BETWEEN DESERT AND FOREST: THE HOLOCENE SAVANNAS OF NE-NIGERIA

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Abstract

Numerous ecologists postulate that West African savannas are mostly the result of degradation of formerly closed forests. This hypothesis can only be tested by palaeoecological investigations. The palynological results summarised in this paper document the history of the Sudanian and Sahelian savanna of NE-Nigeria during the last 11.500 years (uncal. BP). Both sites investigated provide evidence for the persistence of savanna throughout the entire Holocene. Patches of closed dry forest may have occurred, but never completely displaced the savanna vegetation. Humid conditions during the early and mid Holocene (from 10.000 BP onwards) caused a rapid spread of Guinean and Sudanian taxa into the northern vegetation zones. A slow return to drier climatic conditions between ca. 6800 BP and ca. 5500 BP can be recorded at both sites. Finally, between 3800 BP and 3300 BP a strong aridification resulted in the establishment of the modern vegetation zones. In both the Sahelian and Sudanian zone the vegetational changes appear to have been primarily controlled by climatic changes, whereas the effects of human activities remain palynologically silent even for the late Holocene.

Introduction

Savannas, which are defined as tropical grasslands with trees and shrubs (CCTA/CSA 1956), are the predominant formation of the African continent. In West Africa they cover a large area reaching from the rain forest zone with a mean annual rainfall exceeding 1500 mm to the Sahara with rainfall below 150 mm/a. It was argued that the limited resource water is a key factor which controls the competition between the antagonistic life forms grasses and trees (WALTER 1979). According to this hypothesis, only the savannas of the Sahel with a mean annual rainfall between 300-500 mm are regarded as a stable "climatic climax". This rises the question what determinants other than climate maintain the open savanna vegetation in the Sudanian and Guinean zone. The recent environmental changes which took place under the pressure of increasing land use have focussed the discussion on the role of human disturbance as a major factor. Numerous ecologists postulate that the modern distribution of southern savannas in West Africa is mostly the result of a longterm anthropogenic degradation of closed evergreen and dry forests, which are assumed to be the natural vegetation of these zones (e.g. ANHUF 1997, CHEVALLIER 1951, GUINKO 1985). This hypothesis was recently supported by botanical investigations on isolated dry forest stands in the Sudanian zone (GUINKO 1985, HAHN-HADJALI 1998, NEUMANN & MÜLLER-HAUDE 1999) and assessments in protected areas (CHARTER & KEAY 1960, SWAINE 1992), which demonstrate the rapid recolonisation of savanna by forest after the exclusion of fire and human impact. However, the assumption that Sudanian and Guinean savannas are of anthropogenic origin is mainly based on floristic assessments of present vegetation and has never been confirmed by palynological data, which are extremely scarce. Hence, it remains unclear when man started to shape the natural vegetation. For the Sahel a controversial debate has arisen over the relative importance of human impact versus climatic fluctuations. Late Holocene vegetational changes evident in pollen profiles from Tjeri, Lake Tchad and Senegal have been attributed by MALEY (1981) and LEZINE (1989) solely to climatic fluctuations. For the Senegal it was postulated that humid conditions during the early Holocene led to a shift of mesophilous forests up to 16°N, whereas an abrupt aridification from about 2000 BP onwards resulted in the establishment of the modern Sahelian savanna (LEZINE 1989). This strict climatic interpretation was questioned by SCHULZ & POMEL (1992) and BALLOUCHE & NEUMANN (1995) who emphasise an early human impact as a major agent of mid to late Holocene vegetational changes.

The palynological dataset available for the West African savanna zone has recently been expanded through the presentation of pollen diagrams from the Sahelian and Sudanian zone of Northeast Nigeria (Fig. 1). This paper gives a summary of these new palynological results. In the Sahelian Manga Grasslands (near 13°N) multiple pollen profiles from interdune depression allowed a detailed comparative analysis which was conducted in the frame of the German West African Savanna Project (SFB 268) and the British Sahel Project (SALZMANN 1996, SALZMANN & WALLER 1998, WALLER & SALZMANN 1999). The second research site is situated on the Biu Plateau about 300 km south of the Manga Grasslands. The pollen profile taken from the crater Lake Tilla (10°23´N, 12°08´E) provides the first data for a vegetational reconstruction of the southern Sudanian zone over the last 11.500 years BP (SALZMANN 2000, 1999).

Manga Grasslands

The Manga Grasslands are located to the North of the Yobe river complex on the border between Nigeria and Niger. The region consists of barchanoid sand dunes, which are separated by numerous interdune depressions. With a mean annual rainfall of 310 mm (1971-1991, CARTER et al. 1994), the Manga Grassland belong to the Sahelian zone. The vegetation on the dunefields is characterised by the grasses *Cenchrus biflorus* and *Andropogon gayanus* var.

tridentatus with scattered trees and shrubs (e.g. *Balanites aegyptiaca*, *Acacia albida, Calotropis procera* and *Leptadenia pyrotechnica*) (DE LEEUW & TULEY 1972, MORTIMORE 1989). In contrast to the open grasslands on the dunes, the dune depressions are fringed by a dense palm gallery forest, dominated by *Hyphaene thebaica* (dum palm), *Phoenix dactylifera* (date palm) and reedswamp with *Phragmites* sp.

The reconstruction of the Holocene environmental history of the Manga Grasslands is based on pollen diagrams from four interdune depressions. Three are occupied by seasonal playas, Kaigama Oasis (13°15.10'N, 11°34.08'E), Kajemarum Oasis (13°18.30'N, 11°01.73'E) and Kuluwu Oasis (13°13.04'N, 11°33.05'E), while one remains permanently wet (Bal Lake 13°18.41'N, 10°56.96'E). The study of multiple pollen profiles, which cover approximately the last 11.000 years BP (uncal.), allowed a detailed separation of regional (savannas) and local (dune depression) vegetation trends. Particular attention was given to the detection and evaluation of anthropogenic activities and climatic changes. The interpretation of the late Holocene pollen spectra (post 3000 BP), which are only preserved at the site Bal Lake, could be completed by additional evidence from palaeohydrological studies at Kajemarum Oasis (HOLMES et al. 1999, HOLMES et al 1997). A detailed description of the pollen diagrams can be found in SALZMANN & WALLER (1998). Here only the major features of the Manga Grasslands pollen stratigraphy will be summarised (Fig.2).

Open grassland with a few trees, which were mainly restricted to the interdune depression, covered the Manga Grasslands at the end of the late Pleistocene (pre 10.000 BP). The relatively dry climatic conditions may have intensified immediately prior to the onset of the Holocene as indicated by falling lake levels which are recorded at the Bal lake sequence (see also HOLMES et al 1999).

Around ca. 10.000 BP a distinct change in sedimentology and pollen stratigraphy indicates an abrupt climatic change towards more humid conditions. The formation of black organic lake muds demonstrates the presence of permanent lakes at all four sites during the early and mid Holocene. The return of wetter conditions resulted in a rapid northward spread of southern tree taxa from the Sudanian and Guinean zone into the Manga Grasslands (e.g. *Alchornea*, *Syzygium*, *Uapaca*). However, most of these taxa were confined to extrazonal swamp forests, which became established within the interdune depressions. In terms of physiognomy, the vegetational change on the surrounding dune fields was only minor. The savanna remained substantially open although a gradual floristic change towards a Sahelo-Sudanian savanna is indicated by the occurrence of the Sudanian trees *Butyrospermum* and *Bombax*.

From ca. 5500 BP onwards a first decline in Guinean tree taxa points to a slight return to drier environmental conditions. Two peaks in the charcoal particle curve at Kaigama Oasis point to an increase in fire activity between 4000-3500 BP. A further detailed interpretation of the gradual mid Holocene changes of the local swamp forest vegetation remains problematic. The comparison of the four pollen sequences revealed significant differences in timing of pollen stratigraphic events, which might have been caused by variations in the depth of watertables between sites. These time lags of up to 1000 years clearly demonstrate that changes in swamp forest vegetation are linked to local environmental factors, which strongly hampers a detailed interpretation on a regional scale. However, evidence for a climatic deterioration from at least 4100 BP onwards is not only given by palynological but also by palaeohydrological data (HOLMES et al. 1999).

At ca. 3300 BP a distinct biostratigraphical and sedimentological change can be recorded at nearly all sites, which is characterised by an abrupt decline of tree pollen and the deposition of drier calcareous silts. In contrast to the preceding periods, the synchronicity of this event points to a major regional shift towards drier environmental conditions, which finally led to the establishment of a Sahelian savanna similar to that present today.

Lake Tilla (Biu Plateau)

Situated at an altitude of 690 m asl the crater Lake Tilla is the largest lake of the Biu Plateau. The semipermanent lake, which since the early 1970s regularly desiccates during the end of the dry season, is mainly fed by groundwater and shows no visible inlet or outlet. With an annual rainfall of 1000 mm (Biu: 1940-1962, TULEY 1972) the Biu Plateau belongs to the southern Sudanian zone. The vegetation can be characterised as undifferentiated woodland with *Acacia hockii*-savanna and degraded *Terminalia*/*Combretum*-shrubland with a high portion of *Isoberlinia* (DE LEEUW & TULEY 1972). Today most of the plateau is shaped by intensive farming, which established an open park savanna with only few isolated trees. *Isoberlinia doka* became abundant as fallow regrowth, sometimes forming monospecific stands.

Several lake sediment cores up to 16 m were taken during the dry season. The upper 9 m, which cover approximately the last 11.500 years BP, consist of black organic lake muds with an excellent pollen preservation. The palaeoecological results, which are described in detail in SALZMANN (2000, 1999), can be summarised as follows:

At the end of the late Pleistocene (11.500-10.000 BP) the Biu Plateau was covered by an open grass-savanna with *Olea hochstetterii* (syn. *O. capensis*). Unstable, relatively dry climatic conditions are indicated by low and fluctuating lake levels. As with the Manga Grasslands, a distinct dry period, which can be attributed to the global climatic change of the Younger Dryas, can be recorded between 11.000-10.200 BP.

The beginning of the Holocene (ca. 10.000 BP) is marked by rising lake levels and a rapid spreading of Sudanian and Guinean tree taxa (e.g. *Uapaca*, *Hymenocardia*, *Cussonia*, *Alchornea*), which indicate the onset of more humid conditions. Temperatures might have been significantly lower during the early Holocene as suggested by high percentages of the mountainous element *O. hochstetteri* between ca. 10.000 BP and 8500 BP. Whereas this species is absent on the Biu Plateau today, the nearest population can be found on the Jos Plateau and Mandara mountains above 1300 m asl. (LETOUZEY 1985, WHITE 1983). Between ca. 8000 BP and ca. 6800 BP a highly diversified, dense Guinean savanna with patches of dry forest became established. The floristic composition of the mid-Holocene vegetation closely resembles the modern savannas, which can today be found about 350 km south at the forest-savanna boundary with an annual rainfall exceeding 1200 mm (e.g. CLAYTON 1958, JONES 1963, KEAY 1959). High percentages of grass pollen (>52%), the regular occurrence of savanna fires (as shown by charred particles of grass epidermis) and the presence of characteristic savanna trees (e.g. *Lophira*, *Cussonia*, *Burkea africana*, *Monotes kerstingii*) clearly indicate that the savanna on the plateau was never replaced by closed forests. Frequent fires seemed to have played a major role in maintaining the open character of the vegetation. Beside fire, wild herbivores (notably elephants) and edaphic conditions are frequently mentioned as additional factors which can prevent the establishment of forests (e.g. COLE 1986, CUMMING 1982), though the latter was recently disputed by investigation on isolated dry forest stands in Burkina Faso (HAHN-HADJALI 1998, NEUMANN & BALLOUCHE 1995). Nevertheless, on the Biu Plateau soil conditions seem to have played only a minor role as they provide enough nutrients to support an intensive agriculture today (KPARMWANG et al. 1998).

From ca. 6800 BP onwards a gradual, mainly floristic change from a dense Guinean to a Sudano-Guinean savanna (with *Isoberlinia*) suggest a return to drier environmental conditions. The continuos aridification trend, which was accompanied by falling lake levels, might have been enforced at ca. 3800 BP. At the beginning of the late Holocene a Sudanian savanna with Sahelian elements became established on the Biu Plateau. In floristic composition the savanna seem to have closely resembled that present today. Whereas the pollen spectra give no evidence for an early human impact on the vegetation, the change in sedimentation rates, which can be recorded at 2500 BP, cannot be explained by climatic changes alone. With a proceeding climatic deterioration, Lake Tilla might have gained more importance as a water reservoir for early pastoralists, who brought their cattle into the crater during the dry season. Like today, the grazing might have increased the soil erosion on the slopes which enforced the silting-up of the lake basin.

Which environmental factors maintain a savanna?

The pollen profiles from the Sahelian Manga Grasslands and the Sudanian site Lake Tilla document a vegetation history which appears to have been primarily controlled by climatic changes. With a humid early Holocene and a subsequent trend towards drier climatic condition during the mid and late

Holocene the palynological data basically coincide with the general climatic trend described for nearly all other West African palaeoecological sites (e.g. BALLOUCHE & NEUMANN 1995, LEZINE 1989, MALEY 1981, 1991, MALEY & BRENAC 1998, SERVANT 1973, SOWUNMI 1981). However, differences in timing of climatic changes become apparent when these sites are compared on a finer scale. The climatic curve reconstructed for the Lake Chad Basin (SERVANT 1973, Fig. 2) as well as other palaeodata from West Africa give evidence for several climatic fluctuations throughout the mid and late Holocene, which can neither be recorded at Lake Tilla nor at the Manga Grasslands. This is in particular true for distinct dry periods around 7500 BP, 4500 BP and at 2700 BP, which at other sites were partly attributed to major changes of the global climatic regime (e.g. MALEY 1991, VAN GEEL et al. 1998, LEZINE & CASANOVA 1989). The pollen profiles from NE-Nigeria rather reflect a continuos climatic deterioration from about 6800/5500 BP onwards. Between 3800 BP and 3300 BP a strong aridification finally promoted the establishment of the modern vegetation zones. With a delay of about 1000 years possibly caused by the more maritime climate, this abrupt vegetational change can be also recorded in western Senegal (LEZINE 1989, LEZINE & CASANOVA 1989).

While major climatic changes are evident for the late Holocene, it is highly likely that anthropogenic activities increased at the same time. It was argued that early food production was introduced into the Sahel by pastoralists, who immigrated from the desiccating Sahara (MCINTOSH & MCINTOSH 1983). This hypothesis was recently supported by archaeological and archaeobotanical investigations in NE-Nigeria and Burkina Faso, which provide evidence for the introduction of pastoralism and ceramics around 4000 BP and the domestication of *Pennisetum* from at least 3000 BP onwards (e.g. BREUNIG et al. 1996, KLEE & ZACH 1999, NEUMANN et a. 1996). It can be assumed that the emergence of food production as well as metal technology, which was practised on the Jos Plateau (Nigeria) at around 2500 BP (CALVOCORESSI & DAVID 1979), have had a considerable effect on the savanna vegetation. However, neither the profile Lake Tilla nor the Manga Grasslands give evidence for such a major human impact even for the late Holocene. An increase in herbs (notably weeds), charcoal or cultivated trees, which were stressed by BALLOUCHE & NEUMANN 1995, SOWUNMI 1981, SCHULZ 1994 as anthropogenic indicators, are either absent or can equally be attributed to climatic changes. For example, at the Manga Grassland it remains unclear whether the peaks in charcoal at the end of the Mid Holocene were caused by anthropogenic fires or by a climatic induced desiccation of the fringing vegetation, which became more open and thus more sensitive to seasonal fires. At Lake Tilla, increasing sedimentation rates are the only indicators for anthropogenic activities, although a further desiccation being responsible for the thinning of vegetation and increased soil erosion cannot be completely discounted.

The lack of unambiguous anthropogenic indicators even for the late Holocene demonstrates the difficulties of detecting human activity in the open vegetation of the savanna rather than implying such activity was absent

(WALLER & SALZMANN 1999). Without doubt, today most of the West African savannas have to be defined as cultural landscapes. The point at which time this transformation took place remains palynological hidden. However, the new palynological results from NE-Nigeria clearly demonstrate the stability of the savanna formation throughout the entire Holocene. Hence, the hypothesis of anthropogenic origin of the Sahelian and Sudanian savanna (e.g. SCHULZ & POMEL 1992, ANHUF 1997, CHEVALIER 1951) has to be strongly questioned. Even for the more humid early Holocene there is no evidence for a closed forest being the natural vegetation of the Sudanian and southern Sahelian zone – an assumption which is strongly linked with the old view of succession and stable climatic climax of CLEMENTS (1916). Regular fires seem to have played a major role in maintaining the open character of the savannas, whereas climatic fluctuations during the Holocene have mainly affected the floristical composition.

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