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(RESEARCH ARTICLE)

Recent pollen rain analysis in Akoko environment as indicator of the vegetation of Ondo State, Nigeria

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Abstract

The study of Atmospheric Pollen Content (APC) in Akoko environment provides standard baseline information on environmental change, vegetation type, species composition and their utilization for sustainable development. This study was carried out in twenty randomly selected locations to examine the temporal and spatial relationship between the atmospheric pollen content and their vegetation. The palynomorphs were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed 182 pollen types belonging to 76 angiospermic plant families were encountered. Three (3) were identified to family level, 57 to species level, 121 to generic level and one (1) unidentified. The predominant pollen types belong to the family Poaceae, *Elaeis guineensis*, *Alchornea cordifolia*, *Aspilia africana*, *Casuarina equisetiifolia* and *Tridax procumbens.* The presence of *Empetrum nigrum*, *Linnea borealis*, *Stereospermum kunthianum* and *Vitellaria paradoxa* pollen indicates evidence of long distance transport. Pollen of exotic or introduced plants was part of the atmospheric palynomorphs recorded as evidence of human impact. Airborne pollen grains were most abundant between September and January (late rainy season to early dry season). Rainfall and relative humidity had negative effect on pollen concentration. Percentage composition of pollen grains abundance showed that indicators of the Savanna taxa were the highest pollen contributors (55.74%) followed by Open Forest (22.72%), Human Impact (14.32%) and Lowland Rainforest (7.21%) taxa respectively. The various ecological indicators species identified confirmed their origin as coming from the Forest- Savanna ecological zone that is anthropogenically disturbed, which is characteristic of Akoko environment. Pollen assemblages confirmed the vegetation of the study area to be Tropical Rainforest vegetation type despite high level of anthropogenic activities on the environment.

Keywords: Akoko Environment; Airborne; Pollen rain; Ondo State; Vegetation

1. Introduction

The vegetation of an area is an integral and basic component of the ecosystem and is sensitive to changes in the ecosystem [1]. Consequently, vegetation changes are themselves a response to and a reflection of variation in one or more of the factors of the environment, particularly climate. According to Sowunmi [2], a close relationship exists between vegetation and the rest of the environment, particularly climate and soil. Thus, the flora of an area provides a good reflection of the major climatic regime of the area. The influence of climate on other components of the environment is so great that every other climatic zone has its own characteristic vegetation type.

Plants are therefore among the best indicators of the environment especially of the climate, soil and fauna [3]. Certain individual or assemblages of plants are known to be characteristic of specific ecological zone and the occurrence of the fossils of such ecological indicator species in sediments is considered a reflection of contemporary ecological conditions [4]. For example, the tropical rainforest is characterized by broad-leaved species, the savanna characterized by grasses,

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the desert by ephermeral and sclerophyllous plants and the cold regions of the world characterized by evergreen conifers [5].

The study of vegetation and the way in which it has been altered and developed in the course of time indicates past changes that have occurred in our terrestrial environment [6]. Variations in climate and in the intensity of human activities in historic and prehistoric times have made their mark upon vegetation, and the plants themselves have left a record of these changes in the form of vast quantities of pollen grains which have survived in contemporary sediments [7].

The most common plant remains in Quaternary deposits are the pollen grains of flowering plants (Spermatophytes) and the spores of ferns (Pteridophytes) or mosses (Bryophytes); all of which are not visible to the naked eyes. The examination of pollen grains and spores do not only provide qualitative information on the plant present, but also quantitative information on their abundance. Thus, conclusion can be drawn about former vegetation conditions [8], [9].

The relevance of atmospheric pollen content to the vegetation of a region is related to the palynomorphs produced *in situ* and those supplied from the surrounding zones [10], [11]. Pollen and spores are generally produced in excess of the biological needs of the plants. Established observations have shown that anemophilous plants release large quantities of pollen into the air, while entomophilous taxa release smaller amounts [12]. The behavioural patterns lead to differences in the quantity of pollen and spores of various taxa available in the atmosphere, and which of them can be trapped during sampling [13].

Some factors that aid in the dispersal are the size, shape and density of the pollen and spores, the position of the parent plants (that produce them) in the vegetation and the prevailing climatic conditions [14]. The distinctive surface sculptures of pollen grains aid in the identification of their parent plants to at least family level [15]. Their other qualities such as small size, abundance and high resistance to degradation have made them an invaluable evidence of vegetation as well as environmental changes [16]. Because of the transitional location of Akoko division, Ondo State, Nigeria between the tropical rainforest in the South and the true savanna in the North; the area receives particles moving from the South to the Northern part of Nigeria and vice versa. Equally, the movements of the South-West Monsoon and North-East Trade winds across the latitudinal zones of Nigeria carrying along with them large quantities of particles which are deposited along their routes depending on the strength of the winds during the major seasons of the year. The aim of this study is to determine the taxa of pollen types present in the atmosphere of the study environment and the relationship between airborne pollen assemblages with its vegetation.

2. Material and methods

2.1. Location of the study area

Akoko division of Ondo State is located at Latitude 7^0 31'28.13''N and Longitude $5^0$46'9.25''E and an elevation of 526.88 m above sea level. It is comprises of a number of smaller towns, villages and homestead, whose inhabitants have in numerous ways left their impact on the environment.

2.2. Geology

There are two distinct geological regions in Ondo State. First, is the region of sedimentary rocks in the south, and secondly, the region of Precambrian Basement Complex rocks in the north. Some few kilometres north of Aaye occurs the basement complex sedimentary rocks boundary. The sedimentary rocks are mainly of the post-Cretaceous sediments and the Cretaceous Abeokuta Formation. The basement complex is mainly of the medium grained gneisses. These are strongly foliated rocks frequently occurring as outcrops. On the surface of these outcrops, severely contorted, alternating bands of dark and light coloured minerals can be seen. These bands of light coloured minerals are essentially feldspar and quartz, while the dark-coloured bands contain abundant biotic mica. A small proportion of the State, especially to the northeast, overlies the coarse grained granites and gneisses, which are poor in dark ferromagnesian minerals.

2.3. Climate

In the south, the mean monthly temperature is 27°C, with a mean monthly range of 2°C, while mean relative humidity is over seventy five percent. However, in the northern part of the State, the mean monthly temperature and its range are about 30°C and 6°C respectively. The mean monthly relative humidity is less than seventy percent. In the south, rain

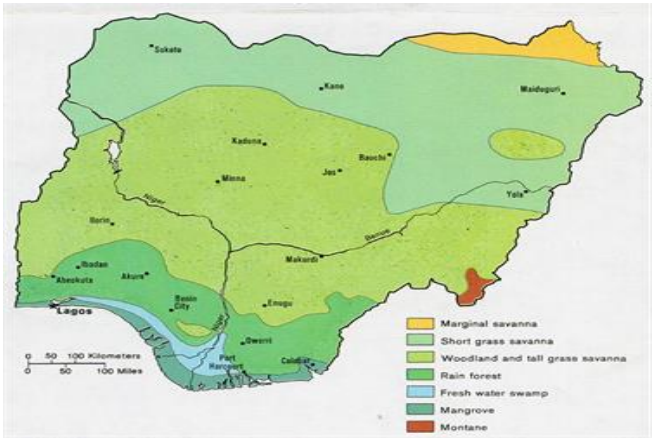
falls throughout the year, but the three months of November, December and January may be relatively dry. The mean annual total rainfall exceeds 2000 millimetres. However, in the north, there is a marked dry season from November to March when little or no rain falls. The total annual rainfall in the north, therefore, drops considerably to about 1800 millimetres.

2.4. Vegetation

The natural vegetation of Ondo State is the Tropical Rainforest type, composed of many varieties of hardwood timber such as *Milicia excelsa*, *Antiaris africana*, *Terminalia superba* and *Symphonia globulifera*. In the northern districts, the vegetation consists of woody savanna featuring such tree species as *Blighia sapida* and *Parkia biglobosa*. The swamp flats are the domain of the fresh water swamp forests in the interior and units of mangrove vegetation near the coast. The sand ridges are characterized by savanna and stunted rain forests taxa. Over most part of the State, the natural vegetation has been very much degraded as a result of human activities, the chief of which is based on the rotation of bush fallow system and lumbering. As a result of anthropogenic activities, Government has restricted the original forest to forest reserves [5], [17].

An important aspect of the vegetation of the Ondo State is the prevalence of tree crops. The major tree crops include *Theobroma cocao*, *Cola nitida*, *Coffee arabica*, *Hevea brasiliensis*, *Elaeis guineensis* and *Citrus* sp.; cocoa being the most prevalent. It is also important to note that rubber and oil palms have been cultivated in large plantations in Odigbo, Okitipupa and Irele Local Government Areas. Trees that are not native have also been introduced as forest plantations. These exotic species have been used to re-vegetate large portions of harvested old forest reserves in Omo and Owo. They include mainly *Tectona grandis* (teak) and *Gmelina arborea* (pulp wood). Map of the study area are shown below:

a.



b.

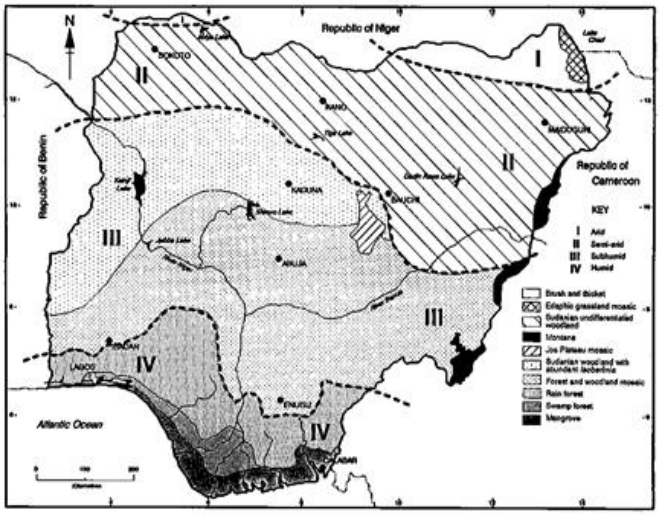


Figure 1 Map of Nigeria showing Vegetation and Climatic Zone of Study Area. (a) After Essien (2019) Pp. 76-77, (b) After White (1983)

2.5. Study design and sampling technique

Twenty locations comprising fourty sampling points were randomly selected within the four Local Government Areas of Akoko division, Ondo State, Nigeria, as sampling sites. The sampling sites for the study was purposely selected to reflect (represent) as far as possible the Local Government Area of the study. In choosing the sites, consideration was also given to urbanization, accessibility and safety of the sampling (experimental materials) instruments among others [18].

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber [19, 20], Pardoe *et al*. [21] and Giesecke *et al*. [22]. Prior to this, a mixture of glycerol (65 ml), formalin (30 ml) and phenol (5 ml) was poured into each of the trap. The positions of the traps at various locations were recorded using a Global Position System (GPS). The solutions in the trap prevented the palynomorphs from drying up, kill insects and also prevented the decay of dead organisms. The trap was left to stand throughout the duration of the study period. Fortnightly of each month, solution collection was done. The traps were washed with water to remove any contaminants and were then recharged with the above mentioned chemical solution. This procedure was repeated bi-monthly from October 2016 to September 2017 (dry season and rainy seasons' samples) for one year. The palynomorphs were recovered through centrifugation at 2000 r.p.m (revolution per minute) for 5 minutes and supernatant decanted each time. The precipitates were washed twice with distilled water and recovered through centrifugation. The sediments were treated with glacial acetic acid to remove water before acetolysis [23]. The recovered precipitates were washed with glacial acetic acid, and finally washed twice with distilled water, centrifuged each time and decanted. The recovered palynomorphs were stored in a plastic vials in glycerin and ethanol solution (2:1).

The palynomorphs were analysed palynologically and microscopically with Olympus microscope at x400 magnification for counting and Leica microscope at x1000 magnification for detailed morphological studies. Palynomorphs identification, counting and classification were done with the help of reference descriptions and photomicrographs from Agwu and Akanbi [25], Bonnefille and Riollet [26], Sowunmi [27] and Shubharani *et al*. [28]. In addition, prepared slides of pollen samples in the Palynological Research Unit; Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba- Akoko, Nigeria were used.

2.6. Statistical analysis of data

The mean monthly pollen counts as well as the locations were subjected to analysis of variance (ANOVA). Means were separated using Duncan Multiple Range Test (DMRT) at $P<0.05$ level of significance. All analyses were performed using the IBM SPSS Statistics Version 22.0.

3. Results and discussion

3.1. Airborne pollen grains

A total of 182 pollen types were identified across the study locations. These pollen types belong to 76 angiospermic plant families, 1gymnosperms and 4 pteridophytes. Out of the 76 plant families encountered, 68 families belong to the dicotyledonous plants, 6 to monocotyledonous plants, 1 gymnospermous plants and 1 was unidentified (Indeterminata) (Tables 1).

However, in absolute counts, the cumulative monthly pollen record showed that a total of 50,661 pollen grains were recorded with the highest monthly pollen counts of 9,297 recorded in November, followed by December (8,416), October (5,788), September (5,600) and the least recorded in August (1,926) and July (1,530) respectively (Table 1). The predominant pollen types belong to the family Poaceae, *Elaeis guineensis*, *Alchornea cordifolia*, *Aspilia africana*, *Casuarina equisetiifolia*, and *Tridax procumbens* among others.

Table 1 Cumulative monthly pollen grains counts for Akoko environment (October, 2016 - September, 2017)

S/N	Pollen type / Month	OCT	NOV	DEC	JAN.	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
A	DICOTYLEDONS													
1	ACANTHACEAE													
	Anisotes sp.	0	0	0	0	0	0	0	5	2	1	0	0	8
	Blepharis sp.	3	0	0	3	0	0	0	0	0	0	0	5	11
	Hypoestes sp.	0	8	0	0	0	0	0	0	0	0	0	0	8
	Justicia sp.	1	5	0	0	0	4	1	3	4	1	2	0	21
2	AMARANTH./ CHENOPOD.	26	28	24	16	11	158	35	53	26	9	3	26	415
3	ANACARDIACEAE													
	Anacardium occidentale	0	6	4	2	0	0	0	12	0	0	0	0	24
	Antrocaryon micraster	0	0	1	0	0	0	0	1	0	2	0	2	6
	Lannea acida	0	121	231	0	0	91	181	71	0	33	51	195	974
	Mangifera indica	0	0	0	0	0	0	9	3	0	0	0	0	12
	Spondias mombin	1	2	0	2	0	1	2	0	2	0	0	0	10
4	ANNONACEAE													
	Annona senegalensis	0	0	2	3	0	3	15	0	0	8	3	0	34
5	APOCYNACEAE													
	Alstonia boonei	1	0	0	0	0	8	2	1	2	2	0	0	16
	Motandra sp.	2	0	0	0	0	3	5	7	0	0	0	3	20
	Rauvolfia vomitoria	0	0	0	0	14	9	0	0	0	0	0	0	23
6	ASTERACEAE													
	Aspilia africana	415	446	31	66	18	10	4	17	20	39	104	77	1247
	Bidens pilosa	3	21	11	4	2	0	0	0	0	0	3	5	49
	Emilia sonchifolia	0	3	0	0	7	0	0	0	0	0	0	0	10

	Gutenbergia sp.	3	0	0	0	0	0	28	54	552	4	1	0	642
	Tridax procumbens	255	478	19	85	11	5	9	9	11	42	100	68	1092
	Vernonia amygdalina	2	7	5	0	0	0	0	0	0	0	0	2	16
7	BIGNONIACEAE													
	Kigelia africana	3	0	14	0	0	0	0	0	0	0	0	8	25
	Newbouldia laevis	0	31	19	0	0	41	0	13	8	11	0	0	123
	Stereospermum kunthianum	0	7	3	14	0	0	0	0	0	0	0	0	24
	Tecoma stans	0	3	5	11	0	0	0	0	0	0	0	0	19
8	BOMBACACEAE													
	Bombax buonopozense	25	11	6	3	4	-	12	17	13	0	3	17	111
	Ceiba pentandra	0	3	0	2	0	2	7	1	0	0	0	0	15
9	BORAGINACEAE													
	Heliotropium sp.	0	0	0	0	0	0	0	3	0	0	0	0	3
10	BURSERACEAE													
	Canarium schweinfurthii	1	0	0	0	0	0	3	0	7	0	0	1	12
	Commiphora africana	0	12	10	0	0	7	19	38	0	0	0	0	86
11	CAESALPINOIDEAE													
	Afzelia africana	0	0	0	0	0	2	2	6	0	0	0	0	10
	Berlinia grandifolia	0	8	5	21	0	4	18	0	0	0	0	0	56
	Brachystergia eurycoma	0	0	0	0	0	22	5	1	0	0	0	0	28
	Daniellia oliveri	34	11	19	0	5	9	1	8	0	0	25	14	126
	Delonix regia	3	17	0	2	0	0	23	6	0	10	1	0	62
	Detarium macrocarpum	0	0	0	0	0	0	0	0	3	12	7	0	22
	Dialium guineense	18	0	0	0	3	0	0	0	0	0	41	38	100
	Piliostigma thonningii	12	8	0	0	0	0	0	0	0	2	4	0	26
	Senna occidentalis	45	59	101	61	68	12	35	28	16	6	14	181	626

	Tessmannia sp.	0	5	3	0	0	3	7	0	0	0	0	11	29
12	CANNABACEAE (ULMACEAE)													
	Celtis sp.	0	0	0	15	0	7	3	1	0	0	2	1	29
13	CAPPARACEAE													
	Capparis sp.	0	0	0	0	0	0	5	1	0	0	0	0	6
	Cleome sp.	1	0	4	0	0	0	4	0	0	0	0	0	9
14	CAPRIFOLIACEAE													
	Knautia sp.	3	0	0	0	0	0	0	0	0	5	2	0	10
	Linnaea borealis	0	5	2	2	0	0	0	0	0	0	0	0	9
15	CARICACEAE													
	Carica papaya	0	0	0	0	0	0	0	0	0	0	11	31	42
16	CASUARINACEAE													
	Casuarina equisetiifolia	719	14	23	27	17	61	31	110	34	33	90	33	1192
17	CELASTRACEAE													
	Maytenus sp.	0	0	0	4	9	0	0	0	0	0	0	0	13
18	CHRYSOBALANACEAE													
	Parinari curatellifolia	0	0	0	0	0	31	5	11	9	0	0	0	56
19	CLUSIACEAE													
	Garcinia kola	4	0	0	0	0	0	3	0	25	29	0	0	61
	Symphonia globulifera	0	2	5	0	0	8	12	5	0	0	0	2	34
20	COCHLOSPERMACEAE													
	Cochlospermum planchonii	0	0	0	0	0	5	0	0	30	1	0	0	36
21	COMBRETACEAE													
	Combretum sp.	11	42	30	24	47	40	31	42	42	12	20	35	376
22	COMMELINACEAE													
	Aneilema sp.	0	0	0	0	0	3	7	0	0	0	0	0	10

23	CONNARACEAE												
	Cnestis ferruginea	0	0	0	0	0	4	1	11	0	0	0	0	16
24	CONVOLVULACEAE												
	Calycobolus sp.	0	0	0	0	4	1	0	0	0	0	0	0	5
	Ipomoea sp.	0	4	0	0	2	0	0	0	0	0	0	0	6
	Merremia sp.	0	2	0	0	0	6	0	0	12	0	0	4	24
25	CUCURBITACEAE												
	Cucumis sp.	0	0	0	0	0	2	4	0	0	0	0	0	6
	Kedrostis africana	0	0	0	0	0	2	6	0	0	0	0	0	8
	Luffa cylindrica	0	0	0	0	0	0	2	3	0	0	0	5	10
26	DICHAPETALACEAE												
	Dichapetalum sp.	0	0	0	0	0	0	0	2	3	0	0	0	5
27	DILLENIACEAE												
	Tetracera sp.	0	3	0	0	0	1	2	4	0	0	0	0	10
28	DIPTILOMIODEAE												
	Lepisanthes senegalensis	0	0	0	0	0	6	9	0	0	0	0	0	15
29	EBENACEAE												
	Diospyros mespiliformis	0	0	0	0	0	0	1	2	10	88	237	0	338
	Diospyros sp.	0	0	0	0	0	0	2	4	8	0	0	0	14
30	ERICACEAE												
	Empetrum nigrum	5	14	0	7	0	0	0	0	0	0	0	0	26
	Sapium sp.	0	0	7	0	0	0	0	0	0	0	0	3	10
31	EUPHORBIACEAE												
	Acalypha sp.	0	4	11	0	0	0	0	0	0	0	0	0	15
	Alchornea cordifolia	15	847	497	196	99	202	99	56	29	7	14	65	2126
	Croton sp.	0	0	2	4	0	9	3	0	0	0	0	0	18

	Euphorbia hirta	8	0	0	0	0	12	17	82	33	0	0	0	152
	Euphorbia sp.	0	0	1	0	1	3	3	0	1	0	0	0	9
	Jatropha curcas	2	0	0	0	0	0	8	0	0	2	2	0	14
	Mallotus subulatus	0	0	0	0	4	2	0	0	0	0	0	0	6
	Manihot esculenta	0	0	0	0	0	1	2	4	1	0	0	0	8
	Ricinus communis	0	0	0	0	0	0	8	6	3	0	0	0	17
32	FAGACEAE													
	Fagus sp.	0	4	1	7	0	0	0	0	0	0	0	0	12
33	GENTIANACEAE													
	Gentianella amarella	0	1	2	3	0	0	0	0	2	2	0	0	10
34	HYPERICACEAE													
	Harungana madagascariensis	35	0	0	2	8	5	21	20	25	27	31	0	174
35	IRVINGIACEAE													
	Irvingia gabonensis	0	7	4	123	15	202	29	31	2	3	3	7	426
36	LAMIACEAE													
	Hyptis suaveolens	12	47	76	24	6	27	9	10	4	1	0	205	421
	Leucas sp.	5	7	9	2	1	0	0	0	2	9	16	7	58
	Ocimum sp.	71	0	0	0	0	0	0	0	3	5	18	31	128
	Platostoma africanum	8	0	0	0	0	0	0	0	0	0	0	3	11
	Solenostemon monostachyus	3	0	0	0	6	0	0	0	0	0	0	0	9
	Vitex doniana	14	2	6	2	18	0	0	0	0	0	0	21	63
	Vitex grandifolia	0	0	0	0	0	0	0	2	26	44	0	0	72
37	LEEACEAE													
	Leea guineensis	0	3	0	0	0	0	0	0	2	0	0	0	5
38	LINACEAE													
	Linum catharticum	0	0	0	2	2	7	5	3	10	18	0	0	47

	Linum sp.	12	0	0	1	3	1	1	9	2	5	8	0	42
39	LOGANIACEAE													
	Anthocleista djalonensis	0	0	13	3	3	2	2	5	2	1	0	0	31
	Spigelia anthelmia	5	0	5	0	0	0	0	0	0	0	0	2	12
40	MALVACEAE													
	Abelmoschus esculentus	0	0	21	0	0	0	0	0	0	0	0	9	30
	Corchorus olitorius	0	3	0	0	2	6	0	0	0	0	0	0	11
	Nesogordonia papaverifera	11	0	21	0	0	0	0	0	0	0	0	9	41
	Sida acuta	24	308	18	49	162	2	9	3	19	1	34	12	641
41	MELASTOMATACEAE													
	Dissotis sp.	41	0	0	0	0	0	0	0	11	26	21	13	112
42	MELIACEAE													
	Azadirachta indica	0	2	9	0	0	5	6	1	7	5	6	2	43
	Khaya ivorensis	0	2	7	3	0	0	0	0	0	0	0	4	16
	Khaya senegalensis	4	15	2	7	7	23	63	9	1	8	9	1	149
	Trichilia prieureana	0	3	3	0	0	3	7	0	0	0	2	0	18
43	MIMOSOIDEAE													
	Acacia senegal	0	3	8	0	0	7	14	5	0	0	0	0	37
	Acacia sp.	0	0	0	0	0	0	0	0	0	3	0	0	3
	Adenanthera pavonina	0	0	0	0	0	2	6	2	1	0	0	0	11
	Albizia sp.	54	0	0	0	0	0	5	24	2	6	25	0	116
	Albizia zygia	0	191	151	177	33	0	0	0	13	17	0	0	582
	Aubrevillea kerstingii	7	11	6	8	0	0	0	0	0	0	0	16	48
	Leucaena leucocephala	0	21	5	0	0	0	0	0	0	0	0	3	29
	Mimosa pigra	0	0	0	19	11	0	121	53	28	0	0	0	232
	Parkia biglobosa	15	137	225	39	18	0	11	182	14	5	4	78	728

	Pentaclethra macrophylla	15	0	0	0	19	37	25	11	21	32	0	0	160
	Prosopis africana	0	0	0	215	291	131	0	0	0	0	0	0	637
44	MORACEAE													
	Ficus exasperata	0	1	2	1	0	9	7	0	0	0	0	0	20
	Milicia excelsa	0	49	141	160	0	253	6	12	5	0	0	19	645
	Morus sp.	0	0	0	0	0	10	4	0	0	0	0	0	14
	Treculia africana	0	0	0	0	0	5	0	0	0	0	0	0	5
45	MYRISTICACEAE													
	Pycnanthus angolensis	0	61	21	32	0	0	0	0	0	0	0	10	124
46	MYRTACEAE													
	Eucalyptus globulus	16	0	0	0	0	0	0	0	0	3	7	0	26
	Euginea sp.	57	61	0	1	3	1	27	94	13	10	41	16	324
	Psidium guajava	0	0	0	0	2	0	0	0	3	0	0	0	5
	Syzygium guineense	7	11	3	8	0	48	22	159	12	4	12	14	300
47	OCHNACEAE													
	Lophira alata	4	9	41	6	10	15	14	14	2	0	4	4	123
48	OLACACEAE													
	Olax subcorpioidea	2	0	0	1	3	0	0	0	0	0	0	0	6
	Olax sp.	0	0	5	6	4	2	0	0	0	0	2	4	23
49	PANDACEAE													
	Microdesmis sp.	1	5	13	11	0	36	21	10	0	0	1	2	100
50	PAPILIONOIDEAE													
	Baphia sp.	0	0	0	0	0	11	9	2	0	0	0	1	23
	Dalbergia sp.	0	4	5	0	0	0	0	0	0	0	0	0	9
	Indigofera sp.	0	8	0	0	0	12	3	7	11	0	0	0	41
	Pterocarpus osum	0	3	2	0	3	1	3	0	2	0	0	0	14

	Rhynchosia sp.	0	0	0	0	0	5	4	3	0	0	0	0	12
	Vigna unguiculata	11	0	9	0	0	0	0	0	0	0	0	5	25
51	PASSIFLORACEAE													
	Barteria nigritiana	0	0	0	0	0	0	1	4	2	0	0	0	7
52	PEDALIACEAE													
	Sesamum indicum	0	72	15	15	0	0	0	0	0	0	0	125	227
53	PERIPLOCACEAE													
	Periploca sp.	0	283	0	224	12	0	1	0	0	0	0	4	524
54	PHYLLANTHACEAE													
	Antidesma sp.	27	3	401	4	2	8	2	2	7	4	0	14	474
	Bridelia ferruginea	0	0	5	0	0	2	2	2	0	0	0	2	13
	Hymenocardia acida	2	30	8	78	18	20	40	229	8	7	7	6	453
	Phyllanthus sp.	4	0	9	24	10	25	15	11	13	10	8	6	135
	Securinega virosa	10	27	12	16	11	5	2	3	5	5	8	8	112
	Uapaca sp.	1	1	0	0	0	0	8	0	26	2	5	0	43
55	PLUMBAGINACEAE													
	Plumbago zeylanica	11	0	0	0	0	0	0	0	0	0	3	7	21
56	POLYGALACEAE													
	Polygala sp.	5	21	15	18	0	0	0	0	0	0	8	10	77
57	PORTULACACEAE													
	Talinum triangulare	18	12	8	0	0	0	0	0	0	0	5	5	48
58	PROTEACEAE													
	Protea elliotii	1	1	0	3	0	0	0	0	0	0	1	0	6
	Protea madiensis	0	0	0	0	3	0	0	0	0	0	0	0	3
59	RHAMNACEAE													
	Lasiodiscus sp.	0	1	2	1	0	9	7	0	0	0	0	0	20

60	ROSACEAE												
	Fillipendula ulmaria	7	11	3	8	0	48	22	159	12	4	12	14	300
61	RUBIACEAE												
	Borreria sp.	0	0	0	0	0	10	4	0	0	0	0	0	14
	Canthium sp.	16	0	0	0	0	5	0	0	0	3	7	0	31
	Crossopteryx febrifuga	0	34	5	13	0	0	0	0	0	0	0	3	55
	Gaertnera paniculata	0	22	9	10	0	0	0	0	0	0	0	5	46
	Gardenia sp.	0	5	7	9	0	0	0	0	0	0	0	2	23
	Morelia senegalensis	0	49	141	160	0	253	6	12	5	0	0	19	645
	Nauclea latifolia	57	1	0	1	5	27	61	94	16	10	41	16	329
62	RUTACEAE												
	Citrus sp.	4	7	35	6	10	12	14	9	2	0	4	4	107
	Zanthoxylum zanthoxyloides	0	2	6	0	0	3	0	5	0	0	0	0	16
63	SAPINDACEAE												
	Allophyllus sp.	0	0	5	6	4	2	0	0	0	0	2	4	23
	Blighia unijugata	0	0	0	0	0	0	5	11	3	0	0	0	19
	Paullinia pinnata	2	0	0	1	3	0	11	36	21	0	0	0	74
64	SAPOTACEAE												
	Vitellaria paradoxa	1	5	11	7	0	27	18	10	0	0	1	2	82
65	SOLANACEAE												
	Physalis angulata	1	1	0	0	0	0	8	0	26	2	5	0	43
	Solanum melongena	27	3	401	4	2	8	2	2	7	4	0	14	474
	Solanum torvum	0	0	5	0	0	2	2	2	0	0	0	2	13
66	STERCULIACEAE												
	Cola sp.	4	0	9	24	10	25	15	11	13	10	8	6	135
	Sterculia sp.	10	27	12	16	11	5	2	3	5	5	8	8	112

	Triplochiton scleroxylon	2	102	23	93	18	20	40	229	8	7	7	131	680
67	URTICACEAE													
	Musanga cecropioides	3	21	10	8	0	0	0	0	0	0	8	7	57
	Tieghemella africana	11	0	0	0	0	0	0	0	0	0	3	7	21
	Trema guineense	12	4	10	10	0	0	0	0	0	0	3	5	44
68	VERBENACEAE													
	Gmelina arborea	8	8	3	0	0	0	0	0	0	0	2	3	24
	Stachytarpheta sp.	1	1	0	3	0	0	0	0	0	0	1	0	6
	Tectona grandis	0	0	0	0	3	0	0	0	0	0	0	0	3
	SUB TOTAL	2300	3970	3099	2248	1078	2184	1433	2206	1330	667	1141	1769	23425
	2.MONOCOTYLEDONS:													
69	ARECACEAE													
	Cocos nucifera	0	0	5	2	5	15	5	10	2	0	0	0	44
	Elaeis guineensis	350	1411	1148	395	247	622	594	320	146	123	187	379	5922
	Raphia sp.	0	0	0	3	6	2	1	0	0	0	0	0	12
70	COLCHICACEAE													
	Gloriosa superba	0	0	0	0	0	5	7	4	2	0	3	0	21
71	COSTACEAE													
	Costus afer	0	2	0	1	0	0	0	3	2	5	0	0	13
72	CYPERACEAE	19	13	12	10	9	17	10	116	42	25	22	26	321
73	DIOSCOREACEAE													
	Dioscorea sp.	0	0	0	0	0	8	3	1	0	0	0	2	14
74	POACEAE	3104	3892	4145	1679	594	551	567	889	699	703	565	3423	20811
75	INDETERMINATA	1	2	7	1	6	1	4	4	1	5	3	4	39
	SUB TOTAL	3479	5320	5317	2091	867	1221	1190	1347	894	861	780	3829	27197
B	GYMNOSPERMS													

76	PINACEAE												
	Pinus caribaea	9	7	0	4	0	1	4	4	1	2	5	2	39
	TOTAL POLLEN COUNTS	5788	9297	8416	4343	1945	3406	2628	3557	2225	1530	1926	5600	50661
C	PTERIDOPHYTES:													
1.	ASPIDIACEAE													
	Cystopteris fragilis	0	0	0	0	0	0	0	0	0	2	4	0	6
	Goniopteris vivipara	0	0	0	0	0	0	22	0	0	0	0	0	22
2.	DAVALLIACEAE													
	Nephrolepis exaltata	0	0	0	0	0	0	11	31	0	0	0	0	42
3.	HYMENOPHYLLACEAE													
	Callistopteris apiifolia	0	0	0	0	0	0	2	3	0	0	0	0	5
4.	PTERIDACEAE													
	Anopteris hexagona	0	0	0	0	0	0	0	3	1	0	0	0	4
	Pteris dentata	0	0	0	0	0	0	2	2	0	0	0	0	4
	Monolete	126	113	23	22	18	8	36	39	36	23	22	411	877
	Trilete	1	1	2	0	1	14	2	5	17	0	0	11	54
	SUB TOTAL	127	114	25	22	19	22	75	83	54	25	26	422	1014
	GRAND TOTAL	5915	9471	8441	4365	1964	3402	2669	3640	2279	1555	1952	6022	51675

Statistical analysis of the mean monthly pollen counts showed that there was a significant difference (P<0.05) in the monthly pollen abundance. Multiple comparison using DMRT showed that the quantity of pollen counts recorded in November was significantly different (P<0.05) from those recorded in the months of March, April, May, June, July, August, September, October, January and February, but not significantly different from the pollen counts recorded in December (Table 2).

Table 2 Mean monthly pollen counts recorded in the study

S/N	Months	Mean pollen grains±S.E
1	October	1.55 ± 0.21^{d}
2	November	2.46 ± 0.27^{e}
3	December	2.23 ± 0.28^{e}
4	January	1.18 ± 0.12^{cd}
5	February	0.52 ± 0.05^{ab}
6	March	0.89 ± 0.08^{abc}
7	April	0.70 ± 0.07^{abc}
8	May	0.96 ± 0.14^{bc}
9	June	0.59 ± 0.12^{ab}
10	July	0.42 ± 0.09^{a}
11	August	0.51 ± 0.07^{ab}
12	September	1.48 ± 0.24^{d}
	pValue	0.000*

Means not followed by the same letter are significantly different at P<0.05 (DMRT).
* - significant at P<0.05

The study also showed that the airborne pollen grains were unevenly distributed throughout the year with many sporadically dispersed monthly and at the study locations (Fig. 2 and 3).

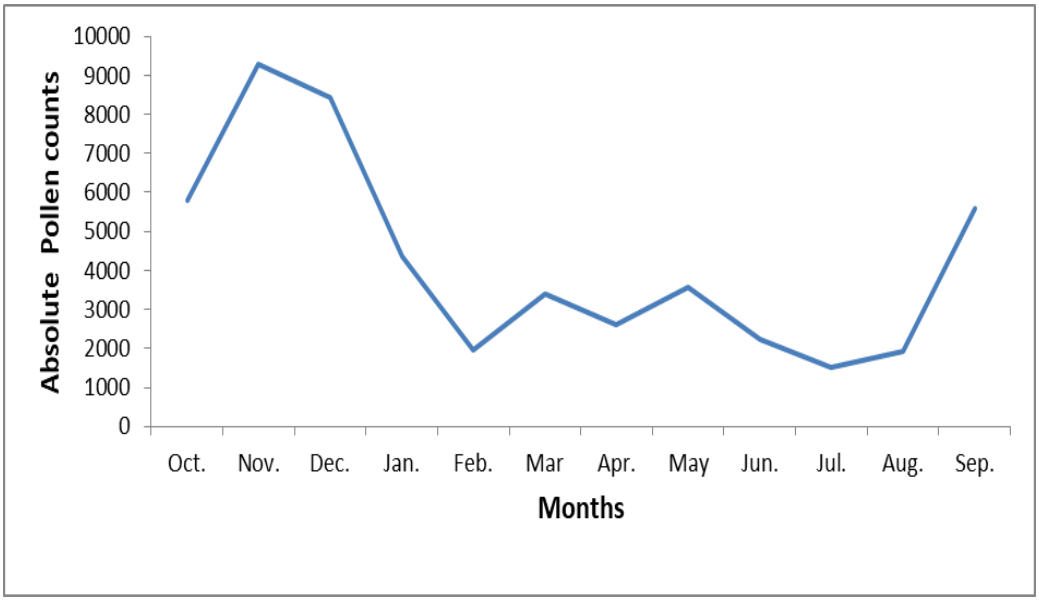


Figure 2 Variation in cumulative monthly pollen counts recorded across the study period

The analysis of variance also showed that there was significant difference in the mean pollen counts recorded across the study locations. Multiple comparisons using Duncan Multiple Range Test (DMRT) showed that the highest mean pollen count was recorded in Ayegunle (2.07±0.45^{d}**)** and was significantly different from those recorded for all other study locations except Ipesi, Ifira and Ipe (Table 3).

Table 3 Mean pollen grains counts recorded at the study locations

S/N	Study location	Mean pollen grains±S.E
1	Ayegunle	2.07±0.45^{d}
2	Ipesi	1.64±0.25^{cd}
3	Ipe	1.54±0.27^{bcd}
4	Ifira	1.51±0.21^{abcd}
5	Akungba	1.31±0.25^{abc}
6	Isua	1.28±0.20^{abc}
7	Akunnu	1.19±0.18^{abc}
8	Iboropa	1.14±0.19^{abc}
9	Auga	1.05±0.17^{abc}
10	Oba	0.97±0.19^{abc}
11	Irun	0.97±0.19^{abc}
12	Sosan	0.97±0.17^{abc}
13	Ikare	0.94±0.18^{abc}
14	Ikaram	0.94±0.17^{abc}
15	Oke-Oka	0.89±0.18^{ab}
16	Ise	0.86±0.17^{ab}
17	Supare	0.86±0.16^{ab}
18	Arigidi	0.80±0.15^{a}
19	Ogbagi	0.79±0.18 ^{a}
20	Oke-Agbe	0.78±0.15^{a}
	p Value	0.000*

Means not followed by the same letter are significantly different at P<0.05 (DMRT).
* - significant at p<0.05

Among the classified plant families, the maximum mean number of pollen counts of 86.71±5.74 was recorded for Poaceae followed by 8.29±0.66 in Arecaceae, 4.97±0.99 in Casuarinaceae and 2.12±0.29 in Asteraceae and the least with 0.02±0.01 in Proteaceae, 0.02±0.01 in Hymenophyllaceae as well as 0.01±0.01 in Boraginaceae and 0.01±0.01 in Pteridaceae. Of the individual plant species *Elaeis guineensis* contributed the maximum mean number of pollen counts (24.65±1.52) followed by *Alchornea cordifolia* (9.25±1.21), *Aspilia africana* (5.19±1.06), *Casuarina equisetiifolia* (4.97±0.99), *Tridax procumbens* (4.55±1.26), *Lannea acida* (4.06±0.55) and the least by *Heliotropium* sp. (0.01±0.01), *Capparis* sp. (0.01±0.01), *Protea madiensis* (0.01±0.01), *Tectona grandis* (0.01±0.01) and *Anopteris hexagona* (0.00±0.00).

There were noticeable monthly increase and decrease in the quantity of pollen grains and other palynomorphs counted. The pollen load of the entire study area varied quantitatively and qualitatively not only from month-to-month but also from location-to-location. Variations in cumulative pollen counts recorded across the study locations are shown in Figure 3.

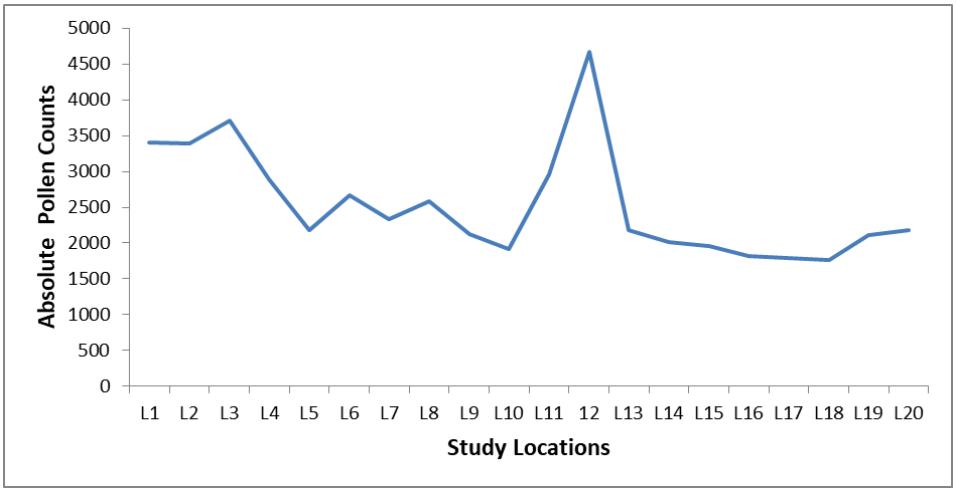


Figure 3 Variation in cumulative pollen counts recorded across the study locations

L1=Ifira, L2=Ipe, L3=Ipesi, L4=Isua, L5=Sosan, L6=Akunnu, L7=Auga, L8=Iboropa, L9=Ikare, 10=Ise, L11=Akungba, L12=Ayegunle, L13=Oba, L14=Oke-Oka, L15=Supare, L16=Arigidi, L17=Ogbagi, L18=Oke-Agbe, L19=Ikaram, L20=Irun.

With reference to the monthly pollen abundance in the atmosphere, the results showed that the concentration of pollen grains in the atmosphere fluctuates considerably with the seasons. The monthly airborne pollen concentrations showed three discernible periods of pollen variability in the atmosphere. The three periods of pollen abundance in the atmosphere showed that the highest mean concentration occurred during the late rainy season to early dry season followed by the period of dry season to early rainy season and the least occurred during the mid-rainy season (Table 4).

Table 4 Season of pollen abundance in the atmosphere

S/N	Seasons	Months	Pollen counts
1	Late rainy season to early dry season	September to January	33,444
2	Dry season to early rainy season	February to June	13,761
3	Mid rainy season	July to August	3,456
	Cumulative total pollen counts		50,661

3.2. Distribution and diversity of airborne pollen grains

Airborne pollen grain exhibits seasonal fluctuations in quantity as well as composition. Unspecified numbers and type of pollen grains remain airborne after the flowering season. It is also possible that pollen grains that had already fallen on the ground were refloated or these extra seasonal pollen grains may have come from plants which continued flowering out of the season, examples are Poaceae and *Elaeis guineensis*.

Elaeis guineensis which is a major pollen contributor in this study is found in all forms of sub-types vegetation in Akoko environment, Ondo State ranging from urban flora to grasslands, farmlands, woodlands and mature nature forests. Akoko people are known for the cultivation and production of oil palm and palm produce. Because of their enormous economic benefits, they are protected and established in farms and plantations. They flower virtually all year round, hence the characteristic increase and decrease in pollen content; turning out large quantities of pollen grains particularly at the major flowering periods. Its presence in the pollen spectra of the study area depicts extension of wooded grassland and traditional forest.

The aerodynamic properties of the pollen grains promote their dispersal and distribution in the turbulent air mass. This accounts for part of the reason why the pollen grains of *Elaeis guineensis* were trapped in the atmosphere throughout the twelve (12) months of study and at each sampling site at least in reasonable proportion. Findings corroborated favourably by the report of Njokuocha [29].

The grass family is reported to be the major contributor to airborne pollen assemblage in most aeropalynological studies [12] [16] [30] [31]. Mabberley [32] in Latorre and Belmonte [33] reported that the Poaceae family has a

cosmopolitan distribution representing 20% of the world's vegetation cover. With the light microscope, it is difficult to separate the Poaceae pollen on the species level.

However, the increase of grass pollen could also be attributed to the fact that most members of this family flower and shed their floral parts and the subsequent shriveling of these flowers eventually makes the entire plant to dry up as the environment approaches extreme dryness and destruction by annual bush burning thereby liberating their pollen into the atmosphere.

Poaceae pollen is present in the atmosphere nearly all year round, but the highest concentrations were observed between the months of September and November- February. The highest concentration of Poaceae pollen could also be attributed to high density and luxuriant growth of some of these grasses such as *Panicum maximum*, *Andropogon tectorum*, *Loudetia arundinacea*, *Schizachyrium brevifolium*, *Hyparrhenia barteri*, *Pennisetum purpureum*, *Imperata cylindica* and seasonal cultivated species such as *Zea mays*, among others, which flower more or less throughout the year and produce enormous amount of pollen grains [34 - 38]. The anemophilous mode of pollination, coupled with good aerodynamic properties of the pollen grains are some of the inherent factors that account for the higher Poaceae pollen concentration.

Alchornea cordifolia is associated with human activities in Akoko environment and also as early colonizers of deforested environment. It is a shrub and often a pioneer colonizer of the Guinean transition woodland, i.e., the transition between the rainforest and the wooded grassland. The human impact on the tropical rainforest probably fostered the growth of *Alchornea cordifolia* and the presence of its pollen reflects the impact of anthropogenic activities on the study environment. The plant is among the pioneer secondary forest taxa and is common in relict forests, humid vegetations and in thick riparian vegetation along the course of lakes and rivers. It is a copious pollen producer, releasing large quantities of its pollen during the flowering season. The high record of its pollen grains is attributed partly to the anemophilous mode of pollination and the buoyant capacity of the pollen grains [5] [12].

3.3. Airborne pollen assemblage and its vegetation

The airborne pollen assemblage trapped in this study generally reflects the regional vegetation of the catchment area which depicts tropical rainforest type. The pollen types recorded in this study represent the subtype vegetation of the study area which includes tropical rainforest, closed/ open forest, riparian forest, woodland shrub grasslands, and human impact ecological zones. The floristic composition of these subtype vegetations are subsumed into three major phyto-ecological groups upon which other small localized subtype vegetations are represented [39]. The site to site variation in number of pollen types portrays not only the existence of subtype vegetations but also the floristic heterogeneity of the vegetation of the study area.

Table 5 Cumulative pollen grains abundance for the phyto-ecological indicator species

S/N	Phyto-ecological Taxa	Total Pollen Count	Percentage Composition
1	Lowland Rainforest	3,651	7.21%
2	Open Forest	11,503	22.72%
3	Savanna	28,218	55.74%
4	Human Impact	7,250	14.32%
	Indeterminata	39	0
	TOTAL	50,661	99.99

Of importance also is the presence of pollen types that are indicators of human impact such as those of horticulture (for example, in schools, health centres, streets, etc.), erosion control, etc. which reflected evidence of agriculture and other anthropogenic activities. However, the result of the study was limited in terms of pollen–vegetation representation relationship. The first major reason is concerned with the differences in pollen production and dispersal among tropical plants in our study area [40 - 42]. The entomophilous taxa are known to produce low quantities of pollen grains with poor dispersal quality and the anemophilous taxa are copious pollen producers with good aerodynamic qualities. This advantage makes the anemophilous plants to be well represented or even to be over-represented in pollen assemblage compared to the entomophilous taxa. A second possible explanation is the difficulty of identification of all pollen grains

to the generic or specific level. For instance, some pollen types are identified only to family level such as Amaranthaceae/ Chenopodiaceae, Cyperaceae and Poaceae.

However, despite these limitations, the identified pollen grains so far still confirm the great floristic diversity and heterogeneity of the vegetation subtypes of the study area and the floristic heterogeneity in the study locations. Similar findings have been reported in Southern Cameroon [42] and South Congo [43].

3.4. The present vegetation status of Akoko environment

The airborne pollen assemblages of Akoko environment reflected the flora of the vegetation in flower from October 2016 to September, 2017. The flora grows vegetatively from May to August and flower in September to December, achieving maximum anthesis in November to late December. High level of anthropogenic activities on the environment such as indiscriminate deforestation, annual bush fire and burning of fossil fuel as a result of rapid urbanization has resulted in the unusual increase in the atmospheric heat balance whose implication is the excessive sensible heat experienced in Akoko environment recently. Long term effect could result to climatic change.

The abundance of charred plant particles and smoke from indiscriminate bush fire have not only pollute the environment but has also increase the concentration of greenhouse gases (carbon (iv) oxide, carbon monoxide, chlorofluorocarbon) in the atmosphere whose long term effect could result to global warming.

The activity of cattle herdsmen (overgrazing) has not only destroyed several flora in the vegetation, but has also exposed the topsoil to various agents of denudation making the environment susceptible to desertification. The activities of people that engaged in hunting expedition with the use of bush fire has destroyed several flora and fauna in the environment, these could result to extinction of biodiversity if appropriate conservation and restoration measures are not applied.

4. Conclusion

The analysis of the atmospheric pollen content of Akoko environment revealed great diversity of palynomorphs consisting of pollen grains and spores among others. The abundance and persistent release of *Elaeis guineensis* pollen grain is related to a large extent, the presence of oil palm farm (wild and cultivated) in and around the study environment. The pollen types documented in the study represent the flora of the regional vegetation of the study area which depicts tropical rainforest. The abundance of anemophilous pollen types in the atmosphere is enhanced by their relatively small size and good aerodynamic properties. In contrast, the entomophilous pollen types are large in size and require strong wind velocity and speed to dislodge them. As a result, they are less represented in the atmospheric air. The dominance of pollen produced by Lowland Rainforest and Open Forest taxa, Savanna and Human Impact taxa characteristic of Akoko vegetation, reveals their source area as being mainly from Akoko environment. Pollen assemblages confirmed the vegetation of the study area to be Tropical Rainforest vegetation type despite high level of anthropogenic activities on the environment.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares that there is no conflict of interest.

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