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Implications of Marine Hydrodynamism in the Dispersal and Modern Distribution of Pollen on the Cameroonian Continental Shelf

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Abstract

This study explores the dynamism of pollen dispersal and sedimentation on the Cameroonian continental shelf, influenced by marine currents and fluvial inputs, in particular those of the Sanaga River, crossing from NE to SW different plant successions ranging from savannah to humid forest. In addition, the monsoon and trade wind flows blow towards the continent, while the NE winds of the Harmattan directed towards the ocean hardly exceed the Savannah-Forest boundary. Through the analysis of 66 dredging samples, 43,131 pollens were identified, belonging to 381 taxa divided into 116 botanical families. The study reveals that the terrigenous inputs are essentially fluvial and concentrated at the front of the mouths. Marine currents play an important role in the distribution of pollen near the coast and offshore. It has been observed that large, flattened pollens are observed near the coasts, while small pollens can be transported easily to the open sea. In addition, *Rhizophora* pollens and spores, often recorded in fossil spectra, vary differently depending on the distance from areas of high mangrove production. The results provide a reference model for the reconstruction of past paleoenvironments and climates.

Keywords

Pollens and Spores, Continental Shelf, Littoral, Dispersion, Sedimentation, Marine Currents, River Inputs, Sanaga River, Cameroon

1. Introduction

Sedimentological studies conducted in Africa and elsewhere in the world, both past and recent, have mainly focused on the mineral fraction of sediments. This research, carried out in various geographical contexts, includes work on lakes [1] [2], margino-littoral deposits [3] [4], as well as marine sediments [5]-[7]. However, very few studies have focused on the organic fraction of marine sediments, in particular pollens and spores, and other palynomorphs which are often associated with the fine mineral fraction, because of their small size similar to that of pelites.

Many pollen diagrams, used to reconstruct paleoenvironments, have been interpreted without a prior understanding of the hydrodynamism of the basins or the origin and dispersal of pollen in sediments [8]-[10]. Laboratory research on the sedimentary dynamics of pollens is that of Holmes [11].

The present study is based on data collected during oceanic dredging campaigns of the seabed of the Cameroonian continental shelf, carried out within the framework of the CAMPUS-Cameroon [12] and CHRIS-Elf (Chronostratigraphy and Sequential Interpretation [13]) programs, in collaboration with the ECOFIT-CNRS & ORSTOM (Long-term Dynamics of Intertropical Forest Ecosystems) program. Previous studies on the same scales have focused mainly on the mineral fraction of sediments [14], and a preliminary pollen study examined the distribution of some mangrove taxa [15].

The objectives of this study are threefold:

- **Verify** whether pollen fluxes on the Cameroonian continental shelf accurately reflect the diversity of adjacent plant ecosystems;
- **Understand** the mechanisms of dispersal and sedimentation of pollens and spores from the flows of coastal rivers, particularly the Sanaga River, confronted with hydrodynamics of the marine environment;
- **Characterize** the current marine pollen spectrum in order to use it as a reference for the reconstruction of past plant environments and climates.

This study therefore aims to contribute to a better understanding of pollen sedimentation processes and to provide a reference model for future paleoenvironmental reconstructions.

2. Material and Methods

2.1. Study Site

2.1.1. Geographical and Geological Context

The Cameroonian continental shelf, located in the central part of the Gulf of Guinea, extends between latitudes 2˚20'N and 4˚30'N and longitudes 8˚20'E and 9˚55'E.

From the north-south coastline, the 200-metre isobath is quickly reached, with a slope that reaches almost 20% above 100 metres depth.

The tectonics of the basin, characterized by horsts and grabens, are associated with the N60 faults resulting from the opening of the South Atlantic from the Albian. Four major lithostratigraphic ensembles are identifiable, including formations dating from the Albian to the Cenomanian, Paleogene facies, middle to late Miocene facies, and Pleistocene facies [16].

This plateau belongs to two basins: the northern basin (Douala-Rio Del Rey) and the southern basin (Campo), separated by the advance of the Precambrian basement at the level of Kribi. In the northern part of the plateau, the sedimentary cover is dominated by loose deltaic complexes from the Sanaga and Niger rivers, incised by channels filled with Pleistocene deposits. In the southern part, where the waters are calm and sedimentation is more limited, there are relict deposits of the last eustatic cycle composed of muddy sands rich in glauconia and bioclastic calcareous sands [7] [14].

2.1.2. Terrigenous Inputs, Atmospheric and Oceanic Circulation

The displacement in latitude of the Inter-Tropical Convergence Zone (Z.C.I.T.) of the air masses is the cause of the monsoon circulating towards the continent and the Harmattan winds of the NE direction blowing towards the ocean [17]-[19]. The marine hydrodynamism of the Gulf of Guinea (**Figure 1**) are determined mainly by the general regime of the oceanic circulation which is expressed near the coast by the action of the waves and tidal currents that affect the Bay of Biafra; a coastal drift current towards the north. Offshore, the deep Guinea Current flows parallel to the coast to the south, carrying part of Nigerien waters [20]-[22].

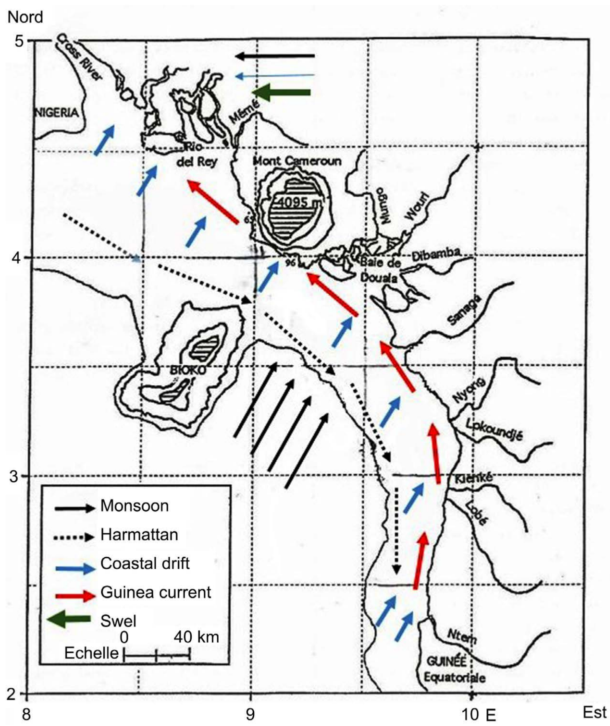

Figure 1. Atmospheric and oceanic circulation.

Terrigenous inputs to the Cameroonian continental shelf are mainly of fluvial origin, with coastal rivers such as the Sanaga, which carries about 6,000,000 tons of sediments per year, mainly composed of clay and silt [23] [24] and pollens and spores [25] [26].

Available oceanographic data confirm the presence of a northwestward coastal drift, with nearshore current velocities ranging from 0.2 to 0.5 m/s, and a southward-flowing Guinea Current offshore, with mean velocities of 0.1 to 0.3 m/s [20] [22]. These values support the inferred role of both currents in transporting sediments and pollen along the shelf.

2.1.3. Climate, Soils and Vegetation

The cycle of the seasons, the annual distribution of precipitation and temperatures act on the vegetation that develops on essentially ferralitic soils linked to the quality of the bedrock [27]-[30]. Plant ecosystems are mainly made up of dense humid forests in the south and savannahs in the north [31]-[33]. Other plant associations characterized by specific taxa linked to specific edaphic or climatic conditions are present, such as along the coast with mangroves with *Rhizophora mangle*, *Avicennia africana*, *Langucularia racemosa* [34] [35]; and at higher altitudes, the mountain formations with *Podocarpus*, *Olea*, *Rapanea* [36]. The distribution of sediment types along the coast, particularly the concentration of fine-grained pélites in estuarine zones and near river mouths [14], also influences vegetation development and pollen preservation. These pélitic zones, rich in clay minerals such as kaolinite, illite, and smectite, and higher in organic matter, create favorable conditions for the accumulation and conservation of pollen grains in marine sediments. This sedimentological context reinforces the connection between coastal vegetation types such as mangroves and the palynological signal recovered offshore.

2.2. Sampling

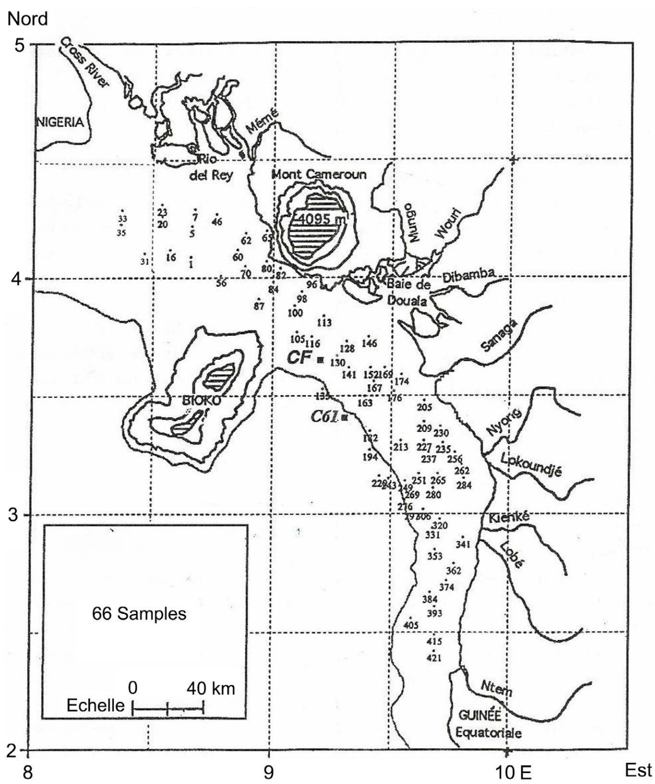

Figure 2. Locating dredging samples.

The samples were collected during three oceanographic missions aboard the *N.O. André Nizery*, as part of the CAMPUS-Cameroon [12] and CHRIS-Elf [13] programs. A total of 472 dredging samples were collected from the Cameroonian continental shelf. Among these, 71 samples were selected for palynological analysis based on their geographical distribution, depth range (from nearshore to ~200 m), distance from the coast, and sediment texture, with a preference for fine-grained sediments (clay and silt) that favor pollen preservation [25] [37] [38].

After laboratory processing, 66 samples retained for the analysis. This final dataset provides a representative coverage of the main hydrodynamic and sedimentological gradients across the shelf, allowing for a robust assessment of pollen and spore dispersal patterns in relation to terrigenous inputs and oceanic circulation, as illustrated in **Figure 2**.

2.3. Analysis

2.3.1. Sample Preparation, Identification and Analysis

The samples were prepared according to classical palynological methods (Cour, 1974; Faegri and Iversen, 1975). Pollen identification was carried out using regional monographs [39]-[42] and slides from the Reference Collection of Current Pollens of the Montpellier Laboratory. The data obtained were organized in the form of contingency matrices [43] [44] and analysed using a correspondence factor analysis (FCA).

Two series of analyses were carried out:

- The first analysis included all samples and taxa.
- The second analysis was carried out after eliminating taxa with a low contribution in the initial FCA, in order to better identify significant groups.

Data processing and graphical representation were carried out using the PAST software [45].

2.3.2. Mapping and Representation of Data

Isopollen maps have been generated to visualize the dispersal of pollen on the continental shelf, according to the same principle as topographic or sedimentological maps. These isopollen curves connect the points where pollen concentrations are similar, thus illustrating the areas of accumulation and dispersal of pollen as a function of the physico-chemical and hydrodynamic conditions of the basin. This method has been used previously by [8] and [9] on the South Atlantic coasts of Africa.

3. Results

3.1. Pollen Identification

The palynological analysis of the **66 samples** collected across the Cameroonian continental shelf revealed a diverse assemblage of taxa representative of the surrounding vegetation cover. From the 66 valid samples, a total of 43,131 pollen grains were counted, of which 42,241 were confidently identified, corresponding

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

Count table of the main taxa or pollen types in samples from the Cameroonian continental shelf

		Ubiquists																Savanah										Forest																											
Samples	Dredges samples CC	Damaged Pollen	Dynocystes	Alchornea type	AMARANTHACEAE-CHENOPODIACEAE	CAESALPINIACEAE	COMBRETACEAE	COMPOSITAE	CYPERACEAE	Elaeis guinensis	Entada	GRAMINAE	Lannea	Lophira	Mallotus	SPORES	Uapaca	Baphia	Ceiba	Dorstenia	Margaritaria	Canthium	Bridelia	Hymenocardia	Tetracera	Anthocleista	Symphonia	Adenia	Bosqueia angolesis	Commelina	Dodonea	Fagara	Irvingia	klainedoxa	Martretia	Hymenodyctyon	Myrianthus	Nauclea	Pandanus	PAPILLIONACEAE	Pycnanthus	RUBIACEAE	SAPOTACEAE	Tetrorchydium	Ziziphus	Calpocalyx	Celtis	Drypetes	Macaranga	Olea	Podocarpus	Rhizophora	Others	UNDETERMINED	Total Pollens and Spores (sample)	Taxonomic diversity
1	CC1	7	2	26	0	1	3	3	4	9	0	25	0	0	2	34	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	5	3	1	285	11	13	433	30
2	CC5	8	0	12	0	0	5	0	0	8	0	18	0	1	7	23	1	0	0	0	0	0	0	1	2	0	0	0	0	2	1	2	6	0	0	0	0	0	3	1	1	0	2	0	0	0	0	6	2	0	0	102	29	36	271	37
3	CC7	0	1	14	0	1	2	2	6	37	2	43	0	0	2	137	0	0	0	0	0	3	0	0	0	0	4	0	0	3	0	0	1	0	0	0	0	0	0	0	2	1	1	5	0	0	0	8	1	0	8	460	50	3	796	43
4	CC16	3	3	20	1	1	0	1	5	5	0	18	0	9	3	42	6	1	1	0	1	0	0	1	0	0	1	0	0	3	0	0	0	5	0	4	0	0	0	0	10	0	1	1	0	0	0	8	4	1	0	484	15	3	655	40
5	CC20	0	0	10	0	2	0	3	3	18	1	30	0	0	5	82	1	0	0	0	0	1	1	0	1	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	6	5	1	1	360	42	8	590	39
6	CC23	1	0	6	0	0	2	2	2	39	0	18	0	0	2	252	2	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	2	1	1	1	0	2	0	0	0	2	2	1	1	445	11	5	804	32
7	CC31	1	1	0	0	0	0	0	0	9	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	36	4
8	CC33	15	0	1	0	0	0	0	0	1	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	27	5
9	CC35	23	0	3	0	2	3	1	1	0	0	21	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	22	6	20	88	16
10	CC46	2	2	17	0	0	2	1	4	4	0	13	0	3	2	59	5	2	0	0	1	1	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	2	3	0	9	0	0	4	0	0	3	0	8	0	1	503	15	10	676	37
11	CC56	3	0	9	0	1	2	1	3	8	0	10	0	0	3	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	8	4	0	0	111	5	5	202	19
12	CC60	0	0	25	2	0	1	0	4	6	0	36	1	0	13	47	2	0	0	0	0	0	2	4	1	0	0	0	0	0	0	1	0	2	0	0	0	1	1	0	7	0	1	0	0	0	2	7	10	0	1	365	26	15	583	40
13	CC62	3	0	10	0	2	1	0	3	9	0	29	0	3	3	28	1	0	0	0	0	2	1	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	2	0	1	0	0	4	3	0	1	301	14	6	428	31
14	CC65	0	0	22	1	1	2	1	4	11	0	16	0	9	3	66	5	0	0	0	0	1	1	0	1	1	0	2	0	8	0	2	1	1	0	0	1	0	0	0	10	0	0	1	0	1	3	5	1	1	3	549	12	8	754	43
15	CC70	2	2	91	2	3	12	7	12	8	0	50	0	37	7	61	14	0	0	0	2	2	0	2	1	1	0	0	0	2	0	3	3	3	1	0	0	4	1	0	12	0	2	2	0	0	3	3	6	2	4	1000	26	5	1394	54
16	CC80	2	1	66	2	8	5	2	15	22	1	72	0	21	0	106	8	1	0	0	1	0	0	2	1	0	0	1	0	10	0	4	2	1	0	0	0	2	1	0	28	2	4	9	0	0	16	2	8	4	0	1298	25	6	1756	52
17	CC82	7	0	7	0	0	2	0	3	3	0	18	0	0	2	17	2	0	0	0	0	0	2	1	1	1	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	1	0	2	0	0	0	7	2	0	1	146	16	10	248	34
18	CC84	3	0	26	2	2	6	3	10	10	0	39	0	6	6	44	5	0	0	0	1	0	1	2	2	0	0	1	1	3	0	2	2	0	0	6	0	2	0	0	4	1	3	1	2	1	1	5	4	0	3	245	38	23	513	54
19	CC87	3	1	85	0	0	10	2	1	11	0	52	0	14	3	94	13	0	0	0	0	0	1	0	1	1	0	0	0	2	0	0	4	0	0	0	0	1	0	0	2	0	3	4	0	0	0	4	2	0	0	648	16	19	993	36
20	CC96	4	0	35	1	0	4	5	11	13	1	27	2	3	2	125	10	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	4	0	0	10	0	0	0	0	12	2	2	5	0	0	2	3	2	0	3	646	19	12	966	45
21	CC98	2	0	21	0	8	1	3	5	8	0	18	0	4	0	123	8	1	0	0	1	1	0	1	0	1	0	0	0	3	0	1	0	1	0	0	0	3	0	0	14	0	1	10	0	0	2	4	4	3	1	560	16	23	850	43
22	CC100	0	0	40	0	2	9	1	22	16	1	61	1	9	5	127	22	0	0	0	1	1	0	0	0	0	0	0	1	3	0	2	0	0	0	2	0	3	1	0	15	0	4	11	1	0	1	3	3	1	2	356	33	11	771	60
23	CC105	4	5	16	3	2	5	3	11	6	1	28	0	4	2	110	16	1	2	0	0	0	0	1	2	0	0	0	1	3	0	1	0	0	0	1	1	0	0	0	7	0	2	5	1	0	3	2	3	0	2	487	21	4	757	48
24	CC113	0	1	20	1	1	6	5	1	22	0	55	1	4	2	130	13	0	1	0	0	2	1	4	0	0	0	1	0	12	0	4	0	0	0	0	0	1	1	0	6	0	1	1	0	0	0	6	1	0	6	255	24	7	595	49
25	CC128	0	0	13	0	8	2	3	8	12	1	66	0	0	2	166	7	0	3	0	0	3	2	1	0	1	0	1	0	7	0	0	1	0	0	0	0	0	1	0	1	0	0	5	0	0	1	4	6	0	6	296	33	14	674	54
26	CC130	0	0	8	0	0	0	2	0	1	0	26	0	0	0	135	11	2	3	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	1	0	0	0	0	2	2	0	1	265	12	6	482	27
27	CC135	0	0	27	0	7	0	0	7	3	0	50	0	1	4	92	6	0	0	0	0	0	0	1	1	0	1	0	0	3	1	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	1	4	2	1	3	252	28	9	508	43
28	CC152	2	1	103	1	3	11	11	51	29	1	112	1	34	21	213	44	3	1	0	2	1	3	3	1	2	0	1	1	7	1	5	5	1	1	9	1	3	0	0	28	0	9	12	0	0	7	8	8	4	7	960	81	20	1830	97
29	CC163	8	1	14	1	5	6	3	16	7	2	36	2	4	3	105	6	1	0	1	2	0	1	0	0	0	0	0	0	1	0	3	1	1	0	3	0	0	0	0	8	0	3	3	0	0	1	3	5	2	4	319	22	14	608	52
30	CC167	33	1	17	0	2	2	6	9	11	2	37	0	4	1	96	9	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	2	0	0	3	0	1	3	0	0	2	3	3	0	4	194	15	13	444	41
31	CC169	25	1	32	0	5	6	4	29	9	0	96	1	4	1	156	13	0	0	0	0	1	1	1	2	0	0	0	0	2	0	0	5	0	0	0	1	1	0	3	6	0	1	3	0	1	1	2	3	0	1	97	16	22	526	43
32	CC174	3	0	25	0	1	11	8	12	9	3	85	4	6	1	125	10	1	2	0	1	1	3	4	0	0	0	2	1	1	0	1	2	0	0	0	0	0	4	2	1	0	4	2	0	0	2	1	1	0	1	14	19	9	379	51
33	CC176	1	9	75	1	0	12	4	42	22	5	180	3	18	5	240	37	0	1	2	1	2	2	5	3	1	0	3	1	4	0	5	3	1	0	2	0	1	2	0	19	0	3	4	1	4	8	1	0	2	3	120	59	21	928	90
34	CC182	0	13	35	0	4	5	2	12	4	1	37	0	3	12	52	3	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	1	1	0	1	3	0	3	5	1	0	0	2	3	0	0	175	13	7	389	40
35	CC194	1	82	36	0	7	1	6	13	4	0	30	0	0	2	213	5	1	0	0	0	6	4	0	0	2	4	0	0	2	1	0	1	0	2	0	0	0	0	0	1	0	5	8	1	0	4	3	4	1	2	52	57	10	488	68
36	CC205	8	7	93	5	9	26	18	65	25	0	160	2	18	0	418	77	2	2	1	2	12	0	10	1	0	8	4	0	12	0	11	6	0	4	6	0	2	1	4	31	2	20	9	2	4	17	3	2	3	8	137	140	19	1401	121
37	CC209	0	18	175	0	23	26	16	39	22	0	71	1	56	5	456	61	3	0	0	3	4	12	3	1	2	2	1	0	9	0	9	9	0	5	10	1	6	0	1	58	1	16	27	1	0	12	13	3	4	4	356	126	24	1677	111
38	CC213	9	57	108	5	12	19	2	23	8	0	66	2	30	0	185	10	4	0	0	4	10	1	7	0	0	7	1	1	4	0	0	1	0	2	7	1	0	0	2	14	1	13	12	0	0	7	2	6	5	30	550	74	32	1268	86
39	CC220	10	25	141	5	0	10	7	44	8	0	88	0	39	0	188	21	2	0	1	2	9	1	11	1	4	0	2	0	7	0	8	1	0	0	0	0	2	0	1	14	0	12	24	0	0	14	0	4	9	22	639	75	25	1441	78
40	CC227	4	5	32	0	2	4	0	1	1	0	13	0	10	0	25	3	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	3	2	5	1	0	52	16	5	184	33
41	CC230	5	7	43	1	4	5	1	8	14	0	33	0	8	0	166	8	3	0	0	1	1	1	1	0	2	0	0	0	2	0	3	3	0	1	6	0	3	0	2	26	0	6	4	1	0	5	7	3	0	1	95	30	14	512	58
42	CC235	2	18	60	0	0	12	2	6	5	1	28	0	13	1	57	12	1	1	1	3	0	0	5	0	0	0	0	0	1	0	2	1	0	0	1	0	0	2	2	5	0	3	10	0	0	4	1	10	0	6	162	27	12	457	52
43	CC237	4	18	122	3	1	20	2	27	8	0	88	1	43	3	130	16	1	0	0	1	0	1	5	1	3	0	0	0	4	1	1	0	0	0	2	0	2	0	1	9	1	1	5	0	0	16	9	2	2	6	128	31	10	707	55
44	CC243	14	35	82	1	5	14	3	6	9	0	36	0	28	0	135	19	2	0	2	2	2	2	2	4	0	1	2	2	8	1	5	5	0	0	12	1	0	0	1	28	0	10	15	0	1	10	0	2	1	1	110	69	18	657	84
45	CC249	5	41	60	0	1	7	4	10	6	0	37	1	30	0	63	5	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	1	1	0	2	0	1	5	0	0	5	1	0	0	5	166	33	10	459	45
46	CC251	16	93	126	1	8	22	4	28	13	1	87	0	43	1	102	13	1	0	0	2	0	1	5	0	2	0	0	0	2	1	4	4	0	0	1	2	3	0	2	6	0	3	11	0	0	12	0	4	1	2	173	22	14	727	50
47	CC256	10	16	67	0	5	10	3	19	15	0	57	0	19	1	138	16	0	0	0	1	1	3	2	1	3	0	2	2	7	0	3	1	0	1	2	0	0	2	0	25	0	3	12	1	1	7	0	2	1	2	117	41	19	612	63
48	CC262	14	35	82	1	5	14	3	6	9	0	36	0	28	0	135	19	2	0	2	2	2	2	2	4	1	0	2	2	8	1	5	5	0	4	12	1	0	0	1	28	0	10	15	0	1	10	0	2	1	1	110	65	18	657	85
49	CC265	3	8	40	1	5	9	2	6	14	1	36	0	18	0	85	10	3	0	0	1	4	0	2	4	2	0	0	0	6	0	5	3	0	0	3	0	2	0	2	16	1	4	9	1	2	6	5	2	1	1	53	26	11	402	61
50	CC269	4	23	42	0	2	8	1	7	1	0	14	1	17	4	52	6	0	0	0	0	1	0	5	11	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	4	0	1	4	0	0	11	3	5	2	3	90	28	11	338	52
51	CC276	10	44	49	0	1	10	2	10	1	0	37	0	21	1	44	4	2	0	0	1	2	0	0	1	1	0	0	0	2	0	0	1	0	1	0	0	0	0	1	4	0	3	4	0	0	1	4	1	0	1	145	22	14	391	47
52	CC280	3	28	91	2	0	12	4	5	5	0	23	1	21	1	74	17	2	0	0	1	0	0	0	0	3	0	0	0	0	0	0	3	0	1	2	0	0	0	0	6	0	1	10	1	0	15	0	4	1	1	98	20	15	440	44
53	CC284	6	10	94	2	6	0	2	13	8	0	37	0	21	3	93	28	0	0	0	0	3	1	6	2	1	1	0	0	6	2	6	4	2	1	4	1	3	2	3	17	1	7	10	2	0	22	0	8	3	4	106	61	21	617	80
54	CC297	13	48	56	1	3	8	0	8	1	1	42	0	15	3	51	18	3	0	0	0	2	1	2	0	0	1	4	0	0	0	0	1	0	0	1	1	0	1	0	8	0	9	4	0	0	8	0	5	4	2	233	28	16	541	57
55	CC306	9	51	102	1	4	23	3	5	0	0	47	0	38	0	83	9	0	0	0	1	2	0	1	1	4	3	0	0	0	0	1	3	0	0	3	0	0	0	0	6	0	10	0	0	0	6	0	2	1	2	167	20	12	560	43
56	CC320	8	66	45	0	8	12	0	5	1	2	27	0	29	0	98	3	0	0	0	1	0	0	0	1	0	2	0	0	2	0	0	2	2	0	7	1	0	0	0	13	0	0	5	0	0	10	0	2	0	0	89	22	10	399	39
57	CC331	7	7	117	0	7	8	7	4	3	0	13	0	16	0	88	22	4	0	0	0	5	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	2	0	2	9	0	11	12	0	2	5	1	0	0	1	126	27	9	506	45
58	CC341	4	72	105	0	15	21	1	8	11	0	34	1	57	0	349	25	2	0	0	4	7	2	5	2	0	3	2	1	8	0	3	7	0	1	11	1	0	1	1	23	2	11	21	1	5	8	0	6	0	2	113	84	19	983	91
59	CC353	7	42	89	1	7	16	3	7	6	0	22	2	49	2	62	16	0	0	0	3	2	0	2	1	1	0	1	1	0	0	1	1	0	1	2	0	1	0	2	6	1	5	7	0	0	8	1	1	1	0	190	42	13	576	69
60	CC362	6	39	117	0	9	9	1	2	4	0	25	0	35	0	59	12	0	0	0	0	2	1	1	5	1	0	0	0	1	0	1	0	2	0	0	0	1	1	2	7	2	10	5	0	1	14	2	2	1	1	143	35	20	534	59
61	CC374	3	42	98	0	9	12	3	4	4	0	21	0	45	5	66	14	0	0	0	4	0	0	2	0	0	0	0	0	0	0	2	2	3	0	0	0	4	1	1	7	0	5	3	0	2	6	0	3	0	2	80	13	12	433	39
62	CC384	2	52	84	1	13	8	3	6	6	0	17	1	26	3	135	13	0	0	0	3	4	2	3	0	1	2	0	0	0	0	4	2	0	1	2	0	0	1	1	4	0	11	15	0	4	6	1	4	3	4	151	33	16	594	56
63	CC393	39	39	97	0	4	8	1	3	3	0	11	1	10	0	38	12	0	0	0	0	0	3	1	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	2	2	1	8	3	0	0	5	0	1	1	4	186	17	9	435	45
64	CC405	3	39	98	0	6	10	1	2	1	0	25	0	57	0	70	17	1	0	0	3	1	0	2	0	1	0	0	1	1	0	2	1	0	1	6	0	0	1	1	9	3	8	7	0	2	5	0	0	1	2	106	42	22	516	61
65	CC415	2	11	45	1	11	6	2	13	6	0	12	0	17	0	178	22	0	0	0	2	11	0	3	1	0	2	0	0	3	0	0	3	0	0	0	0	5	2	2	21	0	6	15	0	3	1	0	0	1	3	168	28	14	607	54
66	CC421	5	30	21	0	36	2	5	20	13	0	15	1	8	0	650	20	1	0	0	0	9	1	1	0	2	7	0	0	0	0	1	0	0	1	0	0	2	2	0	13	0	13	13	0	21	3	0	2	1	3	32	110	29	1058	84
Total taxa (in all samples)		401	1 153	3 548	50	300	510	201	739	625	28	2 713	31	1 066	159	7 834	834	53	17	10	61	129	63	127	64	53	52	35	16	187	11	122	122	26	31	139	15	68	39	49	632	27	284	410	18	56	325	182	210	76	198	17 464	2 232	890	43 131	
Absolute frequency (Presence in the samples)		55	48	65	28	52	59	56	62	64	18	65	21	53	42	66	61	28	10	7	33	41	33	44	33	32	19	20	13	46	10	40	48	14	19	30	14	30	25	30	56	19	54	56	15	17	50	46	58	37	55	66	64	64		

to 381 taxa distributed among 116 botanical families (Table 1). The most abundant family is the Rhizophoraceae, dominated by *Rhizophora* with 17,475 grains (40.52%). Other well-represented groups include spores (18.16%), Euphorbiaceae (10.46%), and Poaceae (6.29%). The Rubiaceae are notable for their high diversity, comprising 35 genera, including *Hymenodictyon*, *Canthium*, *Nauclea*, and *Sabicea*. The Euphorbiaceae, along with the now-separated Phyllanthaceae and Putranjivaceae (formerly grouped in Cronquist's system), are also abundant. Among the Euphorbiaceae, around 30 genera were identified, notably *Alchornea* (3548 grains), *Tetrorchidium* (410), *Macaranga* (210), and *Mallotus* (159). Within the Phyllanthaceae, the most common genera are *Uapaca* (834), *Hymenocardia* (127), *Bridelia* (63), and *Margaritaria* (61), while in the Putranjivaceae, only *Drypetes* was recorded, with 182 grains.

3.2. Factor Correspondence Analysis (FCA)

Two successive correspondence factor analyses (CFA) were carried out. The first, CFA 1 (Figure 3), was applied to a matrix including all 66 samples and the complete set of identified taxa. A second analysis, CFA 2 (Figure 4(a)), was then conducted on a reduced dataset composed of the 73 taxa with the highest contributions in CFA 1. This refinement significantly improved the explanatory power of the first two axes: the inertia of Axis 1 increased from 21.66% to 38.33%, and that of Axis 2 from 9.77% to 16.25%. Figure 4(b) displays the taxon cloud corresponding to those taxa contributing most strongly to the distribution of samples in CFA 2 (see Figure 4(a)), thus providing a clearer ecological interpretation of the main gradients.

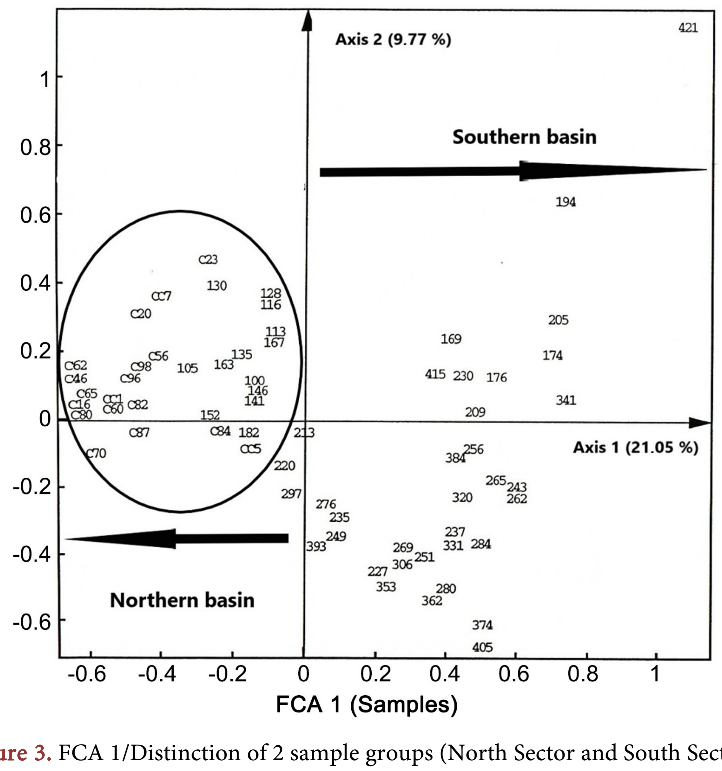

Figure 3. FCA 1/Distinction of 2 sample groups (North Sector and South Sector).

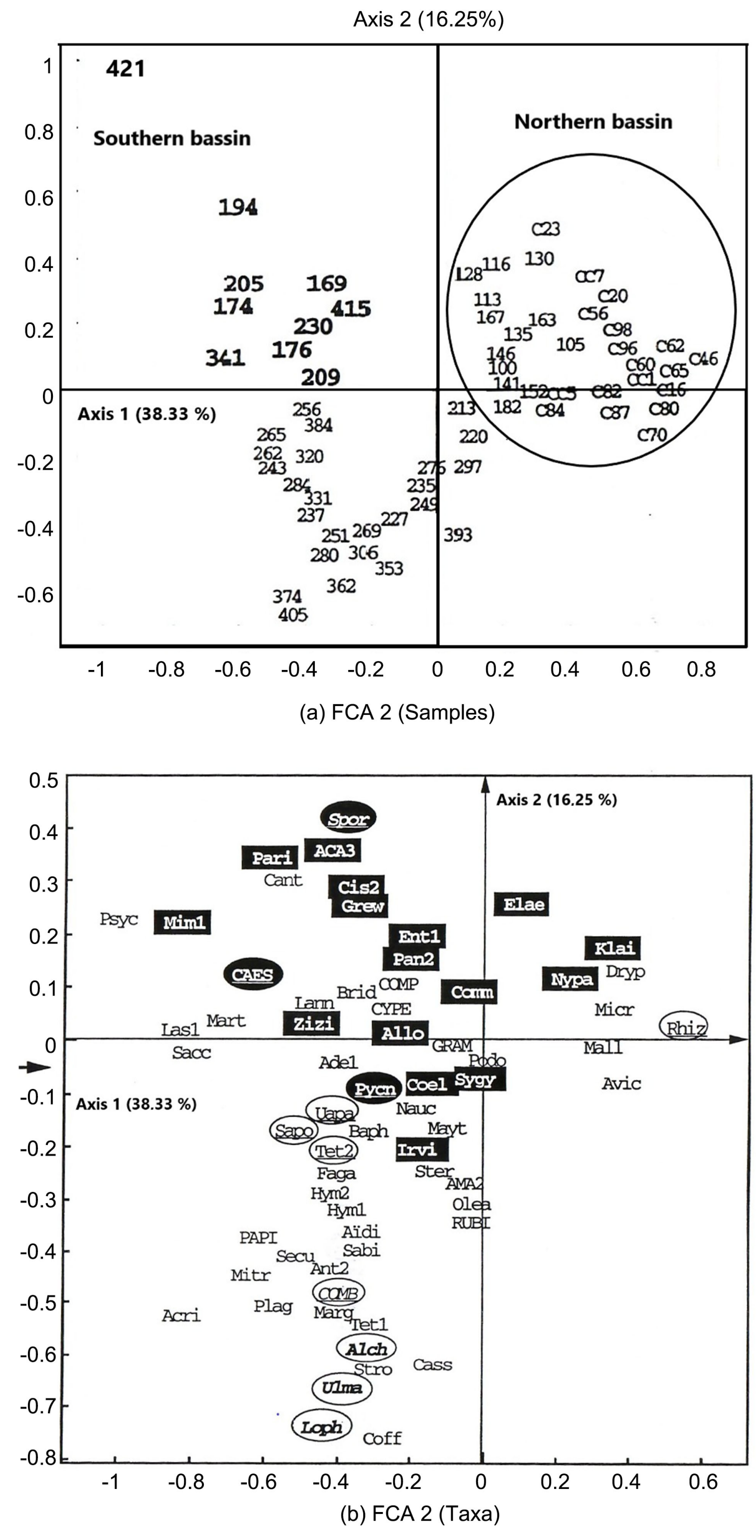

Figure 4. FCA (a) Samples (b) Taxa.

Axis 1 has an ecological significance, showing a cloud formed by groupings of distinct samples, one located in the northern basin containing abundant mangrove pollen, particularly *Rhizophora*, as well as taxa from various plant ecosystems traversed by the Sanaga River, and carried northwards by coastal drift; and the other in the southern basin receiving rivers that pass only through forested areas and rarely transporting taxa from open formations such as Grasses. Furthermore, this southern basin is influenced by nutrient-rich upwellings where dinocysts develop. The second axis is a factor related to marine hydrodynamics, which would influence pollen dispersion according to their size and shape.

3.3. Isopollen Maps and Pollen Distribution

Some maps of the distribution of certain pollens or spores have been chosen in order to illustrate certain apparent phenomena on the Cameroonian continental shelf.

- Near the coast, the high concentrations of spores (Figure 5) are located at the front of the coastal mouths and the distribution legs are oriented towards the NW;

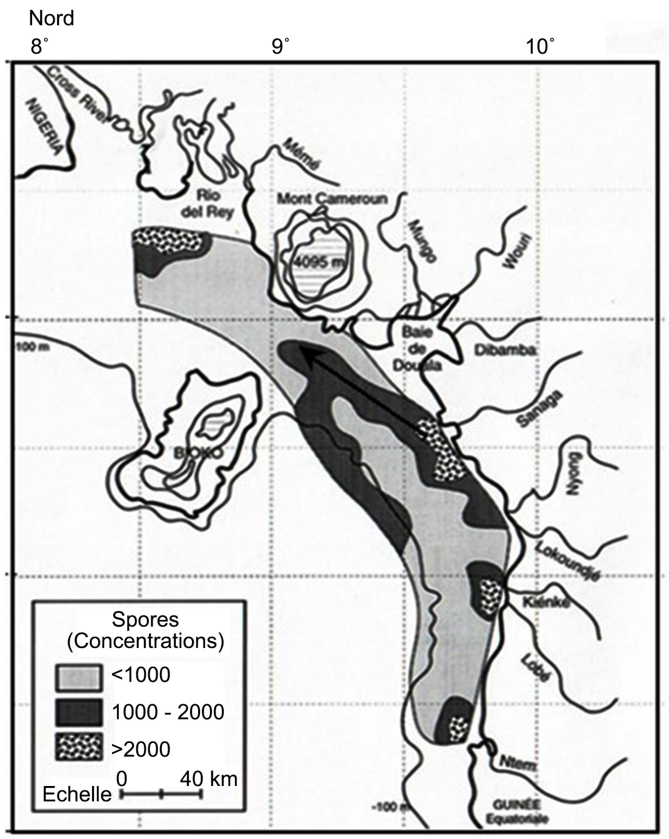

Figure 5. Near the coast, Spore flow shifted to the NW.

- *Rhizophora* pollen concentrations (Figure 6) are high in the bay of Douala and the Del Rey Complex. Offshore, these grades decrease as they move southwards;
- The pollens of Graminae (Poaceae) (Figure 7) and Compositae (Asteraceae) (Figure 8) which grow in the northern savannahs far from the ocean are more located in the basin of the northern sector;

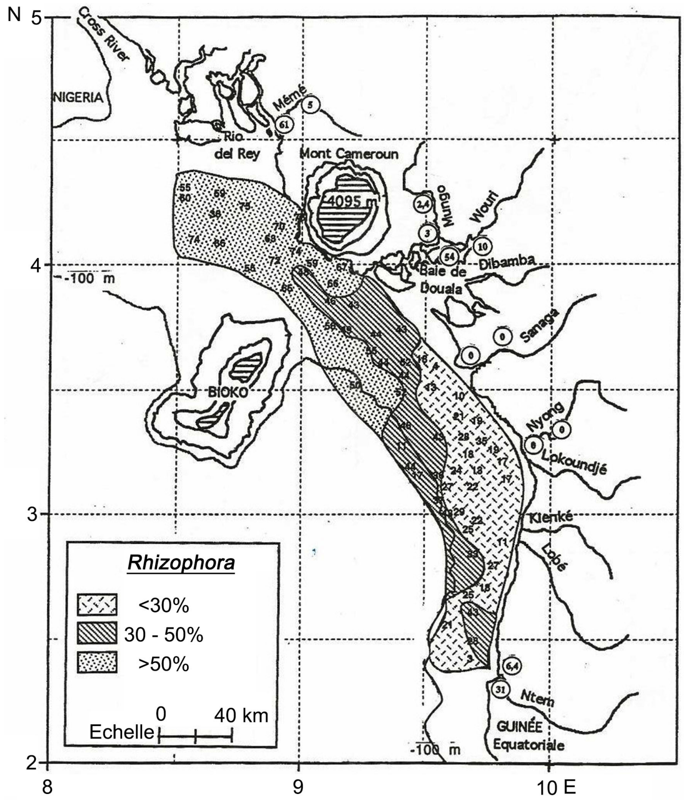

Figure 6. Offshore, the proportions of *Rhizophora* decrease from north to south.

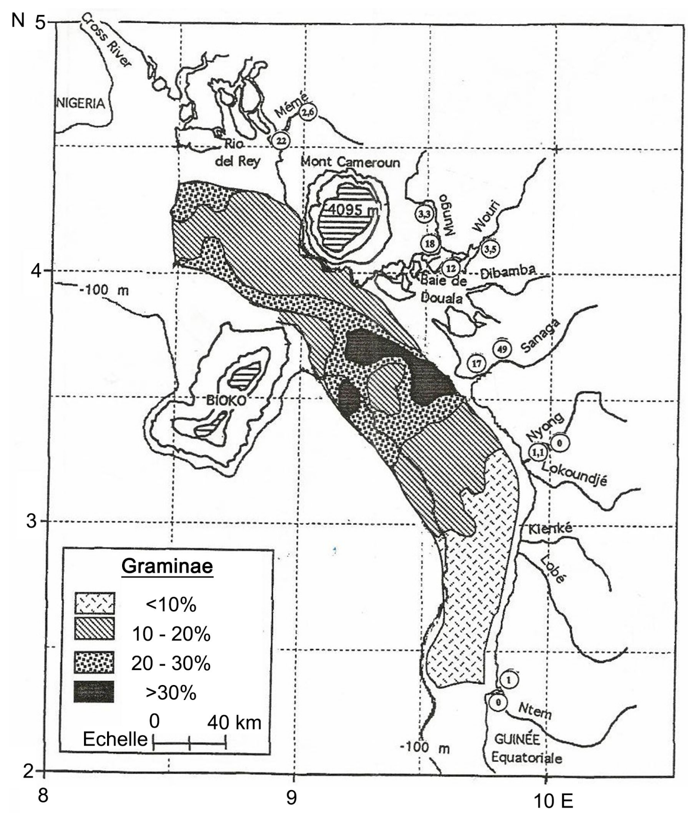

Figure 7. Graminae distribution.

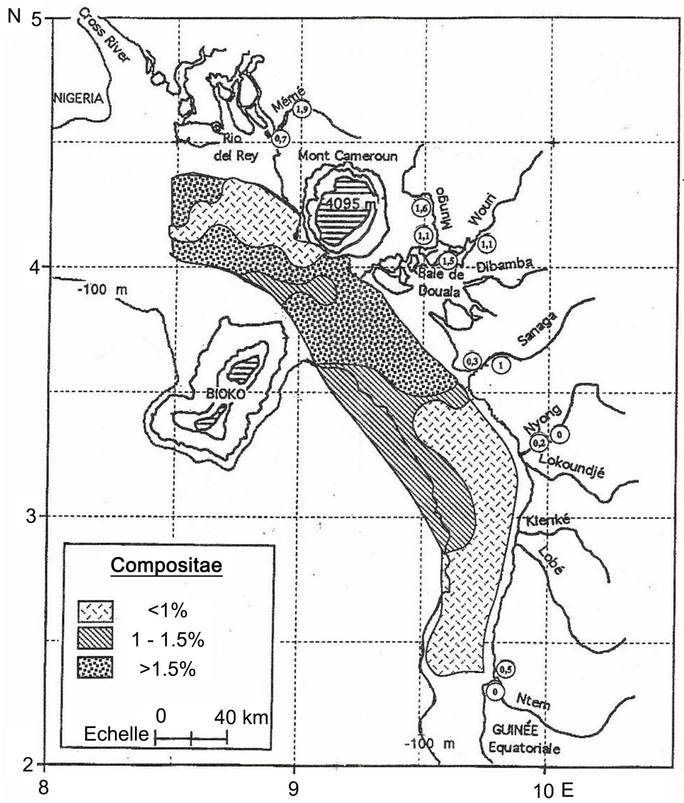

Figure 8. Compositae distribution.

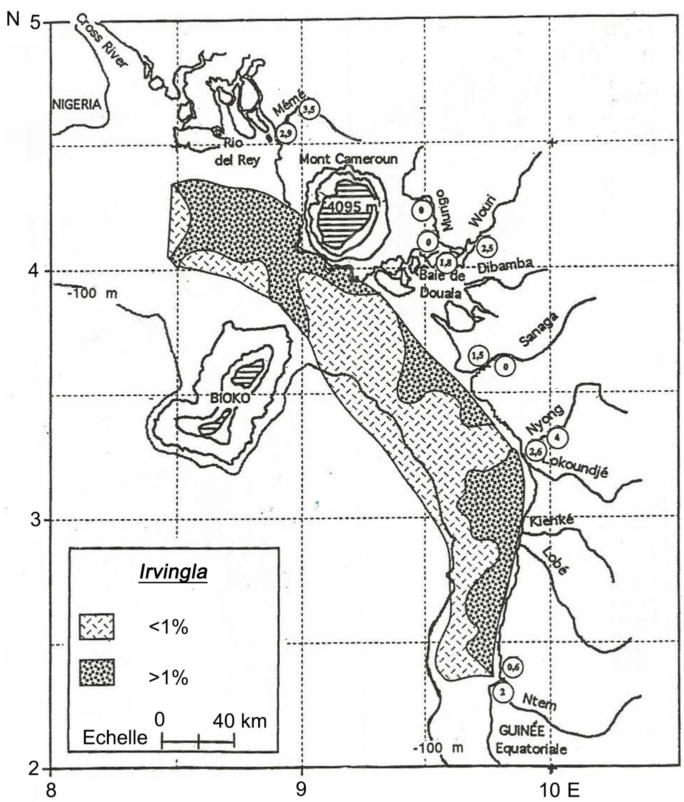

Figure 9. *Irvingia*, flattened pollen are more located at the front of the mouths.

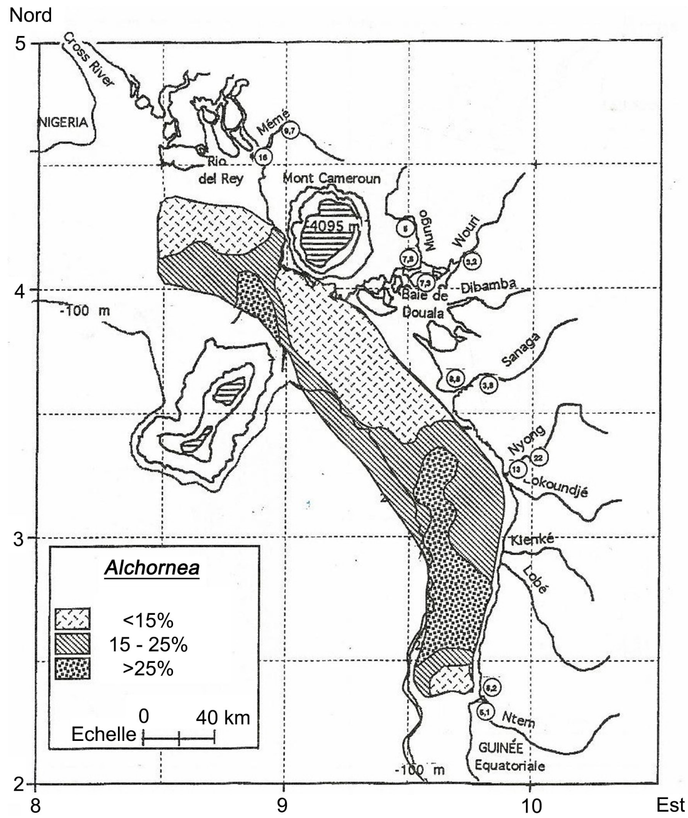

Figure 10. *Alchornea*, small and regular pollen, the higher concentrations are far from the mouths.

- *Irvingia* pollens (Figure 9) of flattened and triangular shape are more located at the front of the mouths, a behavior similar to spores the shape is similar;
- *Alchornea* pollen (Figure 10) of reduced size, the higher or lower concentrations are far from the mouths.

4. Discussion

4.1. The Taxonomic Diversity of Families in Fluvial Inputs from Marine Deposits

On the various pollen distribution maps (Figures 5-10), it can be seen that the high concentrations of pollen are located at the front of the mouths of coastal rivers, they decrease regressively as they move away from the mouth. This confirms that the terrigenous inputs of the Cameroonian Continental Shelf are essentially of fluvial origin, particularly drained by the Sanaga River [26]. However, northern wind inputs (Sahel, Sahara) cannot be neglected, since various data show that pollen has been observed on gauze filters installed on ships cruising far off the Gulf of Guinea [46] and in aerosols off NW Africa [47].

The identification of pollens revealed a significant presence of botanical families and a notable diversity among taxa at the generic and specific level. *Rhizophora* pollens are the most abundant because these plants produce a lot of pollen and the sources of production that are mangroves develop near the coast.

However, most of the taxa of the ecosystems crossed by the main Sanaga River are observed on the continental shelf, even the pollen of Graminae (**Figure 7**) and Compositae (**Figure 8**) that grows in savannahs far from the coast [26]. The pollen diversity observed in different samples distributed throughout the continental shelf reflects the picture of the botanical diversity of the adjacent continent. These results corroborate previous work on terrestrial samples [10] [48] [49]. However, it is important to point out that pollens from more distant ecosystems may be absent or underestimated in marine areas, due to the long distance travelled by these pollens to the ocean. This could thus limit the accuracy of paleoenvironmental reconstructions based solely on marine samples [9]. This spatial distribution faithfully reflects the ecotones between the different vegetation types adjacent to the Cameroonian coast, including mangroves, dense humid forests, and savannahs further inland.

4.2. Characterization of Two Groups of Samples in the North and South Basins

Factor Correspondence Analysis (FCA) made it possible to distinguish two groups of samples, one located in the northern basin; and the other on the southern basin of the continental shelf. The samples from the southern sector are mainly characterized by forest taxa and the virtual absence of mangrove taxa and savannah taxa, in particular the Graminae. The coastal rivers in this sector drain only the forest areas; on the coast, their flows drown in the calm and cold waters where dinocysts are concentrated, at the same time as fish and organisms that proliferate thanks to nutrient-rich upwellings [50] [51], up the coast at the upper limit of the southern sector basin.

The samples from the northern sector are much more characterized by pollen from mangroves (*Rhizophora*, *Avicennia*, *Nypa*) and inputs from the Sanaga (Graminae, *Alchornea*, *Cyperaceae*, *Irvingia*) crossing various plant ecosystems. The pollen carried by the Sanaga is absent in the southern sector because the flows of the river are deported to the northwest by the coastal drift.

4.3. The Influence of Marine Currents in the Dispersion of Pollen Flows Near the Coast by the Coastal Drift and Offshore by the Guinea Current

By juxtaposing the distributions of spores (**Figure 5**) and *Rhizophora* (**Figure 6**), we can see that near the coast, the flows are gradually oriented towards the NW, while offshore the concentrations of *Rhizophora* decrease as they go southwards. In addition, the pollens of Poaceae and Asteraceae, which are known to come from the savannahs and end up on the continental shelf via the Sanaga, are more concentrated in the northern sector. Indeed, in this area, the trade winds blowing towards the mainland reinforce the swells at the origin of coastal currents [22]. Near the coast, these coastal currents constitute the coastal drift that brings up the flows of the coastal rivers to the NW, in particular that of the Sanaga made up in part of the spores. This phenomenon has also been observed on the Cabindan and Congolese plateau, where a large part of the waters of the Congo River are recovered from the open sea by the drift of the N-NE trade winds which brings them back to the coasts of Pointe-Noire and Mayumba [52] [53].

In the northern sector, the mangroves growing abundantly near the coast at the level of the Cross-River, the Rio Del Rey complex and the Bay of Douala discharge pollen directly into the basin, and for this, the percentages of *Rhizophora* reach up to more than 80% in the samples. In these places in the Gulf, marine hydrodynamics can be summed up by the confluence of the flows of the rivers that flow into them, the Nigerien waters, and the waters of the coastal drift coming from the south; this flow is brought out to sea by the tides, and then taken up offshore by the deep Guinea Current which circulates southwards. This is how the pollen content of *Rhizophora* decreases from north to south (**Figure 6**); and moreover and far from the production areas, the proportions of *Rhizophora* are more significant offshore than near the coast.

The deep waters of the Guinea Current are brought back to the coast by the Equatorial Counter Current (ECC) and taken up by the coastal drift, representing a closed circuit marine circulation. A mixing of pollens is carried out that mixes marine pollen flows by providing a pollen spectrum that reflects the instantaneous image of the adjacent continental vegetation, and would be a reference when reconstituting paleoenvironments and paleoclimates; but also reassuring in sequential stratigraphy, when one wants to correlate distant drilling on the same platform during oil prospecting [13].

4.4. Influence of the Size and Shape of Pollen Sedimentation More or Less Distant from the Coast

The difference in distribution between large or flattened pollens, observed near the coast, and small pollens, transported further offshore, can be explained by the various hydrodynamic forces. Large pollens, which are less likely to be trapped in ocean currents, are deposited more quickly, while small pollens, often trapped in the colloids of suspensions, are transported over greater distances. These observations confirm that pollen size and shape play a key role in their dispersal, as described by [11] and [51].

Irvingia pollens (**Figure 7**), which resemble trilete spores, are flattened and triangular in shape, and are preferentially deposited near the coasts and at the front of the mouths. Indeed, the sediments found there are pelites [14], it seems that these relatively large and irregularly shaped pollens are not sufficient to insert themselves into the interstices, they are not transported and are the first to sediment when the flow of the river weakens in contact with marine water at the mouths. On the other hand, the pollens of *Alchornea* (**Figure 8**), which are small in size and round or regular in shape, trapped in the colloids of the suspensions, or clinging to the interstices of the fine particles of the pelites, are carried away from the mouth in the direction of the prevailing currents. Such a result was obtained from the laboratory experiment and field study at Silwood Lake in England of the influence of size on differential sorting in pollen and spore sedimentation processes [11].

4.5. Limitations and Perspectives

While this study acknowledges the key role of marine currents—particularly the northwestward coastal drift and the southward Guinea Current—in pollen dispersal, it does not fully account for the **complex interactions** between these currents, **tidal regimes**, **secondary countercurrents**, and other hydrodynamic factors (e.g., eddies, seasonal changes in salinity or temperature) that may influence pollen transport. A more detailed hydrodynamic model or in situ measurements (e.g., current velocity, turbidity profiles) would help refine the interpretation and better quantify the respective influence of these dynamic processes.

5. Conclusions

This palynological study is based on the analysis of **66 dredged samples** collected from the Cameroonian continental shelf. The high concentrations of pollen and spores near river mouths indicate that pollen deposition is primarily driven by terrigenous inputs from coastal rivers, particularly the Sanaga River. In the northern basin of the shelf, where Sanaga River flows are oriented northwestward, a high diversity of pollen taxa has been identified, reflecting the botanical richness of the various ecosystems it traverses. These include Gramineae (Poaceae) and Compositae (Asteraceae), characteristic of the northern savannahs. In contrast, in the Bay of Douala and the Gulf of Guinea, where mangrove ecosystems dominate, *Rhizophora* pollen is particularly abundant, reflecting the local development of coastal mangroves.

The sedimentation of terrigenous pollen flows is confronted with marine hydrodynamics and dispersal occurs according to the size and shape of the pollens and spores. Near the coast, the coastal currents of the coastal drift carry sediments to the NW, while offshore, the Guinea Depth Current circulates southwards and where the decrease in *Rhizophora* concentrations can be seen. Pollens with a flattened and irregular shape are deposited near the mouth, while small pollens with a rounded or regular shape cling to the interstices of the pelites, so they will settle far from the mouths.

The clear correspondence between current pollen fluxes and adjacent ecosystems suggests that, in older sediments, these same relationships between pollen sources and adjacent ecosystems remain, it can be used as a reference for the reconstruction of paleoenvironments and past climates in the Gulf of Guinea and other tropical areas.

Conflicts of Interest

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

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