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► To cite this version:

Anne-Marie Lézine, Kévin Lemonnier, Cheikh Abdoul Kader Fofana. Sahel environmental variability during the last millennium: Insight from a pollen, charcoal and algae record from the Niayes area, Senegal. *Review of Palaeobotany and Palynology*, 2019, 271, pp.104103. 10.1016/j.revpalbo.2019.104103 . hal-02370143

HAL Id: hal-02370143

<https://hal.science/hal-02370143v1>

Submitted on 20 Dec 2021

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1 **Sahel environmental variability during the last millennium: insight from a pollen, charcoal**
2 **and algae record from the Niayes area, Senegal**

3

4 A.M. Lézine¹, K. Lemonnier¹, C.A.K. Fofana²

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6 ¹ Laboratoire d'Océanographie et du Climat, Expérimentation et Approche numérique/IPSL,
7 Sorbonne Université, CNRS-IRD-MNHN, 4 Place Jussieu, 75005, Paris, France. Anne-
8 marie.lezine@locean-ipsl.upmc.fr

9 orcid.org/0000-0002-3555-5124

10 ² Département de Géologie, Faculté des Sciences et Techniques, Université Cheikh Anta
11 Diop, Dakar, Sénégal

12

13 **Abstract :**

14 The pollen, algae and charcoal record from the “Baobab” depression near Mboro in the
15 Niayes area of Senegal shows that the last millennium was characterized by a gradual
16 aridification which started 1340 CE and culminated 1845 CE. The sub-Guinean gallery forests,
17 which survived the previous environmental crisis dated from the end of the Holocene Humid
18 Period, suddenly collapsed and the Niayes region suffered a dramatic loss of biodiversity. We
19 show that the tipping point between a forested and non-forested state occurred ca 400
20 centuries after the onset of aridity recorded by the lowering of the water level and the
21 progressive salinization of the aquatic environment.

22

23 **Key words :** Pollen, Algae, Charcoal, last millennium, Sahel, Senegal

24

25 **1. Introduction**

26

27 Was the last major Sahelian drought in the 1970s unusual? By studying records of
28 environmental changes and associated forcing mechanisms in the recent past, it is possible
29 to situate this major climate crisis in the context of the natural variability of the west African
30 monsoon climate system. Natural archives such as lake sediments can fill gaps in
31 understanding climate variability by providing access to a long-term perspective
32 encompassing periods out of any anthropogenic influence. In western Africa, such long-term
33 records are rare (e.g., Nash et al., 2016 and references therein) and somewhat contradictory.
34 In particular, the well-known interval of the Little Ice Age (LIA - 1400-1850 CE) when
35 exceptionally cool temperatures were reached in the Northern hemisphere, was described
36 as a dry period in the Lake Bosumtwi area (Ghana) (Shanahan et al., 2009) and a humid
37 period in the Saloum delta (Senegal) (Carré et al., 2018).

38 The littoral depressions of the Niayes area, along the northern coast of Senegal have
39 provided major information on the Holocene history of the West African environments
40 (Lézine et al., 2011; Hély and Lézine, 2014). Local environmental conditions linked to the
41 proximity of the coast have favored accumulation of organic matter and expansion of gallery
42 forests in the bottom of the depressions during the Holocene (Lézine, 1989) which have
43 persisted up to recently thanks to the high level of the water table (Trochain, 1940; Pézeril et
44 al., 1986). It has been shown that these gallery forests were highly sensitive to variations of
45 the level of the water table whatever the temporal resolution considered, from decades
46 (Aguiar, 2010) to centuries (Lézine and Chateauneuf, 1991). Here we present a study
47 combining pollen and diatom analyses on a sedimentary series recovered NW of Mboro in
48 the center of the Niaye area. The aim of our study is to examine the hydrological variations

49 during the last millennium and to discuss their impact on the local vegetation. We also aim
50 at characterizing the signature of human activities on the natural environment.

51

52 **2. Regional setting**

53 The Niaye area consists of depressions formed between linear fixed and partially fixed
54 coastal dune ridges, located between 15° and 16° N, at roughly 17°W along the Atlantic coast
55 of Senegal. These depressions belong to an extensive river system which took place during
56 the Holocene Humid Period ca 12 ka yr BP. (Lézine, 1989). Edification of coastal dunes
57 (Michel, 1973) gradually closed access to the sea of water courses and promoted the
58 development of thick, continuous peat accumulations. The presence of fresh, shallow
59 ground-water near the surface in the bottom of the interdune depressions (Lézine and
60 Chateauneuf, 1991) supports the preservation (though deeply degraded today by intensive
61 agriculture activity) of gallery forests of Guinean phytogeographical affinity, which are the
62 last traces of the northern extension of tropical humid forests during the Holocene (Watrin
63 et al., 2009; Hély and Lézine, 2014). This is the "sub-Guinean domain" of Trochain (1940)
64 consisting of enclaves of aquatic vegetation in open water areas (*Nymphaea*, *Potamogeton*,
65 *Pistia*) and reed-swamp populations (*Typha*, *Phragmites*) associated with *Syzygium*
66 *guineense* in the flooded zone, surrounded by Guinean forest relicts at the foot of the dunes
67 (*Elaeis guineensis*, *Ficus*, *Treculia*, *Phoenix*) followed by *Dodonaea*, *Alchornea*, *Zanthoxylum*,
68 *Combretum* toward the upper limit of the gallery forests, whereas typically Sahelian trees
69 grow at the top of the dunes (*Acacia*, *Balanites*) (Adam, 1953, 1958; Jaeger, 1949; Villiers,
70 1957; Michel et al., 1969; Raynal, 1963) (Figure 1A).

71 Hydrological studies in the Niayes area have shown that the water level varies greatly in
72 phase with local rainfall. Accentuated dryness associated with intensive water pumping in

73 recent decades has led to the lowering of the fresh water table and the penetration of salt
74 waters from the adjacent sea into the depressions closest to the coast (e.g., Faye, 1995;
75 Aguiar, 2008; Maugis et al., 2009).

76

77 **3. Material and methods**

78 A 4 m long sediment core was collected in the center of the so-called "Baobab" depression in
79 2016 (15.149132N; 16.909275W) under few tens cm of water using a "Russian" manual
80 corer (Jowsey, 1966). Baobab lies SW of the main paleoriver channel of M'Boro at the NW
81 extremity of a depression separated from the sea shore by a ridge of ca 2 km wide dunes of
82 recent Holocene age (Michel, 1973) (Figure 1B). The sediment consists of homogeneous
83 organic clay. Samples were taken at 5 cm intervals for pollen and algae analyses.

84 For pollen and non-pollen palynomorph (NPP) analyses samples were processed using the
85 standard HF method described by Faegri and Iversen (1977). After sieving in a 5 µm mesh,
86 the residue was stained with safranin and mounted in glycerine. Pollen identification was
87 based on the reference slide and photo collections of the LOCEAN laboratory and the
88 Museum national d'Histoire naturelle in Paris as well as on pollen atlases of tropical African
89 flora from e.g., Maley (1970), APLF (1974), Ybert (1979) and Bonnefille and Riollet (1980).
90 Pollen nomenclature, which follows the standard defined by the African Pollen Database
91 (Vincens et al., 2007), was based on Lebrun and Stork (1991-2015). The pollen microflora
92 was composed of 86 taxa (Table 1): 44 trees, shrubs, palms and lianas, 17 herbs and 14
93 undifferentiated taxa mainly because of the low level of determination of the grains or when
94 the family or genus level corresponded to several life-forms. In addition, 4 aquatic pollen
95 taxa and 4 ferns were encountered. Pollen taxa were grouped according to the
96 phytogeographical affinity of the parent species following Lézine et al. (2009) in four entities

97 according a decreasing rainfall gradient: Guineo-congolian, Sudanian, Sahelian and Saharan.
98 In addition, some taxa have been selected as indicators of water-table fluctuations according
99 to their distance from the open water area (Raynal, 1963; Michel et al., 1969; Lézine, 1987)
100 (Fig. 2).

101 Pollen percentages were calculated against a sum excluding aquatics and ferns, the
102 percentages of which were calculated separately against a sum including all the pollen grains
103 and fern spores counted.

104 Undifferentiated fungi and 4 green algae (*Botryococcus*, *Coelastrum*, *Pediastrum*, *Tetraedron*)
105 represent the NPP group. NPP are presented as percentages (Fig. 3B) and micro-charcoal as
106 influxes (nbr of particles/cm²/year) (Fig.4).

107 For diatom analyses samples were processed using a standard method (Battarbee, 1986).

108 The residu was diluted in 20 ml of water and 2 ml was taken, then dried and fixed with
109 Naphrax. Diatom identification was based on e.g., Guerneur (1954), Servant-Vildary (1978),
110 Foged (1986), Gasse (1986), Compère (1991), Cocquyt et al. (1993), Bellinger and Sigee
111 (2015). In addition, Ouattara et al. (2000), Sow and Diène (2002), Sow (2001; 2004), Sow et
112 al. (2005) were used to precise the ecological requirement of taxa, particularly in Senegal.

113 Twenty-two diatoms were determined (Table 2). They correspond to three main hydrological
114 conditions: freshwater, freshwater/salt tolerant, brackish/marine waters and
115 undifferentiated. Diatoms are presented as percentages calculated against the sum of all the
116 diatoms counted (Fig. 3A).

117 Both pollen and diatom data are presented under the form of diagrams using Tilia and
118 CONISS (Grimm, 1991). Diversity indices were derived from PAST 3.23 software (Hammer et
119 al., 2001).

120

121 **4. Age control**

122 Age control was established by 3 accelerator mass spectrometry (AMS) radiocarbon dating
123 of total organic matter on the whole Baobab sequence, conducted at UMS-ARTEMIS AMS
124 Facilities (France). An additional control point was given by the first occurrence of *Casuarina*
125 *equisetifolia* pollen grains in our samples the parent trees of which were planted in 1948 in
126 the Niaye area (Ndiaye et al., 1993) (Table 3). According to this, the last millennium is
127 represented by the 121 uppermost centimeters of the 4m-long Baobab sedimentary section.
128 Our analysis has a temporal resolution varying between 70 and 12 years.

129

130 **5. Results**

131 The pollen (Fig. 2), diatom (Fig. 3A) and NPP (Fig. 3B) records display several phases of
132 environmental change over the last millennium with a remarkable coherency. They are
133 described from the base to the top of the sequence.

134

135 **5.1 Pollen**

136 The pollen spectra are characterized by the dominance of Poaceae and the continuous
137 occurrence of Chenopodiaceae/Amaranthaceae and Asteraceae. This, together with the high
138 number of other taxa, mainly herbaceous, from steppes, grasslands and wooded grasslands
139 point to an open and fairly dry regional landscape. Except Poaceae, all the other taxa are
140 poorly represented. This is particularly true for tropical trees which are characterized by a
141 low pollen productivity and an entomophilous way of pollen dispersal (e.g., Watrin et al.,
142 2007). As a consequence, their percentages are rarely higher than 10% (e.g., *Alchornea*).

143 **Zone 1, base-1340 CE:** Zone 1 is typified by tropical tree taxa, e.g., *Alchornea*, *Macaranga*,
144 *Allophylus*, *Detarium* and *Mitragyna inermis* which reach their highest values (%). Aquatics

145 (*Potamogeton*, *Nymphaea*) are also present. All this depict an open water surface
146 surrounded by a relatively developed gallery forest. By the end of this zone, in sub-zone 1b
147 (1235-1340 CE) tropical trees start to decline whereas *Typha* starts to increase showing the
148 onset of lake level lowering under drier conditions. Zone 1b marks the onset of *Elaeis*
149 *guineensis* development.

150 **Zone 2, 1340-1810 CE:** Some tropical tree taxa disappear (*Allophylus*, *Mitragyna inermis*) or
151 decline (*Alchornea*, *Macaranga*). In contrast, *Syzygium guineense* increases, as well as taxa
152 from reed-swamp populations (*Typha*, ferns) both recording low water stands and marsh
153 encroachment.

154 **Zone 3, 1810-1945 CE:** This zone shows a dramatic environmental change with the
155 disappearance of most of the plant taxa replaced almost exclusively by Poaceae (91%). As a
156 consequence, biodiversity falls sharply and Simpson diversity index values, which fluctuated
157 only slightly around 0.6 in the lowermost zones, fall to 0.177 at level dated 1845 CE. The
158 peak of Fungi at this level (Fig. 3B) testify for the at least partial or seasonal desiccation of
159 the Baobab depression.

160 **Zone 4, 1945-2016 CE:** This zone is characterized by the increase in markers of
161 anthropogenic activity with the appearance of pollen from the planted tree *Casuarina*
162 *equisetifolia*. Charcoal remains, which steadily increased since 1370 CE, peaked at 1989 CE,
163 suggesting the dramatic increase in fire occurrence. Increase in diversity compared to zone 3
164 as well as significant percentages of tropical tree taxa suggests a certain recovery of the
165 gallery forest. However, these taxa never reach values as high as in zones 1 and 2. *Typha* and
166 *Syzygium* show that the level of the water table remained low during this zone. The increase
167 of *Suaeda* in the uppermost levels (post 1980 CE: zone 1b) points to the setting of saline
168 conditions.

169

170 **5.2 Algae**

171 **5.2.1 Diatoms**

172 *Aulacoseira granulata* and *Nitzschia* (*N. acicularis* and *N. scalaris*) are the most dominant
173 species and account for up to 95, 49 and 23% respectively (Fig. 3A).

174 **Zone 1, base-1340 CE:** the diatom assemblage is almost exclusively represented by *A.*
175 *granulata*, a planktonic species characteristic of well mixed fresh waters. This taxon is
176 associated with *N. acicularis*, which confirms the presence of enriched turbid waters (zone
177 1a). Towards the top of Zone 1 at levels dated 1235 CE and above, Zone 1b shows an
178 increase in diversity with *N. scalaris*, *Eunotia pectinalis* and *Thalassiosira decipiens* showing
179 the appearance of more brackish/saline conditions.

180 **Zone 2, 1340-1925 CE:** This zone is characterized by the gradual decline of *A. granulata*,
181 which reached its lowest values in year 1906 EC. Three main taxa successively increase: *N.*
182 *scalaris* (Zone 2a), *T. decipiens* (Zone 2b), then *N. acicularis* (Zone 2c) suggesting the gradual
183 increase of dry conditions initiated in Zone 1b.

184 - **Zone 2a** (1340-1600 CE) is characterized by a noticeable increase in diversity and
185 the appearance of periphytic (e.g., *Fragilaria construens*) or bentic (e.g., *F.*
186 *pinnata*, *Pinnularia neomajor*) species. That together with the presence of species
187 either cosmopolite or salt tolerant point to the lowering of the water level and
188 the setting of dry conditions.

189 - **Zone 2b** (1600-1800 CE): *N. scalaris* decrease and is replaced by *T. decipiens* and
190 *C. stelligera* showing that salt waters increased in the aquatic environment.

191 - **Zone 2c** (1800-1925 CE): *N. acicularis* dominate the diatom assemblage is
192 association with *T. descipiens*. Meanwhile *A. granulata* reaches its lowest values.

193 All this suggests that the water level reached its lowest position.

194 **Zone 3, 1925-2001 CE:** The increase of *A. granulata* in the upper levels of the core suggests a
195 certain recovery of the fresh water environment. This remained however highly variable and
196 salty conditions are suggested in the upper level (Zone 3b) by the reappearance of *T.*
197 *decipiens* and *S. Tenera* which were absent from Zone 3a.

198

199 **5.2.2 Green algae**

200 The green algae record (Fig. 3B), shows the opposite trend between *Tetraedron*, *Pediatrum*,
201 *Coelastrum* which gradually decrease from the base to the top of the sequence, though
202 fluctuating, and *Botryococcus*. This pattern illustrates the gradual depletion of nutrient and
203 lowering of the water level. The absence of any other green algae except *Botryococcus* at
204 levels post-1954 CE indicates the emergence of clearly oligotrophic conditions. This nutrient
205 poor environment immediately followed the phase of lake level lowering indicated by the
206 increase of fungi peaking at 1845 CE.

207

208 **6. Discussion**

209 Three main features emerge from our study:

210 **6.1 The dramatic collapse of the Guineo-Congolian gallery forest at 1640 CE.**

211 The end of the HHP, from 4500 cal yrs BP onward (Lézine et al., 2011), was marked the
212 decline of tropical plants that previously widely expanded throughout the Sahel and the
213 Sahara (Watrin et al., 2009; Hély et al. 2014). The abruptness of the forest collapse in the
214 Niayes area (Lézine, 1989) was interpreted as the result of crossing a hydrological threshold,

215 after a long period of increased seasonality in rainfall since the mid-Holocene. The tipping
216 point between a forest environment and an open and degraded environment occurred ca.
217 2500 cal yrs BP (Lézine, 1989), i.e. approximately 2000 years after the end of the HHP in
218 Western Africa. The specific hydrological conditions due to the proximity of the ocean led to
219 maintain a high level of the groundwater at the bottom of the depressions. They
220 compensated for a possible precipitation deficit by maintaining moisture conditions allowing
221 the forest to maintain at the foot of the dunes for an additional two millennia after the end
222 of the HHP.

223 Over the past millennium, tropical plant types stabilized at 30%, reflecting that sub-Guinean
224 gallery forests remained only moderately developed in the Niayes area as compared to the
225 HHP during which these values were at least 80% (Lézine, 1989). These % dramatically fall at
226 1640 CE to a minimum at 1845 CE pointing to the setting of a severe environmental crisis:
227 the biodiversity dramatically declined and the Baobab depression dried up, at least partially.
228 The disappearance of green algae and their replacement by fungi in the lake sediments as
229 well as the high values of salt-tolerant diatoms clearly show that hydrological conditions
230 were more evaporated including pronounced seasonal drying of the depression (Fig. 4). This
231 drought event in the Niayes area of Senegal is contemporaneous with the repeated dry years
232 in the inner delta of the Niger River as recorded by documentary sources since 1639
233 (Coquery-Vidrovitch, 1997) and continuing into the 19th century, particularly between years
234 1800 and 1850 CE (Nicholson et al., 2012 *in* Nash et al., 2016). Similarly, the level of Lake
235 Chad underwent multiple lowering phases (Maley, 1976) and drought conditions developed
236 at Lake Bal, Nigeria (Holmes et al., 1999) during the 17th century.

237 **6.2 The drying trend from 1375 CE to 1900 CE**

238 The forest collapse 1640 CE occurred after several centuries of increasing drought starting
239 from 1340 CE, as revealed by the development of marshy plant populations and of saline
240 conditions in the Baobab depression.

241 The most prominent feature of the hydrological evolution of the Baobab depression during
242 the last millennium is the development of *Syzygium* and *Typha* populations both resulting
243 from the lowering of the water table responsible for a marsh development. As the water
244 level dropped, *Syzygium* trees were able to expand towards the center of the depression.
245 This situation also occurred in the Niayes area during the dry phases of the Holocene as
246 shown by the well preserved woods of *Syzygium* trees north of Baobab, around Diogo
247 (Figure 5).

248 The *Syzygium* development at Baobab occurred during the time interval 1340-1810 CE with a
249 peak at 1490 CE. As the level dropped further, these trees progressively declined and were
250 replaced by reed-swamp (*Typha*) populations that reached their maximum at 1688 CE. The
251 *Typha*:Aquatic Pollen ratio used to illustrate the hydrological evolution of the Baobab
252 depression (Figure 4B) confirms the gradual lowering of the water level. This evolution is also
253 confirmed by the emergence of benthic and periphytic diatom taxa reflecting the lowering of
254 the water level during the time-interval 1600-1925 CE (Diatom Zone 2b and 2c), i.e., during
255 the drought event revealed by the pollen and fungi record. In the meantime, diatom taxa of
256 cosmopolite or saline ecological tolerance reached their maximum testifying for increased
257 evaporation. The development of the freshwater taxon *Typha* at the lake margin during this
258 period is not incompatible with the increase in water salinity revealed by the diatomaceous
259 flora since *Typha* can tolerate brackish water for long periods of time and even develop on
260 dry soils affected by seawater infiltration (Adam, 1964).

261 Our Baobab record does not show the humid event described in the Sahel by Maley (1977)
262 at lake Chad around 1600 CE and Carré et al (2018) in the Saloum area of Senegal, 1500-
263 1800 CE as well as in Eastern Africa by e.g., Verschuren et al., 2000 and Stager et al., 2005.
264 However, it closely matches the Lake Bosumtwi record (Shanahan et al., 2009) which
265 identifies a drought event between 1400 and 1750 CE, "*similar in timing to the Little Ice Age*
266 *(LIA, ~1400 to 1850 CE)*". From our record, the LIA was a period of increased dryness in the
267 Niaye area of Senegal with a particularly severe drought event peaking at 1845 CE.

268 **6.3 The anthropogenic impact**

269 Micro-charcoal fragments are insignificant in number at levels prior to 1600 CE. Then, during
270 the LIA, they increase slightly, reflecting repeated fires during marked and probably longer
271 dry seasons. In contrast, their unprecedented increase over the past two decades suggests a
272 radical change in regional economic activities, probably in relation to the intensification of
273 charcoal production around the cities of Thiès and St-Louis (Gueye, 2000).

274

275 **7. Conclusion**

276 Our pollen, charcoal and algae record of the Baobab sedimentary sequence near Mboro
277 shows that, during the last millennium, the Niayes area of Senegal underwent a gradual
278 aridification which culminated 1845 CE. This drying trend occurred during the Little Ice Age
279 during which the Northern Hemisphere experienced cool climate conditions. In the Niayes
280 area, the sub-Guinean gallery forests, which survived the previous environmental crisis
281 dated from the end of the Holocene Humid Period 2500 years ago, suddenly collapsed and
282 the region suffered a dramatic loss of biodiversity. We show that the tipping point between
283 a forested and a non-forested state occurred ca 400 centuries after the onset of aridity
284 recorded by the lowering of the water level and the progressive salinization of the aquatic

285 environment. This response time of tropical ecosystems to climate change can have critical
286 implications for biodiversity and forest management strategies.

287

288 **Acknowledgements**

289 This work was initiated in the frame of a CNRS INSU LEFE research project headed by M.
290 Carré and an IRD scientific network coordinated by A. Sifeddine (CLIMACTE). It is an
291 "ACCEDE" Belmont Forum contribution (18 BELM 0001 05). Thanks are due to the Institut de
292 Recherche pour le Développement (IRD) in Senegal and the UCAD Geological Department for
293 logistic support in the field and authorizations and to the ECLAIRS international laboratory,
294 Dakar and the LOCEAN laboratory for fundings. AML and KL are funded by CNRS, CAKF by
295 UCAD. Raw data will be stored at NEOTOMA and are also available on request from the first
296 author.

297

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421

422 **Table and Figure captions:**

423 Table 1: List of pollen taxa recovered in the Baobab last millennium sequence. Nomenclature
424 follows Vincens et al., 2007.

425 Table 2: List of Diatom taxa recovered in the Baobab last millennium sequence.

426 Table 3: Radiocarbon measurements (UMS-ARTEMIS AMS Facilities, France) and additional
427 control points: 1948 CE: first appearance of *Casuarina equisetifolia* pollen grains in the
428 sediments; 2016 CE: date of the core recovery).

429

430 Figure 1: The Niaye gallery forest. A: Schematic distribution of plants on dune slopes from
431 the Sahelian steppes at the top of the dunes to the open-water surface at the bottom
432 of the depressions (Raynal, 1963; Michel et al., 1969); B: The Mboro complex of
433 paleodrainages and interdunal depressions filled by organic matter and the location of
434 the study site (black dot) (ORSTOM, 1962).

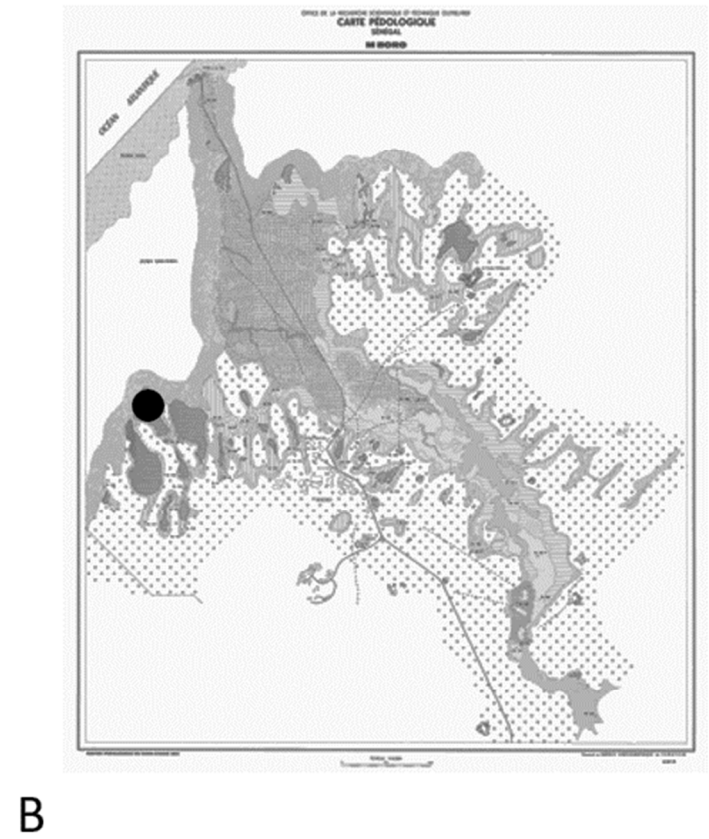
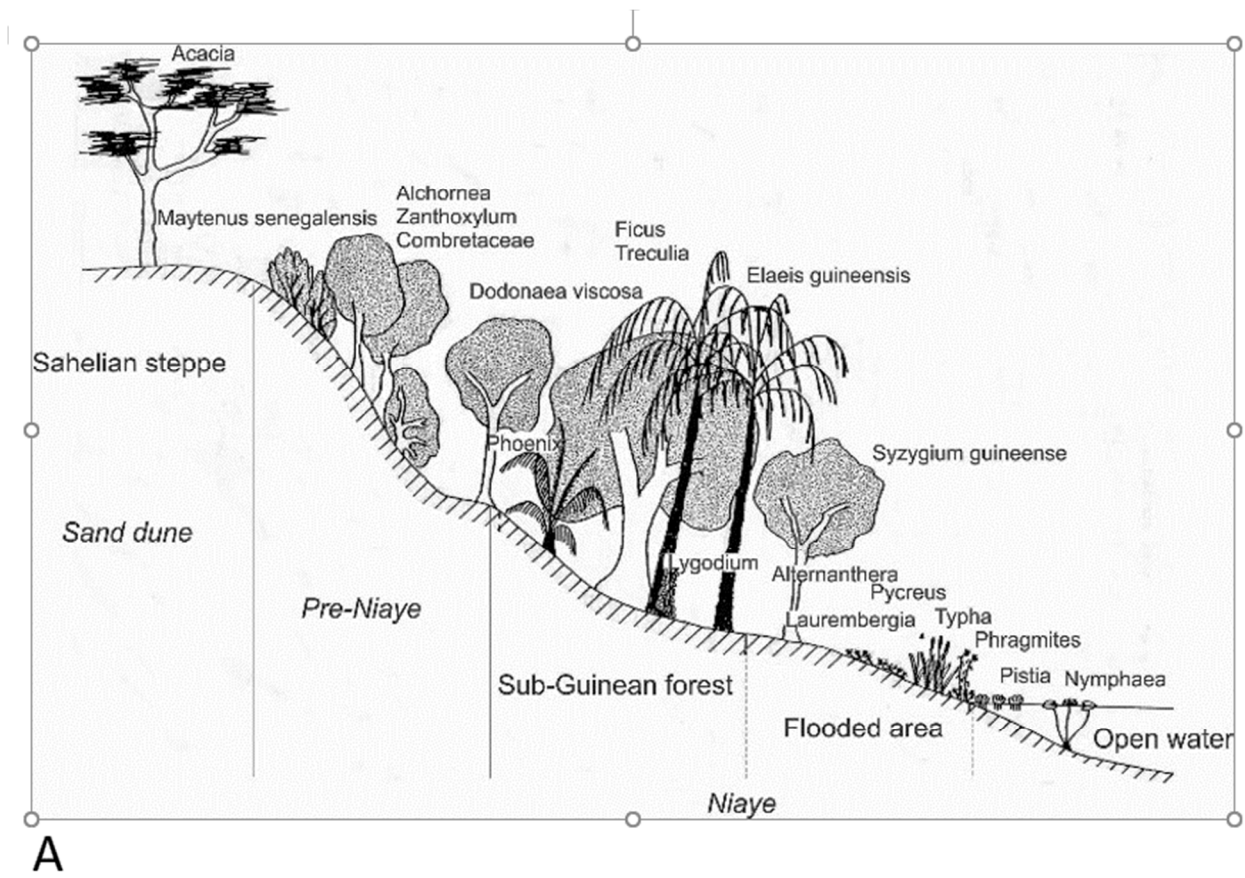
435 Figure 2: Synthetic pollen diagram of the Baobab (last millennium) showing from left to right
436 versus time (in chronology CE) selected plant taxa. On the right, the Simpson D-1 index
437 of diversity.

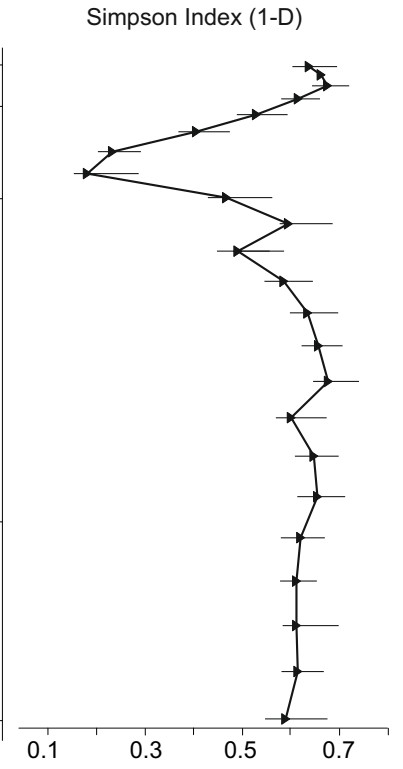
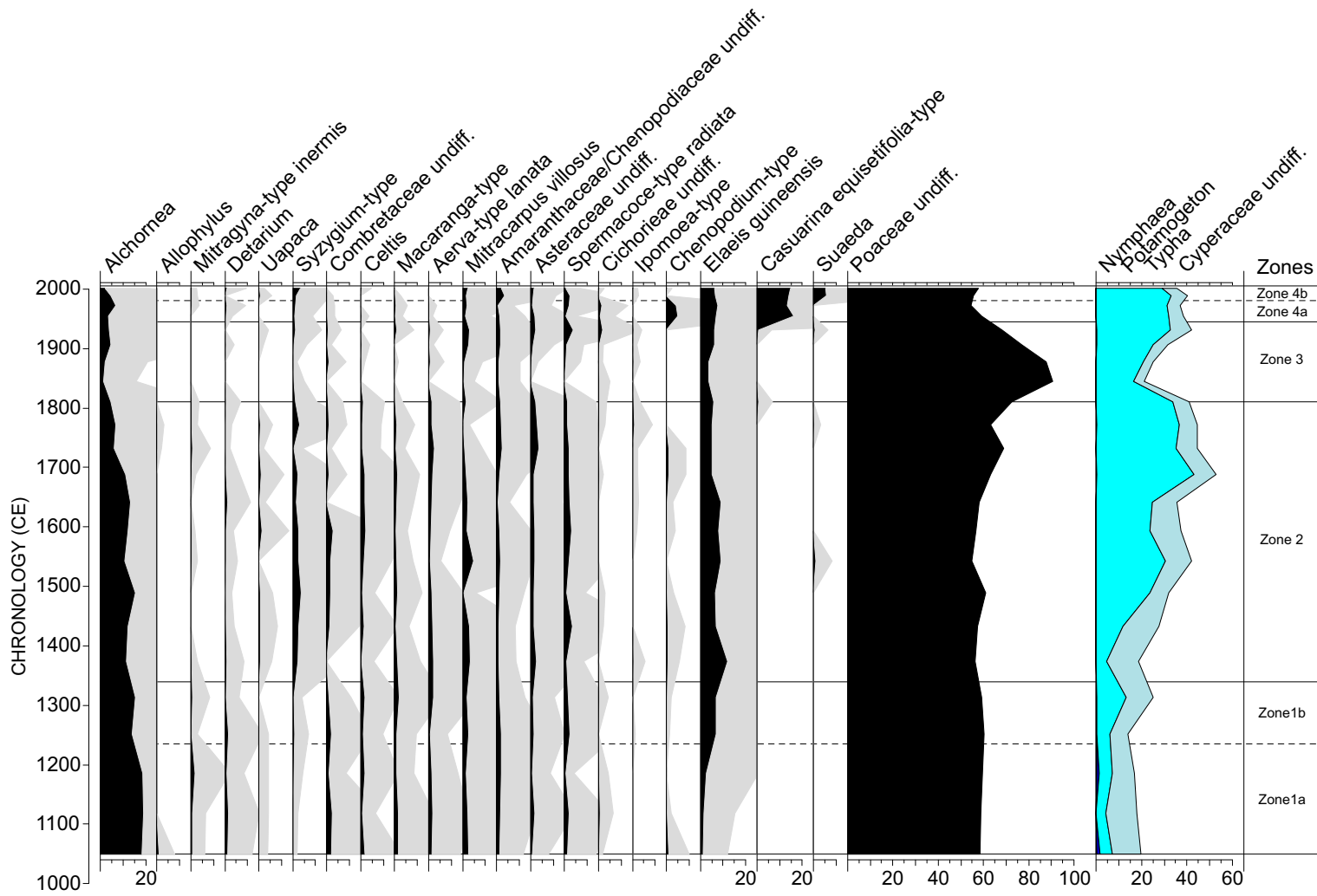
438 Figure 3: Synthetic diagram of the Baobab (last millennium) diatom and NPP record showing
439 from left to right versus time (in chronology CE) A: selected diatom taxa, main groups
440 of diatoms according to their ecological significance, the Simpson D-1 index of diatom
441 diversity and B: the NPP (Fungi and Green Algae) record.

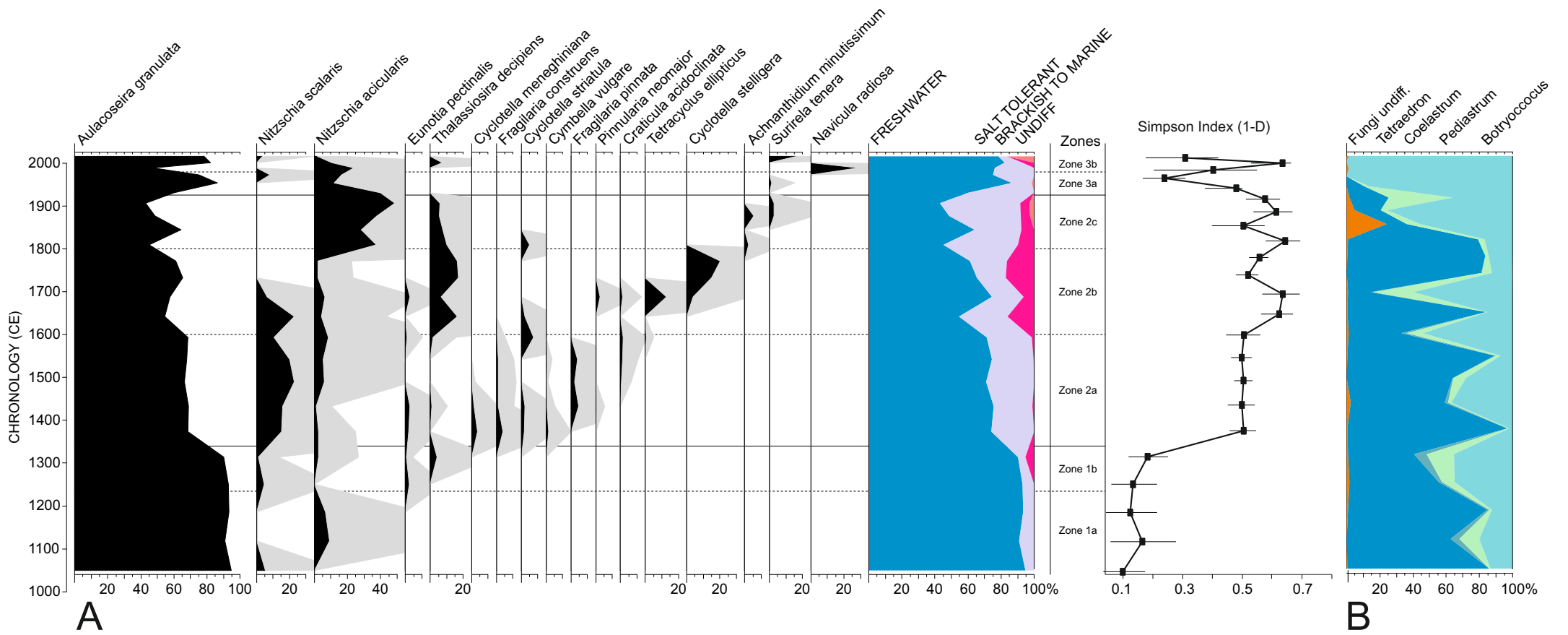
442 Figure 4: Main paleoenvironmental features at Baobab, (Mboro sector of the Niaye area,
443 Senegal) during the last millennium. A: Pollen and Fungi% and Charcoal influxes
444 illustrating the drying trend which led to the main environmental crisis peaking at 1845
445 CE in the Niayes area of Senegal and the increase of the anthropogenic activity during

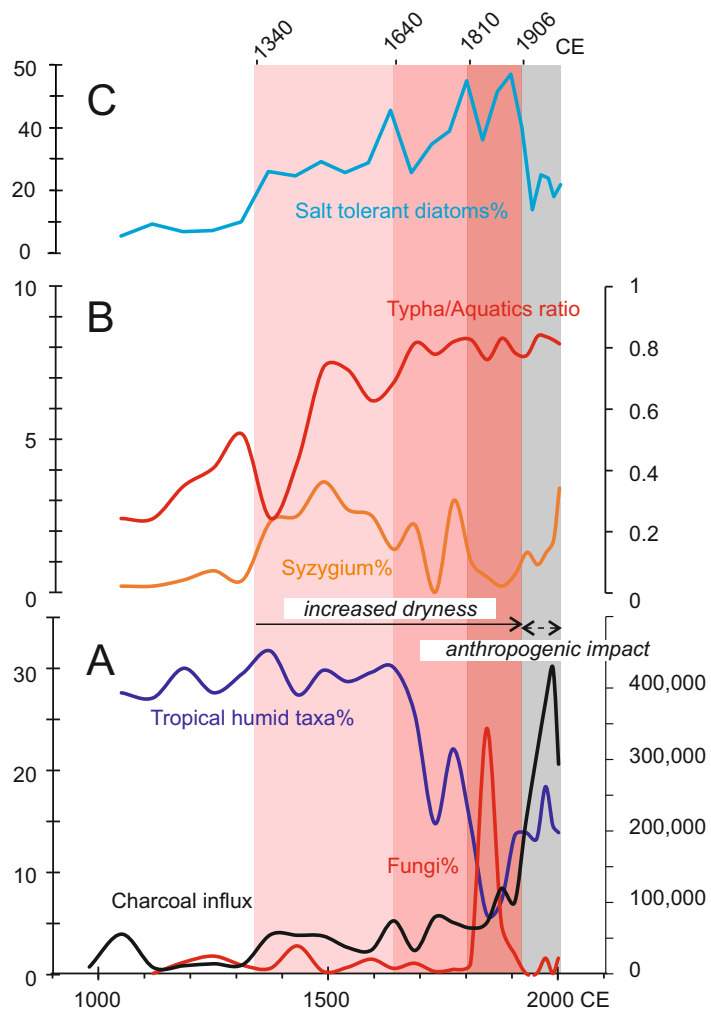
446 the last centuries; B: pollen markers of lake level lowering; C: diatom markers of
447 increased salinity.

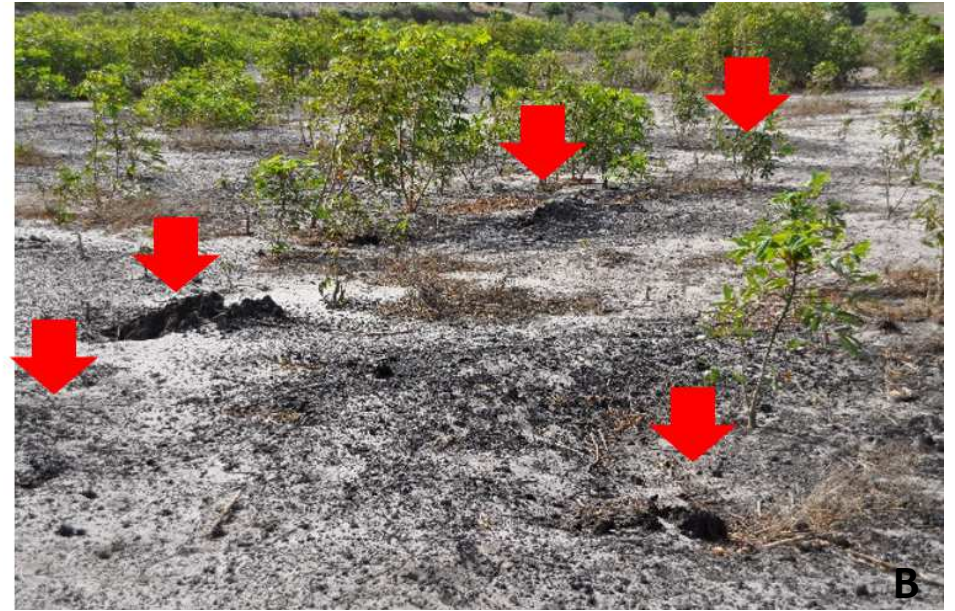
448 Figure 5: Fossil woods of *Syzygium guineense* of late Holocene age preserved in the organic
449 levels of the Niaye sediments (Mandeng-Yogo, work in progress). A: the trunks emerge
450 thanks to the digging of a well; B: the red arrows show the traces of the base of the
451 *Syzygium* trees that formed a dense forest at the bottom of the interdunal
452 depressions.











TREES and SHRUBS

Acacia
Adansonia digitata
Alchornea cordifolia
Allophylus
Anacardiaceae undiff.
Anogeissus-type leiocarpus
Anthostema-type
Bridelia-type
Capparis fascicularis-type
Casuarina equisetifolia-type
Celastraceae undiff.
Celtis
Chrysobalanus icaco/Parinari
Cissampelos-type
Cocculus pendulus-type
Combretaceae undiff.
Combretum-type aculeatum
Combretum-type molle
Commiphora africana-type
Detarium senegalense
Dictyandra
Diospyros
Elaeis guineensis
Ficus
Hymenocardia
Khaya-type senegalensis
Lannea-type
Macaranga-type
Mallotus-type
Mitragyna-type inermis
Morelia senegalensis
Myrianthus-type
Paullinia pinnata
Phoenix reclinata-type
Prosopis-type africana
Salacia
Sapotaceae undiff.
Syzygium-type
Tabernaemontana
Tamarix
Tapinanthus-type
Tetracera
Tinospora bakis
Uapaca
Zanthoxylum-type zanthoxyloides

UNDIFFERENTIATED

Acalypha
Aeschynomene
Amaranthaceae/Chenopodiaceae undiff.
Asteraceae undiff.
Cichorieae undiff.
Hibiscus
Ipomoea-type
Justicia-type
Polygala-type
Rubiaceae undiff.
Solanum-type
Suaeda
Triumfetta-type
Undetermined

HERBS

Achyranthes-type aspera
Aerva-type lanata
Alternanthera
Centaurea-type perrottetii
Cerastium-type
Chenopodium-type
Cleome-type gynandra
Commelina-type benghalensis
Commelina-type forskalaei
Gomphrena
Justicia-type flava
Mitracarpus villosus
Poaceae undiff.
Polycarpaea-type
Polycarpon-type
Spermacoce-type radiata
Tribulus

AQUATICS

Cyperaceae undiff.
Laurembergia tetrandra
Ludwigia-type stolonifera
Nymphaea lotus-type
Polygonum senegalense-type
Potamogeton
Typha

FERNS

Lygodium microphyllum
Monolètes à épines et non lisses autres
Monoletes undiff.
Triletes undiff.

FRESHWATER

Aulacoseira granulata

Craticula acidoclinata

Cymbella vulgare

Fragilaria construens

Fragilaria pinnata

Navicula densa

Navicula radiosa

Pinnularia divergens

Pinnularia neomajor

Tetracyclus ellipticus

SALT TOLERANT

Achnantheidium minutissimum

Cyclotella meneghiniana

Cyclotella stelligera

Cyclotella striatula

Eunotia pectinalis

Nitzschia acicularis

Nitzschia scalaris

Rhopalodia gibba

BRACKISH TO MARINE

Navicula groveoides

Surirela fastuosa

Thalassiosira decipiens

UNDIFF

Surirela tenera

Lab number SacA	Sample (cm)	Nature	Median Age CE	Range 1 σ
49827	BAOBAB 2016 (99-100)	MO	1346	1317-1407
49828	BAOBAB 2016 (299-300)	MO	-1547	1607-1503
49829	BAOBAB 2016 (399-400)	MO	-2349	2454-2289

Additional control points (Age CE)				
	BAOBAB 2016 (0.5)	surface	2016	
	BAOBAB 2016 (30.5)	First record of Casuarina pollen grains	1948	