: Similar to LC-03, composed of light grey, fine-grained, angular, and very well-sorted sand, along with dark grey, hard, non-fissile mudstone. LC-03 and LC-04 exhibit similar lithological characteristics, indicating comparable depositional environments (Table 2). The pH and salinity measurements for the sediment samples are provided in Table 3. Among the samples, LC-03 was the most acidic, while LC-04 was the least acidic, indicating a relatively more basic condition; LC-03 also remained the least basic. The graphical representation of the recovered palynomorph diversity is shown in Figure 2.

Table 1. Presents the pollen spectra of the recovered palynomorphs

Plant taxon	Family	LC-01	LC-02	LC-03	LC-04	Total	(%)
Pollen Grains							
<i>Lannea</i> sp.	Anacardiaceae	0	0	0	7	7	4.12
<i>Rhus longipes</i>	Anacardiaceae	0	0	0	2	2	1.18
<i>Carissa edulis</i>	Apocynaceae	0	0	0	1	1	0.59
<i>Cocos nucifera</i>	Arecaceae	1	0	0	0	1	0.59
<i>Sonchus</i> sp.	Asteraceae	1	0	2	0	3	1.76
<i>Ageratum</i> sp.	Asteraceae	3	0	0	0	3	1.76
<i>Tridax</i> sp.	Asteraceae	0	0	3	0	3	1.76
<i>Diospyros abyssinica</i>	Ebenaceae	0	0	0	7	7	4.12
<i>Euphorbia</i> sp.	Euphorbiaceae	2	0	6	0	8	4.71
<i>Mimosa pudica</i>	Fabaceae	4	0	0	1	5	2.94
<i>Medicago sativa</i>	Fabaceae	2	2	0	0	4	2.35
<i>Parkia</i> sp.	Fabaceae	0	1	0	0	1	0.59
<i>Dalbergia hostilis</i>	Fabaceae	0	0	0	11	11	6.47
<i>Ocimum</i> sp.	Lamiaceae	2	0	0	0	2	1.18
<i>Vitex doniana</i>	Lamiaceae	0	2	2	3	7	4.12
<i>Grewia bicolor</i>	Malvaceae	2	0	0	0	2	1.18
<i>Ficus</i> sp.	Moraceae	3	0	2	8	13	7.65
<i>Psidium guajava</i>	Myrtaceae	0	1	2	0	3	1.76
<i>Olea capensis</i>	Oleaceae	0	0	0	7	7	4.12
<i>Uapaca</i> sp.	Phyllanthaceae	0	0	8	0	8	4.71
<i>Protea</i> sp.	Proteaceae	1	0	0	0	1	0.59
Poaceae	Poaceae	1	2	0	0	3	1.76
<i>Panicum maximum</i>	Poaceae	1	0	0	0	1	0.59
Charred Poaceae cuticle	Poaceae	6	0	0	0	6	3.53
<i>Aroconidiellina loudetiae</i>	Poaceae	0	2	0	0	2	1.18
Pollen indeterminate		3	3	0	0	6	6.53
Plants fragment		0	0	0	2	2	1.18
Fungi spores							
<i>Puccinia</i> teliospores	Pucciniaceae	0	0	1	0	1	0.59
<i>Chaetomium</i> ascospores	Chaetomiaceae	0	0	1	0	1	0.59
<i>Coniochaeta</i> sp.	Coniochaetaceae	5	0	0	0	5	2.94
<i>Glomus</i> sp.	Glomeraceae	1	3	0	0	4	2.35
<i>Cercophora</i> sp.	Mycosphaerellaceae	0	3	0	0	3	1.76
<i>Stemphylium</i> sp.	Pleosporaceae	0	0	0	3	3	1.76
<i>Torula</i> sp.	Saccharomycetaceae	0	0	0	1	1	0.59
<i>Sordaria</i> sp.	Sordariaceae	5	0	0	0	5	2.94
<i>Sporidesmium macrurum</i>	Sporidesmiaceae	0	1	0	0	1	0.59
<i>Brachysporium</i> sp.	Trichosphaeriaceae	7	0	0	0	7	4.12
<i>Nigrospora</i> sp.	Trichosphaeriaceae	4	0	3	3	10	5.88
Myxomycete spores	Arcyriaceae	0	0	6	0	6	6.53
Fern spores							
Polypodiaceae	Polypodiaceae	0	0	2	0	2	1.18
<i>Platyterium</i> sp.	Polypodiaceae	1	0	0	0	1	0.59

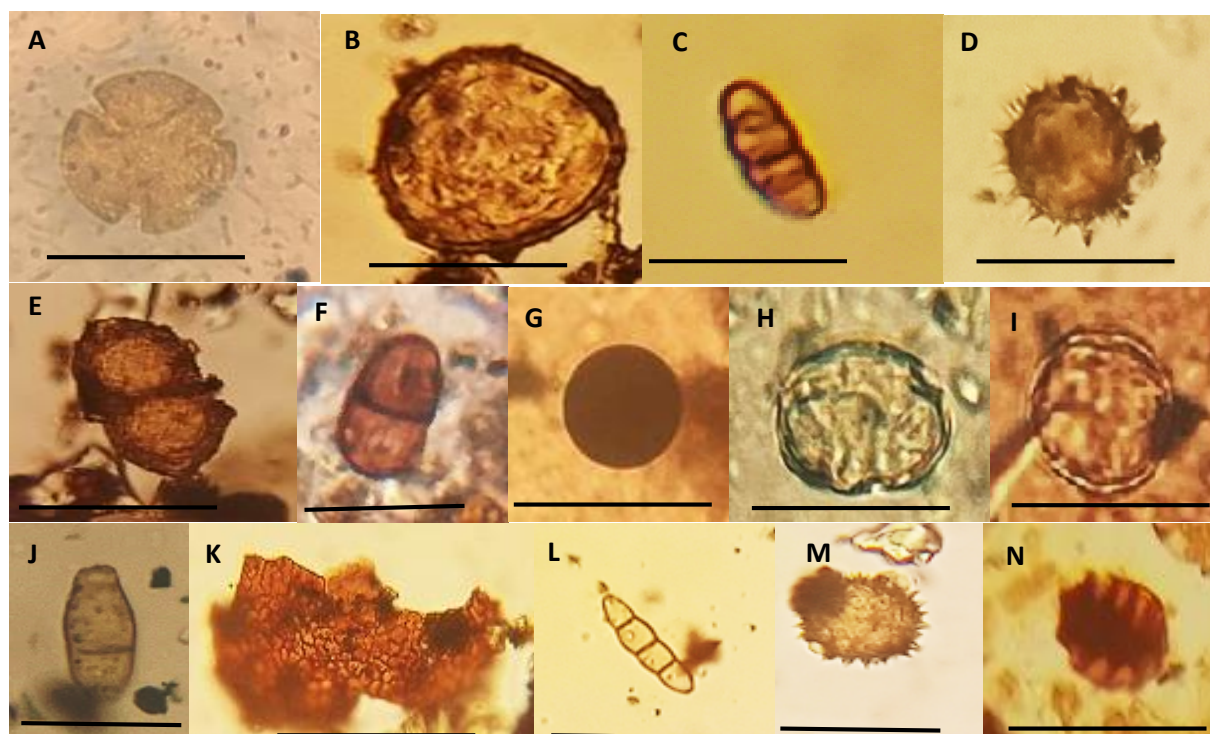


Plate 1. shows the recovered palynomorphs, including (A) *Dalbergia hostilis*, (B) *Polypodiaceae*, (C) *Delitschia* sp., (D) *Tridax procumbens*, (E) *Sporidesmium macrurum*, (F) *Cercophora* sp., (G) *Glomus* sp., (H) *Olea* sp., (I) indeterminate pollen, (J) *Cercophora* sp., (K) charred Poaceae cuticle, (L) indeterminate fungal spore, (M) *Sonchus* sp., and (N) *Alternaria* sp., observed at $\times 40$ magnification with a scale bar of 10 μm .

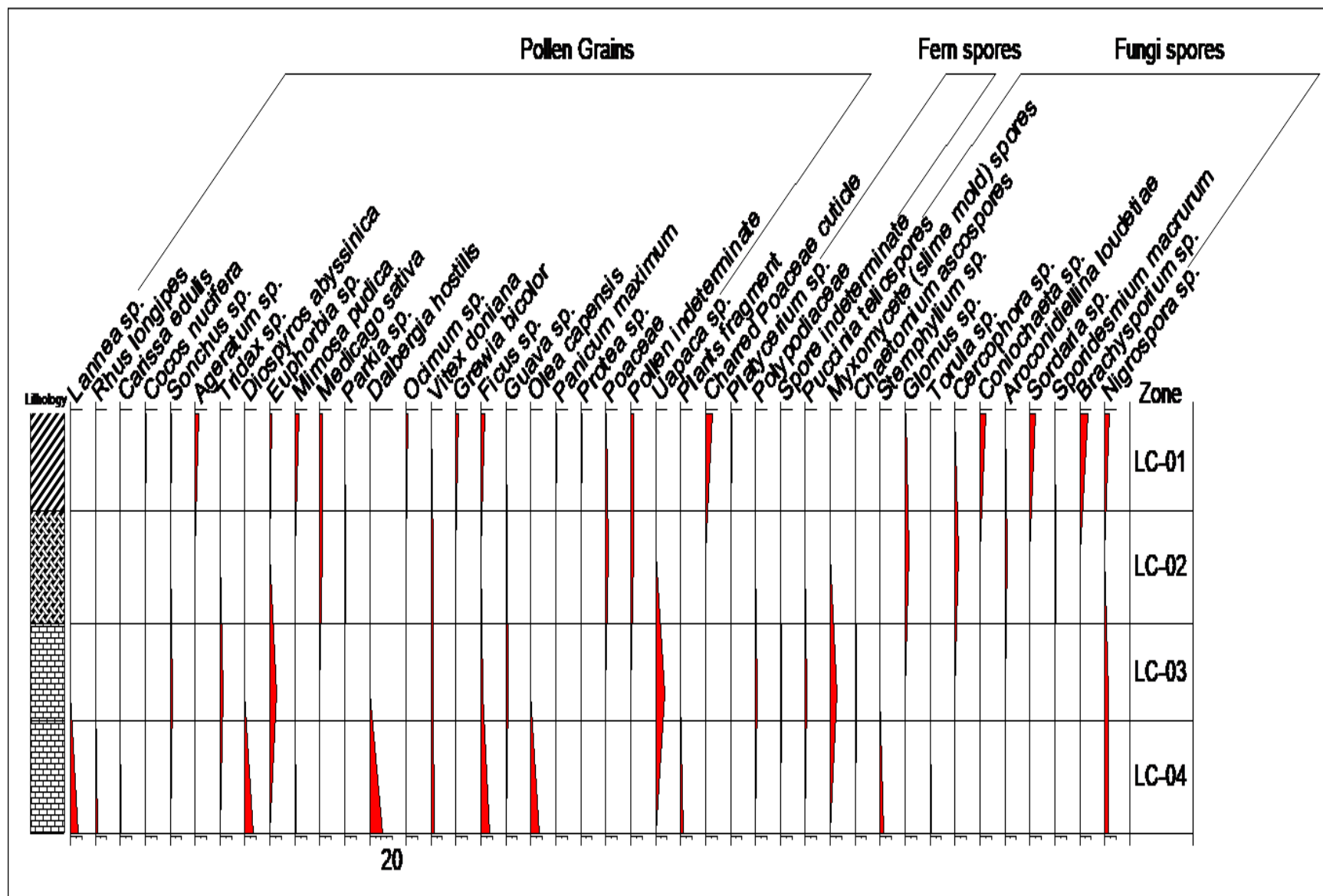


Figure 2. Shows the pollen diagram of the 45 cm sample core

Table 2. Presents the lithological analysis of the samples

Sediment Types	Lithological description
LC-01	Mudstones (>45%): Brown, moderately hard, and non-fissile
LC-02	Sand (<25%): Light grey, very fine/fine grained, angular and well sorted Sand (>45%): Light grey, fine/coarse grained, sub angular and poorly sorted Mudstones (<25%): Brown, moderately soft, and non-fissile Sand (>50%): Light grey, fine grained, angular and very well sorted Mudstones (<40%): Grey, moderately soft and non- fissile. Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<20%): Light grey, fine grained angular and very well sorted Mudstones (>50%): Dark grey, hard and non-fissile.
LC-03	Sand (<20%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile.
LC-04	Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted Mudstones (>85%): Dark grey, hard and non-fissile. Sand (<15%): Light grey, fine grained angular and very well sorted Mudstones (>85%): Dark grey, hard and non-fissile. Sand (<15%): Light grey, fine grained angular and very well sorted Mudstones (>70%): Dark grey, hard and non-fissile. Sand (<30%): Light grey, fine grained angular and very well sorted

Table 3: Presents the pH and salinity values of the samples obtained from the study location

S.N.	Sample code	pH	Salinity
1.	LC-01	6.94	0.02
2.	LC-02	6.88	0.04
3.	LC-03	5.69	0.02
4.	LC-04	7.61	0.03

DISCUSSION

The palynomorphs recovered from the surface sediments of the Ngada reflects a diverse assemblage of taxa, suggesting a mosaic of vegetation types, including tropical rainforest, savanna woodland, disturbed habitats, and anthropogenically influenced environments. The presence and composition of both pollen and fungal spores provide insights into past vegetation patterns and associated climatic conditions in the study area.

The palynological assemblage recovered from the study area indicates a vegetation mosaic dominated by rainforest, savanna woodland, and ecotonal taxa, suggesting that the area has experienced dynamic vegetation changes through time. The co-occurrence of *Ficus* sp., *Uapaca* sp., *Dalbergia hostilis*, and *Nigrospora* sp. demonstrates the simultaneous representation of humid forest and open woodland vegetation. This pattern is consistent with palynological records from tropical rainforest

ecosystems of southern Nigeria, where *Ficus* and *Uapaca* are among the most abundant arboreal pollen taxa and are interpreted as indicators of closed-canopy rainforest conditions (Walter *et al.*, 2023). However, unlike these rainforest assemblages, the relatively high representation of *Dalbergia hostilis* and other woodland taxa in the present study suggests greater vegetation openness and stronger savanna influence, indicating that the study area represents a forest–savanna transition rather than a continuous rainforest.

The abundance of *Dalbergia hostilis* agrees with reports from Sudano-Sahelian and Guinean savanna regions of Nigeria and other parts of West Africa, where members of the Fabaceae are dominant components of woodland vegetation because of their drought tolerance, efficient seed dispersal mechanisms, and ability to thrive under seasonal climatic conditions (Abba *et al.*, 2022; Nodza *et al.*, 2022; Nyairo & Machimura, 2020). Similar observations have been reported in savanna woodlands of East Africa, where Fabaceae pollen commonly increases during periods of reduced forest cover and increasing aridity. The relatively higher proportion of Fabaceae pollen in this study compared with typical rainforest records therefore supports the interpretation of an ecotonal environment influenced by seasonal moisture limitation.

The occurrence of *Lannea* sp., *Rhus longipes*, *Diospyros abyssinica*, *Vitex doniana*, and *Grewia bicolor* further corroborates this interpretation. These taxa have been widely reported from Guineo-Sudanian woodlands and dry deciduous forests across tropical Africa (Nkulu *et al.*, 2022; Sichone *et al.*, 2023). Their presence agrees with previous studies that identified these genera as characteristic components of woodland vegetation occupying intermediate ecological zones between humid forests and open savannas. Compared with pollen spectra from lowland tropical rainforests, where these taxa are generally poorly represented, their relatively greater occurrence in the present study indicates a stronger influence of woodland vegetation and seasonal climatic conditions.

The occurrence of *Olea capensis* is particularly noteworthy because this species is generally associated with montane and submontane forests. Similar isolated occurrences have been documented in other tropical African palynological records and have been interpreted as evidence of localized humid refugia or relic forest patches that persisted during cooler and wetter climatic intervals (Hoffrén *et al.*, 2022). Its low abundance in the present study

therefore suggests localized favourable microclimatic conditions rather than widespread montane vegetation.

The dominance of Poaceae pollen, including *Panicum maximum*, together with abundant charred grass cuticles and the fungal taxon *Aroconidiellina loudetiae*, is consistent with findings from Sudano-Sahelian and savanna woodland environments where grasses dominate the vegetation and frequent burning plays a major role in ecosystem dynamics (Furquim *et al.*, 2024). Similar increases in grass pollen and charcoal have been reported from West African savanna records during periods of increased aridity and anthropogenic landscape modification. Compared with tropical rainforest records, where arboreal pollen generally exceeds grass pollen, the relatively abundant grass indicators observed in this study suggest recurrent fire events and greater vegetation openness.

Anthropogenic influence is also evident from the occurrence of *Ageratum* sp., *Tridax* sp., *Euphorbia* sp., *Mimosa pudica*, *Carissa edulis*, and *Medicago sativa*. Comparable pollen assemblages have been reported from disturbed tropical landscapes across Nigeria and other African countries, where these taxa are closely associated with cultivation, grazing, roadsides, abandoned farmlands, and secondary succession (Waheed *et al.*, 2023). Their presence, together with cultivated species such as *Cocos nucifera* and *Psidium guajava*, indicates that the vegetation has been substantially modified by human activities. Similar evidence of cultivated and ruderal taxa has been documented in recent palynological studies from tropical rainforest margins undergoing agricultural expansion, demonstrating increasing anthropogenic alteration of natural vegetation.

The occurrence of *Protea* sp., although uncommon in lowland tropical environments, has also been reported in several African pollen records where it has been attributed to long-distance wind transport or to cooler climatic intervals that permitted temporary expansion of montane vegetation (Walter *et al.*, 2023). Its rarity in the present assemblage supports this interpretation rather than indicating the existence of extensive montane vegetation within the study area.

Similarly, *Platyserium* sp. and Polypodiaceae support the existence of moist forest understory habitats, particularly in sheltered or shaded environments (Holtum, 2023). Fungal spores such as *Myxomycete*, *Chaetomium*, *Cercophora*, *Coniochaeta*, *Torula*, *Sordaria*, and *Glomus* sp. reflect litter decomposition, herbivore dung, and soil microbial activity, which are

often associated with grazing and agricultural land use (Zhang *et al.*, 2024). The occurrence of *Puccinia teliospores* and *Nigrospora* sp. also suggests that periods of wet conditions were favorable for fungal parasitism and decomposition. The diversity of spores and fungal remains, including *Sporidesmium macrurum*, *Brachysporium* sp., *Stemphylium* sp., and spore indeterminate types, provides further evidence of ongoing microbial and ecological processes in the sediment matrix and reflects a complex interplay between climate, vegetation, and land use. The coexistence of forest and savanna taxa, along with evidence of disturbance species, supports a dynamic landscape that responds to climatic shifts and human land use.

The lithological stratigraphy of the sediment core revealed four distinct units (LC-01 to LC-04), each representing shifts in depositional energy, sediment sources, and paleoenvironmental conditions. These variations provide a critical context for interpreting palynological signals and reconstructing past environmental changes.

Unit LC-01, composed of brown, moderately hard, non-fissile mudstone, is characteristic of fine-grained sedimentation in a low-energy environment, such as a floodplain, overbank setting, or shallow lacustrine basin. Such mudstones typically accumulate in environments with minimal current activity, where suspended sediments settle gradually (Wang *et al.*, 2025). The absence of fissility and the cohesive nature of the mudstone imply limited desiccation and compaction, suggesting subaqueous deposition with relatively consistent moisture availability (Mussini *et al.*, 2025). Palynological assemblages recovered from this unit, including pollen of Poaceae, *Olea*, *Tridax procumbens*, and spores of Polypodiaceae, together with fungal taxa such as *Alternaria* and *Cercophora*, are typical of modern tropical vegetation and soils. These taxa are widely reported in Holocene sediments across tropical Africa, indicating that the deposits most likely correspond to the Holocene epoch, when present-day vegetation patterns became established.

Unit LC-02 comprises light gray, coarse to fine-grained, sub-angular, poorly sorted sand, which is indicative of a high-energy depositional environment, such as a braided river channel or proximal alluvial fan (Abdel-Fattah & Sehsah, 2023). The poor sorting and subangular grain morphology point to rapid deposition and limited transport distance, consistent with episodic fluvial events, such as flash floods or high-discharge flow episodes (Lehmkuhl & Owen, 2024). These sediments likely reflect increased

hydrological energy capable of transporting and depositing mixed grain sizes over a short timeframe. The palynomorph content within this unit is relatively sparse, which is typical of high-energy depositional settings where pollen preservation and accumulation are often reduced. The presence of modern angiosperm pollen and fungal spores suggests that the sediments were deposited under already established vegetation communities, consistent with a Holocene age.

Units LC-03 and LC-04, while stratigraphically distinct, share similar lithological features consisting of light gray, fine-grained, angular, very well-sorted sand interbedded with dark gray, hard, non-fissile mudstone. The well-sorted and fine-grained nature of the sand suggests sustained low-energy fluvial or lacustrine sedimentation, possibly in a distal floodplain or marginal lake setting, where sediment reworking is minimal and deposition occurs primarily through suspension settling (Butt *et al.*, 2024). Interbedding with mudstone layers indicates episodic shifts in hydrodynamic conditions, possibly driven by seasonal flooding or changes in water level (Daraei *et al.*, 2023). The angularity of grains, despite good sorting, might reflect short transport distances from source areas, potentially via tributary inputs.

Palynological assemblages recovered from these upper units are characterized by abundant herbaceous pollen, fern spores, and fungal remains such as *Glomus*, *Sporidesmium macrurum*, and *Delitschia*. These taxa are commonly associated with soil activity, plant litter decomposition, and disturbed terrestrial environments. The dominance of modern pollen taxa and saprophytic fungal spores suggests deposition under recent climatic and ecological conditions, most likely within the Holocene epoch. This interpretation is consistent with regional palynological studies across tropical West Africa, where similar pollen assemblages indicate vegetation development and environmental conditions characteristic of the Holocene epoch.

The lithological similarities between LC-03 and LC-04 suggest a prolonged phase of relatively stable depositional processes interrupted by periodic increases in water or sediment supply. Such conditions are often observed in semi-arid to sub-humid regions, where intermittent hydrological pulses control sedimentation without significantly altering the dominant sedimentary regimes (Lima *et al.*, 2021). These sedimentary conditions likely correspond with palynological assemblages, which also indicate fluctuations in vegetation and climate tied to hydrological variability and anthropogenic

activity. The lithofacies variability across the core reflects a dynamic interaction between climatic drivers, fluvial dynamics, and anthropogenic influences. Based on historical records and land-use patterns in the region, human activities such as subsistence agriculture, logging, bush burning, grazing, and settlement expansion have likely contributed to vegetation disturbance, increased soil erosion, and enhanced sediment input into the depositional system. These activities may have influenced sediment composition and deposition patterns recorded within the core. The integration of lithological and palynological data strengthens the interpretation of environmental stability, punctuated by episodic shifts in energy and sediment supply, which is typical of many tropical fluvial-lacustrine systems.

The results of the geochemical analyses, particularly pH and salinity measurements, provide critical insights into the chemical environment of the depositional setting and the preservation potential of organic microfossils. These parameters, which vary across the sediment core, reflect localized shifts in hydrology, sediment input, and biogeochemical conditions. The lowest pH values (highest acidity) were recorded for sample LC-03, suggesting a more acidic depositional environment than that of the other units. This acidity may have resulted from increased organic matter decomposition, iron and sulfur oxidation, or the input of acidic surface or groundwater, all of which can reduce sediment pH (Asif *et al.*, 2025). Acidic conditions are particularly important because they can selectively degrade more delicate or poorly sporopollenized palynomorphs, thereby biasing the preserved assemblage (Wheeler *et al.*, 2021). As such, the palynological composition of LC-03 may reflect both the original vegetation and taphonomic filtering due to pH-driven diagenesis. In contrast, LC-04 showed relatively alkaline conditions, suggesting either enhanced carbonate input, reduced organic decay, or an influence from basic lithologies or groundwater (Zheng *et al.*, 2021). Alkaline environments are generally more conducive to the preservation of a wide range of palynomorphs, as basic pH tends to stabilize organic matter and reduce chemical degradation (Aggarwal, 2022). The relative alkalinity in LC-04 may help explain the better preservation or higher diversity of palynomorphs observed in that layer, assuming that other factors, such as sedimentation rate and oxygen availability, were favorable.

Salinity values also varied, although within the expected range for continental freshwater to mildly

brackish depositional systems. While no extreme salinity was recorded, slight increases in conductivity can suggest episodes of evapoconcentration, influx of mineral-rich water, or reduced freshwater input (Mushet, 2022). These fluctuations may indicate seasonal or climatic variability, which can affect microbial activity, diagenesis, and the preservation of organic matter (Xu, 2023). However, in this context, the variation in salinity was secondary to pH in controlling palynomorph integrity. The pH and salinity data further support the sedimentological and palynological interpretations, strengthening the belief in dynamic depositional conditions throughout the sequence. Specifically, they highlight the chemical heterogeneity of the sediment-water interface, which plays a crucial role in determining palynomorph preservation potential and the representativeness of recovered assemblages.

CONCLUSION

This study reconstructs past environmental conditions through lithological, palynological, and geochemical analyses of sediment cores. It identified four distinct sedimentary units (LC-01 to LC-04) that reflect transitions from low- to high-energy depositional environments influenced by hydrological variability. Palynological data indicated shifts in vegetation from forest to savanna and disturbed landscapes, providing evidence of both climatic fluctuations and human activity. Geochemical results, particularly variations in pH and salinity, further elucidated patterns of palynomorph preservation, demonstrating how acidic or alkaline conditions affected the integrity of fossils. The study revealed a dynamic environmental history shaped by both natural processes and anthropogenic impacts.

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AUTHORS CONTRIBUTION

OJW and GIN conceptualized the study, designed the methodology, and led field sampling and laboratory analyses. LBA contributed to data analysis, interpretation of palynological results, and manuscript drafting. SAH supported fieldwork, sample preparation, and quality control during

laboratory procedures. TOO assisted with data processing, literature review, and preparation of figures and tables. OTO critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available upon reasonable request from the relevant author.

ETHICAL CONSIDERATION

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare that they have no known competing interest.

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