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Paleovegetation in West Africa for 18.000 B.P. and 8.500 B.P.

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Quaternary, paleoclimate, paleovegetation, savannas, dry forest, semi-deciduous and evergreen rainforests

Abstract: The investigations were concentrated on the reconstruction of former vegetation patterns for the Sudanian and Guinean savannas as well as tropical semi-evergreen and evergreen rainforests. A number of research projects concerning changes in the vegetation cover have shown that even tropical regions have been effected by the enormous climatic oscillations of the last 20,000 years. The problem linked to the judgement of a changing vegetation is the increasing effect of human influence on the appearence of the West African vegetation cover. Thus, all investigations of the temporal change in tropical ecosystems are confronted with the fact that areas which have not been influenced by man can rarely be found. The primary question is which formations of vegetation may allow us to draw conclusions applicable to a nearly natural vegetation. A first step is the estimation of potential forest communities under recent climatic conditions.

The derivation of the paleovegetation of West Africa was based on varied published information concerning paleoclimate and paleovegetation. This information is bound to the subjects of archaeology, geomorphology, dendrochronology, palynology, deep-sea-core and isotope analysis. By derivation of the numeric relations between natural vegetation and climate under recent conditions, according models of analogous vegetation climate of paleoclimatic conditions could be drawn. Presented are paleovegetation maps of West Africa for 18.000 B.P. (glacial climatic pessimum) and 8.500 B.P. (postglacial climatic optimum).

[Paläovegetation in West-Afrika vor 18000 und 8500 Jahren vor heute]

Kurzfassung: Die Arbeiten konzentrierten sich darauf, eine Rekonstruktion früherer Vegetationsmuster für die sudanischen und guineensischen Savannenlandschaften sowie für die tropischen halbimmergrünen und immergrünen Feuchtwälder zu erstellen. Zahlreiche Untersuchungen zum zeitlichen Vegetationswandel haben gezeigt, daß auch die tropischen Regionen von den nachhaltigen Klimaoszillationen der letzten 20.000 Jahre nicht unbeeinflußt geblieben sind. Ein zentrales Problem bei der Beurteilung einer sich wandelnden Vegetation ist der in den jüngeren Zeitabschnitten (ab ca. 8.500 B.P.) zunehmend anthropozoogen induzierte Einfluß auf die Ausprägung der tropischen Pflanzendecke.

So sehen sich sämtliche Arbeiten zum zeitlichen Wandel tropischer Ökosysteme mit dem Problem konfrontiert, daß über die Erfassung der rezenten Vegetationsbedeckung sicherlich nur in Ausnahmefällen die natürliche Vegetation erfaßt wird. Es stellt sich zunächst die Frage, welche Vegetationsformation Hinweise auf ein noch weitgehend naturnahes Pflanzenkleid liefert.

Das Material, das eine vegetationsökologische Analyse der Zeitscheiben 18.000 und 8.500 B.P. ermöglicht, wurde zunächst über eine Dokumentation vorhandener Informationen zu Paläovegetation und Paläoklima zusammengestellt. Es handelt sich dabei um Informationen aus den Sachgebieten Archäologie, Geomorphologie, Dendrochronologie, Paläobotanik, Palynologie, Tiefseebohrung und Isotopenanalyse. Der nächste Schritt enthält die Ableitung rechnerischer Beziehungen der aktuellen Vegetation zu Klima und Boden. Diese Modelle dienen dazu, die rezenten (aktuellen) Analogien Vegetation/Klima auch auf die Paläozeitscheiben anzuwenden. Vorgestellt werden Karten der Vegetationsbedeckung West-Afrikas für 18.000 B.P. (Klimapessimum) und post 8.500 B.P. (nacheiszeitliches Klimaoptimum).

Introduction

Vegetation maps for 18.000 B.P. (higher aridity than today) and 8.500 B.P. (higher humidity than today) were to be drawn. Before these maps could be made the potential quasi-natural vegetation formations in West Africa under recent climatic conditions had to be investigated.

The problem facing nearly all research work on changes in tropical ecological systems is that the registration of contemporary vegetation only seldom encompasses the natural vegetation. Which types of vegetation indicate a more or less natural vegetation, however?

The geo-botanical analysis necessary herefore were undertaken in the Ivory Coast, a country which can be divided in two floristic areas: the Guinea region in the south and the Sudan region in the north.

The tropical ombrophile forests which dominate the floristic Guinea region can again be subdivided into evergreen ombrophile forests, in which the annual dry season does not exceed one to two months, and into semi-deciduous ombrophile forests with not more than three to four months of dry season (ANHUF & FRANKENBERG, 1991).

The Sudan region is dominated by summer-green forests. Most trees shed their leaves during the arid

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season, as it lasts for more than four months. The northward decrease in precipitation which is combined with the prolongation of the arid season allows yet another subdivision of these forests into dense dry forests (forêts denses sèches) and open dry forests (forêts sèches), the latter of which grow in regions in which the arid season lasts longer than half a year (ANHUF & FRANKENBERG, 1991).

Estimating the potential forest types under consideration of the contemporary climatic conditions was the first step of the analysis. The tree as such represents an essential element for the stability of the landscape within a certain forest type, as well as being an important indicator for the West African savanna. An important aspect of the change in vegetation in the sense of landscape degradation is described by the changing patterns of tree types.

But why is this question so important? Is it not enough to simply equalize vegetation and precipitation zones in order to define the borders of landscape areas? The idea that the character, as well as the border of a landscape can be drawn by only one of numerous natural factors automatically leads to the idea of a shrinking or perhaps expanding of the recent existing vegetation formations.

Investigations in Senegal and the Ivory Coast, as well as works of SCHULZ & POMEL (1992) and NEUMANN (1988) have shown that man has hardly been considered in reconstructing the climate and vegetation throughout climatic changes. In actual fact, the landscape-development of West Africa has been influenced by man in three main phases. As early as 7.000 B.P. and even more so after 4.000 B.P., sustainable impacts of man influenced the savanna and forest regions of sub-saharan West Africa. Impact of man during this time changed and formed the vegetation. Primarily, the hunting and grazing fires were of limited effect. Thereafter, increased numbers of livestock caused essential changes in vegetation. On the one hand, this led to a more open landscape and on the other hand it meant a reduction of tree- and shrub-vegetation. Furthermore it creates a different spectrum of plant species. Trees and shrubs such as *Acacia albida* and *Acacia laeta* weresupported by distribution as zoochoric elements.

Not only grazing and burning are responsible for less dense vegetation, however. The main cause lies in the specific selection and support of different trees and shrubs serving human nutrition. The same applies for grasses and herbs. Out of the tree-savannas and open dry-forests so-called park-savannas have emerged because trees and shrubs have been, and still are, of greatest importance for the human diet. These park-savannas can be described as integrated land use systems with fruit trees and crops. Typical trees of park-savannas are: *Balanites aegyptiaca, Acacia, albida, Sclerocarya birrea, Adansonia digitata, Butyrospermum parkii, Parkia biglobosa, Daniellia oliveri, Lophira alata, Borassus aethiopum* and *Elaeis guineensis*.

A further massive impact on the vegetation of the Sudanian and Guinean Zone can be recalled as of 3.000 - 2.500 B.P. when iron ore extraction and iron processing began. The production of iron was based on charcoal: the smelting process required 100 kg of wood to obtain 5 kg of metal (KADOMOURA 1989).

In order to create a map with potential quasi-natural vegetation formations in West Africa, testing areas (1 ha) were chosen in the Sudanian and Guinean domain, in which all tree species were identified and counted. The inventories in anthropogenic or zoogenic influenced testing areas were compared with those of quasi uneffected areas (factor analysis - ANHUF 1994). The comparison of all the 229 savanna and forest test plots enabled a numerical statement of the anthropogenic influenced vegetation, and in addition to this, a reconstruction of the vegetation cover without human impact (fig. 1).

The hyperombrophile forest can not exist in regions with more than 1800 mm of precipitation a year and a maximum one month dry period. This type of forest can only be found in the farthest southwest and southeast of the Ivory Coast.

Most regions with ombrophile evergreen forests have an annual rainfall of approx. 1400/1500 - 1800 mm. Also here the dry period does not last longer than one or two months.

In summary, one can say that the northern boundaries of the ombrophileforests lie at approximately 1400 mm (minimum) annual precipitation.

The continuation of the ombrophile forests is the transitional zone of dense semi-deciduous ombrophile forests which are characterized by a humid season lasting up to eight to nine months. It can be said that its northern expansions reach areas with a maximum dry season of four months. Further, this zone is recognized as the frontier between the floristic Guinea-Zone and the floristic Sudan-Zone.

Within the Sudan-Zone dry forests dominate the landscape. The forest types following the semi-deciduous ones are the dense dry forests (forêts denses sèches). They represent a climax vegetation within the transitional zone of the above described floristics. The dry season is likely to last up to six months. Areas with an even longer dry season (> 6 months) which at the same time have a precipitation of 1000/11000 mm per year are considered again as a transitional zone leading to the open dry forests (forêts sèches). In the Ivory Coast this forest type might again be found (e.g. Parc Nationale de la Comoé) in the farthest northeastern parts near the border to Burkina Faso, as the open dry forests can survive with only four to five humid months a year.

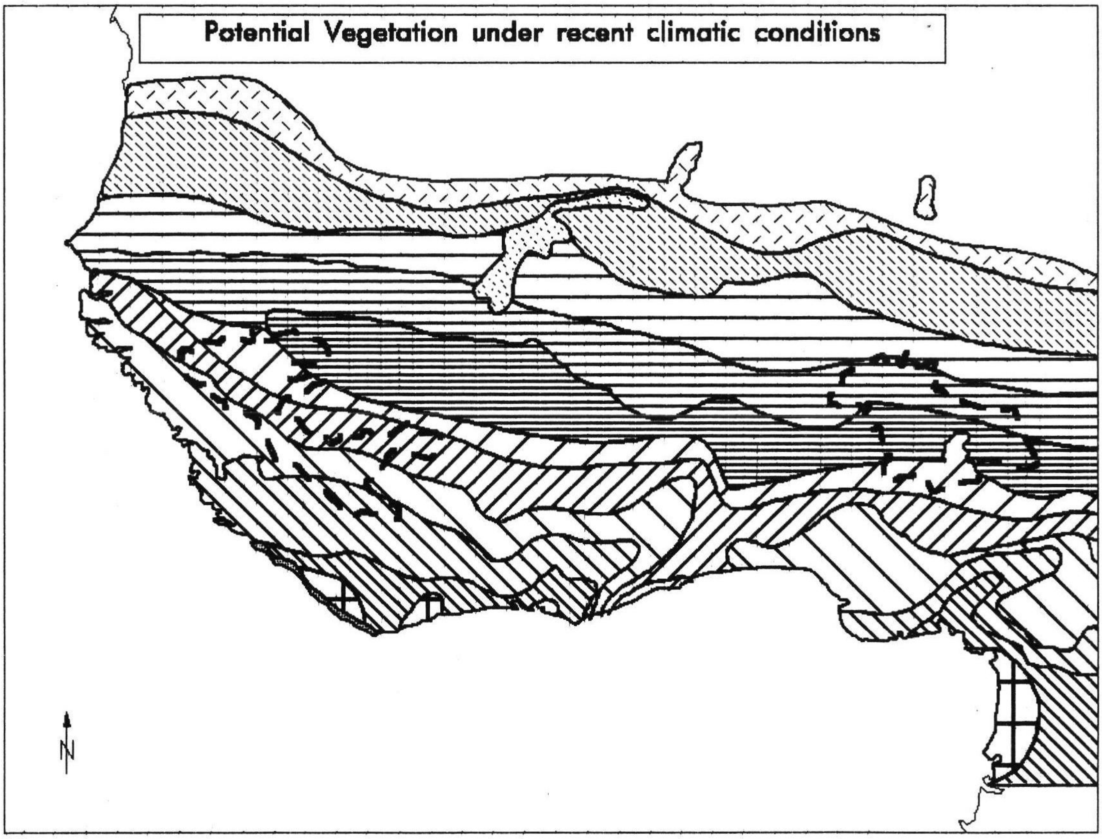

Fig. 1: Natural vegetation cover under recent climatic conditions.
Abb. 1: Naturnahe Vegetationsformation.

Based on results of research work in the Ivory Coast (*Anhuf* 1994), as well as on different literature, a map of the potential quasi natural forest types with contemporary climate parameters was constructed for all of West Africa.

Methods of constructing paleovegetation maps

Maps reflecting the changes of vegetation were constructed with the use of standarized methods. The facts from which an ecological vegetation analysis of the previous mentioned time-schedules could be drawn allowed a documentation of published information concerning paleovegetation and paleoclimates in comparison with recent conditions. The information used for the documentation is bound to the following subjects: geomorphology, palynology, paleobotany, deep-sea-cores, ice cores, oxygen isotope data, dendrochronology, prehistory, and palaeontology (fig. 2).
The resulting publications enabled the establishment of a data-base for climate and vegetation for the time-scales in discussion. The final maps of palaeovegetation however, could only be created by cross-referencing both kinds of information in order to maintain reciprocal correlations and therefore avoid gaps in the data about vegetation. Furthermore this cross-referencing allows a calculation concerning the paleo-water-budget. These calculations required that the relationship between climate and vegetation can be constructed. This model could only be based on contemporary conditions and dependencies. The influencing parameters were a sum of regional differentiated climatic (temperature, precipitation, humidity, evaporation) and soil data. The different values for defining a single parameter were estimated with the help of multi-dimensional statistical procedures. With the help of a reciprocal comparison of paleoclimate and paleovegetation information a relatively acurate reconstruction of vegetation could therefore be guaranteed.

The vegetation map of West Africa around 18.000 B.P.

In the east of the Ivory Coast, near the border to Ghana, only small relicts of the semi-deciduous rain-

1	Atlantik/Westafrika/M1328	Hooghiemstra,H.(1982)
2	Atlantik/Westafrika/M1640	Hooghiemstra,H.(1982)
3	Atlantik/Westafrika/M1323	Hooghiemstra,H.(1982)
4	Atlantik/Westafrika/M1320	Hooghiemstra,H.(1982)
5	Atlantik/Westafrika/M1320	Hooghiemstra,H.(1982)
6	Atlantik / M16415	Dupont,L.M.;Agwu,C.O.C.,(1992)
7	Golf von Guinea, KS 84067	Fredoux, A.(1994)
8	Golf of Guinea/KS12	Lezine&Vergnaud,1993
10	M16776	Lutze et al.,(1988)
11	M16856	Lutze et al.,(1988)
12	M16867	Lutze et al.,(1988)
14	Ofuabo creek, Niger-Delta	Sowumni, A. M. (1981)
16	Golf von Guinea, KW 23	Bengo, M. D., Maley, J. (1991)
18	Bois de Bilanko;Congo	Elenga,H.(1992)
19	Etang de Ngamakala;Congo	Elenga,H.(1992)
23	Cape Barbas/M123-10-4	Agwu,C.O.C., Beug,H.J.,(1982)
28	Senegal/Valdivia 132-18-1	Agwu,C.O.C.,Beug,H.J.,(1982)
29	Sierra Leone/M30(KI184)	Agwu,C.O.C.,Beug,H.J.,(1982)
74	Atlantik/Westafrika	Hooghiemstra,H.(1982)
76	Atlantik/Westafrika	Hooghiemstra,H.(1982)
103	GeoB1008	Dupont,L.M.,(1995)

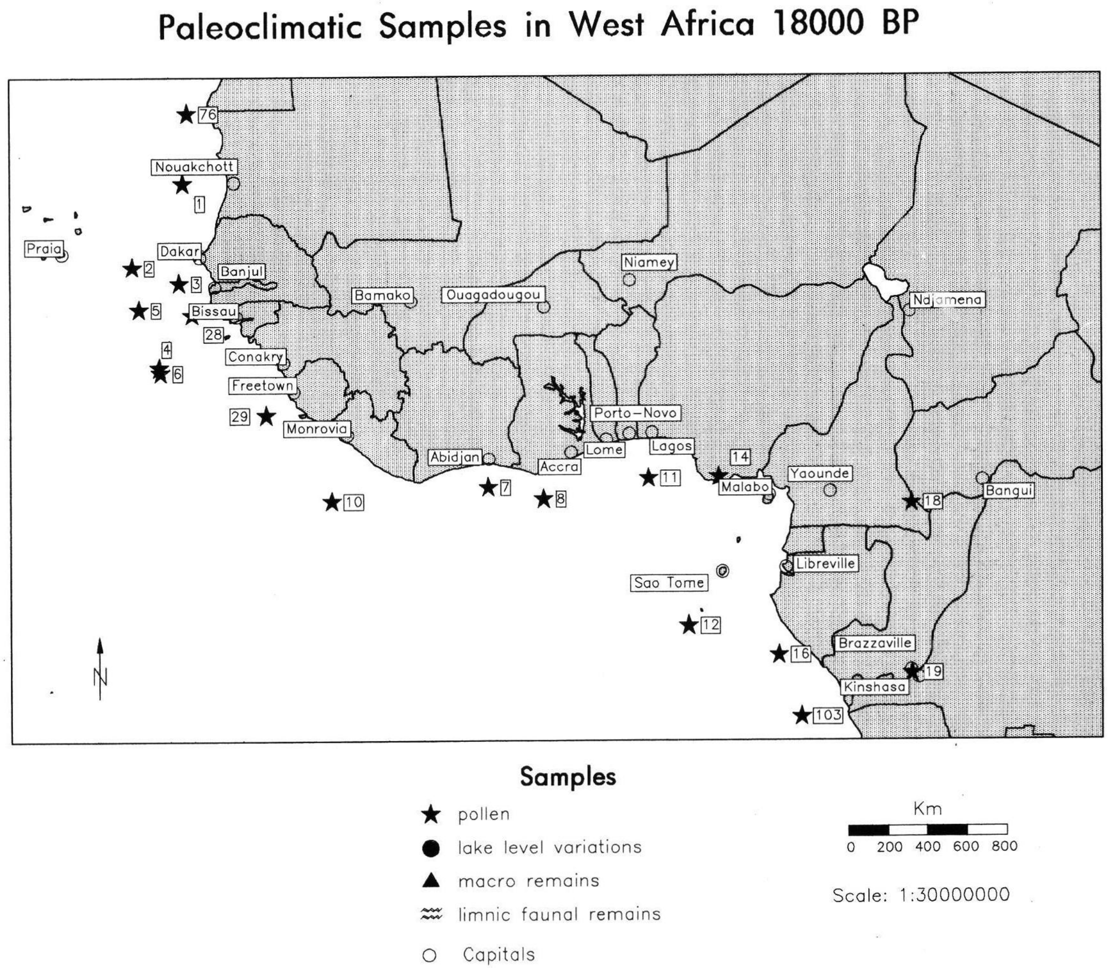

Fig. 2: Map of the locations of pollen-profiles for the LGM, published in literature.
Abb. 2: Karte der veröffentlichten Pollenprofile für das LGM.

forest have survived the last glacial maximum. In contrast, this same forest type in the West remained in the highlands of Guinea as well as in the area of Cape Palmas at the south peak of the West African continent. Even under circumstances of minor precipitation between Greenville (5°1N/9°3W) and Cape Palmas the ecological climatic conditions allowed the survival of a strip of evergreen rainforests along the coast. These conditions can also be found along the Niger Delta and even further to the east, around Douala and its hinterland which again allowed the survival of evergreen rainforests. In the central part of the Ivory Coast, as well as in the area of the Dahomey Gap, dry forests with a high percentage of graminees almost reached the Guinean coast. The area around Accra showed only open tree savannas comparable with the sahelian type of today around 18.000 B.P. The orographic situation of the highlands of Guinea supported the survival of rather humid forest formations even in its northern parts (Fouta Djalon). Because of the general reduction of temperature of four to six degrees, the low mountain range of the Guinean Highlands was effected by a maximum rainfall area (LAUER 1989). Therefore, the evergreen and the dense dry forest types presented in the map should rather be described as elfin and mountain forests (fig.3).

At 18.000 B.P., the transition from the open dry forests, today found in the central and southern Sahelian areas, to the open tree savannas was shifted to 13°N at the western coast, almost to 10°N in the northeastern edge of the Ivory Coast and to 12°N in the region of Kaduna (Nigeria) so that it lay further to the south than today (3-4°). The transition from the grass savannas to the diffuse vegetation of the southern Saharan border lay at 15°N in Senegal and at nearly 14°N in the central part of todays Sudanian Zone (north of Kano/Nigeria). This described northern frontier of the grass savanna in West Africa is comparable to the southern border of moving sand dunes in the Pleistocene (TALBOT 1984).

The Vegetation map of West Africa around 8.500 B.P.

The climatic pessimum in West Africa ended around 12.500 B.P. The marine pollen cores along West Africa are proof for the climatic change which must have been very enormous (AGWU & BEUG 1982, ROSSIGNOL-STRICK & DUZER 1979 A + B, HOOGHIEMSTRA

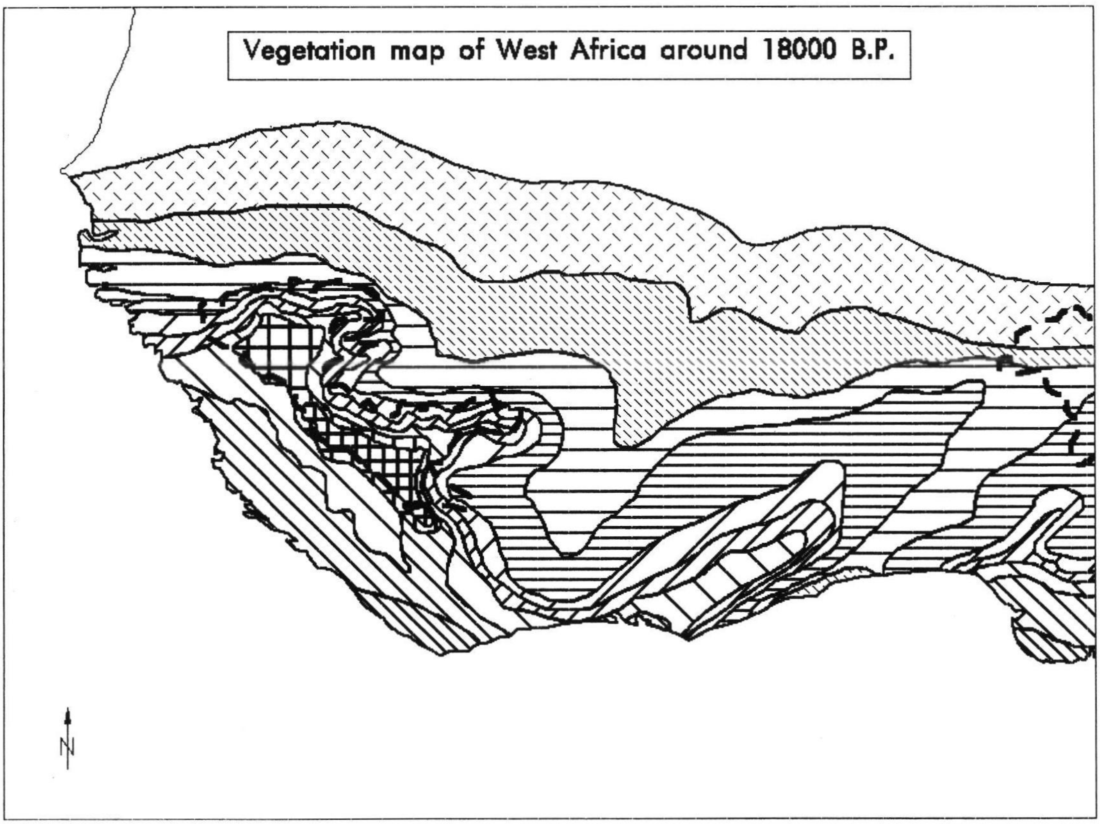

Fig. 3: Vegetation maps of West Africa arround 18.000 B.P.
Abb.3: Karte der Vegetationsformationen Westafrikas um 18.000 B.P.

2 Taoudenni, Mali	Schulz, E. (1987)
6 Atlantik / M16415	Dupont,L.M.;Agwu,C.O.C.,(1992)
9 Lake Bosumtwi, Ghana	Maley, J. (1991)
13 Oursi, Burkina Faso	Ballouche, A., Neumannn, K. (1994)
14 Sebkha of Chemance, Mauretanien	Lezine, A-M. (1987)
17 Ofuabo creek, Niger-Delta	Sowumni, A. M. (1981)
15 Chaine de Gobnangou/Burkina Faso	Neumann,K.; Ballouche,A.(1992)
16 Golf von Guinea, KW 23	Bengo, M. D., Maley, J. (1991)
18 Bois de Bilanko;Congo	Elenga,H.(1992)
19 Etang de Ngamakala;Congo	Elenga,H.(1992)
20 Lake Chad	Adams & Tetzlaf,(1983)
21 Lake Chad	Lezine, A-M. (1987)
25 Niger/Erg von Bilma/Dibella	Baumhauer,R.,(1987)
31 Nigeria/Gajiganna	Ballouche,Neumann,(1994)
32 Nigeria/Lantewa	Ballouche,Neumann,(1994)
36 Seguedine, Niger	Schulz, E. (1987)
62 Tibesti/Chad	Grunert,J.,(1972)
88 Trou au Natron	Böttcher,U., Ergenzinger,P.J.,(1972)
89 Begour-Krater	Böttcher,U., Ergenzinger,P.J.,(1972)
90 Enn. Zoumri/Ouanofou	Böttcher,U., Ergenzinger,P.J.,(1972)
92 Mouskorbé	Böttcher,U., Ergenzinger,P.J.,(1972)
93 Yebbi Bou	Böttcher,U., Ergenzinger,P.J.,(1972)
94 Enn. Zoumri/Oré	Böttcher,U., Ergenzinger,P.J.,(1972)
95 Enn. Tabirou	Böttcher,U., Ergenzinger,P.J.,(1972)
96 Djebel Nero	Böttcher,U., Ergenzinger,P.J.,(1972)
97 Tarso	Böttcher,U., Ergenzinger,P.J.,(1972)
121 El Rhimiya	Petit-Maire,N.,(1991)
124 Amekni	Petit-Maire,N.,(1991)
126 Gabrong	Petit-Maire,N.,(1991)
132 Achelouma	Petit-Maire,N.,(1991)
142 Begour	Petit-Maire,N.,(1991)
143 Adrar Bous	Petit-Maire,N.,(1991)
150 Agadem	Petit-Maire,N.,(1991)
151 Temet	Petit-Maire,N.,(1991)
154 Nemra	Petit-Maire,N.,(1991)
155 Amekni	Petit-Maire,N.,(1991)
158 Dogonboulo	Petit-Maire,N.,(1991)
162 Tin Ouaffadéne	Petit-Maire,N.,(1991)
164 Tagalaga	Petit-Maire,N.,(1991)

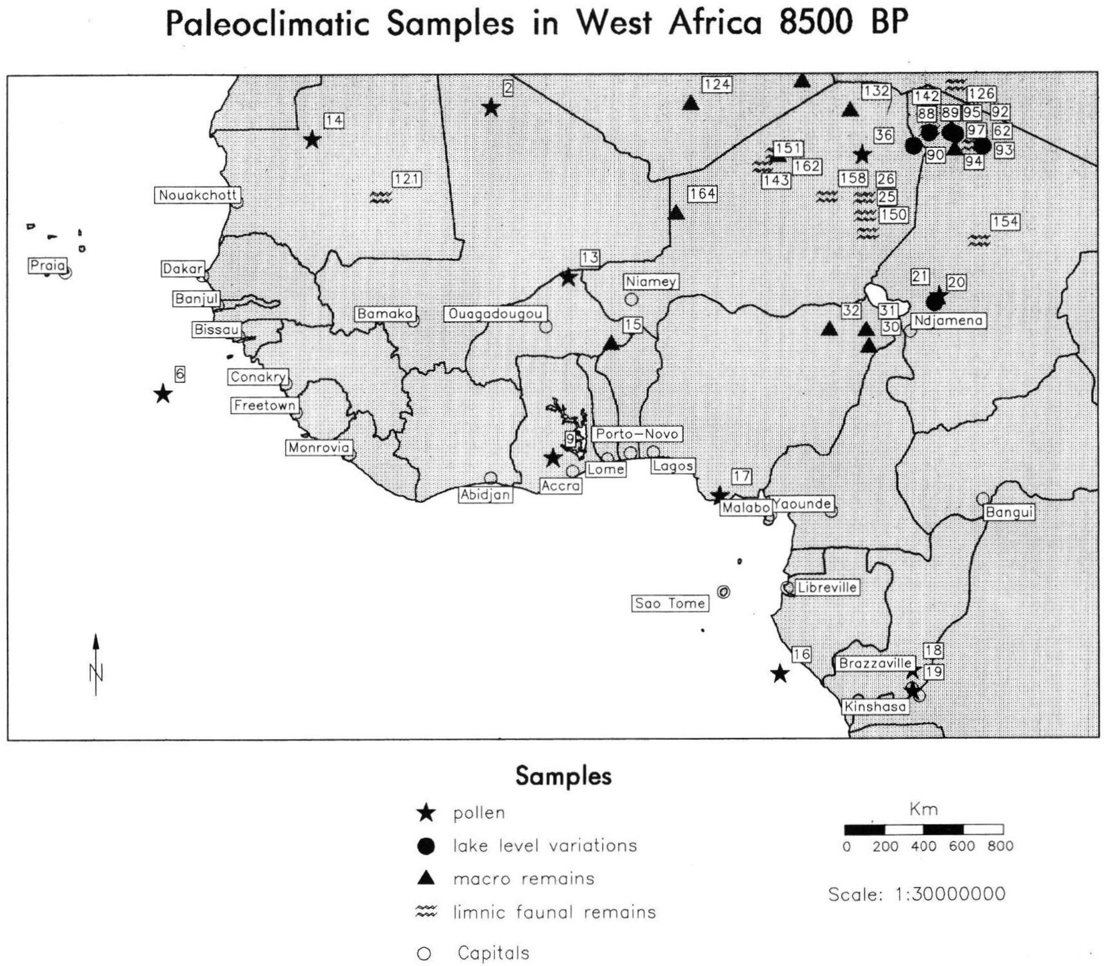

Fig. 4: Map of the locations of pollen-profiles for 8.500 B.P., published in literature.
Abb. 4: Karte der veröffentlichten Pollenprofile für 8.500 B.P.

1988, DUPONT, BEUG, STALLING & TIEDEMANN 1989, DUPONT & AGWU 1992) (fig.4).
At first, the changes in humidity in West Africa took place in the atmospheric circulation. Secondly, the regional water cycle accelerated by having a dense vegetation cover and a therefore higher evapotranspiration in the landscape.
Based on investigations in the Ivory Coast (ANHUF 1994), an extension of moist evergreen rainforest (ANHUF & FRANKENBERG 1991) reaching a latitude of 7 - 7[30]°N (Man) in the west of the Ivory Coast and the area of Sokoto in Togo can be assumed to have occured (fig.5). In the highlands of Guinea, these same forest types can even be expected up to the southern border of Guinea Bissau (11°N). Also in the eastern parts of the Guinea Coast the wet evergreen rainforest expanded up towards the north, up to Lokoja and Makurdi in Nigeria. Continuing to the north, a are again followed by the dense dry forests. In the west of the continent the border of the semi-humid, semi-deciduous rainforests to the dense dry forests lies in the area of today's Gambia. In contrast, the same border is lowered to 11° N in the East. Bauchi, for example, is assumed to have lain in the transitional area of the semi-deciduous rainforest to the dense dry forest. At the same time, the northern frontier of Guinean flora in the West African sector is reached at around 8.500 B.P.
Dense and open dry forests dominate the floral zone of Sudan. At about 8.500 B.P., the border from dense to the open dry forests ran along the line of Linguère, Nara, a bit north of Mopti, Tillabery, and Zinder, as well as south of N'Guigmi at Lake Chad.
The edaphic caused grassland of the Niger-Inland-delta are also thought to have had expanded greatly (PETIT-MAIRE, FABRE, CARBONEL, SCHULZ, AUCOUR 1987).

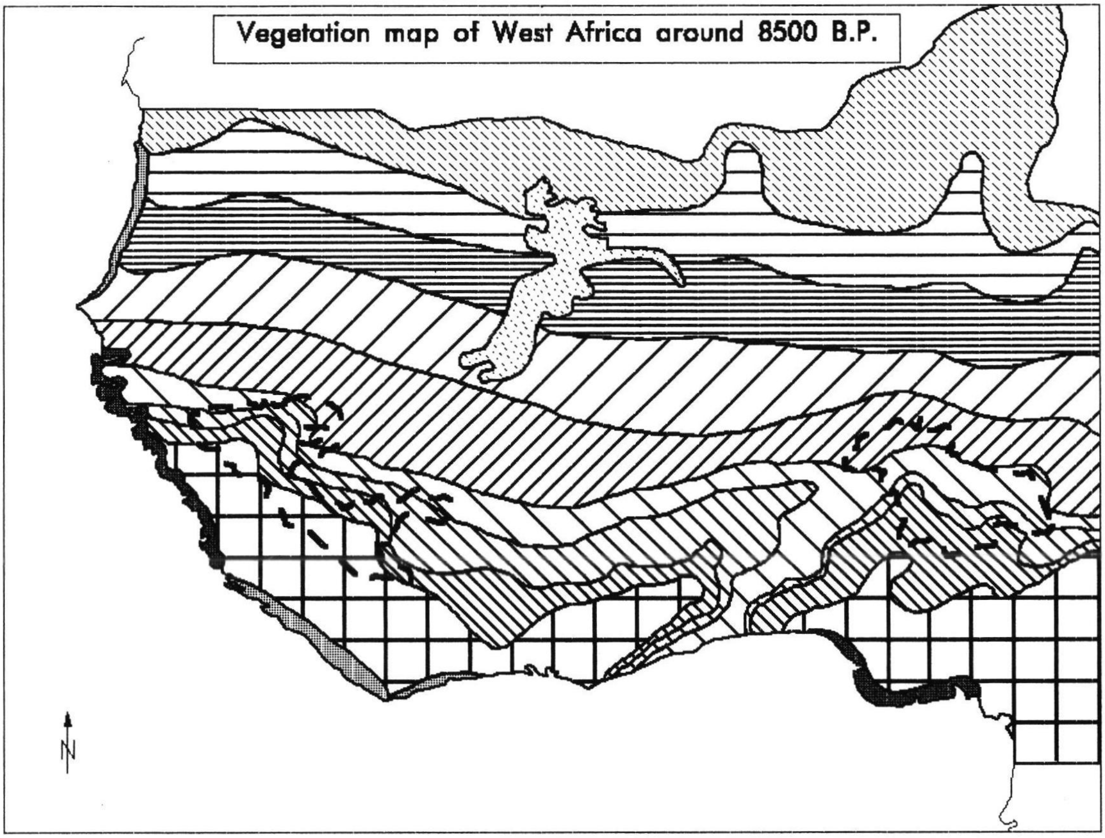

Fig. 5: Vegetation map of West Africa arround 8.500 B.P.
Abb. 5: Karte der Vegetationsformationen Westafrikas um 8.500 B.P.

smaller band of moist evergreen rainforests can be found. This strip leads to the humid semi-deciduous rainforests situated near Bissau (12° N), Kankan in Guinea, north of Bouaké in the Ivory Coast, along the line of Cotonou, Ibadan, Illorin, Kaduna as well as along the southern ridge of the Jos-Plateau. These
The transition from the open dry forests to the tree savanna lay at 19° N. in the central part of West Africa, namely the triangle between the Adrar des Iforas in the West, the Hoggar in the North and the Aïr in the East. The northern Sudanian/Sahelian tree and grass savannas were pushed forward to the north to

the Tropic of Cancer (SCHULZ 1987). The result of research in the most western parts of Africa (westcoast of Senegal) also match this reconstruction (ANHUF & FRANKENBERG 1993).

The transition from the Sahara to the Sahelian flora was only very sparse around 8.500 B.P.

In consequence, the region of Bilma shows clear Saharan species, such as the *Maerua/Acacia*-savanna. Through the analysis of charcoal, NEUMANN (1988) was able to reconstruct a Sudanian vegetation only a few kilometers south of Fachi. Furthermore, the results of recent drilling cores northeast of Niger, SCHULZ et al. (1990) and POMEL & SCHULZ (1992) show that there must have been a direct combination of Saharan and Sudanian vegetation at the time of the Holocene. Palynological and anthracological finds have proven so (NEUMANN 1988). Therefore, it is assumed that at that time the vegetation must have been a combination of the northern parts of the Sudanian dry forests or tree savannas and of the Saharan savanna vegetation. SCHULZ & POMEL (1992) identified this type of Saharan savanna vegetation as the *Acacia-*, *Maerua-*, *Capparis*-savanna. Between 19° and 20° N there was a gradual change to dominant Saharan savannas, whereas at 20° N already there was an obvious border of diffuse tree/grass savanna to Saharan desert vegetation. The desert vegetation is supposed to have been more dense than today.

Acknowledgements

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