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Late Quaternary Paleoenvironmental Dynamics on the Cameroonian Continental Shelf (Gulf of Guinea): Palynological and Sedimentary Insights

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Abstract

The palynological study of core C61, retrieved from the Cameroonian shelf near the Sanaga Delta, offers new insights into the evolution of coastal environments and vegetation dynamics in Central Africa since the end of the Last Glacial Maximum. This 6-meter-long marine sequence spans the transition from the Late Pleistocene to the Late Holocene. Pollen analysis of 26 stratigraphic levels revealed rich and diverse assemblages (224 taxa, 93 families), allowing the identification of three major paleoecological phases: 1) a warm and humid period dominated by shrub savannas (*Cyperaceae*, *Bridelia*, *Combretaceae*) inland and *Rhizophora* mangroves along the coast; 2) a more open landscape phase marked by the expansion of grasses (*Poaceae*), *Commelina*, and spores, though without strong evidence of aridification; 3) a phase characterized by alternating humid and drier intervals, reflected in the decline of herbaceous taxa and the development of forest species (*Caesalpiniaceae*, *Sapotaceae*, *Sacoglottis*, *Podocarpus*). These stages roughly correspond to the Early, Middle, and Late Holocene. While the sequence captures broad environmental trends, gaps in chronological resolution limit the detection of short-term climatic events such as the ca. 2.5 ka dry phase observed in nearby lake archives. The C61 record highlights the high sensitivity of coastal vegetation in Central Africa to Holocene climatic variability, particularly to latitudinal shifts of the Intertropical Convergence Zone (ITCZ). By linking marine pollen signals to regional vegetation dynamics, this study contributes to refining our understanding of the long-term ecological responses of tropical coastal systems to climate forcing.

Keywords

Paleoenvironments, Climate, C61 Marine Core, Pollen, Central Africa, Cameroon, Holocene

1. Introduction

Each year, the Conferences of the Parties (COP) underscore the profound impact of human activities on the environment, particularly through fossil fuel exploitation, urbanization, and deforestation (IPCC, 2021; Malhi et al., 2014). These processes severely disrupt ecosystems and contribute to global climate instability. However, in the context of this study—which focuses on Holocene and Late Pleistocene periods—such anthropogenic impacts are not relevant, as the recorded environmental changes occurred well before significant human intervention.

In this context, the study of natural archives is crucial for improving our understanding of past interactions between climate and vegetation. Paleoenvironmental analyses, especially those based on pollen records, make it possible to compare past and present climatic conditions. In the case of core C61, the focus is not on anticipating future climate change but rather on documenting past environmental dynamics to establish robust paleoecological baselines (Lézine et al., 2009; Dupont, 2011). The palynological approach has been widely employed in Africa to reconstruct past environmental and climatic conditions, both in terrestrial and marine contexts.

In West Africa, numerous studies have examined both continental sedimentary sequences (Maley, 1987; Lézine, 1988; Lézine & Cazet, 2005; Assi-Kaudjhis et al., 2010) and marine sequences (Hooghiemstra et al., 1986; Caratini et al., 1987; Fredoux, 1980; Fredoux, 1994; Marret, 1994; Dupont & Weinelt, 1996; Dupont, 2012). However, detailed knowledge of hydrodynamic processes, the origin of pollen grains, and their modes of transport and deposition within sedimentary basins remains limited (Vincens et al., 1994; Lézine & Casanova, 1989). Recent progress has been achieved through studies of modern pollen dispersal on the Cameroonian continental shelf, which have highlighted the crucial role of marine hydrodynamics in shaping the spatial distribution of pollen grains (Bengo et al., 2025).

In Central Africa, most research has focused on lake sediment sequences (Brenac, 1988; Elenga et al., 1992, 1994, 2001, 2004; Reynaud-Farrera, 1995; Reynaud-Farrera et al., 1996; Stager & Anfang-Sutter, 1999), which provide valuable pollen records for reconstructing local paleoecosystems. These studies have significantly enhanced our understanding of the evolution of equatorial forests and their sensitivity to climatic variability (Ngomanda et al., 2005, 2009a, 2009b; Lebamba et al., 2009, 2012; Maley et al., 2017). However, marine pollen records remain scarce in this region, particularly off the Gulf of Guinea and along the Cameroonian continental shelf (Bengo et al., 2025; Van Campo & Bengo, 2004).

Yet, these marine deposits represent a crucial source of information, as they integrate a regional signal across the Gulf of Guinea (Lopez-Merino et al., 2018; Julier et al., 2018; Hernandez et al., 2021; Tahi, 2022), Central Africa (Bengo & Maley, 1991; Roche, 1991; Runge, 2007), and Eastern and Southern Africa (Dupont et al., 2022; Neumann et al., 2025; Yao et al., 2025).

This local and regional information can be compared with marine and deltaic records from similar tropical environments—for example, offshore the Congo River, where deep-sea fan deposits integrate continental inputs and reflect regional hydro-sedimentary dynamics (Dupont & Agwu, 1991; Giresse et al., 1995); in the Niger Delta, where palynological and sedimentological data document the evolution of fluvio-marine environments in response to climatic and eustatic variations (Giresse et al., 1995); along the Ogooué margin, which provides an integrated 26,000-year record of terrestrial and marine environmental changes off Gabon (Ngomanda et al., 2005; Gasse, 2000); and even along the Amazon margin, where oceanic sediments reveal fluctuations in hydrological and sedimentary inputs linked to tropical climate variability (Maley & Brenac, 1998). Such comparisons provide a better understanding of the sedimentary and ecological dynamics of tropical fluvio-marine systems.

It is within this framework that the present study was undertaken, based on the analysis of core C61, collected from the Cameroonian continental shelf during the oceanographic campaigns CAMPUS-Cameroon, CHRIS-Elf, and ECOFIT (CNRS & ORSTOM). Several datasets from these missions have already been analyzed, particularly focusing on the mineral (Ngueutchoua, 1996) and pollen (Bengo, 1996) fractions of the sediments. These studies identified distinct lithological units and sedimentary structures that were interpreted in relation to the regional Holocene transgression and associated environmental changes (Ngueutchoua, 1996; Giresse et al., 1995), thus providing a stratigraphic and paleoenvironmental framework that underpins the present investigation. However, their potential for integration into a regional paleoclimatic reconstruction remains underexplored.

The main objectives of this study are

- to compare present-day flora with that of past periods in order to highlight major trends in vegetation evolution;
- to reconstruct past environments and climates based on pollen analysis;
- and to identify the main ecological transitions through time by analyzing the variability of key environmental indicators, particularly during the Holocene.

A more specific assessment of possible anthropogenic influences is not attempted here, as this would require a focused analysis of recent intervals (post-2500 or post-1000 BP), which falls outside the scope of the present study.

This study, therefore, aims to enhance our understanding of climate-vegetation interactions in Central Africa by providing a robust reference framework for interpreting ecosystem responses to past and present environmental changes. While future dynamics remain uncertain and cannot be directly inferred from the available data, the paleoclimatic record from core C61 offers valuable insights into the range of natural variability and the resilience of ecosystems to climate fluctuations.

2. Materials and Methods

2.1. Environmental Framework

2.1.1. Location and General Context of the Study Area

Core C61 was collected in the Gulf of Guinea, on the central part of the Cameroonian continental shelf, at a depth of approximately 200 meters (**Figure 1**). This area lies along the upper margin of the continental slope and is strongly influenced by riverine inputs from the Sanaga River, as well as other coastal rivers such as the Wouri, Nyong, and Ntem. These rivers transport fine-grained sediments rich in organic matter and pollen into the marine environment. The Sanaga River watershed, which spans roughly 133,000 km^2, covers a broad ecological gradient from humid equatorial forests in the south to drier savanna regions in the center and north of Cameroon (Bengo et al., 2020). This wide range of source environments contributes to the mixed continental signature of the sedimentary inputs observed offshore. Since most detrital particles reaching the shelf originate from continental erosion, the marine sedimentation in this area primarily reflects terrigenous input, aside from biogenic components produced in situ.

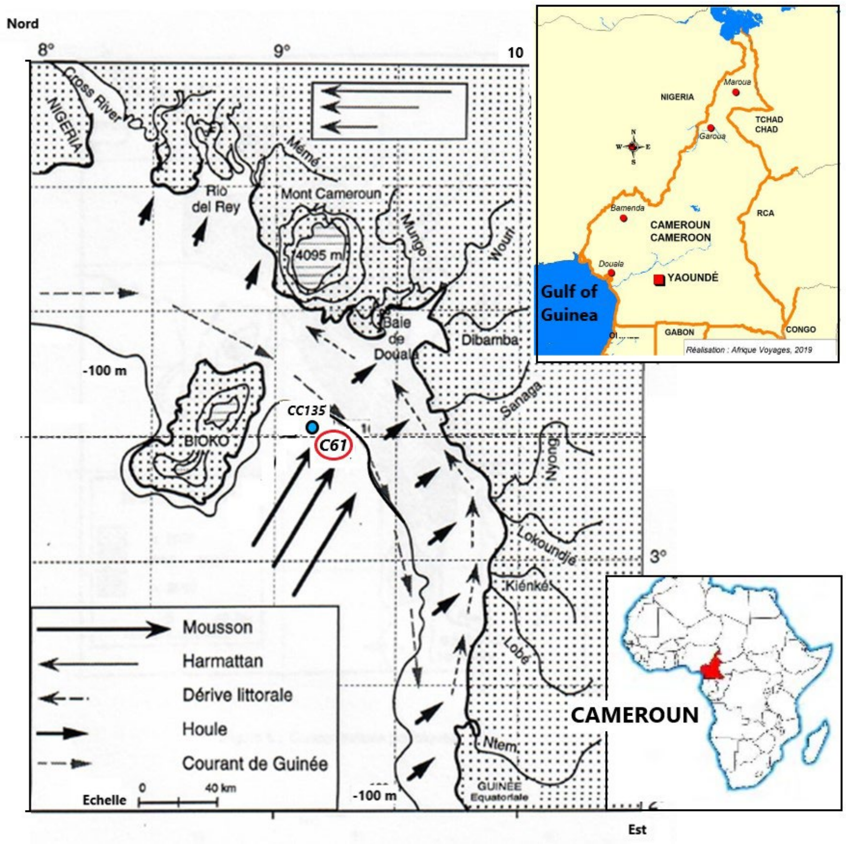


Figure 1. Location of the sampling sites on the Cameroonian continental shelf.

The regional oceanic circulation, dominated by the Equatorial Countercurrent and the Guinea Current (Bourlès et al., 1999; Braga et al., 2004), facilitates the dispersion of particles and the development of a continuous sedimentary record that accurately reflects paleoenvironmental variations from the Late Pleistocene to the recent Holocene (Giresse et al., 1996; Bengo et al., 2025).

2.1.2. Geological and Geomorphological Framework

The Cameroonian continental shelf is a geological structure inherited from the opening of the South Atlantic during the Early Cretaceous, characterized by N60-oriented faults that produced an alternation of horst and graben-type tectonic blocks (Aloisi et al., 1995). The sedimentary cover mainly consists of clayey and silty deposits of fluvial origin, largely supplied by the Sanaga River basin. The continental relief, organized in successive steps from the coastal plain to the Adamawa Plateau, promotes intense erosion and a rapid transfer of terrigenous material to the sea. In marine settings, sedimentary dynamics are expressed by recent deltaic deposits in the north, whereas in the south, relict sediments such as glauconitic and bioclastic sands—remnants of the Last Glacial Maximum and subsequent Holocene transgressions—predominate (Giresse et al., 1995; Ngueutchoua, 1996). Overall, this region represents a complex sedimentary system shaped by the combined influence of tectonic, climatic, and hydrological processes, which together account for the high heterogeneity of the deposits.

2.1.3. Pedological Framework of the Sanaga River Basin

The Sanaga River basin, the main source of sediments supplying the Cameroonian continental shelf, exhibits a wide diversity of soils that directly influence the composition of particles exported to the marine environment. In the humid equatorial zone of southern Cameroon, kaolinite-rich ferralitic soils, developed on ancient Precambrian basement rocks, are predominant. Swampy areas host hydromorphic soils enriched in organic matter, while the volcanic regions of the west and southwest are covered by Andosols derived from basic volcanic rocks (Segalen, 1967; Martin, 1966). Under the combined effects of heavy rainfall and stepped topography, these soil formations undergo intense erosion, resulting in the transport of clays, silts, and pollen grains to the ocean.

2.1.4. Atmospheric and Oceanographic settings

The climate of the Cameroonian coast is largely controlled by the Intertropical Convergence Zone (ITCZ), whose seasonal movements determine an alternation between a wet season dominated by oceanic air masses and a dry season marked by the continental Harmattan winds (Leroux, 1983; Piton, 1987; Suchel, 1988). These atmospheric variations directly influence regional ocean circulation in the Gulf of Guinea (Bourlès et al., 1999; Braga et al., 2004; Kolodziejczyk, 2008), characterized by a northward coastal drift current and the southward-flowing Guinea Current (**Figure 1**). At the surface, these currents facilitate the transport and dispersion of fine particles and pollen material along the coast, while in deeper waters, the Guinea Current promotes sediment redistribution offshore.

2.1.5. Current Climate and Vegetation Formations

The coastal region of Cameroon experiences a humid equatorial climate, characterized by mean annual temperatures ranging from 27 to 29˚C and exceptionally high rainfall, locally exceeding 10,000 mm per year at the foot of Mount Cameroon (Suchel, 1988). This high level of humidity promotes the development of dense and diverse vegetation, dominated by humid evergreen forests rich in Caesalpiniaceae, Euphorbiaceae, and Ulmaceae (Letouzey, 1968; White, 1983). Along the margins of flooded and lagoonal areas, swamp forests and mangroves dominated by *Rhizophora* and *Avicennia* thrive, whereas inland from the coast, semi-deciduous forests give way to wooded savannas in drier regions. This vegetation mosaic, governed by climatic and topographic gradients, illustrates the gradual transition between forest and savanna biomes. Its present-day floristic composition is reflected in the pollen signal preserved in marine sediments, thereby providing an essential reference framework for the reconstruction of Holocene paleoenvironments (Maley, 1987; Bengo et al., 2020; Bengo et al., 2025).

2.2. Methods

2.2.1. Sampling Protocol

A total of 26 samples were collected: 16 at 10 cm intervals in the upper section (0 - 150 cm), where sedimentation was relatively slow, and 10 at 30 cm intervals in the lower section, characterized by more rapid sedimentation. This sampling strategy provides representative coverage of paleoenvironmental variations spanning from the end of the Pleistocene to the Late Holocene.

2.2.2. Palynological Processing

The palynological processing of sediments from core C61 was conducted following the standard procedures described by Faegri and Iversen (1992). Each sample underwent a series of chemical treatments to remove carbonates, silicates, and non-pollen organic matter, followed by repeated washing and centrifugation to obtain clean residues. The resulting fractions were then mounted on microscope slides using glycerine jelly as the mounting medium. This procedure ensured good preservation and optimal visibility of pollen grains and spores for both quantitative and qualitative analyses.

2.2.3. Pollen Observation, Identification, and Classification

Observations were performed using an optical microscope at magnifications ranging from ×400 to ×1000. For each sample, a minimum of 300 pollen and spore grains were counted to ensure adequate statistical representativeness. Taxonomic identification was based on published atlases (Maley, 1970; Bonnefille & Riollet, 1980; Salard-Cheboldaeff, 1980, 1981, 1982, 1983) and on the reference collection of the Palynology Laboratory at the University of Montpellier 2. The identified taxa were subsequently grouped according to their ecological affinities: dense evergreen forests, semi-deciduous forests, savannas, swamp formations, mangroves, and aquatic plants. This classification made it possible to establish ecological indicator groups used for the reconstruction of paleoenvironmental and paleoclimatic conditions.

2.2.4. Ecological Significance and Chronological Framework

The interpretation of pollen assemblages is based on the identification of bioindicator taxa that reflect climatic and ecological conditions through time. *Poaceae* and *Bridelia* indicate dry phases dominated by savanna formations, whereas *Caesalpiniaceae*, *Sapotaceae*, and *Ulmaceae* point to humid periods favorable for the development of dense forest vegetation. The presence of *Podocarpus* is associated with cooler conditions at higher elevations or during episodes of climatic cooling. When considered within the context of the Late Glacial and Holocene, these indicators allow the establishment of a relative chronology of paleoenvironmental changes and enable the correlation of regional vegetation dynamics with major global climatic fluctuations.

3. Results

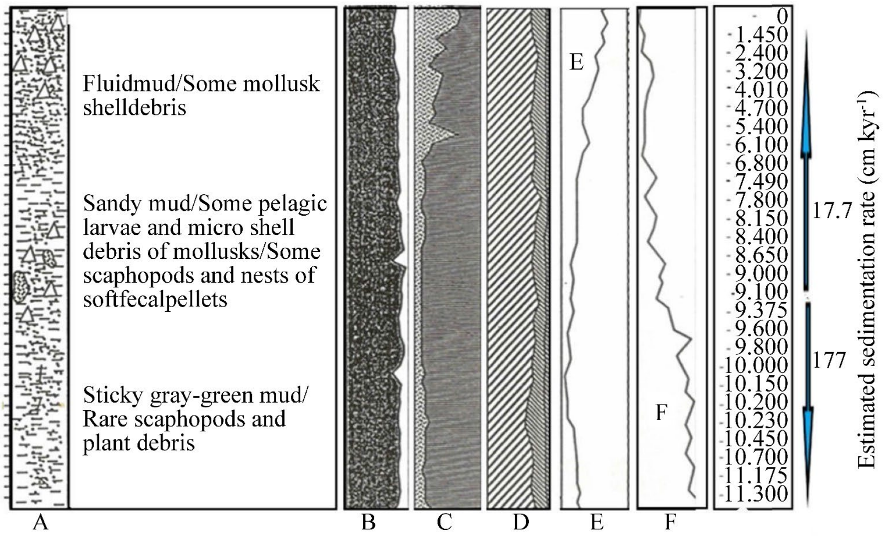
3.1. Litho-Sedimentary Characteristics and Chronology of Core C61

Geochemical analyses of core C61 show a progressive decrease in $CaCO_3$ content toward the top of the sequence, while total organic carbon increases. This trend is interpreted as a shift toward enhanced marine productivity and environmental stabilization in the uppermost levels. The clay mineral assemblage is dominated by kaolinite, with subordinate amounts of smectite and illite, indicating a predominantly continental origin of detrital inputs, primarily from the Sanaga River basin.

The lithological profile of the core, based on previous studies by Ngueutchoua (1996) and Giresse and Ngueutchoua (1998) (**Figure 2**), reveals three main sedimentary units. The basal unit (540 - 355 cm) consists of grey-green clayey mud enriched in plant debris, reflecting strong fluvial input and rapid deposition. The middle section (355 - 145 cm) is composed of sandy mud containing micro-shell fragments, suggesting a transitional depositional environment with increasing marine influence. The uppermost unit (145 - 0 cm) is made up of soft, homogeneous grey mud rich in mollusk remains, characteristic of a low-energy, stabilized marine setting.

To establish the chronological framework of the sequence, six levels of core C61 were dated by radiocarbon (^{14}C) analysis performed on both bulk organic matter and mollusk shells (Ngueutchoua, 1996; Giresse et al., 1995). The resulting calibrated ages (cal yr BP) range from approximately 11,330 cal yr BP at the base to 1450 cal yr BP at the top of the core.

The sedimentation rate was not uniform throughout the sequence. Between 11,300 and 9100 cal yr BP, the average sedimentation rate was approximately 157 cm per 1000 years. After 9100 cal yr BP, the rate dropped sharply to about 24 cm per 1000 years, and during the last millennium, it decreased further to approximately 10 cm per 1000 years (**Figure 3**).



A—Mollusk shell debris and Nests of soft fecal pellets; B—% Water; C—% Sand and % Pelites; D—% Kaolinite + % Smectite + % Illite; E—% $CaCO_3$; F—% Organic carbon. C^{14} dating (0 - 11,300). Estimated sedimentation rate (cm/10^3 years).

Figure 2. Lithological profile of core C61 (Ngueutchoua, 1996).

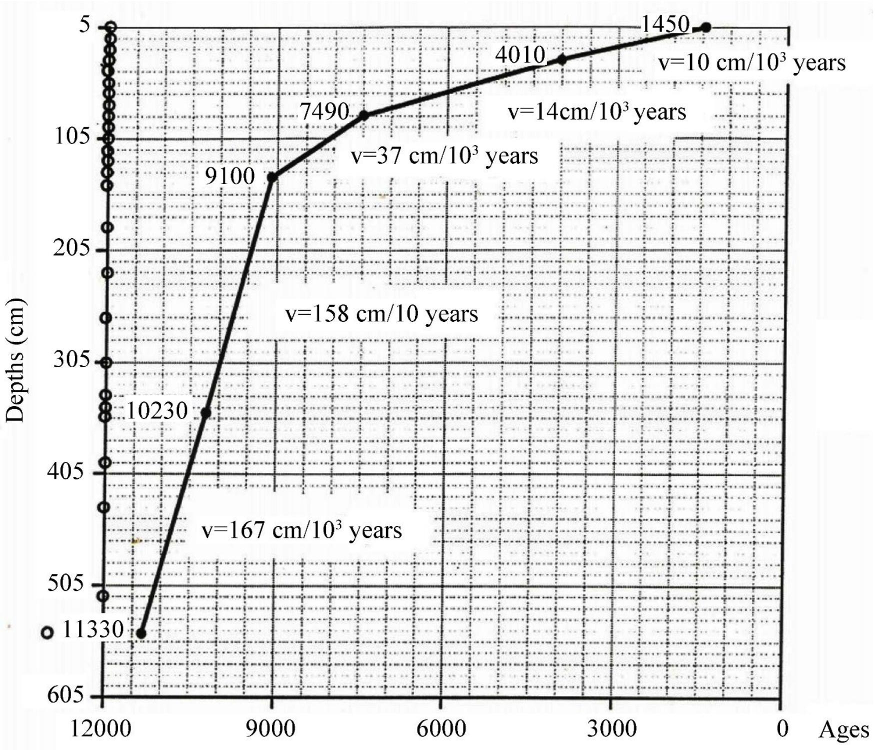


Figure 3. Age-depth model and sedimentation rates derived from calibrated ^{14}C dates (Ngueutchoua, 1996).

3.2. Pollen Identification, Abundance, and Taxonomic Diversity

Table 1. Count of main pollen types in samples from the Cameroonian continental shelf.

		Level	CC135	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130	130 - 140	140 - 150	180 - 190	220 - 230	260 - 270	300 - 310	330 - 340	340 - 350	350 - 360	390 - 400	430 - 440	510 - 520	530 - 540	Total			
		Average depth (cm)	1	5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	185	225	265	305	335	345	355	395	435	515	535				
	Family	Taxa/Ages	0	1450	2400	3200	4000	4700	5400	6100	6800	7500	7800	8150	8400	8650	9000	9200	9375	9600	9800	10,000	10,150	10,200	10,250	10,450	10,700	11,175	11,330	Total_1	Occurrence	Environments	Type
1	RHIZOPHORACEAE	*Rhizophora*	588	1204	210	133	359	414	420	322	262	151	147	166	408	611	156	439	243	170	308	385	373	193	380	327	536	462	257	9625	27	Ma	a
2	SPORES	SPORES	215	186	140	282	348	211	127	192	94	280	382	175	145	324	462	317	42	82	128	163	217	58	110	61	88	145	63	5035	27	F/Sa	H
3	POACEAE	GRAMINAE	117	245	15	116	168	70	49	43	64	95	138	98	89	117	177	110	68	67	142	147	91	61	100	91	81	112	109	2779	27	F	a
4	CYPERACEAE	CYPERACEAE	16	56	13	70	117	18	27	18	22	42	96	54	75	54	98	79	51	88	131	175	142	107	194	124	63	121	126	2175	7	F	A/a
5	EUPHORBIACEAE	*Alchornea type*	63	168	46	103	177	59	34	18	22	12	25	25	63	49	21	44	39	46	63	61	26	28	19	23	14	23	37	1305	10	Sa	H/a
6	PODOCARPACEAE	*Podocarpus*	7	21	10	61	91	28	21	7	14	32	25	5	9	12	30	19	7	7	12	23	7	0	5	12	18	16	0	498	8	F	A/a
7	PHYLLANTHACEAE	*Uapaca*	14	25	13	25	42	11	7	8	11	14	11	12	35	14	9	18	2	16	9	26	14	12	16	21	32	21	14	450	10	F	A
8	CAESALPINIACEAE	CAESALPINIACEAE	16	7	8	19	28	11	11	4	10	16	23	5	7	19	35	12	4	2	14	12	21	5	5	5	25	14	9	346	11	Sa-F	A/a
9	SAPOTACEAE	SAPOTACEAE	2	11	4	7	16	13	8	3	6	16	19	7	7	16	9	18	4	4	14	16	7	7	7	9	4	26	16	274	6	F	A
10	COMBRETACEAE	COMBRETACEAE	0	39	6	4	7	1	8	0	2	0	2	4	5	0	0	9	5	11	12	14	12	7	9	12	21	9	9	205	27	Autres	A/a
11	OLEACEAE	*Olea*	2	14	1	2	5	7	1	4	0	0	2	0	21	7	2	4	12	16	14	16	9	9	7	9	11	21	7	204	6	F	A/a
12	PUTRANJIVACEAE	*Drypetes ituriensis*	9	81	4	11	11	3	0	0	2	4	2	0	2	0	0	4	4	0	7	2	14	4	2	5	0	2	2	172	8	F	A
13	EUPHORBIACEAE	*Tetrorchydium*	2	35	7	14	16	4	3	1	4	4	7	5	2	2	2	9	0	0	5	5	19	2	2	2	7	5	4	168	20	Sa-F	a
14	MYRISTICACEAE	*Pycnanthus*	0	46	1	0	2	1	1	0	0	0	0	2	7	7	2	9	2	9	2	9	12	7	0	12	11	14	4	159	12	F/S	A
15	PALMAE	*Elaeis guinensis*	7	56	1	7	7	7	0	0	1	0	2	0	0	2	2	4	0	2	9	2	9	0	2	5	4	5	5	139	22	Sa-F	A/a/L
16	EUPHORBIACEAE	*Mallotus*	9	18	4	4	12	3	4	3	3	4	0	2	9	9	2	5	0	4	2	9	5	4	5	5	4	7	2	136	24	Sa	H
17	COMMELINACEAE	Commelina	7	14	1	5	9	6	0	3	1	7	11	5	7	2	9	14	0	2	5	2	2	0	5	2	4	5	2	129	23	Sa	H/a
18	ASTERACEAE	COMPOSITAE	0	21	1	9	2	4	1	1	1	2	2	2	5	0	7	4	0	0	2	9	2	5	5	2	18	2	4	111	6	F	A
19	RUBIACEAE	*Canthium venosum type*	0	0	4	4	12	6	3	1	1	7	9	4	0	9	16	4	0	0	0	5	7	0	2	2	4	5	2	105	27	F/S	H
20	MALVACEAE	*Melochia*	0	4	3	5	7	1	4	3	1	2	9	2	0	5	5	7	2	0	5	2	7	2	0	0	0	5	4	82	9	F/S	A
21	OCHNACEAE	*Lophira alata*	2	32	4	0	5	3	1	0	1	0	0	0	5	2	0	2	4	11	0	5	5	0	0	0	0	0	0	81	15	F/S	H/a
22	EUPHORBIACEAE	*Macaranga*	5	7	1	5	2	4	3	1	1	0	5	7	2	0	2	0	2	2	2	5	2	0	0	2	0	2	2	66	20	F	A/a
23	RUBIACEAE	*Hymenodyctyon*	0	0	1	0	0	1	0	1	0	0	0	2	0	0	0	4	2	4	2	2	5	5	9	2	0	14	9	64	20	Cu	A
24	MORACEAE	*Dorstenia*	0	0	3	2	2	0	4	0	1	0	2	0	0	2	0	2	5	0	9	2	0	0	2	0	4	9	9	58	11	Sa	A/a/L
25	IRVINGIACEAE	*Irvingia*	2	11	0	0	0	0	0	1	0	0	0	0	2	0	0	2	2	0	12	2	5	2	0	2	4	5	4	54	10	F	L/a
26	EUPHORBIACEAE	*Hevea*	0	7	0	4	4	0	0	0	0	0	0	0	0	0	2	4	4	2	0	5	2	5	0	0	4	5	0	46	27	Sa	H
27	MELIACEAE	MELIACEAE	0	0	3	7	2	4	0	1	1	5	4	0	0	2	5	2	0	0	5	5	0	0	0	0	0	0	0	45	8	F	A/a
28	CHRYSOBALANACEAE	*Parinari*	2	0	0	4	0	0	1	1	1	7	5	4	2	5	2	0	0	0	0	0	2	0	0	0	4	2	2	45	12	F	A
29	CANNABACEAE	*Celtis*	2	11	0	2	0	0	0	1	0	2	0	0	0	2	0	4	0	4	0	5	0	0	2	0	0	7	2	43	11	Sa-F	A/a
30	DILLENIACEAE	*Tetracera*	2	0	0	0	0	0	0	0	0	0	0	0	5	0	0	2	2	0	0	12	7	0	2	0	4	5	2	41	15	Sa-F	A/a
31	AMARANTHACEAE	AMARANTHACEAE-CHENOP.	0	11	0	2	0	1	0	0	0	5	0	0	0	2	0	0	5	0	2	0	2	0	2	7	0	0	0	40	14	F	A
32	RUBIACEAE	*Psychotria type*	0	0	4	0	7	1	0	0	0	0	2	0	2	2	5	2	2	0	5	2	0	0	0	2	0	2	0	39	7	F	a
33	RUBIACEAE	*Nauclea*	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	2	0	0	9	2	2	0	2	5	0	5	2	34	14	Sa-F	A
34	RUBIACEAE	*Mitragyna*	0	4	0	0	0	1	0	0	0	0	0	2	2	2	0	0	4	2	2	2	0	0	0	2	11	0	0	34	21	F	a/A
35	PHYLLANTHACEAE	*Bridelia*	0	4	0	2	4	0	0	0	0	0	2	2	0	0	0	0	0	7	2	0	0	4	2	0	4	0	2	33	25	F	a
36	CLUSIACEAE	*Symphonia*	2	0	3	4	0	3	1	0	0	4	2	0	0	2	2	5	0	0	2	0	2	0	0	0	0	0	0	33	6	Cu	A
37	CELASTRACEAE	*Maytenus*	0	4	0	0	0	0	0	1	0	2	0	2	0	0	0	2	0	0	0	12	0	0	2	2	4	2	0	32	9	F	A/a
38	PHYLLANTHACEAE	*Hymenocardia*	2	0	0	4	4	1	0	0	0	0	2	0	2	2	0	0	0	2	7	2	0	0	0	0	0	0	4	32	10	F	A/a
39	MIMOSACEAE	*Entada*	0	4	3	2	0	0	0	1	0	0	2	0	2	5	0	0	0	2	2	5	0	4	0	0	0	0	0	30	10	Sa	A/a/L
40	CAESALPINIACEAE	*Berlinia*	0	0	0	0	0	0	3	3	0	2	2	0	0	0	5	4	0	2	2	0	0	0	0	0	7	0	2	30	13	Autres	A/a
41	MALPIGHIACEAE	*Flabellaria*	0	4	3	2	0	0	3	0	0	0	2	2	0	0	7	2	0	0	0	2	0	0	0	0	0	0	2	27	21	F/S	H/a/A
42	RUBIACEAE	*Morelia*	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	4	2	0	2	0	0	2	2	0	0	7	0	25	11	F	A
43	MIMOSACEAE	*Piptadeniastrum*	0	0	0	2	4	3	0	0	0	0	0	0	0	7	7	0	0	0	0	0	0	0	0	2	0	0	0	24	9	Sa	H/a
44	CAESALPINIACEAE	*Dialum*	2	0	0	0	4	0	0	0	0	2	0	2	2	0	0	0	2	0	0	5	0	0	2	2	0	0	0	23	10	Sa-F	a
45	RUBIACEAE	*Sabicea type*	2	4	0	2	2	0	0	0	0	2	0	0	2	0	0	0	2	2	0	2	0	0	0	0	0	0	4	23	24	Mo	A
46	MYRTACEAE	*Syzydium*	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	2	5	0	0	2	5	0	0	4	23	6	F	A
47	PHYLLANTHACEAE	*Martretia*	0	0	0	0	2	0	0	1	0	2	0	4	0	0	2	0	0	2	0	2	2	0	0	0	4	0	2	22	6	Autres	H/A
48	TYPHACEAE	*Typha*	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2	7	2	0	2	0	0	0	0	22	15	F	A
49	APOCYNACEAE	*Rauvolfia*	2	4	0	0	0	1	1	0	0	0	0	0	0	5	0	2	0	0	0	0	2	0	2	0	0	0	2	21	8	F	A
50	RUBIACEAE	*Xeromphis*	0	4	0	0	2	0	0	0	1	0	0	0	0	2	2	0	4	0	2	0	0	0	2	2	0	0	0	21	6	F	A
51	CAESALPINIACEAE	*Pentaclethra*	0	0	0	0	5	1	4	1	0	0	0	2	0	0	0	0	0	2	0	0	0	2	2	0	0	0	0	20	6	F	A/a
		Total_2	**1104**	**2352**	**519**	**919**	**1484**	**909**	**755**	**650**	**527**	**716**	**936**	**599**	**929**	**1311**	**1092**	**1166**	**523**	**565**	**959**	**1176**	**1038**	**532**	**917**	**765**	**984**	**1085**	**721**	**25231**	**96%**		
		TOTAL_Taxa (Base)	**1164**	**2513**	**533**	**961**	**1572**	**937**	**783**	**664**	**548**	**779**	**991**	**621**	**975**	**1353**	**1143**	**1209**	**537**	**593**	**1001**	**1239**	**1080**	**555**	**966**	**807**	**1012**	**1143**	**765**	**#####**			
	UNIDENTIFIED	UNIDENTIFIED	21	53	10	32	25	14	29	15	12	18	39	21	28	23	19	25	35	37	72	63	35	33	58	28	98	54	44	939			
	DEGRADED	DEGRADED	0	25	4	5	5	4	3	1	6	4	4	0	14	2	7	2	4	4	0	0	5	9	5	0	4	9	9	132			
		DYNOCYSTES	7	11	53	114	121	28	57	14	9	107	51	5	19	30	51	19	12	7	9	12	5	18	7	5	0	9	5	**785**			

Table 2. Pollen count data (absolute values).

		LEVELS (Depths)		CC135	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130	130 - 140	140 - 150	180 - 190	220 - 230	260 - 270	300 - 310	330 - 340	340 - 350	350 - 360	390 - 400	430 - 440	510 - 520	530 - 540	Total	
	Family	Taxa/Age (C14)	Abrev.	0	1450	2400	3200	4010	4700	5400	6100	6800	7490	7800	8150	8400	8650	9000	9100	9375	9600	9800	10,000	10,150	10,200	10,230	10,450	10,700	11,175	11,330	%Percentages	Proportions
		Base_1																														
1	RHIZOPHORACEAE	***Rhizophora***	Rhiz	49.61	46.49	38.36	13.33	22.40	43.40	51.55	47.33	46.29	18.82	14.24	25.89	40.14	44.33	13.37	35.55	42.25	26.80	28.70	29.57	33.33	32.26	36.96	39.11	48.11	38.30	31.48	**34.74**	
2	SPORES	**SPORES**	SPOR	18.11	7.16	25.58	28.25	21.75	22.14	15.64	28.19	16.61	35.01	36.95	27.25	14.22	23.52	39.52	25.64	7.29	12.98	11.96	12.54	19.38	9.68	10.66	7.26	7.86	11.99	7.71	**18.70**	
3	PODOCARPACEAE	***Podocarpus***	Podo	0.59	0.81	1.79	6.14	5.68	2.93	2.58	1.03	2.47	3.94	2.37	0.82	0.92	0.85	2.59	1.56	1.22	1.10	1.09	1.79	0.63	0.00	0.45	1.40	1.57	1.35	0.00	**1.77**	
		Base_2																														
4	POACEAE	**GRAMINAE**	GRAM	32.26	21.81	8.40	21.15	19.43	22.52	20.83	28.97	33.33	27.14	29.92	35.00	20.99	27.93	33.78	24.32	27.08	19.49	25.21	21.28	18.57	20.11	21.08	21.67	20.72	20.87	24.41	**24.01**	
5	CYPERACEAE	**CYPERACEAE**	CYPE	4.52	4.98	6.87	12.82	13.56	5.86	11.31	12.15	11.46	12.06	20.83	19.38	17.68	12.85	18.67	17.37	20.14	25.64	23.14	25.34	29.05	35.06	40.69	29.44	16.22	22.61	28.35	**18.45**	
6	EUPHORBIACEAE	***Alchornea type***	Alch	17.42	14.95	25.19	18.91	20.45	18.92	14.29	12.15	11.46	3.52	5.30	8.75	14.92	11.73	4.00	9.65	15.28	13.33	11.16	8.78	5.24	9.20	3.92	5.56	3.60	4.35	8.27	**11.12**	
7	PHYLLANTHACEAE	***Uapaca***	Uapa	3.87	2.18	6.87	4.49	4.86	3.60	2.98	5.61	5.73	4.02	2.27	4.38	8.29	3.35	1.78	3.86	0.69	4.62	1.65	3.72	2.86	4.02	3.43	5.00	8.11	3.91	3.15	**4.05**	
8	CAESALPINIACEAE	**CAESALPINIACEAE**	CAES	4.52	0.62	4.58	3.53	3.24	3.60	4.76	2.80	5.21	4.52	4.92	1.88	1.66	4.47	6.67	2.70	1.39	0.51	2.48	1.69	4.29	1.72	0.98	1.11	6.31	2.61	1.97	**3.14**	
9	SAPOTACEAE	**SAPOTACEAE**	SAPO	0.65	0.93	2.29	1.28	1.82	4.05	3.57	1.87	3.13	4.52	4.17	2.50	1.66	3.91	1.78	3.86	1.39	1.03	2.48	2.36	1.43	2.30	1.47	2.22	0.90	4.78	3.54	**2.44**	
10	OLEACEAE	***Olea***	Olea	0.65	1.25	0.76	0.32	0.61	2.25	0.60	2.80	0.00	0.00	0.38	0.00	4.97	1.68	0.44	0.77	4.86	4.62	2.48	2.36	1.90	2.87	1.47	2.22	2.70	3.91	1.57	**1.79**	
11	COMBRETACEAE	**COMBRETACEAE**	COMB	0.00	3.43	3.05	0.64	0.81	0.45	3.57	0.00	1.04	0.00	0.38	1.25	1.10	0.00	0.00	1.93	2.08	3.08	2.07	2.03	2.38	2.30	1.96	2.78	5.41	1.74	1.97	**1.68**	
12	EUPHORBIACEAE	***Tetrorchydium***	Tet2	0.65	3.12	3.82	2.56	1.82	1.35	1.19	0.93	2.08	1.01	1.52	1.88	0.55	0.56	0.44	1.93	0.00	0.00	0.83	0.68	3.81	0.57	0.49	0.56	1.80	0.87	0.79	**1.33**	
13	EUPHORBIACEAE	***Mallotus***	Mall	2.58	1.56	2.29	0.64	1.42	0.90	1.79	1.87	1.56	1.01	0.00	0.63	2.21	2.23	0.44	1.16	0.00	1.03	0.41	1.35	0.95	1.15	0.98	1.11	0.90	1.30	0.39	**1.18**	
14	MYRISTICACEAE	***Pycnanthus***	Pyc1	0.00	4.05	0.76	0.00	0.20	0.45	0.60	0.00	0.00	0.00	0.00	0.63	1.66	1.68	0.44	1.93	0.69	2.56	0.41	1.35	2.38	2.30	0.00	2.78	2.70	2.61	0.79	**1.15**	
15	PUTRANJIVACEAE	***Drypetes iturtiensis***	Dryp	2.58	7.17	2.29	1.92	1.21	0.90	0.00	0.00	1.04	1.01	0.38	0.00	0.55	0.00	0.00	0.77	1.39	0.00	1.24	0.34	2.86	1.15	0.49	1.11	0.00	0.43	0.39	**1.08**	
16	COMMELINACEAE	**Commelina**	Comm	1.94	1.25	0.76	0.96	1.01	1.80	0.00	1.87	0.52	2.01	2.27	1.88	1.66	0.56	1.78	3.09	0.00	0.51	0.83	0.34	0.48	0.00	0.98	0.56	0.90	0.87	0.39	**1.08**	
17	RUBIACEAE	***Canthium venosum type***	Cant	0.00	0.00	2.29	0.64	1.42	1.80	1.19	0.93	0.52	2.01	1.89	1.25	0.00	2.23	3.11	0.77	0.00	0.00	0.00	0.68	1.43	0.00	0.49	0.56	0.90	0.87	0.39	**0.94**	
18	ASTERACEAE	**COMPOSITAE**	COMP	0.00	1.87	0.76	1.60	0.20	1.35	0.60	0.93	0.52	0.50	0.38	0.63	1.10	0.00	1.33	0.77	0.00	0.00	0.41	1.35	0.48	1.72	0.98	0.56	4.50	0.43	0.79	**0.88**	
19	PALMAE	***Elaeis guinensis***	Elae	1.94	4.98	0.76	1.28	0.81	2.25	0.00	0.00	0.52	0.00	0.38	0.00	0.00	0.56	0.44	0.77	0.00	0.51	1.65	0.34	1.90	0.00	0.49	1.11	0.90	0.87	1.18	**0.88**	
20	MALVACEAE	***Melochia***	Melo	0.00	0.31	1.53	0.96	0.81	0.45	1.79	1.87	0.52	0.50	1.89	0.63	0.00	1.12	0.89	1.54	0.69	0.00	0.83	0.34	1.43	0.57	0.00	0.00	0.00	0.87	0.79	**0.75**	
21	EUPHORBIACEAE	***Macaranga***	Maca	1.29	0.62	0.76	0.96	0.20	1.35	1.19	0.93	0.52	0.00	1.14	2.50	0.55	0.00	0.44	0.00	0.69	0.51	0.41	0.68	0.48	0.00	0.00	0.56	0.00	0.43	0.39	**0.62**	
22	OCHNACEAE	***Lophira alata***	Loph	0.65	2.80	2.29	0.00	0.61	0.90	0.60	0.00	0.52	0.00	0.00	0.00	1.10	0.56	0.00	0.39	1.39	3.08	0.00	0.68	0.95	0.00	0.00	0.00	0.00	0.00	0.00	**0.61**	
23	RUBIACEAE	***Hymenodyctyon***	Hyme	0.00	0.00	0.76	0.00	0.00	0.45	0.00	0.93	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.77	0.69	1.03	0.41	0.34	0.95	1.72	1.96	0.56	0.00	2.61	1.97	**0.58**	
24	MORACEAE	***Dorstenia***	Dors	0.00	0.00	1.53	0.32	0.20	0.00	1.79	0.00	0.52	0.00	0.38	0.00	0.00	0.56	0.00	0.39	2.08	0.00	1.65	0.34	0.00	0.00	0.49	0.00	0.90	1.74	1.97	**0.55**	
25	CHRYSOBALANACEAE	***Parinari***	Pari	0.65	0.00	0.00	0.64	0.00	0.00	0.60	0.93	0.52	2.01	1.14	1.25	0.55	1.12	0.44	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.90	0.43	0.39	**0.45**	
26	MELIACEAE	**MELIACEAE**	MELI	0.00	0.00	1.53	1.28	0.20	1.35	0.00	0.93	0.52	1.51	0.76	0.00	0.00	0.56	0.89	0.39	0.00	0.00	0.83	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.42**	
27	IRVINGIACEAE	***Irvingia***	Irvi	0.65	0.93	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.39	0.69	0.00	2.07	0.34	0.95	0.57	0.00	0.56	0.90	0.87	0.79	**0.41**	
28	EUPHORBIACEAE	***Hevea***	Heve	0.00	0.62	0.00	0.64	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.77	1.39	0.51	0.00	0.68	0.48	1.72	0.00	0.00	0.90	0.87	0.00	**0.35**	
29	RUBIACEAE	***Psychotria type***	Psyc	0.00	0.00	2.29	0.00	0.81	0.45	0.00	0.00	0.00	0.00	0.38	0.00	0.55	0.56	0.89	0.39	0.69	0.00	0.83	0.34	0.00	0.00	0.00	0.56	0.00	0.43	0.00	**0.34**	
30	AMARANTHACEAE	**AMARANTHACEAE-CHENOP.**	AMAR	0.00	0.93	0.00	0.32	0.00	0.45	0.00	0.00	0.00	1.51	0.00	0.00	0.00	0.56	0.00	0.00	2.08	0.00	0.41	0.00	0.48	0.00	0.49	1.67	0.00	0.00	0.00	**0.33**	
31	CLUSIACEAE	***Symphonia***	Symp	0.65	0.00	1.53	0.64	0.00	0.90	0.60	0.00	0.00	1.01	0.38	0.00	0.00	0.56	0.44	1.16	0.00	0.00	0.41	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	**0.32**	
32	CAESALPINIACEAE	***Berlinia***	Berl	0.00	0.00	0.00	0.00	0.00	0.00	1.19	1.87	0.00	0.50	0.38	0.00	0.00	0.00	0.89	0.77	0.00	0.51	0.41	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.39	**0.32**	
33	DILLENIACEAE	***Tetracera***	Tetr	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.39	0.69	0.00	0.00	1.69	1.43	0.00	0.49	0.00	0.90	0.87	0.39	**0.32**	
34	CANNABACEAE	***Celtis***	Celt	0.65	0.93	0.00	0.32	0.00	0.00	0.00	0.93	0.00	0.50	0.00	0.00	0.00	0.56	0.00	0.77	0.00	1.03	0.00	0.68	0.00	0.00	0.49	0.00	0.00	1.30	0.39	**0.32**	
35	MORACEAE	**MORACEAE**	MORA	0.00	0.31	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.63	0.55	0.56	0.00	0.00	1.39	0.51	0.41	0.34	0.00	0.00	0.00	0.56	2.70	0.00	0.00	**0.31**	
36	MIMOSACEAE	***Entada***	Enta	0.00	0.31	1.53	0.32	0.00	0.00	0.00	0.93	0.00	0.00	0.38	0.00	0.55	1.12	0.00	0.00	0.00	0.51	0.41	0.68	0.00	1.15	0.00	0.00	0.00	0.00	0.00	**0.29**	
37	PHYLLANTHACEAE	***Bridelia***	Brid	0.00	0.31	0.00	0.32	0.40	0.00	0.00	0.00	0.00	0.00	0.38	0.63	0.00	0.00	0.00	0.00	0.00	2.05	0.41	0.00	0.00	1.15	0.49	0.00	0.90	0.00	0.39	**0.28**	
38	RUBIACEAE	***Nauclea***	Nauc	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.39	0.00	0.00	1.65	0.34	0.48	0.00	0.49	1.11	0.00	0.87	0.39	**0.27**	
39	CELASTRACEAE	***Maytenus***	Mayt	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.50	0.00	0.63	0.00	0.00	0.00	0.39	0.00	0.00	0.00	1.69	0.00	0.00	0.49	0.56	0.90	0.43	0.00	**0.25**	
40	MALPIGHIACEAE	***Flabellaria***	Flab	0.00	0.31	1.53	0.32	0.00	0.00	1.19	0.00	0.00	0.00	0.38	0.63	0.00	0.00	1.33	0.39	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.39	**0.25**	
41	PHYLLANTHACEAE	***Hymenocardia***	Hyme	0.65	0.00	0.00	0.64	0.40	0.45	0.00	0.00	0.00	0.00	0.38	0.00	0.55	0.56	0.00	0.00	0.00	0.51	1.24	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.79	**0.24**	
42	CAESALPINIACEAE	***Pentaclethra***	Pen2	0.00	0.00	0.00	0.00	0.61	0.45	1.79	0.93	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.57	0.49	0.00	0.00	0.00	0.00	**0.22**	
43	BRASSICACEAE	***Morettia***	More	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.55	0.56	0.00	0.77	0.69	0.00	0.41	0.00	0.00	0.57	0.49	0.00	0.00	1.30	0.00	**0.22**	
44	PHYLLANTHACEAE	***Martretia***	Mart	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.93	0.00	0.50	0.00	1.25	0.00	0.00	0.44	0.00	0.00	0.51	0.00	0.34	0.48	0.00	0.00	0.00	0.90	0.00	0.39	**0.22**	
45	ERICACEAE	**Nypa**	Nypa	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	1.72	1.96	0.00	0.00	0.00	0.00	**0.21**	
46	PHYLLANTHACEAE	***Margaritaria***	Marg	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.93	0.52	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.57	0.00	0.56	0.90	0.43	0.00	**0.21**	
47	HUMIRICACEAE	***Sacoglottis***	Sacc	0.00	0.00	0.76	0.00	0.20	0.00	0.60	0.93	0.00	0.50	0.00	0.63	0.55	0.00	0.00	0.00	0.00	0.51	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	**0.20**	
48	CAESALPINIACEAE	***Duparquetia***	Dupa	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	1.01	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.20**	
49	MIMOSACEAE	***Piptadeniastrum***	Pipt	0.00	0.00	0.00	0.32	0.40	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	**0.19**	
50	CAESALPINIACEAE	***Dialum***	Dial	0.65	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.50	0.00	0.63	0.55	0.00	0.00	0.00	0.69	0.00	0.00	0.68	0.00	0.00	0.49	0.56	0.00	0.00	0.00	**0.19**	
51	CAESALPINIACEAE	***Guibourtia type***	Guib	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.56	0.44	0.39	0.00	0.51	0.00	0.00	0.00	0.00	0.49	0.00	0.90	0.00	0.00	**0.19**	
52	PAPILLIONACEAE	***Baphia***	Baph	0.00	0.00	0.00	0.00	0.00	0.00	2.98	0.00	0.52	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.57	0.00	0.00	0.00	0.00	0.00	**0.18**	
53	RUBIACEAE	***Xeromphis***	Xero	0.00	0.31	0.00	0.00	0.20	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.56	0.44	0.00	1.39	0.00	0.41	0.00	0.00	0.00	0.49	0.56	0.00	0.00	0.00	**0.18**	
54	RUBIACEAE	***Sabicea type***	Sabi	0.65	0.31	0.00	0.32	0.20	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.55	0.00	0.00	0.00	0.69	0.51	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.79	**0.18**	
55	APOCYNACEAE	***Rauvolfia***	Rauv	0.65	0.31	0.00	0.00	0.00	0.45	0.60	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.39	0.00	0.00	0.00	0.00	0.48	0.00	0.49	0.00	0.00	0.00	0.39	**0.18**	
56	TYPHACEAE	***Typha***	Typh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.44	0.00	0.69	0.51	0.41	1.01	0.48	0.00	0.49	0.00	0.00	0.00	0.00	**0.17**	
57	PANDANACEAE	***Pandanus***	Pan2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	0.41	0.00	0.48	0.57	0.00	0.56	0.00	0.00	0.00	**0.14**	
		TOTAL (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**100**	
		Base_1 (Total pollens)		**1164**	**2513**	**533**	**961**	**1572**	**937**	**783**	**664**	**548**	**779**	**991**	**621**	**975**	**1353**	**1143**	**1209**	**537**	**593**	**1001**	**1239**	**1080**	**555**	**966**	**807**	**1012**	**1143**	**765**	**26444**	**100%**
		Base_2 (Without Rhizo et Spores)		**362**	**1124**	**183**	**546**	**865**	**311**	**235**	**150**	**192**	**348**	**462**	**280**	**422**	**418**	**525**	**453**	**252**	**341**	**565**	**691**	**490**	**305**	**476**	**420**	**389**	**537**	**445**	**11784**	**45%**
		Sum (Rhizo + Spores)		803	1390	350	415	707	626	547	514	356	431	529	341	553	936	618	756	285	252	436	548	590	250	490	387	623	607	320	14660	**55%**

Examining three to four transects per slide was generally sufficient to reach the required 300 pollen grains, except at the 70 - 80 cm level (seven transects) and the 430 - 440 cm level (two transects). In total, 26,444 pollen and spore grains were identified. Among other palynomorphs, approximately 939 were indeterminate, 132 were damaged, and 785 corresponded to dinoflagellate cysts (Table 1). The 224 recorded taxa, distributed among 93 families, show a marked dominance of *Rhizophora* (34.3%), spores (18.3%), *Poaceae* (10.1%), *Cyperaceae* (8.2%), and *Alchornea* (4.7%). The highest taxonomic diversity was observed in Rubiaceae (23 genera), followed by Euphorbiaceae (16) and Phyllanthaceae (11). These assemblages reflect the regional mosaic of forested and open vegetation types.

3.3. Pollen Diagram of the Main Taxa

The pollen spectra forming the overall pollen diagram were constructed using two calculation matrices. The bioindicator taxa, which represent the two main pollen groups, were derived from matrix (1), which includes all identified pollen types. Matrix (2), used for the analysis of the other major and characteristic taxa, was generated from a dataset in which *Rhizophora* and spore taxa were excluded (Table 2).

Based on the temporal comparison of pollen spectra, significant changes in floristic composition were identified, allowing the distinction of three major successive palynological zones (Table 3), which correspond to the main paleoecological phases recorded in core C61.

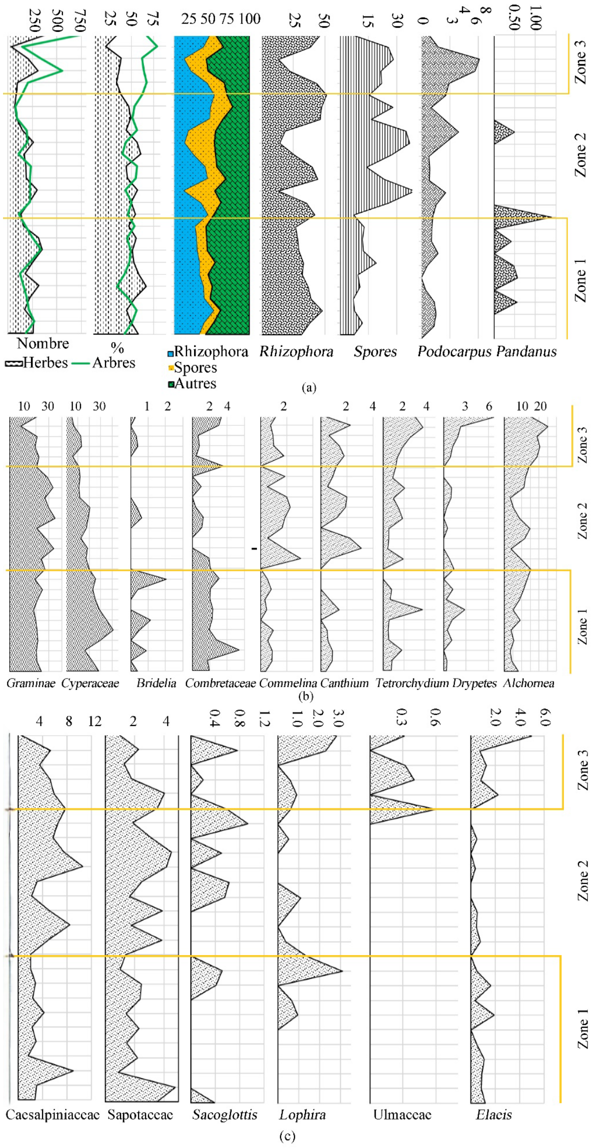
Table 3. Description of the palynological zones.

		Zone 1	**Zone 2**	**Zone 3**
Ages	*Start*	11,400	9400	5400
	End	9400	5400	1450
Depth	*Start*	540	180	60
	End	190	60	0
Périod (years)	-	2.000	4.000	4.000
Thichness (cm)	-	350	120	60
Sedimentation rate	-	175	30	15
Séries	-	**Extensive**	Less condensed	Condensed
Plants	-	Shrub	**Herbs**	Trees
Environments	-	Mangrove	Grassy savanna	Afromontane Forest
Flora	-	*Rhizophora*	Graminae	*Podocarpus*
Spores	-	Low	**Significant**	Medium
Podocarpus	-	Low	Medium	**Significant**
Rhizophora	-	Significant	Contrast with Spores and Podocarpus	

Table 4. Plant types (herbaceous and arboreal forms) and major taxa (*Rhizophora* and spores).

	CC135	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130	130 - 140	140 - 150	180 - 190	220 - 230	260 - 270	300 - 310	330 - 340	340 - 350	350 - 360	390 - 400	430 - 440	510 - 520	530 - 540	Total
Herbs (NAP)	154	385	38	208	310	102	88	70	94	152	261	170	184	189	299	226	137	159	313	352	257	177	317	226	172	266	257	5562
Trees (AP)	208	739	146	338	555	209	147	80	98	196	201	110	238	229	226	228	116	182	252	338	233	128	159	194	217	271	187	6222
Total	**362**	**1124**	**183**	**546**	**865**	**311**	**235**	**150**	**192**	**348**	**462**	**280**	**422**	**418**	**525**	**453**	**252**	**341**	**565**	**691**	**490**	**305**	**476**	**420**	**389**	**537**	**445**	**####**
%Herbs (NAP)	43	34	21	38	36	33	38	47	49	44	56	61	44	45	57	50	54	47	55	51	52	58	67	54	44	50	58	47
%Trees (AP)	57	66	79	62	64	67	63	53	51	56	44	39	56	55	43	50	46	53	45	49	48	42	33	46	56	50	42	53
%Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Rhizophora	588	1204	210	133	359	414	420	322	262	151	147	166	408	611	156	439	243	170	308	385	373	193	380	327	536	462	257	**9625**
Spores	215	186	140	282	348	211	127	192	94	280	382	175	145	324	462	317	42	82	128	163	217	58	110	61	88	145	63	**5035**
Others	362	1124	183	546	865	311	235	150	192	348	462	280	422	418	525	453	252	341	565	691	490	305	476	420	389	537	445	**####**
Total	**1164**	**2513**	**533**	**961**	**1572**	**937**	**783**	**664**	**548**	**779**	**991**	**621**	**975**	**1353**	**1143**	**1209**	**537**	**593**	**1001**	**1239**	**1080**	**555**	**966**	**807**	**1012**	**1143**	**765**	**####**

The pollen groupings (**Table 4**), organized by plant type within the three palynological zones of the overall pollen diagram (**Figure 4**), are characterized by the following main plant assemblages: 1) biological forms (herbaceous and arboreal types); 2) taxa dominant in pollen proportions (*Rhizophora*, spores); 3) taxa serving as environmental and climatic bioindicators (*Rhizophora*, *Pandanus*, *Podocarpus*); and 4) taxa characteristic of the major ecosystems—savanna (*Poaceae*, *Bridelia*, *Combretum*), dense humid forest (*Caesalpiniaceae*, *Sapotaceae*, *Ulmaceae*, *Sacoglottis*), and ubiquitous or pioneer understorey taxa (*Alchornea*, *Tetrorchidium*, *Drypetes*).



Zone 1: Regression of ubiquitous pioneer and undergrowth taxa (**9400 - 11300 years**). **Zone 2**: Increase in spores during the Podocarpus phase, both alternating in contrast with Rhizophora (**5400 - 9400 years**). **Zone 3**: Forest resurgence in favor of Podocarpus (**0 - 5400 years**).

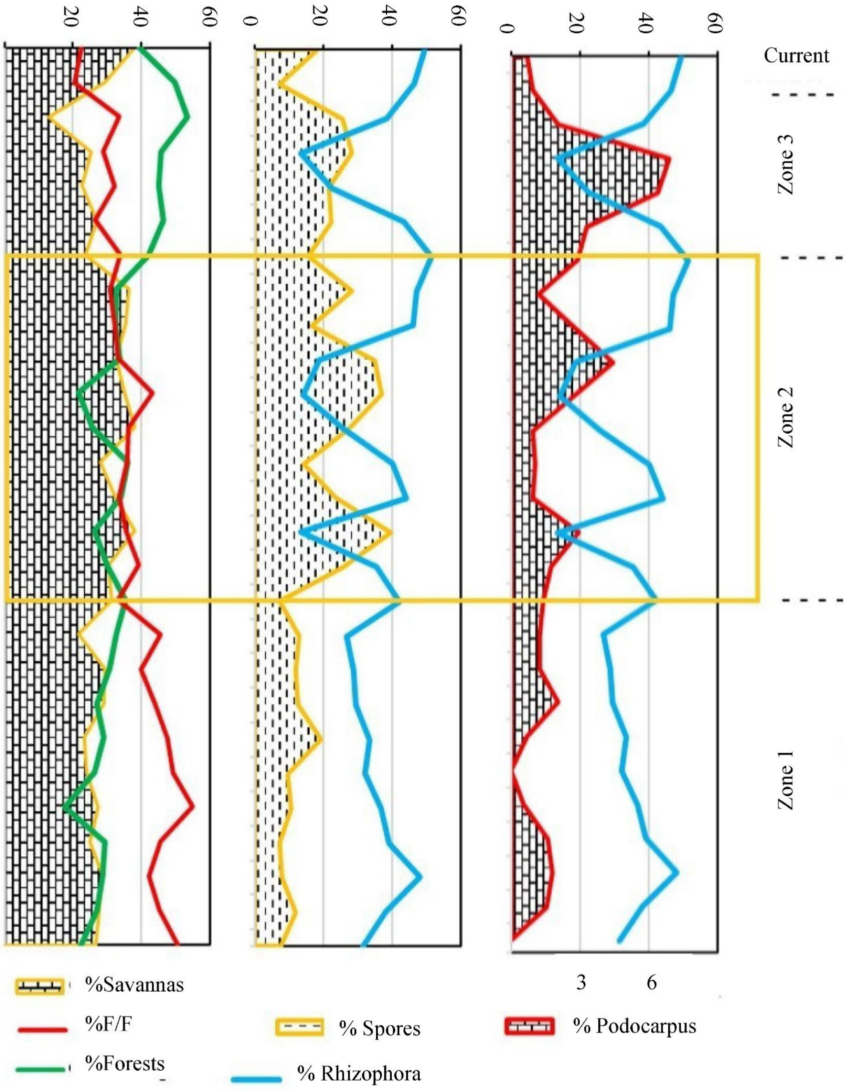
Figure 4. Pollen diagram of ecological bioindicators.

3.4. Spectra of Paleoecological Bioindicators

Table 5. Vegetation types and ecological bioindicators.

	CC135	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130	130 - 140	140 - 150	180 - 190	220 - 230	260 - 270	300 - 310	330 - 340	340 - 350	350 - 360	390 - 400	430 - 440	510 - 520	530 - 540	Total
Forests	142	532	98	249	389	144	99	49	62	117	100	72	152	142	138	137	89	112	173	187	142	81	84	124	112	145	100	3968
F/S	82	221	62	158	277	83	80	46	62	116	200	102	152	140	187	179	84	156	226	303	233	151	261	191	165	243	226	4381
Savannas	138	315	24	138	196	84	56	55	68	114	163	107	119	135	198	138	79	74	166	201	114	74	131	105	112	149	119	3370
Total	**362**	**1068**	**183**	**544**	**861**	**311**	**235**	**150**	**192**	**347**	**462**	**280**	**422**	**418**	**523**	**453**	**252**	**341**	**565**	**691**	**490**	**305**	**476**	**420**	**389**	**537**	**445**	**####**
%Forests	39	50	53	46	45	46	42	33	32	34	22	26	36	34	26	30	35	33	31	27	29	26	18	29	29	27	22	33
%F/S	23	21	34	29	32	27	34	31	32	33	43	36	36	34	36	39	33	46	40	44	48	49	55	46	42	45	51	38
%Savannas	38	30	13	25	23	27	24	36	35	33	35	38	28	32	38	31	31	22	29	29	23	24	27	25	29	28	27	29
%Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
***Rhizophora* (%)**	49.61	####	38.36	13.33	22.40	43.40	51.55	47.33	46.29	18.82	14.24	25.89	40.14	44.33	13.37	35.55	42.25	26.80	28.70	29.57	33.33	32.26	36.96	39.11	48.11	38.30	31.48	**####**
Spores %	18.11	7.16	25.58	28.25	21.75	22.14	15.64	28.19	16.61	35.01	36.95	27.25	14.22	23.52	39.52	25.64	7.29	12.98	11.96	12.54	19.38	9.68	10.66	7.26	7.86	11.99	7.71	**####**
***Podocarpus* %**	0.59	0.81	1.79	6.14	5.68	2.93	2.58	1.03	2.47	3.94	2.37	0.82	0.92	0.85	2.59	1.56	1.22	1.10	1.09	1.79	0.63	0.00	0.45	1.40	1.57	1.35	0.00	**1.77**

The bioindicator diagram, constructed from the data presented in Table 5 and illustrated in Figure 5, reveals marked variations through time. Alternating fluctuations in intensity are observed between, on the one hand, plant formations (forested, savanna, and mixed types) and, on the other hand, specific taxa such as *Rhizophora*, spores, and *Podocarpus*. *Rhizophora* pollen is particularly abundant in Zone 1, whereas spores and *Podocarpus* are only sparsely represented. In Zone 2, the proportion of spores increases significantly, indicating a more open and less humid phase. Finally, in Zone 3, *Podocarpus* exhibits a steady increase toward its maximum abundance, reflecting the expansion of montane or temperate vegetation under cooler and more humid climatic conditions.



Zone 1: Regression of ubiquitous pioneer and undergrowth taxa (**9400 - 11,300 years**). **Zone 2**: Increase in spores during the Podocarpus phase, both alternating in contrast with Rhizophora (**5400 - 9400 years**). **Zone 3**: Forest resurgence in favor of Podocarpus (**0 - 5400 years**)

Figure 5. Evolution of ecological bioindicateurs (*Rhizophora, Podocarpus*, Spores).

4. Discussion

4.1. Taxonomic Diversity of Plant Families

Pollen analysis reveals a substantial representation of numerous plant families, indicating high diversity at both the genus and species levels. The most abundant taxa, in terms of both absolute number and relative proportion, correspond to those identified in recent dredging samples from the Cameroonian continental shelf, notably *Rhizophora*, spores, *Poaceae*, *Cyperaceae*, *Alchornea*, *Drypetes*, *Uapaca*, and *Podocarpus* (Bengo et al., 2020; Bengo et al., 2025). These results corroborate previous observations on marine pollen sedimentation, emphasizing the key role of fluvial inputs, particularly from the Sanaga River—the main drainage system collecting runoff from watersheds that extend from the dense forests of the south to the savannas of central and northern Cameroon (Olivry, 1986; Giresse et al., 1995). Thus, the floristic diversity recorded in core C61 faithfully reflects the botanical richness of the adjacent continent.

However, overall taxonomic diversity remains slightly lower than that observed on land, likely due to taphonomic processes and the constraints imposed by marine dynamics (Fredoux, 1994; Dupont & Agwu, 1991; Vincens et al., 1994). Indeed, incomplete fossilization and the long-distance transport of pollen grains from their continental source can result in the underrepresentation or even absence of certain taxa originating from distant ecosystems. In particular, arboreal taxa characteristic of savanna or semi-deciduous forest, montane or semi-deciduous forests—such *Hymenocardia, Bridelia or Annona*—are often poorly represented or absent in marine records, despite being common in the inland vegetation. This limitation, well documented in marine palynological studies from Central Africa and the Gulf of Guinea (Caratini et al., 1987; Van Campo & Bengo, 2004; Hernandez et al., 2021), may affect the accuracy of paleoenvironmental reconstructions based solely on marine records.

4.2. Holocene Paleoenvironmental Evolution According to Core C61 (Figure 4)

The palynological data from core C61 allow for a detailed reconstruction of paleoenvironmental dynamics on the Cameroonian continental shelf from the onset of the Holocene to approximately 1450 cal yr BP. Rather than beginning with general considerations, we first present the main vegetational and sedimentary stages identified in the core and interpret them in light of regional climatic trends and sea-level changes. Three distinct paleoecological phases are identified, reflecting the evolving balance between coastal dynamics, continental inputs, and climatic forcing.

a) **First Phase (11,400 - 9400 cal yr BP): Coastal Expansion and Fluvio-lagoonal Environments Dominated by Rhizophora and Cyperaceae**

This initial phase, corresponding to Zone 1, is characterized by the dominance of *Rhizophora* and *Cyperaceae*, with a co-occurrence of taxa such as *Combretaceae*, *Bridelia*, and various herbaceous pollen types (**Figure 4**). These assemblages indicate the development of mangrove systems and wetland savannas at the land–sea interface, under the influence of a warm and humid climate. The high abundance of *Rhizophora* suggests a well-established mangrove belt, while *Cyperaceae* and NAP taxa reflect seasonally waterlogged open habitats. *Podocarpus* is poorly represented, likely restricted to mid-altitude zones due to still-elevated regional temperatures (Maley, 1987; Lebamba et al., 2012).

This period follows the Late Dryas and corresponds to a time of increasing monsoon strength and hydrological intensification in Central Africa. Enhanced runoff from the Sanaga watershed, possibly linked to glacial meltwater inputs, likely contributed to accelerated sedimentation on the continental shelf (Giresse et al., 1995; Ngueutchoua, 1996). However, the role of glacial melting as a climatic driver must be interpreted with caution in this tropical basin, where local hydrodynamics and ITCZ displacement are more significant.

b) Second Phase (9400 - 5400 cal yr BP): Stabilization of Coastal Systems and Expansion of Savanna-Grassland Mosaics

During this interval, *Cyperaceae* decline while *Poaceae* and spores increase, accompanied by a retreat of shrubs such as *Bridelia* and *Combretaceae*. This floral transition suggests a shift toward more open environments, such as wooded savannas or anthropogenic clearings, but does not unequivocally signal aridification. Contrary to earlier interpretations, the available data do not support a markedly dry climate during this phase.

Instead, this period likely corresponds to the Holocene Climatic Optimum, characterized regionally by high rainfall and increased vegetation productivity (Ngomanda et al., 2009a, 2009b; Gasse, 2000). The expansion of grasses may reflect disturbance regimes, seasonal contrasts, or hydro-edaphic variability, rather than long-term drought. Simultaneously, a marine transgression reached its maximum around 6000 cal yr BP, gradually distancing the core site from the shoreline. This change in sedimentary context explains the dominance of marine muds and the reduced terrigenous input in this unit (Giresse et al., 1995; Ngueutchoua, 1996).

c) Third Phase (5400 - 1450 cal yr BP): Forest Expansion and Climatic Oscillations in a Stabilized Marine Context

This phase, corresponding to the upper part of the core, is marked by a sharp decrease in sedimentation rate (**Figure 5**), indicating post-transgressive stabilization of the marine depositional environment. The pollen assemblage reveals a diversification of arboreal taxa, including *Caesalpiniaceae*, *Sapotaceae*, and *Ulmaceae*, along with forest species such as *Sacoglottis*, *Lophira*, and *Elaeis*. Pioneer taxa (*Alchornea*, *Tetrorchidium*, *Pycnanthus*, *Uapaca*, *Drypetes*) are also well represented, pointing to mature forest development with dynamic understorey regeneration.

The occurrence of *Podocarpus*, coupled with peak values of spores, indicates episodes of cooler and wetter conditions, possibly linked to cloud-based occult precipitation in upland areas (Maley, 1987). Rather than a simple trend, this period reflects alternating wet and dry subphases, consistent with regional climatic variability during the Late Holocene (Lebamba et al., 2012; Suchel, 1988; Ngomanda et al., 2009a, 2009b). The observed vegetational transitions support a scenario of increased forest cover in the last two millennia, aligning with other Central African paleoecological records (Reynaud-Farrera et al., 1996; Maley et al., 2017; Yao et al., 2025).

4.3. The Importance of Bioindicators in Paleoenvironmental Interpretation

4.3.1. Variations in the Proportion of *Rhizophora* Spores and Pollen

Analyses performed on core C61 reveal that the high proportions of spores observed at various levels mainly result from a decrease in *Rhizophora* pollen. Spores are produced in large quantities by terrestrial or epiphytic ferns in a wide range of environments, from savannas to forests, including transitional zones. Such spore abundance is observed near the mouths of all coastal rivers. This interpretation is supported by modern observations from the Cameroonian continental shelf, which show that present-day concentrations display similar trends—that is, peaks in *Rhizophora* and spore abundance often coincide. However, the relative magnitudes of these peaks vary among dredged samples, and the proportions of each taxon depend on their proximity to mangrove development areas (Bengo et al., 2025).

However, a clear spatial differentiation is observed: in the southern sector, where the coastline is devoid of mangroves, spore values reach high levels, whereas in the north, the presence of tidal influence, extensive mangroves, and the high production of *Rhizophora* pollen maintain these values at lower levels.

4.3.2. Dynamics of Rhizophora, Spores, and the Paleoecological Significance of the Coastal Signal

The variations in *Rhizophora* pollen frequency observed in core C61 reflect changes in the extent or proximity of mangrove ecosystems during the Holocene. *Rhizophora* is an excellent indicator of estuarine and lagoonal zones under saline influence, and its abundant presence generally suggests that the recording site was located relatively close to the shoreline under a stabilized sea level (Fredoux, 1994; Bengo et al., 2025; Giresse et al., 1995). Sharp declines in *Rhizophora* within certain sections of the pollen spectrum may reflect either a gradual offshore shift of the coastline due to Holocene transgression (Ngueutchoua, 1996) or local ecological factors (e.g., sedimentation, salinity, turbidity) unfavorable to mangrove development (Dupont & Agwu, 1991).

In the same intervals, relative increases in spores probably reflect dilution effects in the pollen signal rather than an actual rise in spore production. The inverse alternation between *Rhizophora* and spores, particularly in Zones 2 and 3, therefore indicates variations in fluvial input and coastal vegetation cover, without necessarily implying a regressive or markedly cooler climatic episode (Bengo et al., 2025; Lebamba et al., 2009).

Moreover, the intermittent presence of *Podocarpus* cannot be interpreted as direct evidence of altitudinal migration due to cooling. It is more likely that these occurrences reflect sporadic inputs from mid-altitude areas during wetter phases favorable to its regional development (Maley, 1987; Lebamba et al., 2012). In the absence of independent data on sea level or temperature, caution is warranted in interpreting these signals. Thus, the opposite variations among *Rhizophora*, spores, and *Podocarpus* should be viewed as the combined result of sedimentary dynamics, distance from the coastline, local ecosystem fluctuations, and taphonomic effects inherent to marine environments (Fredoux, 1994; Dupont & Agwu, 1991; Van Campo & Bengo, 2004).

4.4. Regional Comparison and Paleoclimatic Consistency

The palynological sequence from core C61 shows several transitions in vegetation composition that are partly comparable to continental records from Central Africa. However, some key intervals well documented in lake records—such as the forest retreat and climatic instability around 2500 cal yr BP—are not clearly expressed in this marine core.

This retreat has already been highlighted in recent syntheses of Holocene environmental change in Central Africa (Giresse & Ngueutchoua, 1998; Ngueutchoua & Giresse, 2010), which emphasize the widespread nature of the 2.5 ka dry phase, often associated with savanna expansion, lake-level fluctuations, and cultural changes. Its absence or attenuation in core C61 could reflect several factors: the limited number of palynological levels in the upper part of the core, the large intervals between radiocarbon dates, or taphonomic constraints linked to low sedimentation rates (**Figure 3**).

Despite this limitation, the overall trends observed in core C61—namely, mid-Holocene forest expansion and Late Holocene fluctuations—remain broadly consistent with other regional archives, such as Lake Barombi Mbo (Brenac, 1988), Lake Ossa (Reynaud-Farrera, 1995), and Kitina (Elenga et al., 1996). These comparisons highlight the potential of marine pollen records to capture large-scale climatic phases, but also their limits in recording short-term or abrupt events, especially when sampling resolution is low.

Future work should therefore focus on improving the age-depth model of core C61 through additional radiocarbon dates, particularly in the uppermost sections, and increasing palynological resolution between 3000 and 1000 cal yr BP to verify whether regional signals such as the 2.5 ka dry event are preserved in the marine domain.

5. Conclusion

The analysis of core C61 provides useful insights into the evolution of coastal environments along the Cameroonian margin over the past ~11,000 years. Three major vegetation phases were identified: an initial phase dominated by *Rhizophora* and *Cyperaceae* under humid, fluvially active conditions; a second phase reflecting more open landscapes (*Poaceae*, spores); and a third phase indicating the expansion of humid forests (*Caesalpiniaceae*, *Sapotaceae*, *Podocarpus*), likely under more stable climatic conditions.

Despite these constraints, the C61 sequence confirms the potential of marine deposits to reflect long-term regional trends. It also emphasizes the need for high-resolution, multi-proxy approaches to distinguish climatic signals from sedimentary and taphonomic noise.

Conflicts of Interest

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

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