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Applications of Pollen and Spore Studies to Paleo-Vegetation Inferences of Iwopin, Ogun State, Nigeria

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Abstract
Modifications of Land Use Systems is a trigger of change in flora composition. Fossilized pollen and spore assemblages are key to unraveling past climatic and vegetation types. Eight (8) core samples recovered at three centimeters interval each were subjected to standard palynological protocols. The lithology, pH and salinity concentrations of each sample was also determined. The recovered pollen and spore assemblages revealed three distinct zones (24 – 15cm, 15-3cm and 3-0 cm) based on indicator palynomorphs. The lowest stratum in zone 1 (24-21 cm) suggests a mosaic of rainforest and open vegetation taxa. This contrasts with stratum 21-18cm, whose indicative vegetation composition was that of freshwater swamp species. Climatically, top strata are wetter than lower ones. Zone 11 was characterized by open vegetation elements such as Alchornea and Asteraceae which are indicative indices of drier period. However, occurrence of substantial amounts of fern spores at depth 9-12 cm, coinciding with appearance of fresh water elements is suggestive of interplay between terrestrial and aquatic forces. Zone 111 was characterized by representatives of fresh water swamp, open vegetation and rainforest phytoecological groups. Fresh water swamp elements and fern spores dominated this zone, indicating a very wet period. The surface sample indicates an environment purely of an open vegetation type with high distribution of Elaeis guineensis, Pteridophyte spores and fungal spores. The Pteridophytic spores indicate regular flooding, probably from the nearby lagoon. Presence of charred cuticle is presumptive of a people at ease with bush burning, an existential promoter of global warming.
***Keywords**: Climate, fossils, paleo ecology, pollen and spores.*

INTRODUCTION

Fossilized pollen and spore assemblages hold a part of the key to unraveling and decoding past climatic and vegetation dynamics. In Nigeria as in other countries, various industrial efforts and unending quest for developmental projects had inadvertently replaced and/or modified past habitats with one whose species identity and diversity differ significantly from those of prehistoric times (Morrey *et al*., 1988; Oribhabor, 2016; Vasquez et al., 1999; Mishra et al., 2004; [David and Clarence, 2001). In some instances, aquatic environments were totally submerged giving rise to terrestrial landscape (Hugo, 2013) and vice versa. Deliberate and/or natural changes to hydrological regimes has often been fingered as causal factor for species and habitat alteration over time (Zeiringer et al., 2018). Since individual species preference to ecological factors varies markedly, taxon occurrence is implicitly a response to unique or defined range of climatic variations. The uniqueness of taxa as responders to specific climatic conditions was the basis for species evolution as famously captured in the construction of the Evolutionary Time Scale (Hatfield et al., 2011) reported unique temperature ranges for *Glycine max*, *Arabidopsis thaliana* and *Zea mays* just as (Opeyemi et al., 2016) and (Kitren and Louise, 2007), reported defined ranges of rainfall and humidity conditions for *Musa acuminata, Citrus sinensis* and *Fotunella spp* plants. The identity of flowering species in a locality is also partly in response to prevailing wind speed, wind direction and erosion dynamics as exemplified by sediment history. The identity of the dominating climatic factor(s) in an area whose fossil records is dominated by plant taxa with specific seed characteristics is well documented (Li et al., 2012) and (Momohara, 2016). All these aptly demonstrate the importance of fossilized pollen as excellent provider and preservator of past recorded events in any ecological system. While the thickness of the exine of palynomorph and their depositional environment play important roles in the preservation of palynomorphs, examination of their preservation state provides quantitative data concerning the degree of information loss due to alteration of pollen assemblages by syndepositional and post-depositional deterioration (Delcourt and Delcourt, 1991).

Regardless of the paucity of literature on core paleoecological research for coastal environments in Nigeria, the works of Sowunmi published in Sowunmi (1981a); Sowunmi (1986); Sowunmi (1987); Sowunmi (1999); Sowunmi (2002); Sowunmi (2004), gave important insights into paleoecological research. Iwopin is a member of the Dahameyian basin reported by Sowunmi (2004) that underwent paleoecological changes from the inter-tidal mangrove swamps between (ca. 8,576 ± 48 BP comprising predominantly *Rhizophora* to freshwater swamp/ Savannah vegetation around ca. 3,109 ± 26 BP. It was inferred that the disappearance of the previously *Rhizophora* dominated mangrove swamp was in response to a much-reduced sea water inundation coupled with fresh-water intrusion which effectively replaced or suppressed the hyper-saline tidal water, resulting in a marked hydrological change soil type. This ecological phenomenon was accelerated by the transgression phase experience within that time frame, exemplified by the marked decrease in sea levels. The cumulative effects of these ecological events were further confirmed by more recent palynological studies Okwong et al. (2019); Adeonipekun and John (2011); Ajkah et al. (2015); and Ajikah et al. (2019) in this basin confirming vegetation changes.

GIS imagery indicated the Land use systems for 1984 and 2018 when the core samples for the study were recovered. (See Fig 1).

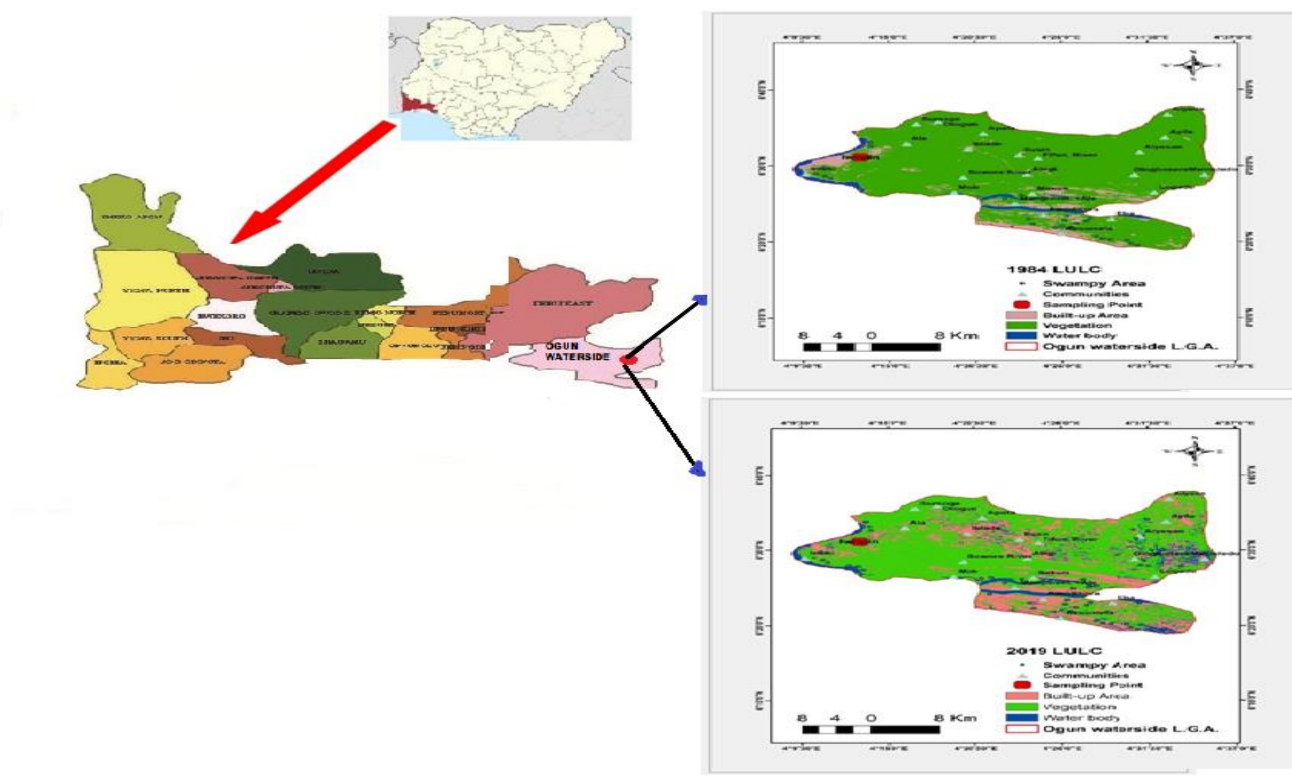

Fig 1. 1984 and 2019 land use-land cover maps of study area
Fig 2. Map of Nigeria showing Ogun State

The land use of the area in 1984 indicated one with reduced anthropogenic influences. This contrasted with present vegetation and land use types which showed increased human pressures (Table 1).

Table 1: Land Use Land Cover Analyses of Ogun water side LGA in 1984 and 2019

1984			**2019**		
CLASS	Area (ha)	**(%)**	**CLASS**	**(%)**	Area (ha)
Built-up	8,981.6	9.4	Built-up	24.8	23,646.3
Vegetation	83,629.6	87.7	Vegetation	66.3	63,278.2
Water body	2,792.1	2.9	Water body	8.9	8,478.8
Total	95,403.3	100.0		100.0	95,403.3

This study is therefore primed in applying palynological and physico chemical studies to decipher the exact flora identities of the past environment, the climate of the past environment and habitat (s) of the past environment. It is also to identify the possible change driver (s) while understanding the mechanisms that triggered the changes.

MATERIALS AND METHODS

Description of surrounding environment

The study area was predominantly a fishing community in Waterside LGA, Ogun State South West Nigeria. Ogun Waterside LGA is the only area of the State with a coastline on the Bight of Benin, and also borders Lagos Lagoon. The sampling site was fresh water swamp, dominated by ferns like *Nephrolepis undulata*, *Nephrolepis biserata*, and *Polypodium*. Other plant species present there *were Ipomoea involucrata, Alchornea cordifolia, Panicum maximum, Luffa aegyptiaca, Musa paradisiaca, Paspalum vaginatum, Bambusa vulgaris, Colocasia esculenta and Penisetum spp.* The river bank was dominated by *Eichhornia crassipes* (water hyacinth), which is an invasive species and was said to have appeared in the area of study in 1989. The area was highly disturbed by farming, fishing activities, and boat making. The terrain was water-logged, with sandy soil type. This posed a challenge during sample collection, as it was not possible to obtain sample at full core. Plate 1 pictorially illustrate sampling operations at site.

Plate 1: Sampling Exercise at Site

Sample collection and laboratory methods

Sample was collected at latitude 6.518942 and longitude 4.219773. The study site is swampy and is drained by Lagos Lagoon and River Sowore (See Fig 1). Corers were used in collecting sediments at 3cm intervals over a depth of 24cm. Collected sediments were sealed, labelled properly and transported to paleobotany and palynology laboratory, University of Lagos. The determined lithological samples were subjected to pH analysis and standard palynological technique treatments (demineralization, heavy liquid separation and acetolysis). All eight samples were sent to BA analytical laboratory, Atlanta, Georgia, USA for radiometric dating.

Microscopy and Photomicrography

Microscopy and photomicrography of the specimens was taken using Am Scope MA1000 camera with an in-built micrometer. Permanent slides of the prepared pollen samples will be deposited in the Department of Botany, University of Lagos.

Identification of Phytoecological Groupings

Pollen grain identification was done by comparison with reference atlases of the region and with published and unpublished descriptions and keys of African pollen grains and spores. Each observed pollen was quantified and placed into phytoecological groups for vegetation and climatic inferences with the help of manuals and atlases such an Outline of Nigerian Vegetation by Keay (1959), Pollen of Nigerian Plant 1 & 2 by Sowunmi (1973), Pollen grains of Lagos lagoon swamp and hinterland vegetation by Adekambi et al. (2009) and a pollen atlas of fossil pollen provided by the department.

RESULTS

The results of the lithological units, pH and salinity concentrations are shown in Table 2

Table 2: Lithological Units Description, pH and Salinity Concentrations

Depth (cm)	Colour	Lithological description	Comment	Salinity(ppt)	pH
Surface	dark grey	predominantly loamy sand with medium grained to coarse grained, poorly sorted, sub-angular to angular particles	very dirty sample	4.14	7.14
0-3	dark brown to dark grey	Evenly distributed portions of loamy sand with medium grained, well sorted angular particles and non-fissile shale	clear sample with fine grained particles	3.81	6.94
3-6	creamy to light brown	predominantly sand with coarse grained, poorly sorted angular particles mixed with smaller portions of non-fissile shale	barren sample: only fungal spores present	3.72	6.81
6-9	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale	barren sample: only fungal spores present	3.39	6.83
9-12	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale	very dirty sample with high organic content and low representation	3.58	6.63
12-15	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale	Clear sample with organic content. Very low representation of pollen and spores	3.72	6.88
15-18	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale	barren sample	3.52	6.49
18-21	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale	Clear sample with organic content. Very low representation of pollen and spores	3.89	6.49
21-24	creamy to light brown	predominantly sand with coarse grained, poorly sorted sub-angular to angular particles with small portions of non-fissile shale and mudstone	Clear sample with organic content. Very low representation of pollen and spores	3.65	6.64

Pollen analysis

The result (Table 3) revealed the basal age of the sample as ca 3$\pm$ 1 BP and that of the last as ca 39 $\pm$ 4 BP. The result showed dominance and diversity of fungal spores, comparatively higher taxa diversity and count in the two upper strata, total palynomorph barrenness at stratum 15 – 18cm, absence of all other palynomorphs except fungal at stratum 3-6cm and 6 – 9cm and episodic intrusions of Cyperaceae, *Ceraptopteris pteroides*, CPC, *Tridax procumbens* and trilete spores.

Table 3 : Palynomorph diversity and count

Depth (cm)	Age (BP)	*Alchonea cordifolia*	*Arecaceae*	*Asteraceae*	*Cyperaceae*	*Elaesis guineensis*	*Ipomea involucarata*	*Nymphea lotus*	*Poaceae*	*Terminalia sp*	*Tridax procumbens*	*CPC*	*Ceraptopteris pteroides*	*Cyclosorus*	Fungi spores	*Nephrolepis sp*	Pteris sp	Trilete spores
0	9					3			2		2				21	4		
3	17	2	3	1	1		1	2	7	1			1	1	57	17	2	2
6	26														2			
9	39														16			
12	54	3	1			1		1	4			2		5		16	1	
15	72			1											8	2		
18	86																	
21	98						3	1	1	1					15			
24	110	1							2	1					6			

The recovered palynomorphs is shown in Plate 2. The recovered palynological assemblage also consists of pollen, pteridophyte spores, and charred cuticular remains of Poaceae. Some pollen grains were identified to species level while others were identified to either generic or family level.

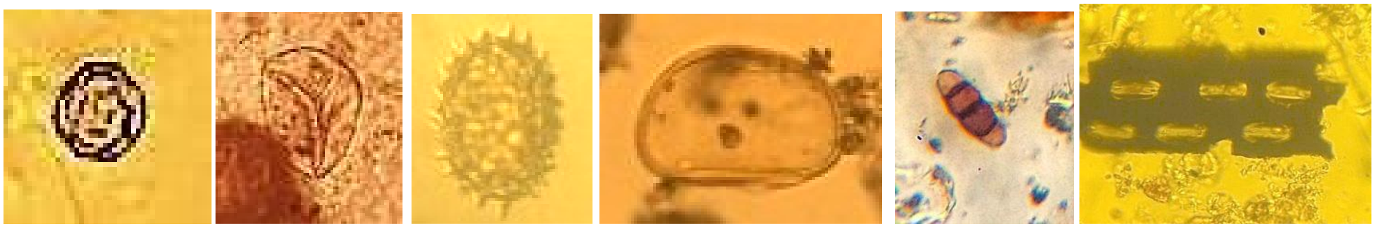

Plate 2: A: *Terminalia* sp. **B:** Trilete Fern spore **C**: Asteraceae **D**: *Cyclosorus afer*
E: fungal spore **F**: Charred Poaceae cuticle (All Magnification x40)

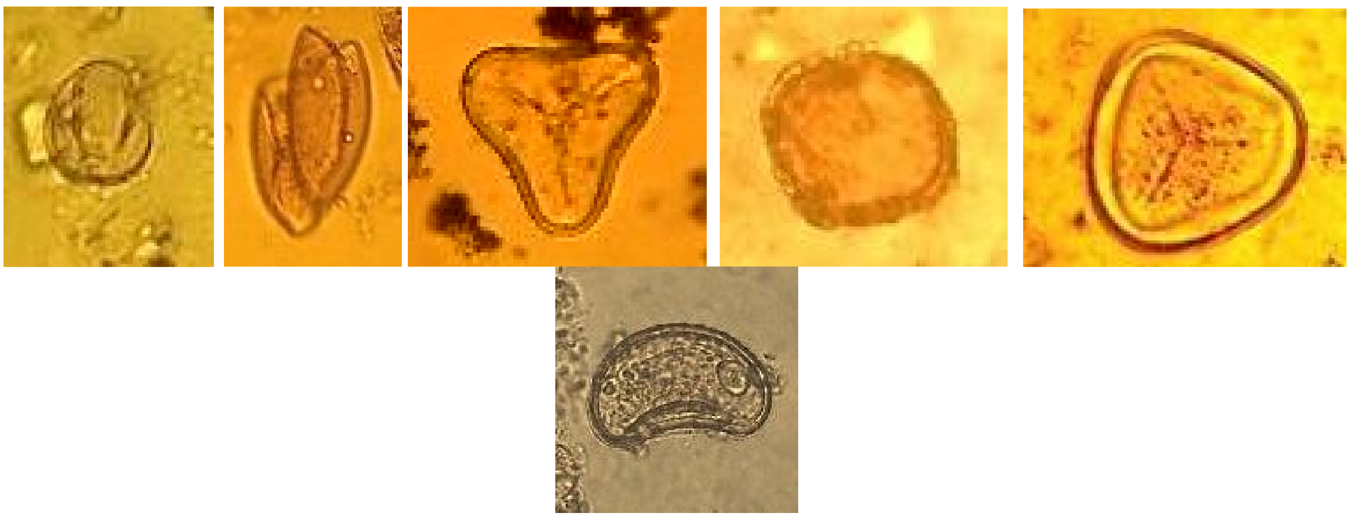

Plate 3: G: Alchornea *chordifolia* **H:** Arecaceae **I***: Elaeis guineensis* **J:** Indeterminate pollen
K: *Pteris*sp **L:** *Nephrolepis undulata* (All Magnification x40)

The pollen diagram (Fig 2) synchronizes taxa diversity and counts with radiometric dating, pH and salinity concentrations.

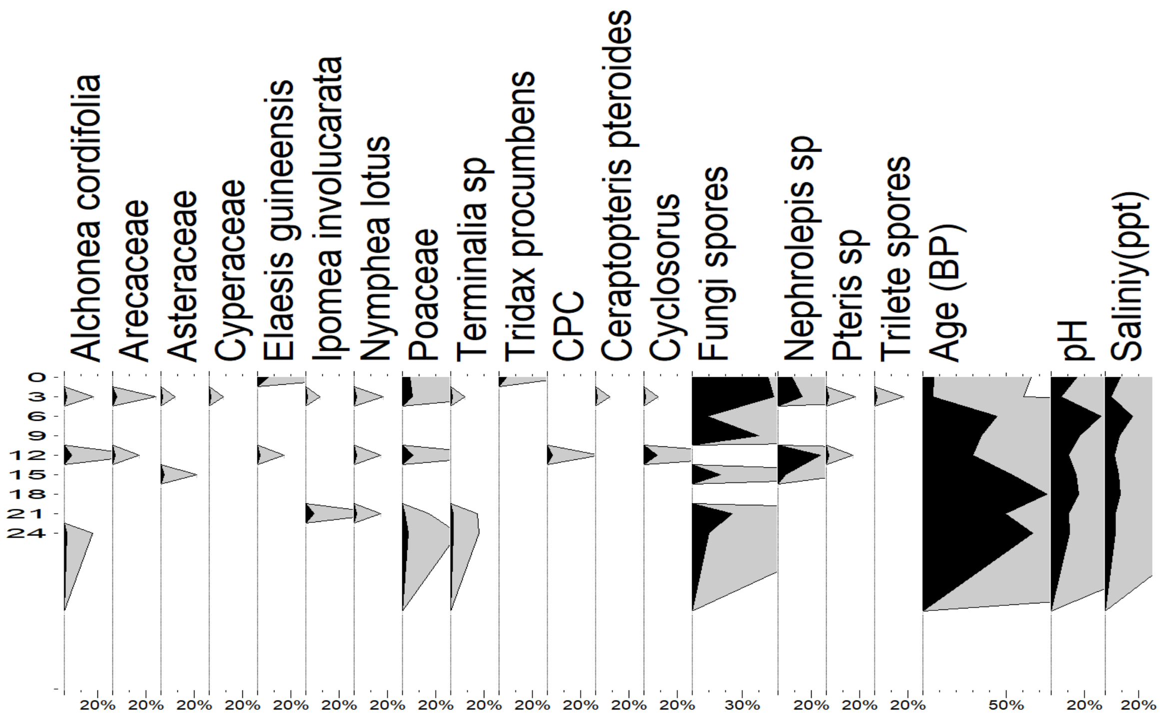

Fig 2. Pollen diagram

Phytoecological groupings (Table 3) present results of pollen abundance per depth based on indicator palynomorphs. The groupings also agree with the works of Hutchinson and Dalziel (1954), Sowunmi (1981b) and Adeonipekun, and John (2011). Poaceae was taken as a group because of its climatic significance in corroboration with the other phytoecological groups (Sowunmi, 1981b) while spores were taken as another independent group due to their hydromorphic nature and their penchant for being high in production during wet climatic phases (Adeonipekun, and John, 2011)

Table 3: Relative Percentage (%) of the Phytoecological Groups

Depth (cm)	FWSF	GLRF	OV	Cyperaceae	Poaceae	Pteridophytic/ fungi spores
Surface	0	0	6.90	0	6.90	86.20
0-3	3.06	1.02	6.12	1.02	7.14	81.64
3-6	0	0	0 0	0 0 0	0 0	100
6-9	0	0	0	0	0	100
9-12	2.94	0	14.71	0	11.76	70.59
12-15	0	0	9.09	0	0	90.91
15-18	0	0	0	0	0	0
18-21	19.05	4.76	0	0	4.76	71.43
21-24	0	10	10	0	20	60
Total	25.05	15.78	46.82	1.02	50.56	660.76

Key: **FWSF**-Fresh water swamp forest, **GLRF**-Guinean Lowland Rainforest and **OV**-Open vegetation

DISCUSSION

Correlation of species preferences for climatic conditions were used to establish boundaries in the section studied. These zones are discussed under vegetation and climatic influences.

Location B Zone I (24-15 Cm)

Vegetation inference

Grey soils as observed in the surface and 0-3cm sampling interval is usually a product of poor iron oxide concentrations (Huang et al., 2016) as opposed to lateritic soils found in most coastal areas of Nigeria (Adeyemi

et al., 2015) where high Fe_2O_3concentrations impact a brownish to brownish to reddish colorations to the soil (Adewole, 2015). All other sampling lithology except the upper two exhibited the latter soil colour types. This colour graduation is indicative of soils progressively richer with Fe_2O_3 concentrations with depth. This trend is expected in soils that are progressively more compacted as depth increases. The medium to well sorted grained sized soil observed in the two upper sampling interval is suggestive of soil with moderate water retention capacity which in this case is loamy. The soil colour type and the loamy textural class conferred a slightly acidic to slightly alkaline nature on the soil as exemplified by the measured pH in the two upper strata as opposed to the more acidic nature observed in lower strata. The alkalinity profile and slightly acidic nature observed at the two upper strata in an otherwise sampling site with high rainfall pattern is suggestive of leaching effect as it ought to be at least moderately acidic (Hui et al., 2019).This position is corroborated by the recorded salinity concentrations in the two upper strata when compared to all the other lower strata. Leaching process have variously been reported as influencing factor on soil organic matter and content (McCauley et al., 2017).
The implied leaching action determined by the measured physico chemical conditions would have certainly impacted hugely on the type and abundance of recovered palynomorphs observed in each sampling stratum.
Dominance of this zone by spores (Fungi and *Nephrolepis*) is indicative of a wet habitat. This assertion is further strengthened by the presence of *Ipomea* and *Nymphea*. Nyannanyo 2006 reported the occurrences of these species in the Nigerian fresh water environments. Presence of a mosaic of Guinean lowland rainforest, *Poaceae* and open vegetation components in the lower stratum of the zone (24-21 cm) suggest anthropogenic influences. This contrasts with the top strata (21-18 cm), whose indicative vegetation composition was exclusively that of freshwater swamp forest elements. The near disappearance of the Guinean lowland and open vegetation members in the top strata suggest the anthropogenic disturbances to be episodic in nature. However, the strength of this assertion is severely impaired due to the poor pollen recovery ratio from the sediment. There was an absence of palynomorphs at (18-15 cm) which may be attributed to the poor conditions of palynomorph preservation; a view which is also supported by the lithological characteristics of the samples (Table 3), as well as its nearly alkaline pH confirming leaching action. This is in agreement with Dimbleby (1957), who stated that soils with low pH are ideal vectors for pollen preservation, while fossil pollen in sediments with pH above 6.0 are often degraded or completely destroyed. Low percentage of Poaceae throughout the zone indicate the presence of a wet, warm climate while the total absence of *Rhizophora* and Cyperaceae may possibly suggest the absence of any coastal environment or soil inundation of any form.

Zone II (15-3 cm)

Vegetation inference

The operational physico chemical conditions in Zone 1 also applicable in Zone 11. However, the poorly sorted grain size and the increasing sub angular nature is informative of sediments subject to perturbations and rapid percolations (Hui and Changing, 2019), a characteristic typical of sandy textural class (Miguel et al., 2017).
This zone is characterized by open vegetation elements such as *Alchornea cordifolia* and Asteraceae which are indicative indices of a drier period than the previous zone. Absence of Cyperaceae pollen in this zone is indicative of drier topographical conditions; conditions that are suitable for the increased growth and proliferation of open vegetation components. Pteridophytic spores and a low percentage of fresh water forest elements as exemplified by fungal and fern members made brief intrusions into the fossil records before completely faded off. The fact that the Pteridophytic assemblages was dominated by a single taxon is perhaps an indication of episodic event that once promoted favorable growth of that species before an abrupt harsher condition sets in that extinguishes it. The fact that it faded out completely within a short period without following a thinning out trend strengthens the argument of an episodic event. The two uppermost depths of this zone are devoid of pollen recovery and this could be traced to lithological characteristics, the pH of the sediment samples and leaching action. In addition to the afore said factors, the complete disappearance of the vegetation in those depths, could also be due to anthropogenic activities that converted predominantly vegetation land use type in 1984 to built-up areas and riparian patches (See Table 1). Interview with the natives

attributed increased flooding episodes, re channelization of drainage course as erosion control measure and also for irrigation farming as causal factors that enlarged the fresh water swamp forest in study area.

Zone III (3-0 cm)
Vegetation inference
This zone is characteristically occupied by representatives of the fresh water swamp, open vegetation and Guinean lowland rainforest phytoecological groups. Fresh water swamp elements and fern spores dominated this zone, indicating a very wet period that may support the inundation of soil with water; the optimum conditions for the growth of fresh water swamp vegetation. This is further corroborated by reduced percentages of Poaceae and open vegetation groups. The presence of Guinean lowland rainforest group (albeit low) indicates a positive confirmation of the wet period. The sudden appearance of a trilete spore, an indication of contamination with the past could have presumably resulted from change in hydrological regime and depositional pathways.

Surface zone
The pollen from the surface sediments sample can be said to be from the immediate extant locality. This surface sample indicates an environment that is purely that of an open vegetation type with high occurrence of *Elaeis guineensis*, Pteridophytic spores and fungal spores. There is a conspicuous absence of all other phytoecological groups excluding the open vegetation and Poaceae. The Pteridophytic spores indicate regularly flooding, probably from the nearby lagoon. The interpretation of this sediment when compared with the previous zones showed that anthropogenic activities such as agriculture (specifically slash and burn), and logging probably for shelter has drastically altered the component vegetation of this area.

CONCLUSION
The study observed palynomorph discrimination with depth confirming leachate actions, episodic events and anthropogenic activities. The sediment travel was observed to be short, a characteristic of sandy soil textural class that promotes rapid percolation. Anthropogenic actions in the project area is changing the hydrological regime with its attendant consequences on habitat alteration and function. The presence of charred cuticle is presumptive of a people at ease with bush burning, an existential promoter of global warming.

RECOMMENDATION
Reforestation of the area is required as an effective mitigation measures against the impacts mediated vegetation and habitat alteration.

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