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(RESEARCH ARTICLE)

Index of the phytoecological indicator species in the prevalent airborne pollen types in Akoko environment, Ondo State, Nigeria

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Abstract

The study of vegetation and the way in which it has been altered and developed in the course of time indicates changes that have occurred in our terrestrial environment and is useful in providing vital information on environmental change, vegetation type, species composition and their utilization for sustainable development. This study was carried out in forty randomly selected locations so as to identify the different phytoecological indicator species and to also ascertain the present status of the vegetation of the catchment environment investigated. The airborne pollen grains were collected with Modified Tauber Sampler using simple random sampling technique and analyzed palynologically. Results showed 50,661 pollen grains counts comprising of 182 pollen types belonging to 74 angiospermic plant families were encountered. Three (3) of these pollen types were identified to family level, 57 to species level, 121 to generic level and one (1) unidentified. The pollen types identified in this study reflect to a large extent the phytoecological vegetation of the study area. Indicators of the Savanna taxa were the highest pollen contributors (55.74%) followed by Open forest taxa (22.72%), Human impact taxa (14.32%) and Lowland rainforest taxa (7.21%) respectively. About 44.19% of the plant sources identified are trees; the shrubs constitute about 25.96%, herbs 21.54%, herbaceous climbers 6.61%, lianas 1.10% and sedges 0.55%. The various ecological indicators species identified confirmed their origin as coming from the Forest-Savanna ecological zone that is anthropogenically disturbed. Such taxa could be properly conserved and their exploitation managed to prevent extinction thereby enhancing biodiversity sustainability.

Keywords: Airborne-pollen; Index; Indicator species; Phytoecology; 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. 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 [1]. 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.

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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 characteristics 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. For example, the tropical rainforest is characterized by broad-leaved species, the savanna characterized by grasses, the desert by ephermeral and sclerophyllous plants and the cold regions of the world characterized by evergreen conifers [4].

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. 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 [5]. The most common plant remains in Quaternary deposits are the pollen grains of flowering plants (Spermatophyte) and the spores of ferns (Pteridophyte) 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 [6].

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 [7-8]. 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. The behavioral patterns leads 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 [9].

Germeraad *et al*. [10] and Traverse [11] in Ige [12] reported that there has been no significant change in the floras at the family and generic levels, since the Miocene in tropical low latitudes, including the Niger Delta (of Southern Nigeria where Akoko environment is a part). Rymer [13] and Birks and Birks [14] reported that the relationships between plants and climates have not changed with time at least from the time period of the Neogene. Several investigations for example, [15-19] have demonstrated that characteristics pollen assemblages are associated with regions of distinct vegetation. Thus, pollen-producing plants that are characteristic of or adapted morphologically and physiologically to specific ecological conditions and which have a restricted distribution are among the best indicators of their depositional environments.

Interpretation of pollen assemblages are based on empirically determined relationship between modern pollen and modern vegetation. Correspondence between pollen assemblage types and vegetation has been found in all parts of the world. It can be shown on one site that the percentages of pollen are unequal to the percentages of plants in the vegetation. This is largely because there are differences in the amounts of pollen produced by different species. There are also differences in the case with which pollen grains of different types are dispersed by the wind, differences in resistance to decay, and so forth [4].

Consequently, the nature of the vegetation cannot be deduced intuitively, from the frequencies of pollen in the assemblage. This is so even though geographic trends in modern pollen percentages are often similar (although not precisely parallel) to the trends in the abundance of species in the vegetation. But despite the lack of a simple one-to-one correlation between pollen and plant frequencies, the pollen in the sediments is uniquely related to the frequencies of plants [1], [5]. Some plants inhabiting specific environments tend to become genetically adapted to the environmental conditions such that they become more predominant than others [20]. They are generally the most conspicuous and may be indicator of a particular ecological zone and may also be used as standard in identifying similar communities elsewhere [3]. This study is aimed at identifying the phytoecological indicator species and to determine the present status of the vegetation of the catchment environment investigated. The results of this study are anticipated to provide useful information on the conservation and sustainable exploitation of these indicator species through appropriate biotechnological measures.

2. Material and methods

Forty locations were randomly selected within the four Local Government Areas of Akoko division, Ondo State, Nigeria as sampling sites. The sampling sites for the study were purposely selected to reflect 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 [21].

At each site, a pollen trap (Modified Tauber Sampler) was mounted according to the methods of Tauber [22, 23], Pardoe *et al*. [24] and Giesecke *et al*. [25]. 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 solutions. This procedure was repeated bi-monthly from October 2016 to December 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 [26, 27]. 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 [27], Bonnefille and Riollet [28], Sowunmi [29] and Shubharani *et al*. [30]. 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.

3. Results and discussion

A total of 182 pollen types were identified across the study locations. These pollen types belong to 74 angiospermic plant families (Table 1). Out of these 74 plant families encountered, 66 families belong to the dicotyledonous plants, 6 to monocotyledonous plants, and 1 was unidentified (Indeterminata). Photomicrographs of pollen grains of some selected indicator species are shown in Figure 1.

Generally, the pollen types identified in this study reflected to a large extent the phytoecological vegetation of the study area. Some of the pollen types identified reflected plant species of different ecological indicators based on the classification of White [31] and Agwu [8]. Absolute pollen counts for the phytoecological indicator species across the study period is presented in Table 1. Statistical analysis using Duncan Multiple Range Test showed that there was significant differences ($P<0.05$) in the Mean pollen grains abundance classified based on phytoecological indicator species. Indicators of the Savanna taxa were the highest pollen contributors (55.74%) followed by Open forest taxa (22.72%), Human impact taxa (14.32%) and Lowland rainforest taxa (7.21%) respectively (Table 2). The various phytoecological indicators species identified confirmed their origin as coming from the Forest- Savanna ecological zone that is anthropogenically disturbed.

3.1. Lowland rainforest taxa

Absolute pollen counts for the phytoecological indicator species across the study period showed that a total of 3,651 pollen grains were counted for Lowland Rainforest taxa with a percentage composition of 7.21% (Table 1). Analysis of variance showed that the Mean pollen grains abundance recorded for these taxa is 0.39 ± 0.02^{a} (Table 2). The characteristic plants in this group include *Aneilema* sp., *Bombax buonopozense, Berlinia grandiflora, Bidens pilosa*, *Brachystegia eurycoma*, *Canarium schweinforthii*, *Ceiba pentandra, Celtis* sp., *Cola* sp., *Combretum* sp., *Costus afer*, *Dissotis* sp., *Euginea* sp., *Garcinia kola*, *Gardenia* sp., *Gentianella amarella*, *Lapisanthes senegalensis*, *Lophira alata*, *Mallotus subulatus*, *Merremia* sp., *Microdesmis* sp., *Milicia excelsa*, *Morus* sp., *Musanga cercropioides*, *Nesogordonia papaverifera, Parinari curatellifolia, Paullinia pinnata, Pentaclethra macrophylla, Sapium sp., Spondias mombin, Sterculia sp., Symphonia globulifera, Talinum triangulare, Tessmania sp., Treculia africana, Trema guineense* and *Triplochiton scleroxylon* etc.

Table 1: Absolute monthly pollen grains counts for the phyto-ecological indicator species across the study period

Pollen type / Month	**Plant Form**	**Plant Family**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Total**
LOWLAND RAINFOREST TAXA															
Aneilema sp.	Herb	Commelinaceae	0	0	0	0	0	3	7	0	0	0	0	0	10
Berlinia grandifolia	Tree	Caesalpinoideae	0	8	5	21	0	4	18	0	0	0	0	0	56
Bidens pilosa	Herb	Asteraceae	5	21	11	4	2	0	0	0	0	0	3	3	49
Bombax buonopozense	Tree	Bombacaceae	17	11	6	3	4	0	12	17	13	0	3	25	111
Brachystegia eurycoma	Tree	Caesalpinoideae	0	0	0	0	0	22	5	1	0	0	0	0	28
Canarium schweinforthii	Tree	Burseraceae	1	0	0	0	0	0	3	0	7	0	0	1	12
Ceiba pentandra	Tree	Bombacaceae	0	3	0	2	0	2	7	1	0	0	0	0	15
Celtis sp.	Tree	Cannabaceae	1	0	0	15	0	7	3	1	0	0	2	0	29
Cola sp.	Tree	Sterculiaceae	6	0	9	24	10	25	15	11	13	10	8	4	135
Combretum sp.	Shrub	Combretaceae	35	42	30	24	47	40	31	42	42	12	20	11	376
Costus afer	Herb	Costaceae	0	2	0	1	0	0	0	3	2	5	0	0	13
Dissotis sp.	Shrub	Melastomataceae	13	0	0	0	0	0	0	0	11	26	21	41	112
Euginea sp.	Shrub	Myrtaceae	16	61	0	1	3	1	27	94	13	10	41	57	324
Garcinia kola	Tree	Clusiaceae	0	0	0	0	0	0	3	0	25	29	0	4	61
Gardenia sp.	Tree	Rubiaceae	2	5	7	9	0	0	0	0	0	0	0	0	23
Gentianella amerella	Herb	Gentianaceae	0	1	2	3	0	0	0	0	2	2	0	0	10
Lepisanthes senegalensis	Shrub	Diptilomiodeae	0	0	0	0	0	6	9	0	0	0	0	0	15
Lophira alata	Tree	Ochnaceae	4	9	41	6	10	15	14	14	2	0	4	4	123
Mallotus subulatus	Shrub	Euphorbiaceae	0	0	0	0	4	2	0	0	0	0	0	0	6

Merremia sp.	H/ Climber	Convolvulaceae	4	2	0	0	0	6	0	0	12	0	0	0	24
Microdesmis sp.	Shrub	Pandaceae	2	5	13	11	0	36	21	10	0	0	1	1	100
Milicia excelsa	Tree	Moraceae	19	49	141	160	0	253	6	12	5	0	0	0	645
Morus sp.	Shrub	Moraceae	0	0	0	0	0	10	4	0	0	0	0	0	14
Musanga cercropioides	Tree	Urticaceae	7	21	10	8	0	0	0	0	0	0	8	3	57
Nesogordonia papaverifera	Tree	Malvaceae	9	0	21	0	0	0	0	0	0	0	0	11	41
Parinari curatellifolia	Tree	Chrysobalanaceae	0	0	0	0	0	31	5	11	9	0	0	0	56
Paullinia pinnata	H/ Climber	Sapindaceae	0	0	0	1	3	0	11	36	21	0	0	2	74
Pentaclethra macrophylla	Tree	Mimosoideae	0	0	0	0	19	37	25	11	21	32	0	15	160
Sapium sp.	Shrub	Euphorbiaceae	3	0	7	0	0	0	0	0	0	0	0	0	10
Spondias mombin	Tree	Anacardiaceae	0	2	0	2	0	1	2	0	2	0	0	1	10
Sterculia sp.	Tree	Sterculiaceae	8	27	12	16	11	5	2	3	5	5	8	10	112
Symphonia globulifera	Tree	Clusiaceae	2	2	5	0	0	8	12	5	0	0	0	0	34
Talinum triangulare	Herb	Portulacaceae	5	12	8	0	0	0	0	0	0	0	5	18	48
Tessmania sp.	Herb	Caesalpinoideae	11	5	3	0	0	3	7	0	0	0	0	0	29
Treculia africana	Tree	Moraceae	0	0	0	0	0	5	0	0	0	0	0	0	5
Trema guineense	Tree	Urticaceae	5	4	10	10	0	0	0	0	0	0	3	12	44
Triplochiton scleroxylon	Tree	Sterculiaceae	131	102	23	93	18	20	40	229	8	7	7	2	680
SUB TOTAL			306	394	364	414	131	542	289	501	213	138	134	225	3, 651
% COMPOSITION															7.21%
OPEN FOREST TAXA															

Afzelia africana	Tree	Caesalpinoideae	0	0	0	0	0	2	2	6	0	0	0	0	10
Albizia sp.	Tree	Mimosoideae	0	0	0	0	0	0	5	24	2	6	25	54	116
Albizia zygia	Tree	Mimosoideae	0	191	151	177	33	0	0	0	13	17	0	0	582
Alchornea cordifolia	Shrub	Euphorbiaceae	65	847	497	196	99	202	99	56	29	7	14	15	2126
Allophyllus africanus	Shrub	Sapindaceae	4	0	5	6	4	2	0	0	0	0	2	0	23
Alstonia boonei	Tree	Apocynaceae	0	0	0	0	0	8	2	1	2	2	0	1	16
Anisotes sp.	Shrub	Acanthaceae	0	0	0	0	0	0	0	5	2	1	0	0	8
Anthocleista djalonensis	Tree	Loganiaceae	0	0	13	3	3	2	2	5	2	1	0	0	31
Baphia sp.	Shrub	Papilionoideae	1	0	0	0	0	11	9	2	0	0	0	0	23
Blighia unijugata	Tree	Sapindaceae	0	0	0	0	0	0	5	11	3	0	0	0	19
Canthium sp.	Tree	Rubiaceae	0	0	0	0	0	5	0	0	0	3	7	16	31
Cnestis ferruginea	Shrub	Connaraceae	0	0	0	0	0	4	1	11	0	0	0	0	16
Cocos nucifera	Tree	Arecaceae	0	0	5	2	5	15	5	10	2	0	0	0	44
Commiphora africana	Tree	Burseraceae	0	12	10	0	0	7	19	38	0	0	0	0	86
Croton sp.	Herb	Euphorbiaceae	0	0	2	4	0	9	3	0	0	0	0	0	18
Dalbergia sp.	Tree	Papilionoideae	0	4	5	0	0	0	0	0	0	0	0	0	9
Dichapetalum sp.	Shrub	Dichapetalaceae	0	0	0	0	0	0	0	2	3	0	0	0	5
Elaeis guineensis	Tree	Arecaceae	379	1411	1148	395	247	622	594	320	146	123	187	350	5922
Ficus exasperate	Tree	Moraceae	0	1	2	1	0	9	7	0	0	0	0	0	20
Gaertnera paniculata	Shrub	Rubiaceae	5	22	9	10	0	0	0	0	0	0	0	0	46
Gutenbergia sp.	Herb	Asteraceae	0	0	0	0	0	0	28	54	552	4	1	3	642
Harungana madagascariensis	Tree	Hypericaceae	0	0	0	2	8	5	21	20	25	27	31	35	174
Irvingia gabonensis	Tree	Irvingiaceae	7	7	4	123	15	202	29	31	2	3	3	0	426

Kedrostis africana	H/ Climber	Cucurbitaceae	0	0	0	0	0	2	6	0	0	0	0	0	8
Kigelia africana	Tree	Bignoniaceae	8	0	14	0	0	0	0	0	0	0	0	3	25
Lasiodiscus sp.	Tree	Rhamnaceae	0	1	2	1	0	9	7	0	0	0	0	0	20
Motandra sp.	Lianas	Apocynaceae	3	0	0	0	0	3	5	7	0	0	0	2	20
Newbouldia laevis	Shrub	Bigniniaceae	0	31	19	0	0	41	0	13	8	11	0	0	123
Periploaca sp.	Shrub	Apocynaceae	4	283	0	224	12	0	1	0	0	0	0	0	524
Pinus caribaea	Tree	Pinaceae	2	7	0	4	0	1	4	4	1	2	5	9	39
Plumbago zeylanica	Herb	Plumbaginaceae	7	0	0	0	0	0	0	0	0	0	3	11	21
Pterocarpus osum	Tree	Papilionoideae	0	3	2	0	3	1	3	0	2	0	0	0	14
Pycnanthus angolensis	Tree	Myristicaceae	10	61	21	32	0	0	0	0	0	0	0	0	124
Raphia sp.	Tree	Arecaceae	0	0	0	3	6	2	1	0	0	0	0	0	12
Securinega virosa	Shrub	Phyllanthaceae	8	27	12	16	11	5	2	3	5	5	8	10	112
Solenostemon monostacyus	Herb	Lamiaceae	0	0	0	0	6	0	0	0	0	0	0	3	9
Uapaca sp.	Tree	Phyllanthaceae	0	1	0	0	0	0	8	0	26	2	5	1	43
Vernonia amygdalina	Shrub	Asteraceae	2	7	5	0	0	0	0	0	0	0	0	2	16
SUB TOTAL			505	2916	1926	1199	452	1169	868	623	825	214	291	515	11, 503
% COMPOSITION															22.72%
SAVANNA TAXA															
Acacia senegal	Shrub	Mimosoideae	0	3	8	0	0	7	14	5	0	0	0	0	37
Acacia sp.	Shrub	Mimosoideae	0	0	0	0	0	0	0	0	0	3	0	0	3
Acalypha sp.	Herb	Euphorbiaceae	0	4	11	0	0	0	0	0	0	0	0	0	15
Annona senegalensis	Tree	Annonaceae	0	0	2	3	0	3	15	0	0	8	3	0	34
Anthrocaryon micraster	Tree	Anacardiaceae	2	0	1	0	0	0	0	1	0	2	0	0	6

Aubrevillea kerstingii	Tree	Mimosoideae	16	11	6	8	0	0	0	0	0	0	0	7	48
Barteria nigritiana	Shrub	Passifloraceae	0	0	0	0	0	0	1	4	2	0	0	0	7
Blepharis sp.	Herb	Acanthaceae	5	0	0	3	0	0	0	0	0	0	0	3	11
Borreria sp.	Herb	Rubiaceae	0	0	0	0	0	10	4	0	0	0	0	0	14
Bridellia ferruginea	Shrub	Phyllanthaceae	2	0	5	0	0	2	2	2	0	0	0	0	13
Cochlospermum planchonii	Shrub	Cochlospermaceae	0	0	0	0	0	5	0	0	30	1	0	0	36
Crossopteryx febrifuga	Tree	Rubiaceae	3	34	5	13	0	0	0	0	0	0	0	0	55
Cyperaceae	Sedges	Cyperaceae	26	13	12	10	9	17	10	116	42	25	22	19	321
Daniellia oliveri	Tree	Caesalpinoideae	14	11	19	0	5	9	1	8	0	0	25	34	126
Deterium macrocarpum	Tree	Caesalpinoideae	0	0	0	0	0	0	0	0	3	12	7	0	22
Diallium guineense	Tree	Caesalpinoideae	38	0	0	0	3	0	0	0	0	0	41	18	100
Diospyros mespiliformis	Tree	Ebenaceae	0	0	0	0	0	0	1	2	10	88	237	0	338
Diospyros sp.	Tree	Ebenaceae	0	0	0	0	0	0	2	4	8	0	0	0	14
Fillipendula ulmaria	Herb	Rosaceae	14	11	3	8	0	48	22	159	12	4	12	7	300
Gloriosa superba	H/ Climber	Colchicaceae	0	0	0	0	0	5	7	4	2	0	3	0	21
Hymenocardia acida	Shrub	Phyllanthaceae	6	30	8	78	18	20	40	229	8	7	7	2	453
Hypoestes sp.	Herb	Acanthaceae	0	8	0	0	0	0	0	0	0	0	0	0	8
Indigofera sp.	Herb	Papilionoideae	0	8	0	0	0	12	3	7	11	0	0	0	41
Khaya ivorensis	Tree	Meliaceae	4	2	7	3	0	0	0	0	0	0	0	0	16
Khaya senegalensis	Tree	Meliaceae	1	15	2	7	7	23	63	9	1	8	9	4	149
Knautia sp.	Herb	Caprifoliaceae	0	0	0	0	0	0	0	0	0	5	2	3	10
Lannea acida	Tree	Anacardiaceae	195	121	231	0	0	91	181	71	0	33	51	0	974
Leucas sp.	Herb	Lamiaceae	7	7	9	2	1	0	0	0	2	9	16	5	58

Linum catharticum	Herb	Linaceae	0	0	0	2	2	7	5	3	10	18	0	0	47
Linum sp.	Herb	Linaceae	0	0	0	1	3	1	1	9	2	5	8	12	42
Maytenus sp.	Shrub	Celastraceae	0	0	0	4	9	0	0	0	0	0	0	0	13
Mimosa pigra	Tree	Mimosoideae	0	0	0	19	11	0	121	53	28	0	0	0	232
Morelia senegalensis	Shrub	Rubiaceae	19	49	141	160	0	253	6	12	5	0	0	0	645
Nauclea latifolia	Tree	Rubiaceae	16	1	0	1	5	27	61	94	16	10	41	57	329
Olax subcorpioidea	Tree	Olacaceae	0	0	0	1	3	0	0	0	0	0	0	2	6
Olax sp.	Tree	Olacaceae	4	0	5	6	4	2	0	0	0	0	2	0	23
Parkia biglobosa	Tree	Mimosoideae	78	137	225	39	18	0	11	182	14	5	4	15	728
Phyllanthus sp.	Herb	Phyllanthaceae	6	0	9	24	10	25	15	11	13	10	8	4	135
Platostoma africanum	Herb	Lamiaceae	3	0	0	0	0	0	0	0	0	0	0	8	11
Piliostigma thonningii	Tree	Caesalpinoideae	0	8	0	0	0	0	0	0	0	2	4	12	26
Poaceae	Herb	Poaceae	3418	3892	4145	1679	594	551	567	889	699	703	565	3109	20811
Prosopis africana	Tree	Mimosoideae	0	0	0	215	291	131	0	0	0	0	0	0	637
Rauvolfia vomitoria	Shrub	Apocynaceae	0	0	0	0	14	9	0	0	0	0	0	0	23
Rhynchosia sp.	Herb	Papilionoideae	0	0	0	0	0	5	4	3	0	0	0	0	12
Sesamum indicum	Herb	Pedaliaceae	125	72	15	15	0	0	0	0	0	0	0	0	227
Sida acuta	Shrub	Malvaceae	12	308	18	49	162	2	9	3	19	1	34	24	641
Syzygium guineense	Tree	Myrtaceae	14	11	3	8	0	48	22	159	12	4	12	7	300
Trichilia prieureana	Tree	Meliaceae	0	3	3	0	0	3	7	0	0	0	2	0	18
Vitellaria paradoxa	Tree	Sapotaceae	2	5	11	7	0	27	18	10	0	0	1	1	82
SUB TOTAL			4030	4764	4904	2365	1169	1343	1213	2049	949	963	1116	3353	28, 218
% COMPOSITION															55.74%
HUMAN IMPACT															

TAXA															
Abelmoschus esculentus	Herb	Malvaceae	9	0	21	0	0	0	0	0	0	0	0	0	30
Adenanthera pavonina	Tree	Mimosoideae	0	0	0	0	0	2	6	2	1	0	0	0	11
Amaranthaceae/ Chenopiaceae	Herb	Amaranthaceae/ Chenopodiaceae	26	28	24	16	11	158	35	53	26	9	3	26	415
Anacardium occidentale	Tree	Anacardiaceae	0	6	4	2	0	0	0	12	0	0	0	0	24
Antidesma sp.	Shrub	Phyllanthaceae	14	3	401	4	2	8	2	2	7	4	0	27	474
Aspilia africana	Herb	Asteraceae	77	446	31	66	18	10	4	17	20	39	104	415	1247
Azadirachta indica	Tree	Meliaceae	2	2	9	0	0	5	6	1	7	5	6	0	43
Calycobolus sp.	H/ Climber	Convolvulaceae	0	0	0	0	4	1	0	0	0	0	0	0	5
Capparis sp.	Shrub	Capparaceae	0	0	0	0	0	0	5	1	0	0	0	0	6
Carica papaya	Herb	Caricaceae	31	0	0	0	0	0	0	0	0	0	11	0	42
Casuarina equisetifolia	Tree	Casuarinaceae	33	14	23	27	17	61	31	110	34	33	90	719	1192
Citrus sp.	Tree	Rutaceae	4	7	35	6	10	12	14	9	2	0	4	4	107
Cleome sp.	Herb	Capparaceae	0	0	4	0	0	0	4	0	0	0	0	1	9
Corchorus olitorius	Herb	Malvaceae	0	3	0	0	2	6	0	0	0	0	0	0	11
Cucumis sp.	H/ Climber	Cucurbitaceae	0	0	0	0	0	2	4	0	0	0	0	0	6
Delonix regia	Tree	Caesalpinoideae	0	17	0	2	0	0	23	6	0	10	1	3	62
Dioscorea sp.	Lianas	Dioscoreaceae	2	0	0	0	0	8	3	1	0	0	0	0	14
Emilia sonchifolia	Herb	Asteraceae	0	3	0	0	7	0	0	0	0	0	0	0	10
Empetrum nigrum	Shrub	Caesalpinoideae	0	14	0	7	0	0	0	0	0	0	0	5	26
Eucalyptus globus	Tree	Myrtaceae	0	0	0	0	0	0	0	0	0	3	7	16	26
Euphorbia hirta	Herb	Euphorbiaceae	0	0	0	0	0	12	17	82	33	0	0	8	152
Euphorbia sp.	Herb	Euphorbiaceae	0	0	1	0	1	3	3	0	1	0	0	0	9

Fagus sp.	Tree	Fagaceae	0	4	1	7	0	0	0	0	0	0	0	0	12
Gmelina arborea	Tree	Verbenaceae	3	8	3	0	0	0	0	0	0	0	2	8	24
Heliotropium sp.	Herb	Boraginaceae	0	0	0	0	0	0	0	3	0	0	0	0	3
Hyptis suaveolens	Herb	Lamiaceae	205	47	76	24	6	27	9	10	4	1	0	12	421
Ipomoea sp.	H/ Climber	Convolvulaceae	0	4	0	0	2	0	0	0	0	0	0	0	6
Jatropha curcas	Shrub	Euphorbiaceae	0	0	0	0	0	0	8	0	0	2	2	2	14
Justicia sp.	Herb	Acanthaceae	0	5	0	0	0	4	1	3	4	1	2	1	21
Leea guineensis	Shrub	Leeaceae	0	3	0	0	0	0	0	0	2	0	0	0	5
Leucaeana leucocephala	Tree	Caesalpinoideae	3	21	5	0	0	0	0	0	0	0	0	0	29
Linnaea borealis	Shrub	Caprifoliaceae	0	5	2	2	0	0	0	0	0	0	0	0	9
Luffa cylindrical	H/ Climber	Cucurbitaceae	5	0	0	0	0	0	2	3	0	0	0	0	10
Mangifera indica	Tree	Anacardiaceae	0	0	0	0	0	0	9	3	0	0	0	0	12
Manihot esculenta	Shrub	Euphorbiaceae	0	0	0	0	0	1	2	4	1	0	0	0	8
Ocimum sp.	Shrub	Lamiaceae	31	0	0	0	0	0	0	0	3	5	18	71	128
Physalis angulata	Herb	Solanaceae	0	1	0	0	0	0	8	0	26	2	5	1	43
Protea elliotii	Shrub	Proteaceae	0	1	0	3	0	0	0	0	0	0	1	1	6
Protea madiensis	Shrub	Proteaceae	0	0	0	0	3	0	0	0	0	0	0	0	3
Psidium guajava	Shrub	Myrtaceae	0	0	0	0	2	0	0	0	3	0	0	0	5
Ricinus communis	Shrub	Euphorbiaceae	0	0	0	0	0	0	8	6	3	0	0	0	17
Senna occidentale	Tree	Caesalpinoideae	181	59	101	61	68	12	35	28	16	6	14	45	626
Solanum melongena	Shrub	Solanaceae	14	3	401	4	2	8	2	2	7	4	0	27	474
Solanum torvum	Shrub	Solanaceae	2	0	5	0	0	2	2	2	0	0	0	0	13
Spigelia anthelmia	Herb	Loganiaceae	2	0	5	0	0	0	0	0	0	0	0	5	12
Stachytarpheta sp.	Shrub	Verbenaceae	0	1	0	3	0	0	0	0	0	0	1	1	6

Stereospermum kunthianum	Tree	Bignoniaceae	0	7	3	14	0	0	0	0	0	0	0	0	24
Tecoma stans	Shrub	Bignoniaceae	0	3	5	11	0	0	0	0	0	0	0	0	19
Tectona grandis	Tree	Verbenaceae	0	0	0	0	3	0	0	0	0	0	0	0	3
Tetracera sp.	H/ Climber	Dilleniaceae	0	3	0	0	0	1	2	4	0	0	0	0	10
Tieghemella africana	Tree	Urticaceae	7	0	0	0	0	0	0	0	0	0	3	11	21
Tridax procumbens	Herb	Asteraceae	68	478	19	85	11	5	9	9	11	42	100	255	1092
Vigna unguiculata	H/ Climber	Papilionoideae	5	0	9	0	0	0	0	0	0	0	0	11	25
Vitex doniana	Tree	Lamiaceae	21	2	6	2	18	0	0	0	0	0	0	14	63
Vitex grandifolia	Tree	Lamiaceae	0	0	0	0	0	0	0	2	26	44	0	0	72
Polygala sp.	H/ Climber	Polygalaceae	10	21	15	18	0	0	0	0	0	0	8	5	77
Zanthoxylum zanthoxyloides	Tree	Rutaceae	0	2	6	0	0	3	0	5	0	0	0	0	16
SUB TOTAL			755	1221	1215	364	187	351	254	380	237	210	382	1694	7, 250
% COMPOSITION															14.32%
INDETERMINATA			1	2	7	1	6	1	4	4	1	5	3	4	39
GRAND TOTAL			5597	9297	8416	4343	1945	3406	2628	3557	2225	1530	1926	5791	50, 661

H/Climber = Herbaceous Climber

Figure 1 Photomicrograph of pollen grains of some selected indicator species

Table 2 Mean pollen grains abundance classified based on phytoecological indicator species

S/N	Phytoecological Group	Mean Pollen count±S.E
1	Savanna Taxa	2.39±0.16[c]
2	Open Forest Taxa	1.29±0.08[b]
3	Human Impact Taxa	0.54±0.05[a]
4	Lowland Rainforest Taxa	0.39±0.02[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

Table 3 Mean pollen grains abundance classified based on plant form

S/N	Plant Form	Mean Pollen count±S.E
1	Herbs	44.02±3.47[c]
2	Shrubs	2.87±1.26[b]
3	Trees	0.86±0.36[a]
4	Sedges	0.48±0.39[a]
5	Herbaceous climber	0.16±0.03[a]
6	Lianas	0.07±0.02[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.

Table 4 Percentage composition of pollen grains abundance classified based on plant form

S/N	Plant Form	No of Species present	No of Pollen counted	% Composition
1.	Herbs	41	26,078	51.47
2.	Trees	82	16,813	33.18
3.	Shrubs	45	7,109	14.03
4.	Sedges	1	321	0.63
5.	Herbaceous climbers	11	266	0.52
6.	Lianas	2	34	0.06
	Grand Total	**182**	**50661**	**99.89**

3.2. Open forest taxa

These taxa contributed 11,503 pollen grains with percentage abundance of 22.72% in terms of absolute pollen count classified based on the phytoecological indicator species (Table 1). Statistical analysis using Duncan Multiple Range Test showed that the Mean pollen grains abundance of 1.29 ± 0.08^{b} was documented for this group (Table 2). The characteristic plants in this group include *Afzelia africana, Albizia* sp., *Albizia zygia, Alchornea cordifolia, Allophyllus africanus*, *Alstonia boonei*, *Anisotes* sp., *Anthocleistha djalonensis*, *Baphia* sp., *Blighia unijugata*, *Canthium* sp., *Cnestis ferruginea*, *Cocos nucifera*, *Commiphora africana*, *Croton* sp., *Dalbergia* sp., *Dichapetalum* sp., *Elaeis guineensis, Ficus exaspirata*, *Gaertnera paniculata*, *Gutenbergia* sp., *Harungana madagascariensis*, *Irvingia gabonensis*, *Kedrostis africana*, *Kigelia africana, Lasiodiscus* sp., *Motandra* sp., *Newbouldia leavis, Periploca* sp., *Pinus caribaea*, *Plumbago zeylanica*, *Pterocarpus osum*, *Pycnanthus angolensis*, *Raphia* sp., *Securinega virosa*, *Solenostemon monostacyus*, *Uapaca* sp., and *Vernonia amygdalina* etc.

3.3. Savanna taxa

In terms of absolute pollen counts for the phytoecological indicator species across the study period, some Savanna indicator species were also identified in the samples and results showed that these taxa were the largest pollen contributor. A total of 28,218 pollen grains were counted for these taxa with a percentage composition of 55.74% (Table 1). Duncan Multiple Range Test showed that the Mean pollen grains abundance of 2.39 ± 0.16^{c} was documented for this group (Table 2). The species in these taxa includes the Families Cyperaceae and Poaceae as well as *Acacia senegalensis*, *Acacia* sp., *Acalypha* sp., *Annona senegalensis*, *Anthrocaryon micraster*, *Aubrevillea kerstingii*, *Barteria nigritiana*, *Blepharis* sp., *Borreria* sp., *Bridelia ferruginea*, *Cochlospermum planchonii*, *Crossopteryx febrifuga*, *Daniellia oliveri*, *Deterium macrocarpum*, *Diallium guineense*, *Diospyros mespiliformis*, *Diospyros* sp., *Fillipendula ulmaria*, *Gloriosa superba*, *Hymenocardia acida, Hypoestes* sp., *Indigofera* sp., *Khaya ivorensis*, *Khaya senegalensis*, *Knautia* sp., *Lannea acida, Leucas* sp., *Linum catharticum*, *Limum* sp., *Maytenus* sp., *Mimosa pigra*, *Morelia senegalensis*, *Nauclea latifolia, Olax subcorpioides*, *Olax* sp., *Parkia biglobosa*, *Phyllanthus* sp., *Platostoma africana*, *Piliostigma thonningii*, *Prosopis africana*, *Rauvolfia vomitoria*, *Rhynchosia* sp., *Sesamum indicum*, *Sida acuta*, *Syzygium guineense*, *Trichilia prieureana* and *Vitellaria paradoxa.*

3.4. Human impact taxa

The results of this study showed that numerous bioparticles indicative of human impact taxa were documented. Absolute counts of 7,250 pollen grains with percentage composition of 14.32% were documented for these taxa (Table 1). Statistical analysis using Duncan Multiple Range Test showed that the Mean pollen grains abundance of 0.54 ± 0.05^{a} was documented for this group (Table 2). These taxa include pollen types of plant species associated with horticulture and agricultural activities such as *Abelmoschus esculentus*, *Adenanthera pavonina*, Amaranthaceae/ Chenopodiaceae, *Anacardium occidentale*, *Antidesma* sp., *Aspilia africana*, *Azadirachta indica*, *Calycobolus* sp., *Capparis* sp., *Carica papaya*, *Casuarina equisetifolia*, *Citrus* sp., *Cleome* sp., *Corchorus olitorius*, *Cucumis* sp., *Delonix regia*, *Dioscorea* sp., *Emilia sonchifolia*, *Empetrum nigrum*, *Eucalyptus globus*, *Euphorbia hirta*, *Euphorbia* sp., *Fagus* sp., *Gmelina arborea*, *Heliotropium* sp., *Hyptis suaveolens*, *Ipomoea* sp., *Jatropha curcus*, *Justicia* sp., *Leea guineensis*, *Leuceana leucocephalus*, *Linnaea borealis*, *Luffa cylindrica*, *Mangifera indica*, *Manihot esculenta*, *Ocimum* sp., *Physalis angulata*, *Pinus caribaea*, *Protea elliotii*, *Protea madiensis*, *Psidium guajava*, *Ricinus communis*, *Senna occidentale*, *Solanum melongena*, *Solanum torvum*, *Spigelia anthelmia*, *Stachytarpheta* sp., *Stereospermum kunthianum*, *Tecoma stans*, *Tectona grandis*, *Tetracera* sp., *Tieghemella africana*, *Tridax procumbens*, *Vigna unguiculata*, *Vitex doniana*, *Vitex grandifolia*, *Polygala* sp., and *Zanthoxylum zanthoxyloides*.

For most of these indicator species, their pollen grains were recorded sporadically where they appeared in some of the study locations, while the pollen of such plants as *Azadirachta indica*, *Casuarina equisetifolia*, *Hyptis suaveolens*, and the members of the families Asteraceae and Amaranthaceae/ Chenopodiaceae were recorded in more than 10 locations.

Moreso, the pollen of some taxa such as *Aspilia africana*, *Nauclea latifolia*, *Sida acuta* and the Family Poaceae were documented in all the study locations. Also, other indicators of human impact/ activities included charred plant particles and diatom frustules.

3.5. Plant form

With respect to plant forms (habits), six groups of plants: trees, shrubs, herbs, lianas, sedges, and herbaceous climbers contributed greatly to the total pollen rain. About 44.19% of the plant sources identified are trees; the shrubs constitute about 25.96%, herbs 21.54%, herbaceous climbers 6.61%, lianas 1.10% and sedges 0.55%. The quantity of pollen contributed by each of these groups varied considerably. Herbs contributed the highest percentage of pollen

concentration (51.47%) in the pollen record followed by trees (33.18%), shrubs (14.03%), sedges (0.63), herbaceous climbers (0.52%) and lianas (0.06%). The percentage contributions are in terms of the pollen contributed by the constituent species of each plant group. The Mean quantity of pollen grains classified based on Plant Form is shown in Tables 3 and 4 respectively.

3.6. Relationship between airborne pollen grains assemblage and vegetation

The airborne pollen assemblage trapped in this study generally reflects the regional vegetation of the catchment area which depicts tropical rainforest type (Tables 1). 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 phytoecological groups upon which other small localized subtype vegetations are represented. These are (i) the tropical rainforest, closed/open forest species represented by pollen of *Elaeis guineensis*, Cyperaceae, Moraceae, *Senna occidentalis*, *Alchornea cordifolia, Bombax buonopozense*, *Irvingia gabonensis*, *Anthocleista djalonensis*, *Canarium schweinfurthii*, *Musanga cecropiodes*, *Pentaclethra macrophylla* and *Pycnanthus angolensis* among others; (ii) the woodland shrub components represented by pollen grains of Poaceae, *Afzelia africana*, *Berlinia grandifolia*, Combretum sp., *Crossopteryx febrifuga*, *Daniellia oliveri*, *Dissotis* sp., *Euginea* sp., *Gloriosa superba*, *Hymenocardia acida, Khaya senagalensis, Lannea acida, Lophira alata, Nauclea latifolia, Parkia biglobosa, Phyllanthus* sp., *Prosopis africana*, *Protea* sp., *Rauvolfia vomitoria*, *Syzygium guineense,* and *Uapaca* sp. among others; (iii) the human impact species represented by pollen of exotic plants that serves aesthetic, economic and agricultural purposes as well as other related functions. They include *Abelmoschus esculentus*, Amaranthaceae/Chenopodiaceae, *Anacardium occidentale*, *Azadirachta indica*, *Carica papaya*, *Casuarina equisetifolia*, *Cocos nucifera*, *Cola* sp., *Delonix regia*, *Dioscorea* sp*., Gmelina arborea*, *Jatropha* sp*.*, *Justicia* sp., *Luffa cylindrica*, *Mangifera indica*, *Manihot esculenta*, *Mimosa pigra*, *Pentaclethra macrophylla, Pinus caribaea*, *Ricinus communis*, *Sida acuta* and *Solanum melongena* among others. Most of these plants have been recorded in various studies in Nsukka (Enugu State); Aguata (Anambra State); Anyigba (Kogi State), Shomolu, Gbagada, Ayetoro-Itele (Lagos State) Nigeria [8, 27, 32, 33, 34, 35], [36, 37], [3, 38, 39, 40, 7], [41, 42]. 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.

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. reflected evidence of agriculture and other anthropogenic activities. The impact of human on the vegetation has also resulted in the disappearance of some flora. Disappearance of some species is brought about by a combination of factors, including annual bush burning, excessive lumbering and firewood gathering, shifting cultivation and excessive grazing by livestock among others. As a result of these factors, the vegetation of the studied area has become impoverished with several economic species at the verge of extinction.

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 [43, 44]. 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 South Congo [45], Nigeria [3, 4, 33, and 34] and Southern Cameroon [44].

4. Conclusion

The pollen types identified in this study reflect to a large extent the phytoecological vegetation of the studied environment. The presence of pollen types from exotic plants as part of the content of the atmospheric pollen content indicates clearly the impact of man on the environment. Pollen assemblages reflected tropical rainforest vegetation type despite high level of anthropogenic activities on the local vegetation. Most of these indicator species are at the verge of extinction through series of anthropogenic activities. Such flora could be properly conserved and their exploitation adequately managed through appropriate biotechnological interventions.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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