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A new contribution to the Holocene vegetation history of the West African Sahel: pollen from Oursi, Burkina Faso and charcoal from three sites in northeast Nigeria

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Abstract. A pollen diagram from Oursi in Burkina Faso is compared with anthracological (charcoal analysis) results from three sites in northeast Nigeria (Konduga, Gajiganna, Lantewa). The present-day vegetation at all four sites is Sahelian or Sahelo-Sudanian and under heavy human impact. At Oursi, a closed grassland with only few trees and almost no Sudanian elements can be reconstructed for the middle Holocene. At the Nigerian sites, on the other hand, Sudanian woody plants were present during this period. We assume that the Sahel was not a uniform zone during the middle Holocene but rather a mosaic of different vegetation types according to local site conditions. In the light of these results, a simple model of latitudinally shifting vegetation zones is not applicable. Around 3000 B.P. the closed grassland at Oursi was opened by agro-pastoral activities, and at Gajiganna, plants characteristic of pasture lands can be directly related with the presence of cattle. Human impact seems to have been the dominant factor in the vegetation history of the Sahel from 3000 B.P. until today, masking possible effects of climatic change.

Key words: West Africa – Sahel – Pollen analysis – Anthracology – Middle/late Holocene

Résumé

Les données d'un diagramme pollinique d'Oursi (Burkina Faso) sont comparées à celles de l'étude anthracologique de trois sites du NE du Nigeria (Konduga, Gajiganna, Lantewa). La végétation actuelle des quatre sites est de type sahélien ou soudano-sahélien sous fort impact anthropique. A Oursi, la végétation de l'Holocène moyen a dû être une couverture graminéenne fermée avec peu d'arbres et la quasi-absence d'éléments soudaniens. D'autre part, sur les sites nigérians, des espèces ligneuses soudaniennes sont présentes à la même époque. Nous présumons par là que le Sahel, à l'Holocène moyen n'était pas uniforme mais consistait en une mosaïque de types de végétation divers selon les conditions locales. A la lumière de ces résultats, un simple modèle de fluctuation latitudinale des zones de végétations ne peut être retenu. Vers 3000 ans B.P., la formation graminéenne fermée d'Oursi est ouverte sous l'effet d'activités agro-pastorales, tandis que à Gajiganna, des plantes indicatrices de pâturage peuvent être mises en relation avec la présence de bétail. Depuis 3000 ans B.P., la végétation du Sahel semble évoluer essentiellement sous l'effet dominant de l'action de l'homme qui peut masquer d'éventuelles contributions des changements climatiques.

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Introduction

During the late Quaternary period, the vegetation of West Africa underwent considerable changes, evident in the data from marine and terrestrial palynology (for example Agwu and Beug 1984; Dupont and Agwu 1992; Lézine 1989a,b; Maley 1981; Schulz 1987) as well as from anthracology, the study of charred wood (Neumann 1992). As the modern vegetation zones and isohyets (lines of places with equal rainfall) are arranged more or less parallel to the equator, the most logical concept for vegetation history seems to be a "belt model". According to this theory, vegetation zones will shift to the north during moister periods and retreat to the south with increasing aridity. For West Africa, such shifts have been discussed by Dupont (1993) and by Dupont and Agwu (1992) for the last 700,000 years and by Lézine (1989a,b) for the last 20,000 years. A similar explanation is given by Wickens (1982), Neumann (1989a,b) and Ritchie and Haynes (1987) for the Holocene vegetation history of the Sudan.

All these studies emphasize the role of climate as the major factor in the changes of plant cover. Likewise, the Holocene vegetation history of the Sahel ecoclimatic zone between the 100 mm and the 600 mm isohyets (Le Houérou 1989), has been exclusively interpreted from the climatic aspect. The Holocene, on the other hand, is a period of considerable development in west African prehistoric economies (McIntosh and McIntosh 1983).

It can be assumed that the emergence of food production and metal technology should have had some effect on the vegetation which today consists of an open savanna with a sparse tree cover and mostly annual grasses. Therefore, the validity of a strictly climatic interpretation has been questioned by Schulz and Pomel (1992), who consider that the Sahel is an anthropogenic landscape which did not exist as an independent phytogeographical unit before 5000 B.P. However there are only a few basic data (compiled by Lézine 1989a,b, Lézine and Casanova 1989). They come from Senegal (Michel and Assémien 1969/70; Lézine 1988a,b) and Chad (Maley 1981), two areas separated by a gap of 3000 km. This paper presents the first data from this gap, palynological and anthracological results from four sites in Burkina Faso and northeast Nigeria (Fig. 1). In the light of the contradictory explanation models, they will be discussed with respect to the role of both climate and human impact as possible factors in vegetation history.

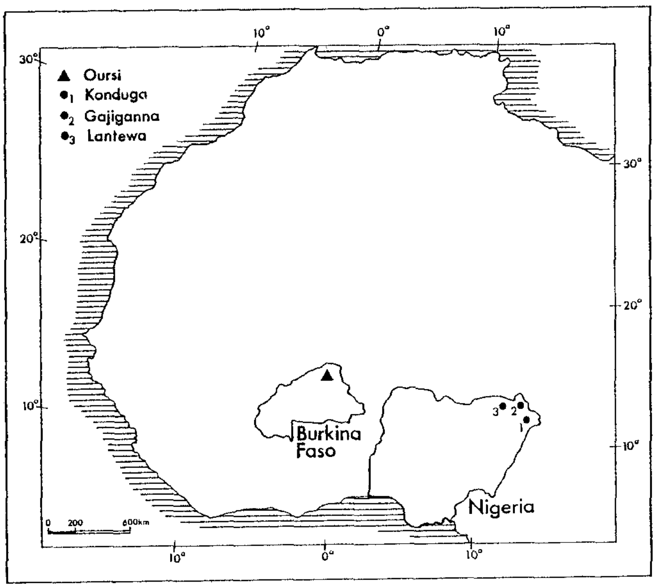


Fig. 1. Map of research areas with sites mentioned in the text

Material and methods

A 25 mm diameter core was collected in the Mare d'Oursi. Since the clayey sediment compacted, consecutive partial cores of 20 cm length were taken down to a depth of 293 cm. Subsamples of 0.28 cm^3 were taken from the core every 5 cm. They were processed in the Palaeobotany and Palynology laboratory at Utrecht university with KOH, HCl, Sodium pyrophosphate and HF, and finally acetolyzed. For quantitative analysis, *Lycopodium* tablets were added (Stockmarr 1971). The pollen diagram was produced with the drawing program TILIA 1.18 and TILIAGRAPH. The curves, five times exaggerated in the depth bars, show the percentages with regard to the total pollen sum.

The charcoal from the archaeological sites NA 90/1 and NA 90/5B were sampled by hand from 10 cm strata. At the pedological site Th 91/Ni 52 single charcoal pieces were picked out from a soil profile. The fragments were fractured manually in the three diagnostic planes, transversal, radial and tangential, then embedded loosely in sand and observed with an incident light microscope. They were identified with the help of a reference collection containing slides of modern Sahelian and Sudanian woods. Furthermore the computer identification program DELTA (Dallwitz 1980, Dallwitz and Paine 1986) was used with the character list of Espinoza de Pernia and Miller (1991) which has been slightly modified for charcoal identification. Since there are small numbers of fragments in the samples, the interpretation has to be qualitative, on the basis of presence or absence of the various taxa. Fragments which could not be identified because of their bad preservation have not been included in the sum. Selection for good firewood may have influenced the composition of the charcoal assemblages. However, species producing high and medium quality firewood (Maydell 1983) were also present in the samples. It is therefore reasonable to suppose that the charcoal samples represent, more or less, the woody vegetation around the sites. If only one or a few small samples are available as is the case in this study, one can say little about absent taxa.

For the species list of the recent woody vegetation at the Nigerian sites, all tree and shrub species, disregarding their frequency, have been recorded in a radius of 500 m around the sites.

Radiocarbon dates were obtained from sediment samples containing organic material (Oursi) and from charcoal (Nigerian sites). Dates with UtC laboratory numbers result from AMS dating and have been calibrated for 1σ-probability, while date KI-3605 has been calibrated for 2σ-probability.

Results and interpretation

Burkina Faso, Oursi *(14°38'N, 0°30'W)*

The area of Oursi, situated in northeast Burkina Faso (Province Oudalan), belongs to the Sahel proper (Guinko 1984, Le Houérou 1989). Mean annual precipitation is 462 mm at the meteorological station of Gorom and 402 mm at Markoye (Claude at al. 1991). The Mare d'Oursi ("mare" is a temporary lake) lies within a depression which is delimited on the northern side by a chain of Pleistocene dunes. The lake receives its waters from a catchment area with a surface of 263 km^2. This is largely formed by a glacis (pediment) with crystalline outcrops. Clayey sediments have been formed by weathering of the alkaline gabbros and deposited in the depression. These montmorillonitic clays are responsible for the comparatively good preservation of the organic material in the sediments. This is an exceptional situation in comparison to other temporary lakes in northern Burkina Faso. In several cores from these lakes, no pollen was found to be preserved, which is probably due to oxidation processes. Likewise in Oursi, some parts of the sediments have obviously been subject to oxidation resulting in a very low pollen content of the samples. According to different stages of preservation, the pollen sums therefore lie generally between 100 and 500.

Today, several types of vegetation can be found in the area of Oursi, according to the different geomorphological units (Claude et al. 1991). Apart from the seasonal aquatic communities, the inundated parts of the depression are covered with a dense sward of *Echinochloa* spp. and *Oryza barthii*. The "thalwegs" (lines of the valleys) and the edges of the depression carry thickets of *Acacia nilotica* and *Acacia seyal*. On the dunes, the plant cover has been heavily damaged by grazing and by *Pennisetum* cultivation. The natural vegetation, where it is still preserved, consists of grasses such as *Cenchrus biflorus*, *Aristida mutabilis* and *Schoenfeldia gracilis* with a very sparse cover of woody plants (mainly *Combretum glutinosum* and *Balanites aegyptiaca*). The pediment south of the lake is almost bare of any tree growth, with only very few specimens of *Acacia laeta* and *Acacia raddiana*. *Schoenefeldia gracilis* is the dominant species of the grass cover.

The pollen profile BS 2 was recovered at the western edge of the lake which is subject to annual flooding, in the estuary of the main "thalweg" draining the western and southwestern parts of the catchment area. The sediments of the profile consisted of black solid clays and silts with a macroscopically uniform appearance throughout the profile. Since the lowermost ^{14}C date is younger than the next one, there may have been some disturbance of the sediments. Micromorphological studies are currently conducted in Frankfurt to elucidate the deposition processes of the sediments and their sequence of development.

Pollen samples from 51 levels have been examined, containing 79 taxa, dominated by Gramineae, Cyperaceae and *Nymphaea* (Fig. 2). Two pollen zones can be distinguished:

Zone A from 275 - 175 cm, ^{14}C dates:

275 cm: 7720±80 B.P. (UtC 2311),
6620-6451 cal B.C.
224 cm: 8870±70 B.P. (UtC 3198),
8011-7904, 7754-7746 cal B.C.
178 cm: 3130±80 B.P. (UtC 2922),
1495-1485, 1451-1304 cal B.C.

In this zone, the ratio of the Gramineae usually exceeds 70% and reaches 84% in one sample. Arboreal pollen is very weakly represented with less than 5%. *Acacia* is the only arboreal pollen showing a regular, though discontinuous, curve. Pollen of *Polygonum senegalense*-type is present in a continuous curve.

Zone B from 175 to 0 cm, ^{14}C dates:

159 cm: 2850±50 B.P. (UtC 2211),
1093-975, 965-932 cal B.C.
58 cm: 610±40 B.P. (UtC 2921),
1305-1368, 1372-1403 cal A.D.

Although the Gramineae are still the dominant group, their percentage is generally under 60-70%. The percentages of Cyperaceae increase, sometimes exceeding 20%. Arboreal pollen is slightly higher than in zone A and sometimes reaches 5%, but now the main taxon is Combretaceae. A group of taxa including Chenopodiaceae/Amaranthaceae, *Indigofera*, *Mitracarpus* and Lamiaceae, which is only sporadically present in zone A, shows a strong development in zone B. Their percentages increase markedly between 170 and 65 cm and even more above 60 cm. *Polygonum senegalense*-type decreases and is only present episodically. This pollen zone can be further divided into two subzones B1 and B2. In B2, the percentages of Combretaceae and the herbaceous taxa Chenopodiaceae/Amaranthaceae, *Mitracarpus* and Lamiaceae are significantly higher than in B1.

The weak representation of arboreal pollen as well as the dominance of Gramineae in the whole profile points to an open type of vegetation. Studies on the modern pollen rain in the Sahel and the Sudanian zone (Lézine 1989a, Lézine and Edorh 1991; Neumann and Ballouche 1992; Schulz 1990) have shown that trees are usually under-represented while grasses are dominant in the samples. But even if we consider that a large number of Sudanian trees is entomogamous (insect-pollinated), the absence of Sudanian elements sensu strictu in the diagram is striking. The arboreal pollen comes exclusively from plants whose modern distribution areas include at least the southern Sahel (Maydell 1983).

For the period represented in zone A which covers the middle Holocene, a dense grassland with scattered trees can be reconstructed. This vegetation was probably similar to the recent grasslands in the Sahel, but one has to be careful with a direct comparison, as the species composition of the ancient grassland is unknown. The trees and shrubs, mostly *Acacia* with some Combretaceae, *Celtis*, *Mitragyna* and *Ziziphus*, were growing in favourable habitats on the dunes and more densely concentrated around the lake and in the depression. The lake in the depression was probably always more or less temporary. In the time of zone A, the continuous presence of the aquatic *Polygonum senegalense*-type indicates that the frequency of the dry phases was lower and the periods of desiccation were shorter and less severe than today.

Around 3000 B.P., an important change must have taken place in the history of the landscape. In a strictly climatic interpretation, the increase of Combretaceae pollen would point to a period of higher precipitation, as this group is usually regarded as a Sudanian element. On the other hand, the decreasing percentages of *Polygonum senegalense*-type show that the hydrological situation of the mare was different from that in the middle Holocene, so that the desiccation phases of the lake were longer and more severe. Furthermore, the decreasing values of Gramineae and the increase of Chenopodiaceae/Amaranthaceae, *Indigofera*, *Mitracarpus* and Lamiaceae might be interpreted as indications of aridification. Therefore, an exclusively climatic viewpoint leads to an unsolvable contradiction in the interpretation of this part of the diagram. It might be better understood if we consider that its uppermost part represents the recent vegetation around the mare which, as Claude et al. (1991) have clearly shown, is highly influenced by human impact. Most probably the Combretaceae pollen came from *Combretum glutinosum* which is a dominant tree species on the dunes today. *Acacia* pollen came from *A. seyal* and *A. nilotica* on the edges of the depression and by *Acacia raddiana* on the dunes. However, it is remarkable that the pollen of *Balanites aegyptiaca*, the most dominant species in the area of Oursi, is almost absent in the upper part of the diagram. The pollen of Gramineae and

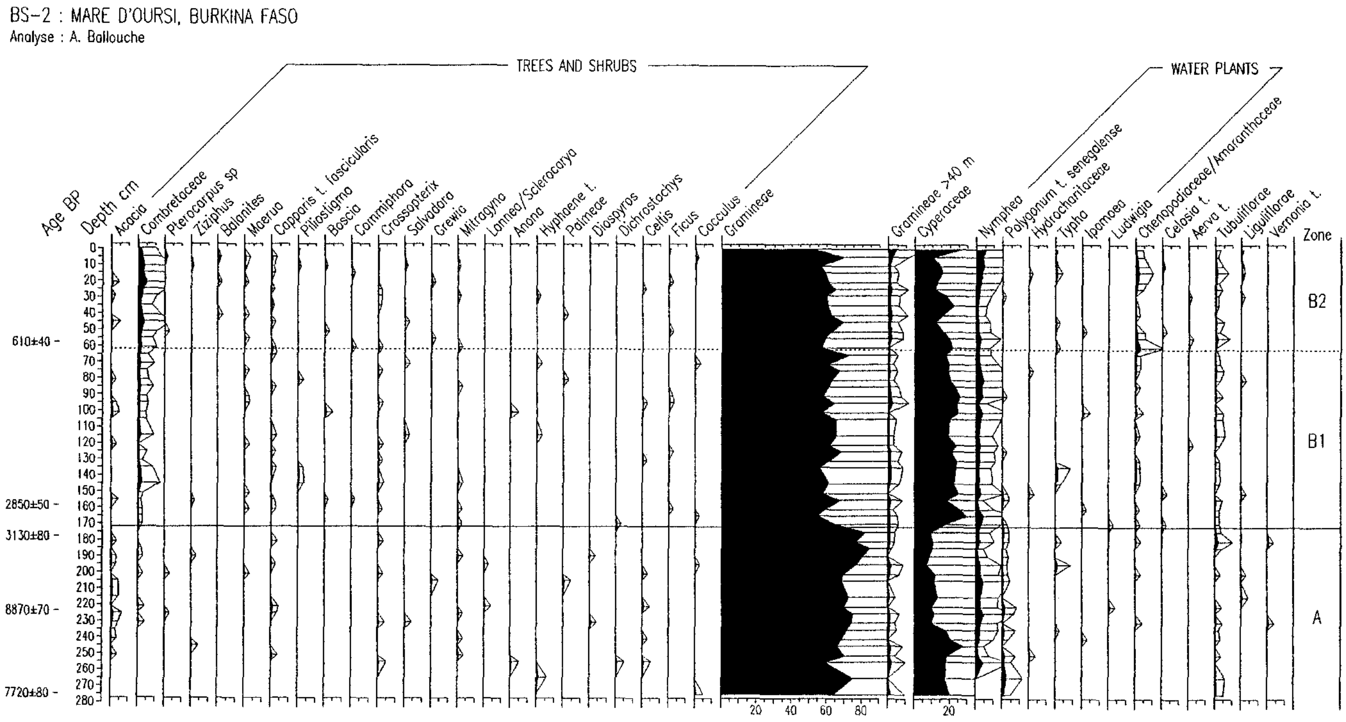


Fig. 2. The pollen diagram from Oursi

herbaceous plants represents the herb layer on the inundated clay plains, the pediment and the dunes, with a high percentage of annuals. Thus zone B of the diagram can be interpreted as representing a special development of the vegetation under human impact, starting around 3000 B.P., intensifying after 600 B.P. and finally leading to the present situation. The most prominent feature of this development is the opening of a closed grass cover and the creation of new habitats. Today *Mitracarpus* and the majority of species in the groups *Indigofera*, Lamiaceae and Chenopodiaceae/Amaranthaceae are common in Sahelian fields, fallows and ruderal communities. The modern extensive distribution of *Combretum glutinosum* in the southern Sahel is due to shifting cultivation with a mosaic of fields and fallows serving as pastures (Trochain 1940, pp 171 ff., Cisse et al. 1993). Therefore it seems possible that the upper part of the Oursi pollen diagram reflects early agricultural impact. This does not exclude the possibility that the prehistoric settlers had domesticated animals which were grazing on the fallows.

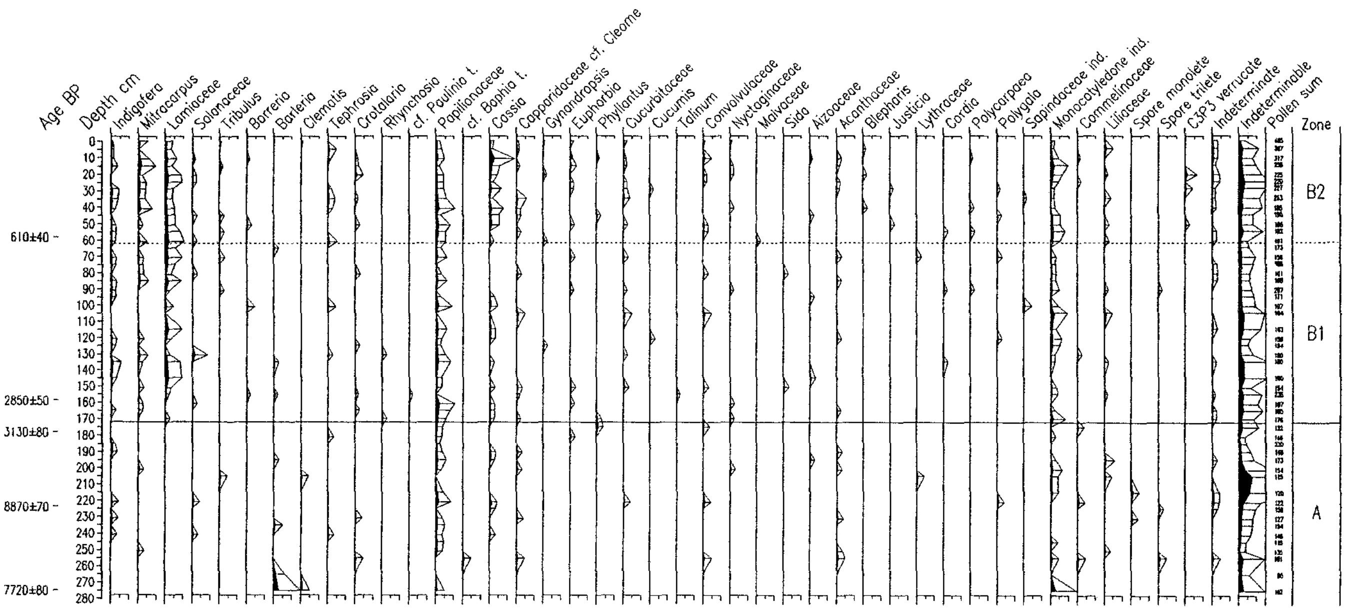
Nigeria

Konduga, Lantewa and Gajiganna are three sites in northeast Nigeria, Borno State. Today, the mean annual rainfall in the Konduga area is about 650-750 mm and about 500-650 mm at Lantewa and Gajiganna (Aitchison et al. 1972). After the definition of Le Houérou (1989), Gajiganna and Lantewa would be placed in the Sudano-Sahelian transition zone and Konduga in the Sudan zone. In his vegetation map of Nigeria, Keay (1959) draws the northern limit of the Sudan zone (in a phytogeographical sense) in Borno between 12°N and 13°N, which includes all three sites. However, the modern vegetation around the sites cannot be called Sudanian. Typical Sudanian species are only rarely present and Sahelian elements like *Balanites aegyptiaca* and *Guiera senegalensis* are dominant (Table 1). One reason for this inconsistency might be sought in the different definitions of the terms "Sahel" and "Sudan zone" used by various authors. But it is more likely that the present character of the vegetation is due to human impact and that agriculture and grazing pressure have led to a "sahelisation" of the plant cover. This process has probably been accelerated by the extreme drought in the period between 1970 and 1985 when mean precipitation was around 30-40% less than the long-term average (Le Houérou 1989, p 44).

1. Konduga

The archeological site NA 90/1 (11°38'14"N, 13°25'55"E) is situated a few kilometres southeast of Konduga on the "Bama ridge", a sand wall which is interpreted as an old shoreline of the former Lake Chad (Grove 1959; Thiemeyer 1992a). In a sand pit, pottery associated with charcoal was excavated down to a depth of 120 cm. Charcoal from the lowest level (Konduga 1, 100-120 cm) gave two ^{14}C dates of 6340±250 B.P. (KN-4300) and 6180±60 B.P. (UtC-2248), 5232-5061 cal B.C. The ^{14}C dates from the middle and the upper levels (Konduga 2, 60-90 cm and Konduga 3, 10-50 cm) were modern, and there is some doubt about the

BS-2 : MARE D'OURSI, BURKINA FASO
Analyse : A. Ballouche



stratigraphical association with the pottery which is regarded as being considerably older (Breunig in press). No other botanical or zoological remains were found, so that the economy of these pottery-producing people remains unknown.

The recent vegetation in the vicinity of the site consists of *Pennisetum* fields and fallow lands used for pasture. On the fields, *Acacia albida* and *Azadirachta indica* are almost the only tree species. This plant community corresponds to type 26 described by de Leeuw and Tuley (1972). On the fallows, which are heavily grazed by cattle, *Acacia albida* and *Azadirachta indica* show natural regeneration, and there are some other woody species tolerant of browsing, as for example *Balanites aegyptiaca* (Table 1). *Brachiaria xantholeuca* and *Dactyloctenium aegyptium* are the dominant constituents of the herbal layer. To the southwest of the ridge there is a temporary lake, the edges of which are almost bare of any woody vegetation.

The charcoal samples from the lowest level (100-120 cm), dated around 6200 B.P., and from the intermediate level (90-100 cm) contain a set of 11 taxa (Table 2) with a recent Sudanian or Sudano-Guinean distribution (Aubréville 1950). This points to a moister climate during that period. Two of the taxa (Leguminosae type 1 and unknown type) could not yet be identified. Most probably these are taxa with a more southern affinity, which are not present in the reference collection. As it cannot be excluded that the charcoal was transported with the waters of the Palaeochad (Thiemeyer 1992a), the possibilities for a reconstruction of the local vegetation remain limited. A Sudanian woodland in the broadest sense can be assumed, but we are not able to determine the ratio of grasses in this vegetation formation. The presence of *Allophylus* and *Isoberlinia doka* indicates that woods might have existed: *Allophylus* is a typical constituent of the understorey in recent dry forests of southwest Burkina Faso, and the Sudano-Guinean *Isoberlinia doka* today can be found in the fire-resistant *Isoberlinia* woodlands but also in small relicts of dry forest (Aubréville 1950, p 232). However, our limited data do not allow us to give information on the former extent of this forest in the Konduga area.

In the middle and upper layers, the charcoal samples are poor in species and the dominant taxon is *Terminalia*. The ^{14}C dates were gained by accelerator on single fragments of *Terminalia*. So it is sure that this tree was present in the vegetation around the site in the recent past. Today *Terminalia* which is most probably a major constituent of the potential natural vegetation of this area, has been substituted by the woody taxa of the cultural landscape.

2. Gajiganna

The area of Gajiganna is part of the "Bama Deltaic Complex" consisting of slightly undulating dunes and clay depressions (Aitchison et al. 1972). The features of this landscape result from a complex history of aeolian, limnic and deltaic processes during the late Pleistocene and the Holocene. The archaeological site NA 90/5B is situated on a small dune at the edge of a former lagoon which was most probably in contact with the Paleochad around 3000 B.P. The former position of this lagoon is indicated by extensive clay sediments.

Table 1. Modern distribution of trees and shrubs around the anthracological (charcoal) sites, a) on free-draining soils, b) in well-watered depressions

	Konduga		Gajiganna		Lantewa	
	a	b	a	b	a	b
Acacia albida	x	.	x	.	x	.
Acacia nilotica	.	x	.	.	.	.
Acacia senegal	x	.	.	.	.	.
Anogeissus leiocarpus	.	.	.	.	.	x
Anona senegalensis	x	.	.	.	x	.
Azadirachta indica	x	.	.	.	.	.
Balanites aegyptiaca	x	.	x	x	.	.
Bauhinia rufescens	x	.	.	.	.	.
Boscia senegalensis	.	.	x	.	.	.
Cadaba farinosa	.	.	x	.	.	.
Calotropis procera	.	.	x	.	x	.
Capparis corymbosa	x	.	x	x	.	.
Cassia italica	x	.	.	.	x	.
Cassia singueana	.	.	.	.	x	.
Celtis integrifolia	.	.	.	x	.	.
Combretum aculeatum	.	.	x	.	.	.
Combretum glutinosum	.	.	x	.	x	x
Commiphora africana	.	.	.	.	.	x
Diospyros mespiliformis	.	x	.	.	.	.
Guiera senegalensis	.	.	x	x	x	x
Leptadenia hastata	x	.	.	.	x	.
Leptadenia pyrotechnica	.	.	x	.	.	.
Maerua crassifolia	.	.	.	x	.	.
Mitragyna inermis	.	.	.	x	.	.
Piliostigma reticulatum	.	.	x	.	x	.
Sclerocarya birrea	.	.	.	.	x	.
Tamarindus indica	.	.	.	.	.	x
Terminalia avicennioides	.	.	.	.	.	x
Ziziphus mauritiana	.	.	x	.	.	.

The recent vegetation is strongly affected by *Pennisetum* cultivation, fallows and grazing and browsing by cattle. Two other main vegetation types occur according to the different geomorphological setting (Table 1). The small dunes with their irregular relief - NA 90/5B is lying on top of such a dune - are permanently used for pasture. Only a few woody plants such as *Boscia senegalensis*, *Calotropis procera*, *Ziziphus mauritiana*, *Guiera senegalensis* and *Balanites aegyptiaca* are able to withstand the heavy browsing pressure. The woody plants are usually only 50-100 cm high and very sparsely distributed. In the herbal layer which is sometimes almost completely destroyed, the Gramineae *Brachiaria xantholeuca* and *Dactyloctenium aegyptium* are the dominant elements. Similar plant communities have been described by de Leeuw and Tuley (1972, type 24/29) and by de Leeuw et al. (1972, type 4). In the depressions regularly subject to inundations larger trees can be found, mainly *Mitragyna inermis* and *Celtis integrifolia*. The latter is intensively cut for fodder in the dry season.

Site NA 90/5B (12°14'20"N, 13°13'00"E) is part of a larger, village-like complex dated around 3000 B.P. (Breunig et al. 1992, Breunig in press, Breuning et al. 1993, Breunig et al. in press). In NA 90/5B, as well as in other comparable excavated sites, two cultural layers can be distinguished. A radiocarbon sample from the upper layer gave an age of 2740±50 B.P. (UtC 2331), 927-833 cal B.C., and there are three dates from the lower layer: 3150±70 B.P. (UtC 2330), 1514-1328 cal B.C.; 3140±110 B.P. (UtC 2332), 1520-1310 cal B.C.; 3040±120 B.P. (KI 3605), 1560-920 cal B.C. Besides a large amount of pottery and stone tools, the bones of cattle, small livestock, various wild mammals and aquatic animals (fish, turtles and molluscs) were recovered (identification by Wim van Neer, Tervuren). In spite of an intensive search for botanical remains using different archaeobotanical techniques, no signs of agriculture have been found so far. It seems that the economy was mainly based on the keeping of cattle and goats and on hunting and fishing.

In the charcoal samples from the upper and the lower layer, 15 taxa have been identified (Table 3), six of which are present in the recent vegetation. In the lower layer the number of species is higher than in the upper one, but this is probably due to the larger number of identified fragments. As for the small number of charcoal fragments, the two layers are treated as a single unit covering a time span of several hundred years. The reconstructed vegetation was a Sahelo-Sudanian woodland with a denser tree cover than today. The firewood was collected on the dunes as well as in the inundated depressions. Taxa such as *Ziziphus* sp. and *Balanites aegyptiaca* indicate that grazing and browsing occurred, but the impact on the vegetation was probably not as severe as can be observed today. Characteristic elements of the recent degraded pastures, such as *Guiera senegalensis*, *Boscia senegalensis* or *Calotropis procera*, are missing in the samples. Typical forest plants, such as those which have been found in Konduga, are equally not present. Nevertheless, the bones of the forest duiker testify that there must have been some denser woodland or even patches of forest (Breunig et al. in press). Either the

Table 2. Konduga NA 90/1, identified charcoal fragments from archaeological strata, depths in cm

	10-50	50-60	60-90	90-100	100-120
Terminalia	19	8	20	1	1
Monocotyledoneae	.	1	.	.	.
Acacia	.	.	8	.	.
Euphorbiaceae	.	.	6	.	.
Grewia cf. *mollis*	.	.	1	.	
Securinega/*Hymenocardia*	.	.	.	1	1
Parinari polyandra	.	.	.	2	.
Leguminosae type *Parkia*	.	.	.	.	2
Allophylus	.	.	.	.	2
Rubiaceae	.	.	.	.	6
Leguminosae type 1	.	.	.	.	8
Lannea/*Sclerocarya*	.	.	.	.	1
Anona senegalensis	.	.	.	.	1
Isoberlinia doka	.	.	.	.	1
unknown type	.	.	.	.	4
SUM	19	9	35	4	27

Table 3. Gajiganna NA 90/5B, identified charcoal fragments from archaeological strata, depths in cm

	upper cultural layer								lower cultural layer				
	90	100	110	120	130	160	180	190	200	270	340	370	380
Acacia type *raddiana*	1	.	3	35	1	.	.	.	.	.	4	5	3
Acacia cf. *nilotica*	.	.	.	.	1	.	.	.	.	.	.	.	.
Balanites aegyptiaca	.	.	4	.	1	.	2	.	1	.	4	.	5
Celtis integrifolia	.	.	.	.	.	.	.	.	1	.	.	.	.
Combretum	.	.	.	.	.	.	.	.	.	.	.	1	.
Ficus	.	.	.	.	.	.	.	.	1	.	.	.	.
Grewia	.	.	.	.	.	.	.	.	.	.	.	.	1
Lannea/Sclerocarya	.	.	.	.	.	.	.	.	.	.	1	1	3
Leguminosae type 2	.	.	.	.	.	.	.	.	.	.	57	8	28
Piliostigma	.	.	.	.	.	.	.	.	.	.	.	.	1
Prosopis africana	.	.	5	1	.	.	.	.	.	.	.	.	2
Rubiaceae type *Mitragyna*	3	1	.	.	.	.	.	.	.	.	1	.	2
Terminalia	.	.	3	1	7	1	.	.	.	.	.	.	.
Ximenia americana	.	.	.	.	.	.	.	.	.	.	1	.	.
Ziziphus	.	.	3	.	4	.	2	6	7	5	6	33	30
SUM	4	1	18	38	14	1	4	6	10	5	74	48	75

woody species of this denser formation were the same as in the savanna, or the firewood was only collected from the open vegetation in the direct vicinity of the site.

Ten out of 16 taxa in the charcoal samples are no longer present in the vegetation. The modern phytogeographical distribution of these taxa includes the Sahelo-Sudanian zone, and all the taxa could be supported by the mean annual rainfall in the Gajiganna area as it was measured up to the seventies (Aitchison et al. 1972). Taxa such as *Terminalia* and *Prosopis africana* are known for their excellent qualities as firewood, charcoal and for construction purposes (Maydell 1983). For that reason it seems reasonable to suppose that over-exploitation in the course of the past 3000 years is responsible for the impoverishment of the vegetation. Small-scale climatic fluctuations like the great drought of the seventies might well have accelerated the extinction of those species which reach the northern limit of their distribution in the Gajiganna area.

3. Lantewa

The landscape of the Lantewa dune field between Damaturu and Geidam is dominated by longitudinal dunes of Pleistocene origin. The modern vegetation is arranged in a dichotomous pattern with a very sparse cover on the dunes, and dense woody plant communities in the inter-dune depressions (Table 1). On the sandy soils of the dunes *Pennisetum* is grown, and the fallows are used for pasture. *Piliostigma reticulatum*, *Combretum glutinosum*, *Guiera senegalensis* and *Calotropis procera* are the most important species of the woody vegetation (corresponding to type 24 of de Leeuw and Tuley 1972), and *Cenchrus biflorus* of the grass cover. Well-developed specimens of *Anogeissus leiocarpus* give the impression of an open forest in the temporarily inundated depressions.

The charcoal sample was recovered from the pedological site Th 91/Ni52 (12°15'12"N, 11°44'75"E), a profile of a chromic arenosol which is the most common soil type on the longitudinal dunes (Thiemeyer 1992b). It contained the Combretaceae *Terminalia* sp. (7 fragments), *Anogeissus leiocarpus* (1), *Combretum* sp. (1), and the Leguminosae *Prosopis africana* (3), *Afrormosia laxiflora* (2) and *Detarium* (5). One fragment of *Detarium* gave an accelerator date of 5170±70 B.P. (UtC 2313), 4037-4013 cal B.C., 4008-3955 cal B.C., 3839-3826 cal B.C. All taxa belonging to the Combretaceae are still growing in the present-day vegetation - even though *Anogeissus* and *Terminalia* can only be found in well-watered depressions. Charcoal of *Prosopis africana* has been also found in four other pedological dune sites. As at Gajiganna, this species might have been eliminated in comparatively recent times by over-exploitation. *Afrormosia laxiflora* and *Detarium*, on the other hand, are trees from the south, nowadays distributed in the southern Sudan zone and the Guinea zone. Their presence points to moister climatic conditions and a northward shift of Sudanian and Guinean species during the middle Holocene. At Lantewa they must have formed a dense woodland. We do not know anything about the extension of this formation. Taking into consideration the clear dichotomy of the landscape, woodlands might well have been restricted to the moister depressions, representing extrazonal outliers of the Sudan zone sensu strictu.

Discussion

The middle Holocene

For the middle Holocene, the data from Oursi can be compared with those from Lantewa and Konduga, revealing some striking differences. Of course, palynological and anthracological results cannot be directly compared as they represent different parts of the vegetation. Neither do we know anything about a hypothetical grassland at Lantewa and Konduga, nor about the hypothetical presence of under-represented entomogamous taxa at Oursi. However, the absence of Sudanian elements sensu strictu in the pollen diagram from Oursi is in contradiction with the palynological results from other sites in the Sahel. Hydrological evidence points to more humid conditions in this area after 9000 B.P. (Lézine and Casanova 1989). Lézine (1989a,b) states that the moister climate of the middle Holocene resulted in an overall presence of Sudanian elements in the Sahelian zone. At Lantewa and Konduga, a comparable response of the vegetation to moister conditions is clearly visible. The data from Oursi which seem to be in contradiction with this development might be the result of special local conditions. The dune sands of Oursi must have been extremely poor in nutrients during the initial phases of pedogenesis after the Pleistocene dry period. Maybe it is this edaphic situation which was responsible for the establishment of a closed grass cover at the expense of woody Sudanian plants. In addition, the maintenance of the grassland was probably favoured by the presence of wild mammals.

From our data, we have to assume that the Sahel was not a uniform zone during the middle Holocene, but rather a mosaic of quite different vegetation types according to local site conditions. The contemporary presence of Sudanian and Sahelian elements has also been demonstrated in Senegal from 6000 B.P. onwards (Lézine 1988a), and in the Bilma region (Niger) for the early and middle Holocene (Schulz et al. 1990). In the light of these results, a strict separation of the Sahelian and the Sudanian zones as they can be observed today must be questioned for this period, and a simple model of latitudinally shifting vegetation zones is not applicable.

The sites of Lantewa and Konduga show some similarities with southeast Burkina Faso, situated in the modern Sudanian zone. In the charcoal samples from archaeological site BF 89/1 in the Chaine de Gobnangou, some of the taxa also found in Nigeria are present. For the period dated from 7500 to 7000 B.P, a dry forest has been reconstructed in which *Prosopis africana, Allophylus*, *Anogeissus leiocarpus* and *Afrormosia laxiflora* were well represented (Neumann and Ballouche 1992). On the basis of their recent distribution and ecological requirements, Aubréville (1950) regards these species as typical constituents of dry and semi-dry forests which, he says, were formerly widely distributed in the Sudan zone before being reduced to a few relicts. Maybe these species are some kind of indicator for a ancient type of forest which was rich in Leguminosae and covered larger parts of the recent Sudan and Sudan-Sahel zones, in the latter probably restricted to extrazonal outliers on favourable sites.

The period after 3000 B.P.

From 3000 B.P. onwards, a parallel development of the vegetation can be seen in Nigeria and Burkina Faso. Even though we do not know anything about the prehistoric economies around 3000 B.P. at Oursi, the palynological results suggest that the closed grassland, opened up by agro-pastoral activities, changed into a mosaic including disturbed habitats and bushland. At Gajiganna, the woody plants characteristic of pasture lands can be directly correlated with the presence of cattle. Various authors have stated that the later Stone Age herders of the Sahara were forced to move farther south as the Sahara desiccated. Between 4000 B.P. and 3000 B.P. there is a concentration of settlements with domestic cattle and ovocaprines south of 19°N (McIntosh and McIntosh 1983). It seems that around 3000 B.P. prehistoric populations reached the area of the modern Sahel. From that time, human impact must have been the dominant factor in the development of the vegetation. Events such as the drying-out of Lake Chad suggest that the climate has become constantly drier during the last 3000 years. This desiccation is, however, masked by man-made changes in the composition of the vegetation. Neither in Nigeria nor in Burkina Faso can a climatic barrier around 2000 B.P, as stated by Lézine (1989a) and Lézine and Casanova (1989), be detected. Further evidence comes from southeast Burkina Faso where there is evidence of woodland clearance by man-made fire and the development of savanna vegetation around 2600 B.P. (Neumann and Ballouche 1992). The results from Oursi as well as from southeast Burkina Faso show that human impact does not necessarily lead to an impoverishment of the plant cover. As in the Holocene vegetation history of central Europe (Behre and Jacomet 1991), disturbance by humans can equally result in the creation of new habitats and an increased species diversity. However, a number of Sudanian taxa were eliminated by overexploitation. In this way, the Sudanian relics in the Sahel (compiled by Lézine 1989a) can be interpreted not only as the evidence of a former moister climate but also of a hypothetical natural vegetation which today could be far more extended if there was little or no human impact. It seems that the uniformity of the modern Sahelian vegetation and the disappearance of Sudanian taxa are at least partly due to the land-use systems which today are more or less the same from Senegal to the Red Sea, and which can be traced back 3000 years.

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References

Agwu COC, Beug HJ (1984) Palynologische Untersuchungen an marinen Sedimenten vor der westafrikanischen Küste. Palaeoecol Africa 16: 37-52

Aitchison PJ, Bawden MG, Carroll DM, Glover PE, Klinkenberg K, Leeuw PN de, Tuley P (1972) The land resources of north east Nigeria, 1, The environment. Surbiton

Aubréville A (1950) Flore forestière soudano-guinéenne. Société d'éditions géographiques, maritimes et coloniales, Paris

Behre KE, Jacomet S (1991) The ecological interpretation of archaeobotanical data. In: Zeist W van, Wasylikowa K, Behre KE (eds) Progress in Old World palaeoethnobotany. Balkema, Rotterdam, pp 81-108

Breunig P (in press) Gajiganna und Konduga - Zur frühen Besiedlung des Tschadbeckens in Nigeria. Beitr Allg Vergl Archäol

Breunig P, Garba A, Waziri I (1992) Recent archaeological surveys in Borno, northeast Nigeria. Nyame Akuma 37: 10-17

Breunig P, Ballouche A, Neumann K, Rösing F, Thiemeyer H, Wendt P, Neer W van (1993) Gajiganna - new data on early settlement and environment in the Chad Basin. Berichte des Sonderforschungsbereichs 268, 2, Frankfurt/Main, pp. 51-74

Breuning P, Neumann K, Van Neer W (in press) New research on the Holocene settlement and environment of the Chad Basin in Nigeria. Afr Arch Rev

Cisse MI, Hiernaux P, Diarra L (1993) Intégration agro-pastorale au Sahel: dynamique et potentiel fourrager des jachères. In: Floret C, Serpantié G (eds) La jachère en Afrique de l'Ouest. ORSTOM, Paris, pp. 297-305

Claude J, Grouzis M, Milleville P (1991) Un espace sahélien. La Mare d'Oursi, Burkina Faso. ORSTOM, Paris

Dallwitz MJ (1980) A general system for coding taxonomic descriptions. Taxon 29: 41-46

Dallwitz MJ, Paine TA (1986) User's guide to the DELTA system - a general system for processing taxonomic descriptions. CSIRO Austr. Div. Entomol. Rep. 13, Canberra

Leeuw PN de, Tuley P (1972) Vegetation. In: Aitchison PJ et al. The land resources of north east Nigeria, 1, The environment. Surbiton, pp. 121-155

Leeuw PN de, Lesslie A, Tuley P (1972) The land resources of north east Nigeria, 4, Present and potential land use. Surbiton

Dupont LM (1993) Vegetation zones in NW Africa during the Brunhes chron reconstructed from marine palynological data. Quat Sci Rev 12: 189-202

Dupont LM, Agwu COC (1992) Latitudinal shifts of forest and savanna in NW Africa during the Brunhes chron: further marine palynological results from site M 16415 (9°N, 19°W). Veget Hist Archaeobot 1: 163-175

Espinoza de Pernia N, Miller RB (1991) Adapting the IAWA list of microscopic features for hardwood identification to DELTA. IAWA Bull n.s. 12(1): 34-50

Grove AT (1959) A note on the former extent of Lake Chad. Geogr J 125: 465-467

Guinko S (1984) Végétation de la Haute Volta. Thesis, Bordeaux III university

Houérou HN le (1989) The grazing land ecosystems in the African Sahel. Springer, Berlin

Keay RWJ (1959) An outline of Nigerian vegetation. Govt. Printers, Lagos

Lézine A (1988a) New pollen data from the Sahel, Senegal. Rev Palaeobot Palynol 55: 141-154

Lézine AM (1988b) Les variations de la couverture forestière mésophile de l'Afrique occidentale au cours de l'Holocène. Compt Rend Hebdomad Seance Acad Sci 307: 439-445

Lézine AM (1989a) Late Quaternary vegetation and climate of the Sahel. Quat Res 32: 317-334

Lézine AM (1989b) Le Sahel: 20000 ans d'histoire de la végétation. Bull Soc Géol France 8,V,1: 35-42

Lézine AM, Casanova J (1989) Pollen and hydrological evidence for the interpretation of past climates in tropical West Africa during the Holocene. Quat Sci Rev 8: 45-55

Lézine AM, Edorh TM (1991) Modern pollen deposition in West African Sudanian environments. Rev Palaeobot Palynol 67: 41-58

Maley J (1981) Etudes palynologiques dans le bassin du Tchad et paléoclimatologie de l'Afrique nord-tropicale de 30000 ans à l'époche actuelle. Palaeoecol Africa 13: 45-52

Maydell HJ von (1983) Arbres et arbustes du Sahel. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn

McIntosh SK, McIntosh RJ (1983) Current directions in West African prehistory. Ann Rev Anthropol 12: 215-258

Michel P, Assémien P (1969/79) Etudes sédimentologique et palynologique des sondages de Bogié (basse vallée du Sénégal) et leur interprétation morphoclimatique. Rev Géomorph Dyn 19(3): 97-113

Neumann K (1989a) Vegetationsgeschichte der Ostsahara im Holozän. Holzkohlen aus prähistorischen Fundstellen. In: Kuper R (ed) Forschungen zur Umweltgeschichte der Ostsahara, Heinrich-Barth-Institut, Köln, pp 13-181

Neumann K (1989b) Holocene vegetation of the eastern Sahara: charcoal from prehistoric sites. African Archaeol Rev 7: 97-116

Neumann K (1992) Une flore soudanienne au Sahara central vers 7000 B.P.: les charbons de bois de Fachi, Niger. Bull Soc Bot France 139, Actual Bot (2/3/4): 565-569

Neumann K, Ballouche A (1992) Die Chaine de Gobnangou in SE Burkina Faso - ein Beitrag zur Vegetationsgeschichte der Sudanzone W-Afrikas. Geobot Kolloq 8: 53-68

Ritchie JC, Haynes CV (1987) Holocene vegetation zonation in the eastern Sahara. Nature 330: 645-647

Schulz E (1987) Die holozäne Vegetation der zentralen Sahara (N-Mali, N-Niger, SW-Libyen). Palaeoecol Africa 18: 143-161

Schulz E (1990) Zwischen Syrte und Tschad. Der aktuelle Pollenniederschlag in der Sahara. Berliner Geogr Studien 30: 193-220

Schulz E, Pomel S (1992) Die anthropogene Entstehung des Sahel. Würzburger Geogr Arb 84: 263-288

Schulz E, Alain J, Baumhauer R., Schultze E, Sponholz B (1990) Upper Pleistocene and Holocene history of the Bilma region (Kawar, NE Niger). 15e Coll. Géol. Afr., Etudes récentes sur la géologie de l'Afrique, Publ. Occ. CIFEG, pp. 281-284

Stockmarr J (1971) Tablets with spores used in absolute pollen analysis. Pollen Spores 13: 615-621

Thiemeyer H (1992a) On the age of the Bama Ridge - A new ^{14}C record from Konduga area, Borno State, NE-Nigeria. Z Geomorph NF 36(1): 113-118

Thiemeyer H (1992b) Desertification in the ancient erg of NE Nigeria. Z Geomorph NF Suppl Bd 91: 197-208

Trochain J (1940) Contribution à l'étude de la végétation du Sénégal. Mém. de l'IFAN 2, Larose, Paris.

Wickens GE (1982) Palaeobotanical speculations and Quaternary environments in the Sudan. In: Williams MAJ, Adamson DA (eds) A land between two Niles. Quaternary geology and biology of the central Sudan, Balkema, Rotterdam, pp 23-50