Berichte des Sonderforschungsbereichs 268, Band 8, Frankfurt a.M. 1996: 335-348

NATURAL ENVIRONMENT AND LAND USE IN THE CHAD BASIN, NE-NIGERIA. PRELIMINARY RESULTS OF AN INTERDISCIPLINARY RESEARCH

Hans-Jürgen Sturm, Ina Franke, Holger Kirscht, Mandingo Ataholo and Thomas Skorupinski

Area and objectives of investigation

Research in the Chad Basin is carried out by members of the joint research project since 1990. The initial work concentrated on the land use systems of the area. In 1992 interdisciplinary research began with soil surveys (BRAUKÄMPER et al. 1993, PLATTE & THIEMEYER 1995) and continued with botanical investigations and the interpretation of remote sensing data in 1995.

The natural environment of the research area is composed of lagoonal clay plains interrupted by slightly elevated sand islands. The differences in sediment cover together with the high variability in rainfall cause extremely different ecological conditions. The main natural factor is the availability of water which influences not only the natural plant growth and species composition but also the land use pattern of the Kanuri - the major ethnic group. The Kanuri had to face this heterogeneity of their milieu. As a consequence they developed a differentiated land use system with rainfed cultivation on the sandy soils and a special method of dry season cropping on the clay plains. The dry season farming was subject of an interdisciplinary research focus (G1) within the SFB 268 (ZACH et al. 1996, this volume).

The objective of this paper is to combine the environmental conception of the Kanuri with detailed findings of pedological and botanical field investigations. Interpretation of multitemporal satellite data and aerial photographs should provide land cover and land use information for an extended area.

The area of investigation was outlined within the transitional zone from the clay plains to the sandy areas by interpretation of satellite images. The presented subset of a SPOT-XS-satellite image shows part of the Marte Local Government Area with its capital Old Marte in the north-eastern part of the image. The darker colours represent the clay plains while the lighter parts are related to the sandy areas. Almost half of the research area is covered by clay but all settlements are located on the slightly elevated sandy areas. Within these sandy areas different gray shades demonstrate the pattern of the rainy season farming area. Differences in colour within the clay plains are mainly due to variances in soil, water content and vegetation cover. In the north-eastern part of the image irrigation channels of the South Chad Irrigation Project are visible. The main attention, especially of the pedological and botanical research, was directed towards the south-western part of the subset in the vicinity of the villages of Wulwa, Dura, Kajere and Ngubdori.

Land use

Land use systems are usually depending on cultural as well as environmental factors. In our area, the Kanuri who represent the older population are cultivators, while the Shuwa Arabs, who migrated into the area during the 18th and 19th century, came as cattle herders. Meanwhile the Shuwa are using the same farming methods as the Kanuri do. But still, a stronger emphasis is put on cattle breeding. Most of the Shuwa are now living in permanent settlements, which are easily distinguishable from the Kanuri villages by their large thatched wooden houses. The Kanuri of the region own cattle too, but other than the Shuwa, who have developed a system of annual cattle migrations, they prefer to keep their animals in the vicinity of the settlements.

For the pastoralists the availability of fodder is the most determining environmental factor. Because of the low annual precipitation they are forced to migrate. Only during the four months of the rainy season, food is plenty. Soon after the end of the rain the grasses dry up and food for the animals gets scarce. To cope with this limitation the Shuwa are utilizing a system of transhumance where parts of the group carry out annual migrations. At the beginning of the rainy season they migrate westwards and build up the rainy season camps in the Gajiram area. Later in the year when grasses get scarce they slowly move towards the east. The dry season camps are finally established close to the shores of Lake Chad.

Apart from the limitation of low rainfall, the quality of soil is another important environmental factor for cultivators. As far as the Shuwa seem to have adopted a lot of their agricultural knowledge from the Kanuri, there is hardly any difference in the methods used by the two groups. Regional variations are therefore mainly due to the domination of certain soil types in the region and not to ethnic differences. The availability of clay or sandy soils, or the existence of both types allows or predicts a concentration on certain cultivation methods (KIRSCHT & SKORUPINSKI 1996, this volume).

On sandy soil (*cesa*) rainfed farming is performed. In May, before the beginning of regular rainfall, the fields are weeded with hoes. When the rain is about to start, millet is planted in holes dug along a line with the help of a long handled planting hoe. Later, after the first rain, beans are usually intercropped. If the rains do not begin at the expected time, a second or even a third planting is attempted. After two or three (sometimes more) additional weedings harvesting begins in October.

On the dark clay soil (*firgi*) a unique system of dry season cultivation is practised. Starting in the dry season high dams and ditches are dug, surrounding the farms. The aim is to keep as much as possible of the rain water on the fields. The weeding and hoeing of the clay farms is usually done during the rain period when the soil is soft. If much water stays stagnant on the fields, weeds are usually only torn out and left aside to rot, or they are burned after drying up.

In August, certain sorghum varieties locally called *ngawuli firgibe* and also known as *masawa* or *masakwa*, are sown into small seed beds. After allowing the seedlings four to six weeks to grow, the seedlings are removed and transplanted onto the clay fields. This happens usually in September or October, after the end of the rain. The fields have to be dry on the surface before transplanting starts. During the process of transplanting 30 to 40 cm deep holes are dug into the ground with the help of a heavy planting stick (*sharawa*). The distance between the holes is 80 to 120 cm depending on the water absorption of the soil. Then a small calabash of water is poured into the holes and two to three seedlings are added. The planting hole is not covered. The plant uses the receding moisture and the dew to grow. Only one additional weeding has to be done. A work called *bongoro*, whereby the surface of the soil is loosened with a hoe, at the immediate surrounding of each plant is necessary too. According to local beliefs *bongoro* is necessary to enable the soil and the plant to collect the morning dew. Harvesting time is in January and after allowing the plants two to three weeks to dry, the sorghum is threshed right on the farm. If the harvest was good, only the amount of grain needed for immediate consumption is carried to the villages. The excess production is stored in subterranean granaries in secret places close to the farms (see PLATTE & THIEMEYER 1995).

These are the main cultivation systems in the study area, whereby the rainy season cultivation is more important in the region west of Dura, while dry season cultivation is prevailing in the region south-east of Marte down to the Balge area south of Ngala. In settlements like Marte, Njine, Alá, along the borderline of the pure clay plains both techniques are used, in order to minimize the risk of crop failure and to expand the agricultural period. In years with heavy rainfall farming on clay is preferred because of the high yield, but in years with low precipitation at least a small yield can be obtained on sandy fields.

Soils

For better understanding of the land use pattern an investigation of the constitution of the sediments and soils is necessary. In the study area the underground consists of a very fine sand of eolian origin. This sand is differentiated in horizons by different colours. The profiles often show white, black, red and green sand horizons. The former surface of the sandy sediment shows an undulating relief.

The sands are covered by a grey silty to clay-rich sediment. The thickness of this clay layer reaches up to three metres. During the rainy season the lower parts of the landscape are flooded. There the clay sedimentation still continues. In the flood plains the clay layer is the parent material for the soil development.

The elevated areas are places of a younger eolian sand deposition. The deposited material is a brown or red silty sand. These sands are reworked due to the impact of man.

A preliminary map on the basis of the Kanuri soil classification was established. The map covers an area of about twenty square kilometres and is based on the information of farmers from Dura and Wulwa. From a pedological view five main „soil“ types can be distinguished: *firgi*, *motusku*, *kafe shinowu*, *kafe kumbu* and *cesa* (see KIRSCHT & SKORUPINSKI, this volume).

The clay plains are covered with *firgi*. This type is developed from a grey silty clay. Deep cracks reach down to more than 1.3 m. At the beginning of the rainy season *firgi* takes up a large quantity of water. The absorption of the water causes the swelling of the clay which becomes therefore impermeable. The saturated permeability was determined to be less than 0.1 cm per day. The roots which follow mainly the soil structure reach down to 0.8 m depth.

The transition from the clay plains to the more elevated sandy areas is covered by *motusku*. This type is developed from a clay layer less than one metre. In the upper part of the profile the sand content increases. This leads to a higher water permeability of *motusku* compared to *firgi*.

Kafe shinowu has a higher sand content than *motusku*. Measurements with a double ring infiltrometer show infiltration rates from 0.2 to 0.4 cm/min.

The type *cesa* is developed from a young deposited brown to red silty sand. Some profiles show pronounced clay laminations. Potsherds and charcoal findings in the upper sand layer indicate the young redeposition. The infiltration rate reaches from 0.6 to 1.3 cm/min.

After the destruction of the vegetation cover by cultivation and grazing the sand was redeposited by wind. As a result of this wind erosion there is a high number of blow-outs. The farmers call these places *kafe kumbu*. During the rainy season these places are waterlogged for some days because of the hard compacted surface. The infiltration rate is low from 0.05 to 0.1 cm/min.

Vegetation

The vegetation cover in the Lake Chad Basin depends largely on one factor, the water availability. Therefore the amount of rainfall and the soil characteristics are of predominant importance for the species composition, which may vary extremely between the years.

The vegetation was analysed along a soil catena between two sandy dunes. All major soil types according to the established soil map have been investigated. The main vegetation types where registered according to the method of BRAUN-BLANQUET (1964). The following description of these investigations gives a first overview of the vegetation in the Lake Chad Basin.

The typical vegetation on sandy positions (*cesa*) is the *Brachiaria*-type, which belongs after SCHNELL (1976) and GROUZIS (1988) to the Sahelian flora. Apart of *Brachiaria xantholeuca* species like *Borreria chaetocephala, Leucas martinicensis, Eragrostis tremula* and *Ceratotheca sesamoides* can be found in the herb layer. The presence of species like *Zornia glochidiata* indicates the influence of cattle grazing. The shrub layer is dominated by *Balanites aegyptiaca, Bauhinia rufescens* and *Calotropis procera*. Trees - mainly *Azadirachta indica* and *Balanites aegyptiaca* - appear only in settlements. Rainfed cultivation is limited to these sandy areas. In years with sufficient rainfall this type of cultivation is expanded to the *kafe* soils.

The *kafe* soil types obtain a mixture of sand and clay. Typical species for these positions are *Dactyloctenium aegyptium, Eleusine indica, Monechama ciliatum, Zornia glochidiata, Mollugo nudicaulis*. An easily recognisable vegetation type is the one dominated by *Setaria pallide-fusca*.

The high preference of *motusku* soils for the dry season cultivation makes it very difficult to describe undisturbed vegetation on these soils. The vegetation cover reflects more or less segetale vegetation types after the first field preparation work. Dominant is *Cyperus escultentus*. Other important species are *Corchorus fascicularis, Phyllanthus amarus, Meremia emarginata, Echinochloa colona* and *E. stagnina*. The two latter Poaceae can also be found on the bordering *firgi* plains.

In relation to the relief position and the amount of rainfall, different vegetation types can be identified in the *firgi* areas. *Hibiscus* sp. characterize the driest variation, more humid types are dominated in changing quantities by *Ipomea aquatica, Celosia argentea* and *Hygrophylla auriculata*. In the wettest variation *Oryza barthii* is predominant.

There is evidence for a marked relationship between soil characteristics and species composition. But also the relief position plays an important role as we can see in the example of the *firgi* vegetation. Even small differences in the relief cause a change in species dominance[1]. This is due to water availability. In describing the vegetation distribution we also have to consider the climatic conditions, especially the interannual variations in rainfall. 1995, the year of the field work, was a quite normal year. The above listed data are reflecting this situation.

In 1994 there was a year with heavy precipitation. Rainfall lasted until the end of October and an amount of 635 mm had been registered. Asking the peasants about the vegetation in 1994, they told us that the *firgi* soils were dominated by *Oryza barthii, Cyperus* sp. and *Hygrophila* sp. In years of medium rainfall *Celosia argentea* gets dominant, which is joined by *Hibiscus*

[1] The Kanuri distinguish between "highland" and "lowland" areas in the transitional zone between sandy and clay soils (PLATTE & THIEMEYER 1995).

sp. in dry years. Beside of the total amount of rainfall, the seasonal distribution influences the species composition. Heavy rainfall at the beginning of the rainy season disturbs the appearance of many plant species; the vegetation cover is lower. In contrast rainfall concentrated at the middle or the end of the rainy season gives the opportunity for many plants to germinate and to grow. Peasants prefer the first case, because of the reduced weed vegetation. The peasant is confronted with a totally different situation from year to year.

Not only the *firgi* vegetation is influenced by these variations in water availability. Interviews recorded in 1994 and 1995 in different regions of the Chad Basin show evidence of a very different vegetation on the sandy areas too. The weed vegetation changes between the years. This makes it difficult for a peasant to calculate the necessary time for weeding.

Ethnobotanical investigations

During the last years, information on the use of different plant species in the Lake Chad Basin have been collected especially by the anthropologists BRAUKÄMPER, KIRSCHT and PLATTE. Following the results of these investigations, wild plants play an important role in many different fields of utilization. During the field work of 1995 about 150 different plants have been collected with their local names, and information on the utilization. Tab. 1: Selection of wild plants in use for human nutrition in the Lake Chad Basin

Species	Parts in use
Annona senegalensis	fruits
Balanites aegyptiaca	fruits
Brachiaria ssp.	seeds
Cassia tora	leaves
Ceratotheca sesamoides	seeds
Citrullus ssp.	fruits
Corchorus fascicularis	leaves
Corchorus olitorius	leaves
Corchorus tridens	leaves
Digitaria ssp.	seeds
Hibiscus cannabinus	leaves
Hibiscus esculentus	fruits
Hibiscus sabdariffa	leaves
Ipomea ssp.	leaves
Mormodica sp.	leaves
Oryza barthii	seeds
Tamarindus indica	fruits
Ziziphus spina-christi	fruits

Many of these plants are collected for food purposes as *Digitaria* sp., *Oryza barthii* etc. who provide grain for human nutrition. Table 1 gives a first impression on the variability of this resource.

The collection of these resources is practised all over the year with a seasonal peak in the dry season. Some of the fruits or leaves of wild plants are used as a regular addition to the daily diet. Nevertheless, in years of normal rainfall the use of grains from wild plants is only an addition to the staple food. In drought years their availability becomes a question of survival. With the amelioration of the infrastructural conditions, the necessity of collecting wild plants gets lower, but it is still important.

To collect these plants the Kanuri women, as they are responsible for the collection, have to know quite well the places where to find them. At the moment the time needed for collection can only be estimated.

Satellite image interpretation

Apart from a visual interpretation an unsupervised automatic classification as first interpretation step was calculated (RICHARDS 1994: 75-88). After dividing the pixel of the satellite image into different classes according to their statistical properties which represent in turn the spectral properties of the objects an assignment of the statistical classes to land cover and land use classes was carried out, using the collected field information.

For the presented unsupervised classification eight classes were calculated and the results could be interpreted in most cases. There are three classes representing the clay areas. One of them (class 5) is the region where logging water disappeared only recently. No classification errors were recognized for these classes. Differences between the two remaining clay classes (classes 1 and 2) have to be observed closer. Class 1 represents the lowest areas with only very limited vegetation (*firgi*), while class 2 is located closer to the transition zone and to the sand areas (*firgi-motusku)*. Variances in clay and water content as well as the vegetation distribution are responsible for the clear differentiation between these two categories. For the best classification results concerning soil and sediment differentiation a dry season satellite image is preferable.

Two classes are obviously assigned to the sandy (*cesa*) areas whereby the farming pattern is clearly visible. The class 6 relates to grassland with some shrubs which is mostly not cultivated. The second class (class 7) contains the different kinds of farmland. It is difficult to distinguish between the crops at the October image, because most of the plants are dried up, and millet (*Pennisetum sp*.) and a little later also guinea corn (*Sorghum sp*.) is harvested. While on some farms millet is already harvested, intercropped beans remain on the fields. Others still show ripened millet and guinea corn. At this time the bean plants contain a great amount of active biomass. Simultaneously the actual density of the plant cover differs widely. Both factors lead to completely different spectral signals within the same land use class.

Waterbodies normally show high absorption, while bare ground shows high reflection in the used spectral channels. In our case pixel describing flat waterbodies are in the same class (class 8) as pixel representing bare ground on the sandy areas. An explanation could be that the water is very shallow and contains an amount of sediment.

The remaining two classes are related to the vegetation cover. One (class 4) contains a higher amount of active biomass and a more dense vegetation. Class 4 is mainly located on the transition zone from the sandy areas to the clay areas (*kafe/motusku*). On the clay areas itself (*firgi*) the vegetation in October is less dense (class 3). On one hand water was logging for a longer period and impeded plant growing. On the other hand crops were planted on the clay areas only at the beginning of the dry season.

Surprisingly the unsupervised classification of only one SPOT-XS-scene with three spectral channels provides very good results. In a first evaluation the classes that were discriminated by statistical parameters extracted from spectral possessions could be assigned to different land cover and land use units in the area.

Up to now the identified classes represent relatively coarse units. In following investigations by using three SPOT images of different registration times of the season 1995/96 and by making use of the detailed pedological and botanical investigations the classification units should be refined. Extensive investigations with different classification methods shall demonstrate which landscape units can be differentiated and which algorithms deliver the best overall results.

While the second type of automatic classification methods (supervised classification) with the application of field information prior to the classification decision provides much better information for less structured areas (like U.S.A. and Europe) it has to be shown, if classification results can also be ameliorated in the investigated area.

After having obtained a reasonable classification result for the season 95/96 the results shall be compared to the season 94/95 and also to older satellite images. Aerial photographs can provide additional information to detect landuse changes.

Summary and perspectives

Interdisciplinary research in the fields of ethnology, soil science, botany and remote sensing demonstrated the close relationship between natural environment and landuse pattern in the Lake Chad Basin. The profound knowledge of the peasants about their environment and special farming techniques guarantee the survival in an area with extreme changes of the most important factor - the annual rainfall.

Further research work is carried out to obtain a more detailed description of the sediments and soils and their physical and chemical properties. The relationship between soil distribution and species composition in different environments shall be worked out.

Based on detailed soil and vegetation analysis satellite images shall be interpreted to get a more detailed classification of land cover and land use. In addition digital image interpretation shall deliver information for a more extended area in the Chad Basin.

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