BAYREUTHER
GEOWISSENSCHAFTLICHE ARBEITEN

Volume 6

Ecological Imbalance in the Republic of the Sudan – with Reference to Desertification in Darfur

by
Fouad N. Ibrahim

Bayreuth 1984

Druckhaus Bayreuth Verlagsgesellschaft mbH

Ecological Imbalance in the Republic of the Sudan – with Reference to Desertification in Darfur

BAYREUTHER GEOWISSENSCHAFTLICHE ARBEITEN

Volume 6

Ecological Imbalance in the Republic of the Sudan – with Reference to Desertification in Darfur

by

Fouad N. Ibrahim

Bayreuth 1984

Bayreuth 1984

Druckhaus Bayreuth Verlagsgesellschaft mbH

Author's Address:

Prof. Dr. Fouad N. Ibrahim
Department of Regional Geography of Africa
Geo-Sciences
University of Bayreuth
D-8580 Bayreuth, F. R. Germany

Enquiries concerning the printing of scientific works are to be directed at the editors. Exchange of books is basically possible. Ordering single works or the whole series is possible only through bookshops or directly through Druckhaus Bayreuth Verlagsgesellschaft mbH, Theodor-Schmidt-Str. 17, D-8580 Bayreuth.

Printed by Druckhaus Bayreuth

ISBN-No.: 3-922808-09-3

Preface

Since the World Desertification Conference in Nairobi in 1977 there has been an ever-increasing demand for multidisciplinary references on the hazards of ecological imbalance in the Sahelian zone. In fact, it is one of the major reasons behind the failure of many development projects in the Sahel that politicians and technicians sometimes lack detailed information on the highly intricate problem they are trying to solve. So far, only a few comprehensive studies have been carried out and reported on in the field of combatting desertification.

In this present book the author attempts to fill in a gap in the knowledge of ecological imbalance in the Sahel and the problems involved. As this imbalance is man-made, human ecology plays a central role in this work. The author has given here the essence of his long-year work in the Sahelian zone. The results of this research-work have been partly published in several treatises in various German scientific reviews. This comprehensive work is now published in English in order to make it accessible to a broader, international public, particularly in the Sahelian countries themselves. As special reference is made to the Republic of the Sudan, it is hoped that the findings and the maps provided in this volume can be a help in enticing further research-work and ultimately in combatting desertification in the Sahelian zone of the Sudan.

Acknowledgement is made to the Government of Niedersachsen (Lower Saxony, Federal Republic of Germany) and to the United Nations Sudano-Sahelian Office (UNSO) for funding the printing expenses of this book, to the German Research Council (DFG) for funding part of the research, to the people of Darfur who offered me great help during my field-work in the past eleven years, and to Professor Dr.H.Mensching for promoting my research-work in the Sudan for many years. Thanks are also due to Frau R.Zeranski for typing the greater part of this book and to Herr H.Thor for his cartographic and photographic work.

Fouad N. Ibrahim

Bayreuth, July 1984

Photo 1: The most dramatic phase of desertification is the large-scale movement of sandy soils leading to the formation of erg-dune fields which encroach onto arable land. The occurrence of *Acacia albida* and *Leptadenia pyrotechnica* proves that we are here not in a climatic, but in a man-made desert.
Between El Bashiri and Bara, northern Kordofan (250 mm precipitation).
Sept. 1983

Contents

Page

Figures

Tables

		Page

Photos

MAPS

ARABIC CONSONANTS USED IN THE TEXT

Sign	Pronunciation
ḍ	emphatic "d", as in English *door*
ġ or *gh*	as French "r" in *Paris*
ḥ	aspired "h"
ḫ or *kh*	as German "ch" in "Buch"
dj	as English "j" in *just*
ṣ	emphatic "s", as in English *sword*
ṭ	emphatic "t", as in English "torn"
c ʿ	glottal sound
ʾ	glottal stop
¯	prolongation

1. Desertification in the Sahel

The often reported advance of the desert on all continents lowers the yield capacity of the earth and deprives the populations in the affected areas of their nutritional basis. Worldwide, about five million hectares of land are lost each year to desertification, another 30 million square kilometres, i.e. a fifth of the land area of our planet, are threatened by the spread of the deserts or have already been partially affected.

The presently observed advance is called desertification. It is a process which slowly destroys the regenerative capacity of the vulnerable ecosystem in arid and semi-arid regions with land use methods which are not adapted to natural conditions. Soils, plants, soil-water balance, and thereby also the local climate, are seriously affected so that desert-like conditions are spreading. The so-called "man-made desert" is created.

In the past fifty years, the Sahara alone has taken over 650,000 square kilometres through desertification of the Sahel, the areas to the south of the desert. When the Sahel was parched by the drought catastrophe of 1969-1973, it was at first thought that this was a purely climatic phenomenon. Only after the UN World Conference on Desertification in 1977, the experts began to realize that man is the real cause of this desertification.

What is the Sahel, which is still suffering from drought conditions? The "Sahel" - "coast, fringe" in Arabic - is a 7,000 km long and 500 km wide zone south of the Sahara, crossing Africa. Botanically, it is a zone of thorn bush savanna. Culturally, it is the zone where nomadic camel breeders and sedentary millet farmers meet. Main causes for the desertification of the Sahel are overcultivation, overgrazing, and excessive clearing of forests, which leads to their destruction. Man uses the land without regard for the relatively small potential of this tropical region.

Although the average population density in the Sahel zone is less than 10 inhabitants per square kilometre, it is in fact overpopulated, for two reasons: First, the population is concentrated in regions where the drinking water supply is secured. Second, soil productivity is low. This concentration of the population around the watering places and the inherent destruction of the yield capacity of the soil was further accelerated by the settling of nomads since the beginning of this century.

While nomadism makes it possible to use the various regions of the thorn bush savanna evenly, stock raising, which goes hand in hand with crop farming, leads to rapid depletion of natural resources, since it constitutes excessive land use. The population in the Sahel region has doubled in the last 25 years.

During the same period, the number of animals doubled to tripled. Simultaneously, the grazing land area decreased in size and quality.

The semi-arid zone of the Republic of the Sudan embraces an area of no less than 1 million square kilometres, extending roughly between the latitudes 10°N and 17°N. In this zone, which is severely stricken by desertification, live 70% (14 million) of the Sudanese population, with farming and animal husbandry as main sources of living. Despite the existence of large irrigation schemes (e.g., Gezira Scheme) and large mechanized farms (especially in Gedaref), the majority of the rural population live on subsistence production, which has been exposed to the severe hazards of drought in the last 15 years. The precipitation deficit has amounted to 40%-50%, compared with the preceding 15 years.

The problem of drought is not a new one. The people of the Sudan remember at least four drought disasters which have occurred in the last 100 years. The first, in 1886 during the Mahdi Revolution, was named *Sanat Setta*, i.e., "the year six", referring to the Hidjra Year 1306 of the Islamic Calendar. *Golo* was the next drought disaster which struck the country between the years 1910 and 1920. It was probably during one of these early drought phases that the Meidob nomads made charcoal out of the dead trees, crushed the charcoal and gave it to their animals instead of green fodder which was lacking everywhere. The drought phase of the years 1940-1945 is known as *Malwa*, referring to the smallest unit of measure for millet, indicating its acute scarcity. The latest drought disaster, 1970-1973, was called *Ifza'una*, i.e., "rescue us", referring to the severe hunger of that time.

Neither is the problem of desertification a new one. NACHTIGAL (1889) already described the barrenness of the perimeter of El Fasher in 1873. Also STEBBING studied Saharan creep (1935). Since the 1940's the Sudanese authorities have made various attempts to assess and control soil and vegetation degradation in the dry savanna. The most recent programme is the Desert Encroachment Control and Rehabilitation Programme (DECARP). A permanent office within the Ministry of Agriculture was established to implement this programme. On an international level, the United Nations Sudano-Sahelian Office (UNSO) has been established so as to help the African countries which suffer most from the problem of desertification. The UNSO has helped the Sudan in funding and carrying out many anti-desertification projects so far.

Compared to some other countries of the Sahelian zone, the Sudan has a good chance to combat desertification, for there are still vast areas within the Savanna belt which have not yet been desertified, though they are quite exposed to desertification hazards. These areas lie roughly south of the 500 mm-isohyet. At present, enhanced immigration from the northern desertified belt has increased human and animal pressure to an alarming degree. If measures are not immediately taken to control land use to make it compatible to the limits of land productivity, the right moment will be missed and desertification will be inevitable.

Priority should, therefore, be given to measures in controlling land use in this area, for the very practical reason that it is much easier to reorganize and control the use of land which has not yet been degraded than to reclaim already desertified areas. Considering the slow pace at which rehabilitation projects proceeded in the past, there is good reason to fear that while the Sudanese are involved in a desperate battle at the desert front in the northern Sahel, the interior Sudan-Sahel belt is being slowly desertified.

The rapid expansion of mechanized rain-fed cultivation is causing considerable desertification in the Sudan zone at present. Unless strict control is exercised in the dry savanna belt (between 400 and 900 mm), devastation will be great. By control is meant not mere soil and vegetation conservation, but adapting land use to the ecological conditions to ensure lasting productivity.

The urgency of the problem of ecological imbalance in the Sudan is wellknown to the authorities. The DECARP report published by the National Council for Research in 1976 delineates the problem as follows:

"Desert encroachment is a serious problem in the Sudan, threatening all Nile irrigation schemes, 2.5 million feddans (2.6 million acres or 1.05 million ha) of pump irrigation, 7 million feddans (7.27 million acres or 3 million ha) of mechanized crop farming, 75% of the world's gum arabic production, pasturage for about 10 million animal units of livestock and vast areas of woodlands. Surveys have shown that the desert had advanced 90 to 100 km within a 17-year period, and is currently advancing at the rate of 5 to 6 km per year." (p. II)
"The outlook for the future is grim. If corrective action is not soon undertaken, the whole area will become desert. Unfortunately, the desert will not confine itself to the Programme Area's boundaries. The highly productive southern savannah region and the Butana area east of the Nile will also become deserts. In fact, desertification is already taking place in these areas because of increased population and resulting increase in human activities .... Now it is time for action." (p. 92)

Gradually, decision-makers have begun to realize that drought is only partly responsible for the decrease of land productivity; and that land use methods incompatible with the given natural conditions are the major causes of destruction of agricultural resources in the Sahelian zone. Overstocking of pastures, regardless of their actual carrying capacity, and the permanent grazing of areas which are, at most, suitable for seasonal use hinder the natural rehabilitation of grasses and shrubs. The extension of rain-fed farming far beyond the agronomic dry boundary is one of the most important causes of desertification in the Sahelian zone of the Republic of the Sudan. Also through excessive felling of trees the tree-stock of the savanna is disappearing rapidly. Here, the demand for rural energy and timber is to be made responsible.

2. Methods of Monitoring Ecological Imbalance in the Sahelian Zone of the Republic of the Sudan

2.1 Inventory of the Natural and Human Resources

In order to monitor desertification successfully and to plan rehabilitation projects which are both effective and adapted to the given environmental conditions, it is very important to possess reliable data about the affected zone. For planning purposes, this inventory should be summed up and displayed in maps depicting the natural and human potentials relevant to the problem of desertification. These maps should include the following themes:

- Land classification in ecological units
- Present land use
- Population, settlement and infrastructure

As the available topographic maps at the scale of 1 : 250,000 are partly incomplete and too old (1910 - 1920) to assess human resources properly, field work is necessary. Relief and drainage data should be completed and corrected by the help of satellite imagery and aerial photos. In some cases, ground check will be indispensable.

2.1.1 Mapping the Ecological Units (Map 5)

The major variables governing ecological variation within the Sudano-Sahelian zone are precipitation, soil and land use. An expression of the interaction of these factors is the vegetation cover with its varying associations.

2.1.1.1 Climatic Zonation

Within the semi-arid zone of the Sudan (e.g., the Sudano-Sahelian zone) there are four distinct climatic types with their respective vegetation cover and predominant system of land use. These are shown in Table 1.

2.1.1.2 Soil Variation

Certain soil characteristics are especially relevant to desertification, for, they render the soils either more vulnerable or more resistant to degradation processes. These characteristics concern their permeability, structure of top soil, depth,

Table 1: **CLIMATIC - VEGETATIONAL ZONES OF THE ARID AND SEMIARID SUDAN**
(SUDANO - SAHELIAN ZONE)

Type	Precipitation in mm	Mean Rainfall Variability	Arid Months after Thornthwaite	Dominant Vegetation	Dominant Land Use (excluding irrigation)
I hyper-arid to arid Saharan marginal zone	50 - 200	35% - 50%	11 - 12	Sparse thorn-scrub grasslands in favourable areas. *Acacia tortilis, A. mellifera*	nomadic and semi-nomadic grazing, limited millet cultivation
II arid northern Sahel	200 - 400	27% - 35%	10	thorn-scrub savanna with a dominance of *Acacia tortilis, A. mellifera, A. nubica, Balanites aegyptiaca, Commifora africana, A. senegal*	grazing combined with millet cultivation for subsistence, gum arabic planting
III semi-arid southern Sahel	400 - 600	25%	9	degraded low-rainfall woodland savanna with a dominance of *Acacia senegal, Adansonia digitata. Hyphaene thebaica, A. mellifera, A. tortilis, Balanites aegyptiaca, A. seyal, Guiera senegalensis, Combretum cordofanum*	cultivation of millet and sorghum combined with ground-nuts and sesame as cash-crops, pastoral and sedentary animal husbandry
IV semi-arid Sudan zone	600 - 900	20%	6 1/2 - 8	partly degraded low-rainfall woodland savanna with a dominance of *A. seyal, A. albida, Combretum cordofanum, Cordia gharaf, Dalbergia melanoxylon, Anogeissus schimperi*	intensive cultivation of millet, sorghum, maize and ground-nuts; spread of large mechanized rain-fed farming in recent years, pastoral and sedentary animal husbandry

looseness, mobility, liability to encrustation and topographic situation.
The following types of soils occur at a large scale in the Sahelian zone of the Sudan:

Wind-Blown Sand Sheets

These are the loose soils of recent dunes and aeolian sand sheets. They have not developed a top soil and possess high permeability. Vegetation cover is either sparse of completely missing. Because of the lack of humus and other nutrients this soil is extremely barren.

Alluvial Sands in Valleys

Sands in wadi-beds are exposed to fluvial transport in the wet season and to aeolian transport in the dry season. They usually carry a seasonal cover of ephemeral grasses and herbs, while trees usually grow on the margins of the water courses. Because of the relative high humidity of alluvial sands, they are used for planting sorghum, vegetables and chewing tobacco.

Stabilized Goz

Goz is the common name of the sandy soils of the old dune belt especially in western Sudan. The stability of these soils is due both to the effect of the roots of grasses and herbs and to the binding effect of the weathered iron and clay minerals. The compactness of the Goz sands renders them less permeable than loose sands and, therefore, more favourable for the plants. Water, which otherwise seeps quickly through the sandy soil, is kept longer in the root zone. The stability of the Goz dunes for some thousand years allowed the development of a top soil of about 15 - 20 cm depth, which is richer in organic matter than the deeper horizon. Because of its suitability for both field crops (millet, ground-nuts) and the growth of natural grasses, a strong rivalry has arisen between cultivators and animal breeders on the Goz belt.

Mobile Goz

Owing to excessive millet cultivation combined with permanent overgrazing the "fixed" Goz soils have been reactivated in several areas of the Sahelian zone. The loss of the more fertile top soil and the loosening of the soil disturbed the former more favourable soil-water balance and ultimately led to a drastic decrease of land productivity. The mobilization of the old sand dunes is the most spectacular phenomenon of desertification. It is erroneously called desert encroachment, as if the sands were blown from the Sahara.

Clayey Soils

There are four types of clayey soils in the Sudano-Sahelian zone apart from those of the Nile basin:

- Clay plain soils, especially those of eastern Sudan
- *Gardud* soils which are hard, capped, brown loamy soils of the peneplains
- Alluvial clay and sand soils in valleys
- *Nag'a* soils in depressions which are seasonally flooded

Clayey soils are again classified into cracking and non-cracking clayey soils. Decisive, however, is the portion of sand which makes the clayey soils more favourable both for cultivation and the growth of natural plants. The loss of the plant cover leads to the concretion of clayey soils and enhances surface run-off. This makes less plants grow there, and thus a vicious circle is created. In contrast to sandy soils clayey ones do not favour the growth of grasses. Woody species are dominant. In the drier locations *Acacia mellifera, A. nubica, A. tortilis* grow, while in the wetter locations *A. seyal, A. albida, A. arabica* and *A. nilotica* occur. Owing to their hardness clayey and loamy soils have been less attractive for the Sahel cultivators. If methods of water harvesting are developed, flood cultivation can be used to grow sorghum and vegetables on these soils.

Skeletic Soils on Hills and Pediments

These soils are constantly exposed to fluvial and aeolian erosion. Soil development is, therefore, strongly impeded. In the drainage lines, fine sediments are gathered to form favourable conditions for the growth of thorn-scrubs (*A. mellifera* and *A. nubica*). Such vegetation patterns can be easily recognized on air photos by their similarity to the *brousse tigrée* of the laterite plateaus.

Terraced Soils

On the volcanic soils of Jebel Marra in Darfur the inhabitants have formerly constructed cultivation terraces up to an altitude of 2,700 m above sea level. These terraces are a very effective protection against soil erosion. They help the formation of a favourable soil catena on steep slopes with skeletic soils. They allow soils to retain their moisture for a long time.

2.1.1.3 Surveying the Vegetation Cover

A dominant vegetation association corresponds to each ecological unit, which is conditioned by the above-mentioned climatic and pedological factors. Very often, however, the strong human impact has resulted in the disappearance of plants which have given the name of a certain zone, as is the case of the *Acacia senegal* belt of western Sudan. It is, therefore, misleading to rely on former plant associations for designating present ecological zones.

Vegetation Density

Data on the density of both grasses and woody species are very important before embarking on any system of monitoring desertification. At least three categories of vegetation density are required for this purpose:

- Fairly dense (more than 50 % coverage)
- In patches and lines
- Sparsely scattered

Degree of Degradation

Prior to monitoring desertification, it is also necessary to know the degree of degradation of both plant and soil, which is extremely difficult, because the starting position is merely conjectural. Though the forms of degradation are well-known and parameters for their assessment can be found, yet degradation is only relative to a supposed natural ecological system. Whatever parameters are used, three stages of degradation can be distinctly recognized:

- Highly degraded: over-used with obvious signs of deterioration, as in the case of excessive cultivation
- Moderately degraded: moderately used with a balance between ecological rehabilitation and land exploitation, as in the case of pastoralism or cultivation with long fallow periods
- Not degraded: under-used with sound ecological conditions, as in the case of light nomadic pastoralism

2.1.2 MAPPING LAND USE (Map 3)

A preliminary survey of agricultural land use in the semi-arid zone of the Republic of the Sudan can be conducted by interpreting LANDSAT imagery combined with some verification by using the available aerial photos. Using agricultural statistics of the Ministry of Agriculture, Food and Natural Resources, one gains further knowledge of intensive land-use systems which occupy smaller areas. Ground check is the most certain method of surveying. However, owing to the inaccessibility of the greater part of the area under survey, ground check should be sample-wise. The land use chart (Table 2) given here sums up

Table 2 :

PATTERNS OF LAND USE
IN THE SEMIARID ZONE OF THE SUDAN

- **CULTIVATION**
  - RAIN-FED FARMING
    - Traditional Farming
      - Subsistence Farming
        - millet on sandy soils
        - sorghum on clayey soils
      - Subistence and Marketing
        - millet, ground-nuts & sesame on sandy soils
        - sorghum & some sesame on clayey soils
      - (Subsistence Farming / Subistence and Marketing:) terraced cultivation on the J.Marra slopes (millet, sorghum, wheat, sugar-cane, citrus trees, onions, garlic, tomatoes, potatoes & pepper-mint)
    - Mechanized Farming (mostly sorghum)
      - Private Farms
      - State Farms
  - IRRIGATED CULTIVATION
    - Surface-water Irrigation
      - Modern irrigation schemes
      - Traditional Nile irrigation
      - Jerif cultivation (river - terrace flood cultivation)
      - Taras cultivation (flood cultivation with earthen dams in seasonally in-undated plains)
    - Ground-water Irrigation
      - Traditional wells
      - Motor-pumps
- **GRAZING**
  - RANGE ENCLOSURES
  - PASTURES
    - Cattle with sheep & goats
      - permanent
      - in the dry season
      - in the rainy season
      - in the cool season
    - Camels with sheep & goats
      - permanent
      - in the dry season
      - in the rainy season
      - in the cool season
  - GRAZING ROUTES
    - permanent
    - in the dry season
    - in the rainy season
    - in the cool season
- **FORESTRY**
  - CONSERVATION AREAS
  - AFFORESTATION
  - FIREWOOD & CHARCOAL PRODUCTION AREAS
  - GAME RESERVES
  - GUM ARABIC AREAS

the kinds of land use relevant to the question of desertification. While cultivation areas can be easily recognized on satellite imagery and aerial photos, pastures and their seasonal use are difficult to identify. Such data can be collected from pastoralists and range officers in each particular area. To map forestry activities, one needs to apply all these methods of data collection.

By combining the map of land use and that of ecological classification, it would be possible to indicate whether the present land use is adapted to the ecological conditions. The northern limit of rain-fed cultivation should be drawn on the maps. Also the limit of ecologically adapted rain-fed cultivation should appear on the maps. For though the actual limit of rain-fed cultivation on the sandy soils of western Sudan lies along the 250 mm isohyet and on the clayey soils of eastern Sudan along the 300 mm isohyet, the ecologically adapted limit should run along the 500 mm and the 600 mm isohyets respectively. It is, however, almost impossible to advise land use planners to stop cultivation north of these lines, unless an acceptable alternative can be offered. But future planning should take these suggestions into consideration so that new areas north of the 500 mm isohyet should not be projected for cultivation, but for grazing and forestry (e.g., gum arabic) uses. Farming should be permitted in the semi-arid areas lying south of the 500 mm isohyet, but this farming should be controlled so as not to lead to land degradation (e.g.,by practising a suitable fallow-cultivation rotation).

2.1.3 Surveying Human Ecology

As the actual initiator of ecological degradation in the Sahelian zone is man himself, it is extremely important to make an assessment of the human assets and constraints of each particular area before planning and implementing solution measures. Data should be collected on human biology, ethnic, social, historical, economic, cultural and political aspects. Population studies should be made to raise data on population development, mobility, distribution, density and occupation. Human settlement and conditions of infrastructure are also relevant to the question of environmental monitoring.

Beside presenting data and analysing them, a map of population, settlement and infrastructure should be made including the following components.

2.1.3.1 Population

- Dominant tribes situated in their traditional tribal areas
- Population migration indicated by arrows

- Population density according to the ecological units
- Owing to the fact that most of the population in a given administrative district is usually concentrated around water points, along major valleys and around urban centres, it is advisable to demarcate these areas of population concentration so as not to dilute their population density figure by adding practically vacant areas. This may produce more realistic results, though they may be less precise from the statistical point of view.

2.1.3.2 Settlement

Settlement classification can be made either according to the number of inhabitants or according to administrative and other central functions.

2.1.3.3 Infrastructure (Map 4)

In addition to the central services mentioned above the following services should be displayed on the map:

- Schools:
  Primary
  Intermediate
  Secondary
  Vocational
  University, Higher Institute

If possible, it should be made clear whether these schools are for boys or for girls and how large they are (number of students).

- Medical Service:
  Hospital
  Health Centre
  Dispensary
  Dressing Point
  Health Unit

If possible, information on the number of doctors and beds should be included.

- Veterinary Services of different kinds
- Cultural and Social Services of different kinds
- Handicraft and Industrial Concerns
- Markets:
  Local
  Regional
  Supraregional
  (Daily, weekly)
- Means of Communication:
  Telephone and wireless

Railway
Lorry station
Bus line
Airport

- Roads:
  Paved roads
  Main track
  Side track
  Trail

Some of the above-mentioned infrastructural facilities may seem irrelevant to the question of monitoring and controlling ecological degradation. But considering the fact that infrastructural difficulties in underdeveloped countries greatly constrain the agricultural development there, it is clear that such extension services are of vital importance.

2.2 Monitoring Desertification in the Semi-Arid Zone of the Sudan

To be able to monitor the complex process of desertification with both its ecological and its socio-economic aspects, one would have to reconstruct the pre-desertification conditions. This can be partly achieved through the above-mentioned inventory of ecological and human preconditions. The rest is guesswork, unless there is reliable information on past conditions. In the case of the Sudan, some valid information can be acquired from G. NACHTIGAL about the conditions prevailing in the 1870's. During British rule (1898 - 1956) topographic maps were made and a number of climatic stations were established. Moreover, some reliable reports on vegetation and land use were written in that period.

Considering the uncertainty of ecological information of the past, it is advisable to limit studies to the more recent desertification phases. Their initial preconditions are easier to investigate than those of the older phases of land degradation. Considering the great urgency of the problem of desertification in the Sudan and its serious impact on the economic development of the country, monitoring desertification ought to concentrate on the main aspects and ignore the subsidiary ones, at least in the initial phase. A more pragmatic approach in solving the more serious problems has to be adopted, if quick success is desired. For there exists a great disparity between what scientists and experts prescribe and what is feasible.

Practical solutions are urgently needed, as the Sudan belongs to the 25 poorest countries of the world and therefore has little chance of solving such problems alone. It has to depend on international help which is at present limited. Methods must therefore be identified to enable the Sudanese to solve their own desertification problems with a minimum of external help.

Valuable research work on monitoring desertification in the Sudan has been done by H. MENSCHING since 1973 and by U. HELLDEN, C. MORALES, L. OLSSON and A. RAPP (1978 - 1981). Ongoing research work is also being carried out by D. L. JOHNSON, K. GIESSNER, V. HAARMANN, A. SCHULZ, D. ANHUF, B. Y. MOHAMED, K. S. A. HAMED, A. A. BABIKER, A. BAKHIT, M. M. Khogali and Y. A. MOHAMED. One of the main difficulties is to isolate the indicators of desertification from those which belong to other processes. This applies both to ecological and to socio-economic indicators. Soil erosion on a certain slope, for instance, is a natural process which can be enhanced by human impact. Similarly, population migration from a certain semi-arid region could have various causes, one of which is desertification. It is, therefore, necessary to monitor a set of interrelating indicators to be able to assess the progress of desertification in a certain area. Diagnosing land degradation by means of single indicators is risky.

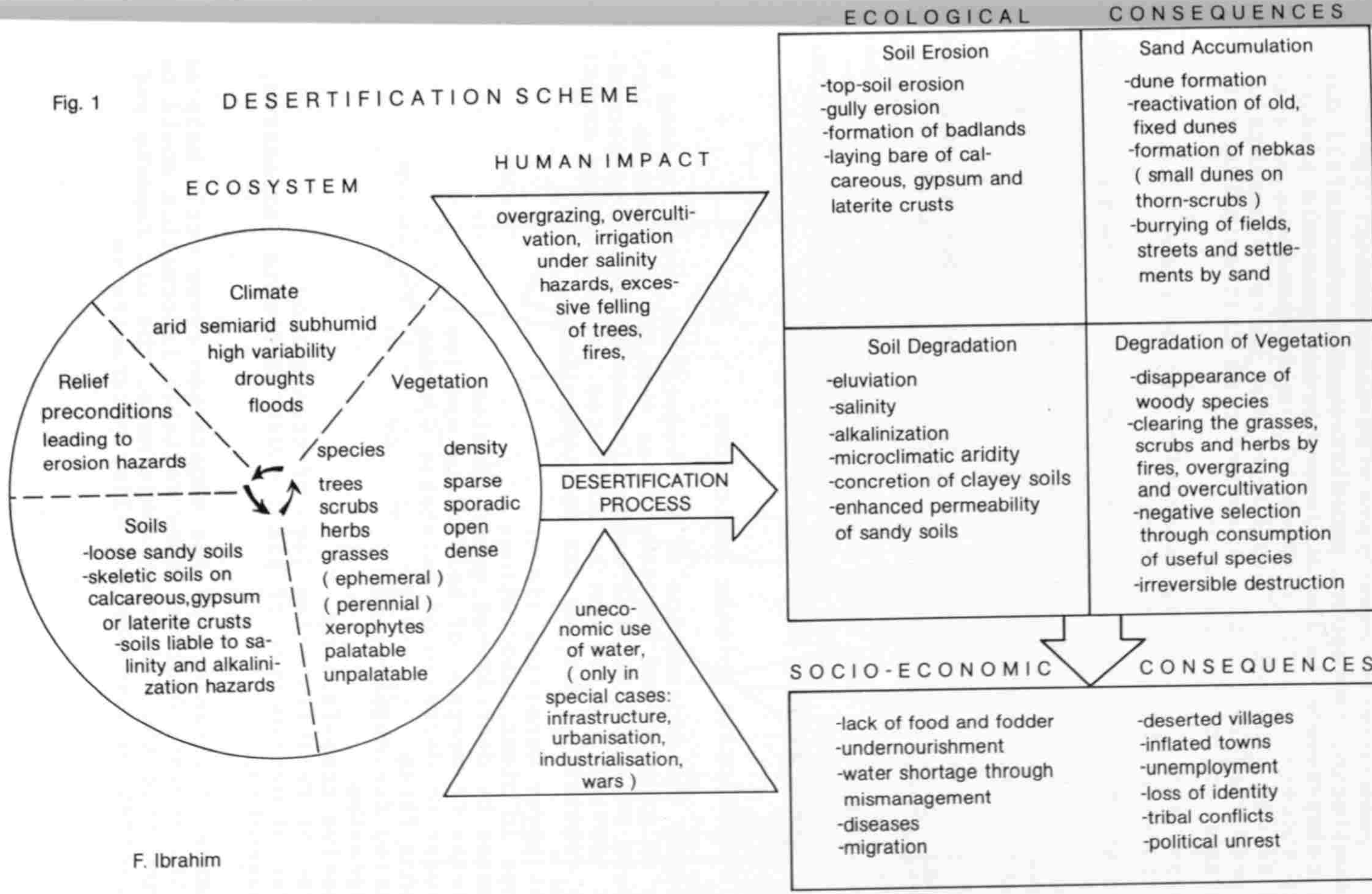
The most relevant indicators can be easily deduced from the scheme of desertification given in Figure 1, which shows that there are two groups of indicators to be monitored: the physical set of indicators and the socio-economic (human) one.

2.2.1 Monitoring Physical Indicators (Maps 1, 2, 5)

2.2.1.1 Monitoring Climatic Indicators

- Collecting and interpreting relevant climatic data is one of the first steps towards monitoring the climatic changes.
- Monitoring the albedo could throw some light on the question whether desertification leads to more desertification (self-strengthening effect). According to OTTERMAN (1974) the destruction of the vegetation cover increases the albedo, which leads to the cooling of the air strata near the earth. The conduction of heat in the atmosphere is thus reduced, which reduces the possibility of convectional precipitation. CHARNEY (1975) considers the increase of the albedo (0.35 in sandy deserts) as being responsible for the increase of temperature and the lowering of humidity. For the cooling down of the earth surface must lead to a descending movement of the air masses to create a balance of temperature. The adiabatic heating reduces the relative humidity. So, aridity enhances aridity in a feedback mechanism.

Fig. 1 DESERTIFICATION SCHEME



F. Ibrahim

- By monitoring the amount and distribution of rainfall during the rainy season in the different areas one could predict crop success or failure as well as the conditions of grazing and animal husbandry. Thus hunger and thirst disasters could be predicted long before they occur so that suitable relief measures could then be taken.
- Micro-climatic changes, especially the decrease of soil moisture should be monitored.
- Dust-storms (*Haboob*) serve as indicators for deflation of top soil in degraded areas. The positive correlation between the increase of soil deflation and the increase of the frequency of poor visibility (under 1,000 m) has been observed by IBRAHIM (1977, 1978, 1980) (Fig. 2).

To monitor desertification better the Sudan needs a denser net of climatic stations urgently. At present, the distances between such stations are more than 400 km. It is to be regretted that stations which were regularly functioning in the past have been neglected in the last decade, although the need of climatic control has become even greater, because of the continuation of the dry phase which began in 1968.

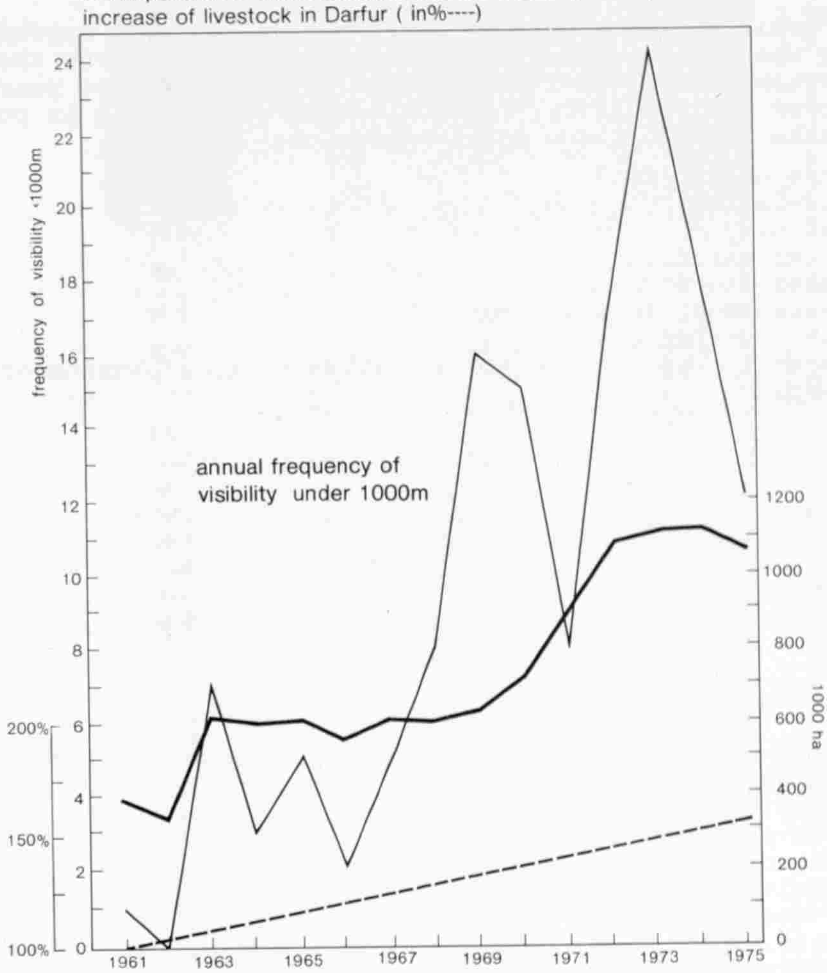
2.2.1.2 Monitoring Botanic Indicators

Monitoring the degradation of the vegetation cover is done more easily in grazing and forestry areas than in cultivation land, for it is only the natural vegetation cover (primary, secondary or tertiary) which can be monitored. The following aspects of the vegetation changes can be controlled:

- Plant cover densities (in %)
- Change in plant associations
- Increase or decrease of grass species
- Increase of decrase of herbaceous species
- Increase or decrease of palatable species
- Savanna fires
- Clearing for cultivation
- Overgrazing
- Excessive tree-felling
- Degree of rehabilitation (age of tree stock)
- Degree of destruction of plant cover (moderate, excessive, irreversible)

This table of inventory of the vegetation cover would help as a starting-point. Besides, some reliable information could be collected from the old topographic maps, the old reports and oral information given by the elderly inhabitants.

Fig.2 Correlation between the increase of aerosol in El Fasher (shown by the annual frequency of visibility under 1000m –), the expansion of millet cultivation in the Sudan (in ha–) and the increase of livestock in Darfur (in%----)



2.2.1.3 Monitoring Indicators of Soil Degradation

The ordinary farmer in the Sudan recognizes soil degradation only when land productivity decreases. In his words the soil then has become "cool" and should be left for some years to recover its fertility. For monitoring purposes it is possible to make the following differentiation:

- Loss of top soil
- Eluviation
- Salinity
- Alkalinisation
- Water-logging
- Decrease of soil moisture
- Soil concretion
- Loosening of sandy soils and subsequent quickening of water seepage

2.2.1.4 Monitoring Morphodynamic Indicators

The morphodynamic processes which serve as indicators of desertification are principally natural processes which are reactivated or enhanced by excessive land use activities. The morphological processes which are possible to monitor in this connection are those of erosion, transport and accumulation:

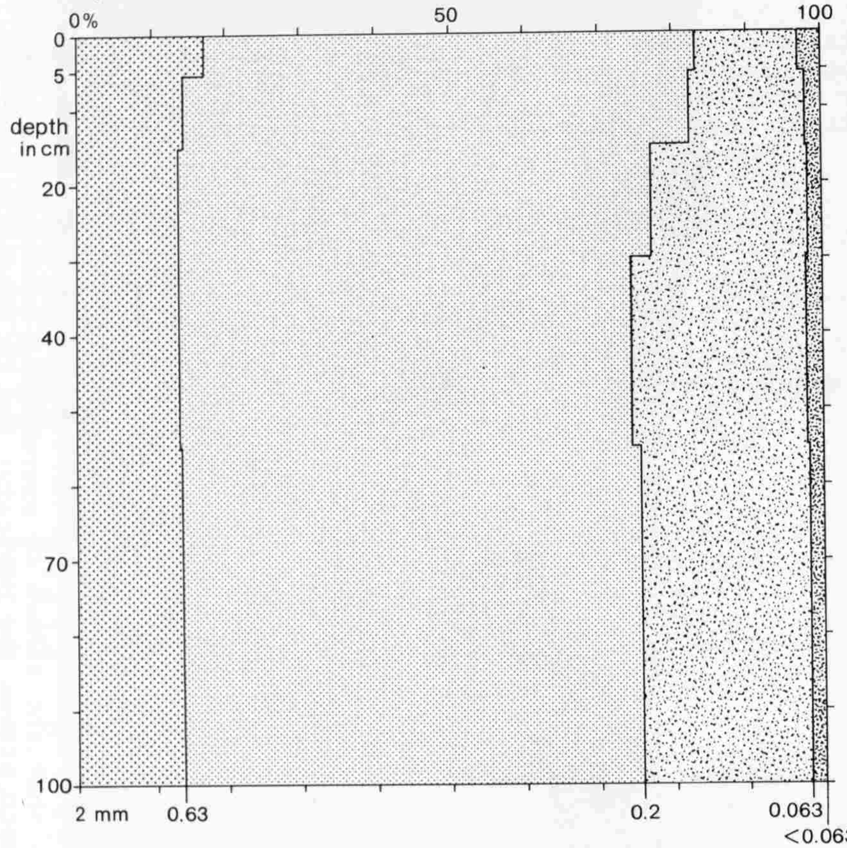
Deflation of the Top Soil of the Old Dunes

The old dune belt of the Sahelian zone, which is known in the Sudan as Goz, has developed, in the course of time, a fairly productive top soil of about 15 cm thickness. Owing to the growth of a dense grass cover, this top soil has become richer in organic matter than the underlying sand masses. Through overcultivation and overgrazing the vegetation cover has become too sparse to protect soils against deflation. In addition to this, sandy soils have been loosened by excessive use and thus have become more vulnerable to both aeolian and fluvial erosion (Photo 2).

One of the methods of monitoring top soil wind-erosion is to compare the grain-sizes of the top soil with those of the underlying horizons. Figure 3 and Table 3 show clearly that the top horizon of a Goz soil which is excessively used for millet cultivation reveals a higher percentage of coarse sands than the underlying horizons. The reasons for this phenomenon are both the deflation of finer particles and the wandering of silt particles down to the B horizon, 30 - 50 cm deep. The decrease of finer particles in the A horizon leads to the quicker infiltration of water, so that the shallow roots of millet and natural grasses (about 20 cm deep) cannot avail themselves of the rain water.

Photo 2: A wide-spread fallacy is that the Sahara is encroaching southwards in form of mobile dunes. This photo proves the contrary: Due to excessive land use in the Sahelian zone the wind erodes the sandy top soil - proved by the exposed tree roots - and accumulates it in dune form in the same zone. El Bashiri, northern Kordofan. Sept. 1983

Fig.3 Grain-size analysis of the horizons of a Goz-soil profile
(between Mellit and Khurreit/El Koma, northern Darfur, Sudan)



Tab.3: Grain-size analysis of different horizons of a Goz-soil profile in%

Depth/Size	0.63 – 2mm	0.2 – 0.63mm	0.063 – 0.2mm	0.063mm	Total
Surface	17.2	65	14	2.8	99
5 cm	14.4	67.4	15.6	2	99.4
20 cm	13.8	62.6	21	1.8	99.2
40 cm	13.7	60.4	23.4	2	99.5
70 cm	14	61	22.6	1.8	99.4

Recent Accumulation of Wind-Blown Sands on the Slopes of Outcrops and Mountain Ridges

Comparing old and recent air photos one will realize that especially on the leeside of outcrops, inselbergs, scarps and mountain ridges fresh sand trails have been formed.
These sands can be easily distinguished from the Goz sands by their mobility and lack of vegetation cover. Apart from the fact that these sand masses encroach on pastures and arable soils, they serve as an indicator of desertification processes taking place in the surrounding catchment areas.

The accumulation of wind-blown sand trails in connection with rock outcrops in northern Kordofan and northern Darfur is also associated with the drainage lines. The order pattern of the resulting forms is very much influenced by the lineaments of the geologic structure of the Precambrian Basement Complex and, more or less coincidentally, by the NE-SW direction of the trade winds.

The Recent Submergence of Wadis by Wind-Blown Sand Sheets

In the more arid belt of the northern Sahel, where the struggle between fluvial erosion and aeolian accumulation takes dramatic features, many wadis are buried under wind-blown sand sheets during the dry phases and are fluvially reactivated during the wet phases. This natural process usually takes place in the marginal southern Saharan zone which receives less than 200 mm mean annual precipitation. An anthropogenic enhancement of this process is effected when vast areas are stripped off their soil-protecting plant cover. Formerly fixed soil particles become thus exposed to be blown away by the wind whose velocity is enhanced by the disappearance of trees and shrubs (wind breakers). The concurrence of an arid phase and heavy human impact in the Sudan since 1968 has led to the submergence of numerous periodic and episodic drainage lines by wind-blown sands. Band 4 of the Landsat imagery reveals this recently buried drainage net (Photos 3 , 4 ; Fig. 4).

Appearance of Sand Ripples on the Crests of the Goz Dunes

The phenomenon of wind-formed sand ripples, which is typical of sandy deserts provides a clear indicator of desertification processes within the savanna belt on the old fixed dunes in western Sudan. One may speak here of a phase of reactivation of these old dunes. The process of ripple formation displays an advanced stage of desertification, for the natural ecosystem of the affected areas receives between 250 and 500 mm of mean annual precipitation. It thus possesses a more or less dense grass cover (*Aristida* species and *Cenchrus biflorus)* interspersed with trees *(Acacia senegal, Boscia senegalensis,*

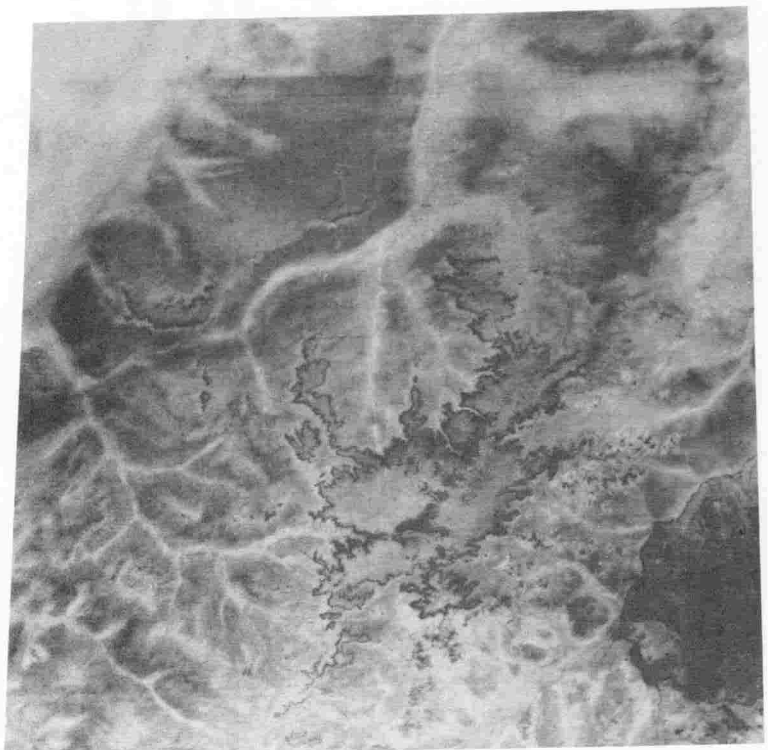
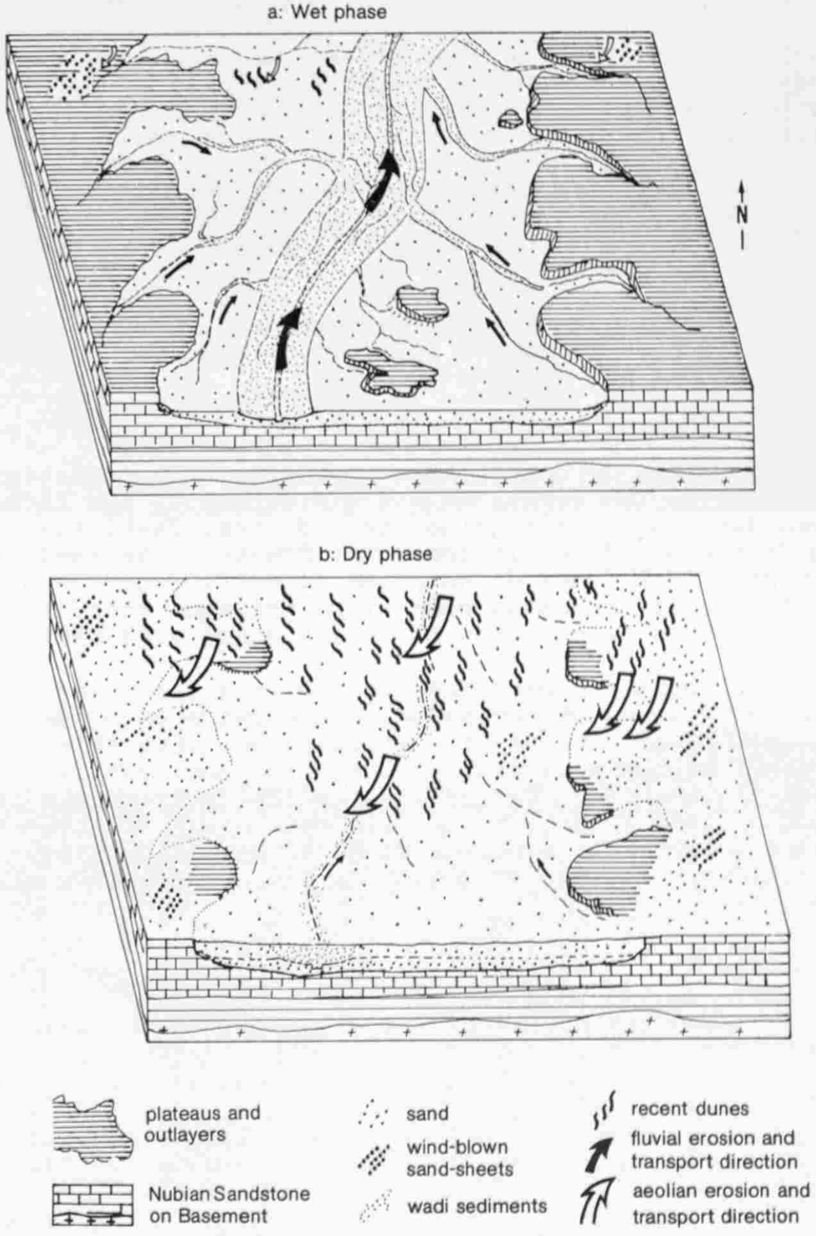


Photo 3: Band 4 of the LANDSAT imagery of the Teiga Plateau and Wadi Howar (NW corner) in Darfur shows clearly the drainage system and the dark surface of the Nubian Sandstone underlying the sand cover.

Photo 4: Band 7 reveals little of the preceding morphodynamics and of the "older" relief generation buried under the active sand masses.

Fig.4 Scheme of the morphodynamics in northern Darfur



Balanites aegyptiaca, Maerua crassifolia and *Commifora africana)*. The tree density varies between 50 and 300 trees and bushes per hectare. In this park-like landscape hardly any sand ripples have a chance of being formed by the wind. However excessive use, especially overcultivation, can lead to the disappearance of the woody species which serve as wind breakers, and to the deterioration of the grass cover. Loosening the soil through farming sets the sands moving. As a result, sand ripples appear, first on the crests of the so far stabilized dunes, and then on the slopes and lower parts as well. The fact that these sand ripples appear in overused areas in the vicinity of settlements, while less-used areas still preserve a part of the rich, original plant cover, proves that ripple formation is anthropogenically conditioned.

Recent Dune Formation

An advanced stage of desertification, after the formation of sand ripples on the crests of the old dunes, is the formation of fresh dunes on or alongside the old ones. Then, the reactivation of the old dunes is complete. However, the sands which form these recent dunes do not come directly from the old dunes. A part of the sands comes from the wadi beds. This accounts for the association of recent dunes with wadi courses.

Recent dune formation provides for the inhabitants of the arid and semi-arid zones of the Sudan a sure evidence of desertification. But it is not easy to convince them that this phenomenon is not simply a naturally controlled one, but is a consequence of human impact, a process which is triggered off and enhanced by land misuse in the catchment areas of these sands. The recent dunes in the surroundings of Bara, Kordofan, are a typical example of this process in areas of excessive millet cultivation.

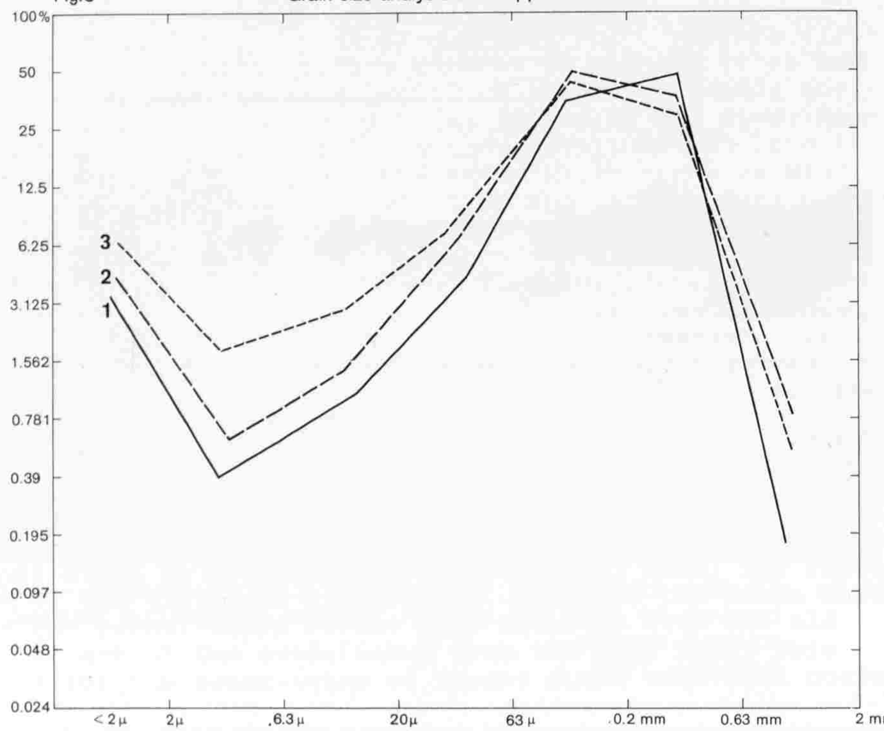
Nebka Formation

Nebkas are known in northern Africa as small dunes which are formed around the scrubs of *Ziziphus* (Arab.: *nebaka, nabaga)*. The connection between nebka formation and desertification was investigated in Tunisia by IBRAHIM and MENSCHING (1976). Similar results were obtained by IBRAHIM in western Sudan (1980 a). There, however, nebkas grow not only around *Ziziphus* scrubs, but around other scrubs as well, such as *Capparis decidua* (Photo 5), *Maerua crassifolia, Acacia nubica,* and in some cases also around *Hyphaene thebaica* (dom-palm). The fact that nebka dunes occur in large numbers in areas of high human and animal pressure, especially in areas of excessive millet cultivation, shows that they are indicators of desertification. This has been supported by the results of grain-size analysis (Figure 5 and Table 4) of the sands of such dunes at different

Photo 5: In the dry phases Wadi Golo, S of El Fasher, is partly buried by aeolian sands. Nebkas are being formed around scrubs.
October 1981

Photo 6: Arroyo formation is the type of deep dissection of the Goz area of El Fasher due to the clearing of the natural vegetation for farming.
Sept. 1983

Fig.5 Grain-size analysis of a capparis dune



Tab.4: Grain-size analysis of a capparis dune

	depth	coarse sand 0,63-2mm	middle sand 0.2-0.63mm	fine sand 0.063-0.2mm	coarse silt 20-63μ	middle silt 6.3-20μ	fine silt 2-6.3μ	clay < 2μ
1	40cm	0.2 %	51.8 %	39.6 %	3.4 %	0.9 %	0.4 %	3.7 %
2	80cm	0.6 %	39.1 %	51 %	7.6 %	1.5 %	0.7 %	5.5 %
3	180cm	0.8 %	27.2 %	49.4 %	9.6 %	3.4 %	1.8 %	7.8 %

depths (IBRAHIM 1980 a). They show great similarity to those of the nebkas investigated in Tunisia, which indicates that they are of recent formation (probably within this century).

Like other dune formations the creation of nebkas is a natural process which has been enhanced by the increased supply of aeolian sands in the last few decades. These sands come either from the millet fields in the surroundings or from farther areas of desertification, being transported partly fluvially in the wadi beds and partly by the wind. This accounts for the denser occurrence of nebkas alongside wadi courses. They also occur in ranges on both sides of main roads. These roads being unpaved are a rich source of mobile sands which supply the scrubs with the necessary material for building nebkas. Even in areas of poor vegetation (e.g., skeletic soils), road sides are favourable locations for pioneer scrubs to settle, because cars and trucks raise large amounts of dust and sand which ultimately accumulate alongside the roads. These accumulations provide possible locations for the growth of scrubs, which, in turn, catch more dust and sand to grow into nebka dunes.

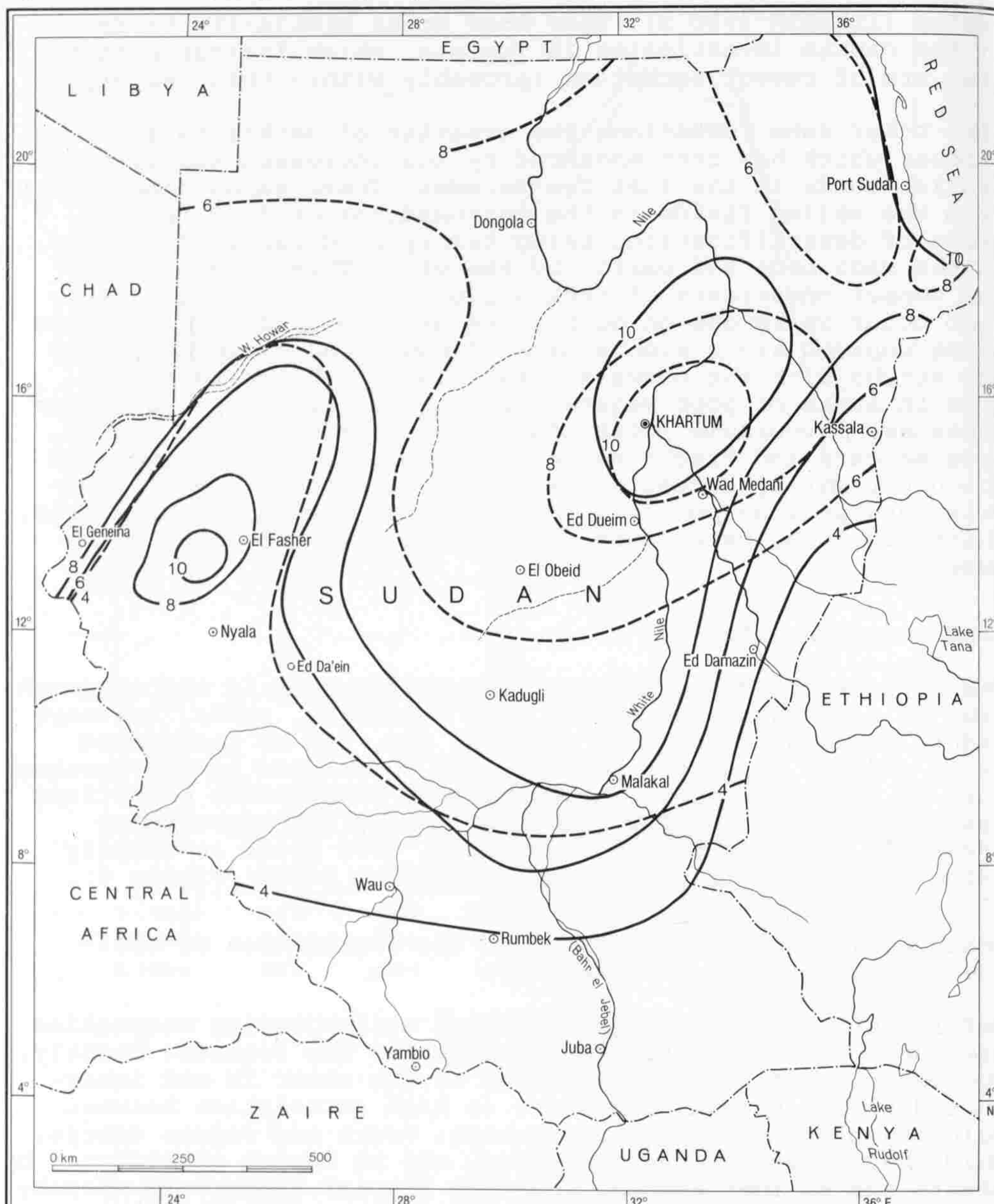
Sand Encroachments

The most dramatic indicator of desertification is the encroachment of sand masses or sheets upon buildings, roads, railways and cultivated areas. This process, too, can be considered quite natural in desert regions. Its occurrence in the savanna zone of the Sudan shows, however, that desert-like conditions have been created by the impact of man in the surrounding areas. In areas of sparse vegetation, wind speed is usually twice as high as in areas with vegetation cover (Figure 6).

Enhanced Fluvial Soil Erosion and the Degradation of Soil-Covering Vegetation (Photo 6)

Deforestation and the degradation of soil-covering vegetation are known to enhance fluvial erosion for two reasons. Firstly, the velocity of run-off increases if the water is not interrupted by the plants, and there is high correlation between velocity of run-off and erosiveness. Rocks and coarse debris, which have a strong erosive power, are no longer intercepted by plants and so they are set free for fluvial transport, whereby they act as erosive weapons. Secondly, the soils which have been deprived of their vegetation cover are highly erodable. Gauges of run-off and soil erosion in an area of 200 mm annual precipitation in Senegal showed that soils with a natural vegetation cover absorbed 99 % of the rain. Erosion rate there was 0.08 t/ha. On burned surfaces it was 0.18 t/ha. while on cultivated ones it reached 7 - 10 t/ha (UNESCO 1979).

Fig.6 Wind speed in m. p. h. (Dec.-Mar.: —— ; July-Sept. ----) in the Sudan



BHALOTRA, 1964

Cartography: P. U. Thomsen

Fluvial soil erosion is indicated either by the formation of skeletic surfaces, mostly on slopes and pediments or shallow soils, or by deep dissection and the formation of gullies and gorges. Gully formation has been observed in western Sudan both on mountain glacis and on the Goz dunes bordering wadis or mountains (source of fluvial activity). On the slightly undulating dunes, little fluvial erosion takes place on account of the high permeability of the sandy soil, which results in a poor run-off.

Enhanced Silting up of Water Reservoirs

Owing to the enhanced fluvial soil erosion described above, the silting up of water reservoirs in enhanced. A. RAPP (1975) proved that the dams in Tansania are being completely silted up in 25 years as a result of an annual soil loss of 0.2 - 0.7 mm in the catchment area. Siltation has become one of the most serious processes threatening the supply of drinking water in many arid and semi-arid areas in the Sudan in recent years. Desilting is a relatively difficult technical enterprise. When the reservoir is dry, silt becomes too hard to dig out, and when the reservoir contains water, special digging-vehicles are needed to wade through the slimy mass (Photos 7 and 8).

Changes in Run-Off

Enhanced erosion and sediment transport have caused many wadis to alter their courses in recent years. Owing to the high run-off fluctuation, the wadis carry huge sediment loads from the catchment areas, which they unload suddenly, thus damming up their own courses. If subsequent run-offs are too weak to wash off these freshly deposited dams, wadis alter their courses sideways. Satellite and air photos show wadis meandering around their depositional islands and deltas. Examples of this process are indicated by Wadi Golo-El Ku' and Wadi El Koma in northern Darfur.

2.2.2 Monitoring Anthropogenic Indicators

Monitoring anthropogenic indicators of desertification is much more difficult than monitoring physical indicators. The reason lies in the fact that the latter are more direct ones while the social consequences are indirect. JOHNSON (1981) suggests a matrix of possible social indicators of environmental change (Table 5). Though this matrix is very general, it provides a good step towards solving this difficult methodological problem and allows for future elaboration.

The desertification scheme shown in Fig. 1 gives a list of socio-economic consequences which can serve as a catalogue of

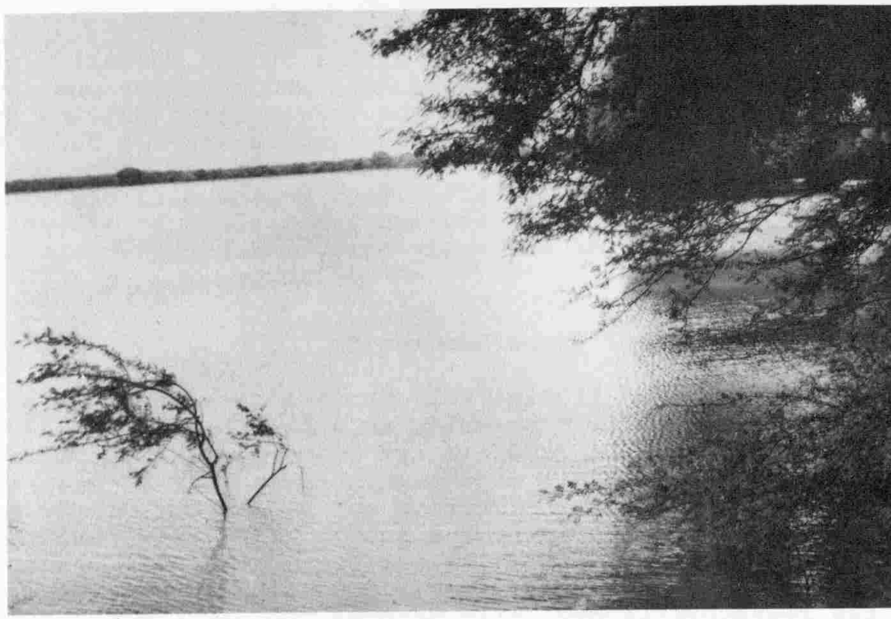


Photo 7: The Golo water reservoir, NW of El Fasher, underlies a high seasonal fluctuation.
Sept. 1976

Photo 8: The Golo water reservoir turns into a plain of cracking clay in the dry season. Desertification of the catchment area quickens the silting up of the reservoi
March 1977

Table 5 : **POSSIBLE SOCIAL INDICATORS OF ENVIRONMENTAL CHANGE**

(D. L. JOHNSON, 1981, unpublished paper)

INDICATOR	TYPE	SCALE	LIVELIHOOD (SOCIO-ECONOMIC TYPE)	DATA RELIABILITY AND OBTAINABILITY
Migration flows (by sex and age group)	Population	Local National Regional	Traditional (sedentary and pastoral) and modern	Good
Infant and old age mortality	Population dynamics	Local	Traditional sedentary and pastoral	Moderate
Female fertility	Population dynamics	Local	Traditional sedentary	Difficult to obtain
Cash income	Production	Local National	Modern	Good
Cash versus subsistence cropping	Production	Local	Traditional (sedentary)	Good/moderate
Abnormal grazing patterns	Production	Local National Regional	Traditional and modern pastoral	Good
Famine foods	Production	Local	Traditional sedentary and pastoral	Moderate/good
Vulnerability index	Production (measures range of eco-options available)	Local	Traditional	Moderate
Redistribution failure	Social	Local	Traditional	Difficult to obtain

anthropogenic indicators of desertification. The following phenomena are especially suitable for monitoring desertification:

- Lack of food and fodder in traditionally self-sufficient areas
- Undernourishment, deterioration of health and spread of diseases
- Compelled migration
- Deserted villages
- Population decrease in rural areas
- Increase of the proportion of aged population and women
- Inflation of towns in arid and semiarid areas
- Tribal conflicts, especially those between nomadic pastoralists and sedentary cultivators

To make sure that the indicators chosen actually relate to the process of desertification, it is advisable to concentrate on those phenomena which are relatively recent in the affected areas. Problems which have persisted in a certain area for a long time are liable to have causes other than desertification. It is not advisable to select a single indicator for proving the existence of a desertification process in a certain area. It is preferable to take a combination of several physical and human indicators for this purpose.

3. Desertification in Northern Darfur and its Physical Geographical Preconditions

INTRODUCTORY

The case-study presented here was carried out in the Province of Northern Darfur in the years 1976 - 1977 and followed up till 1983. The situation of northern Darfur in the far west of the Republic of the Sudan, bordering on the Republic of Chad, almost in the middle of the African continent, is extremely isolated. Together with the Province of Southern Darfur it forms the Darfur Region which has its own Regional Government. The case study was limited to the area between 12°N - 16°N and 22°E - 27°30'E leaving out the territory of Chad. But desertification processes do not make a halt at the political borders. The surveyed area is about 180,000 km² (Maps 1 - 5).

The climatic vegetational conditions of the study area are typical of the Sahelian zone. Within this area relief is the major differentiating factor. The Jebel Marra massif and its northern prolongation divides the western highlands from the lowlands in the east. While the former are dominated by shallow skeletic soils and fluvial erosion the latter are covered by thick sandy soils of old dunes. Ethnic boundaries are more fluid in the south than in the north where they are controlled by semi-nomadic groups (*Zeiyadiya, Meidob, Zaghawa*) for grazing reasons. The main area is, however, occupied by the settled tribes of cultivators (*Berti, Fur, Masalit*). Though the drawing of national borders between the former British and French colonies has impaired the traditional tribal authority, it has not succeeded in stopping the movement of the people across the borders. Of the tribes affected by this arbitrary division of territory the *Masalit*, the *Zaghawa* and the *Bedayat* are worth mentioning. During the civil war in Chad they played a decisive role. In drought times the influx of migrants into the Sudan is strongly enhanced. Besides, millet is smuggled in great quantities into Chad where its prices soar rapidly with the outbreak of hunger disaster.

The major aim of this case study is the assessment of the physical and cultural geographical process complex of desertification in northern Darfur as an example of the Sahelian zone. Both the natural and the socio-economic factors are to be analysed, the consequences for the ecosystem and for man himself are to be worked out and measures for combatting desertification to be suggested. Regional variations within the area are to be taken into consideration. Beside these more general objectives, we should like to help those peasants and nomads with whom we have often discussed the hazards of desertification.

Methodogogically it is rather difficult to grasp the processes of desertification. It is much easier to identify the status than the process of ecological degradation. Moreover, assessing the process of desertification requires a long time of monitoring. However, the fact that desertification in northern Darfur is currently taking place at different locations and at different stages renders it possible to identify and study the different stages of desertification occurring simultaneously. Besides, knowledge of environmental changes can be won by comparing the conditions prevailing today with those which prevailed some decades ago. Reliable sources of information on ecological changes have also been detected from the topographic maps (published from 1919/1920 onwards), from aerial photos (1954, 1960, 1969, 1978) and from LANDSAT imagery (1972 - 1980; bands 4,5 and 7).

To collect data on the socio-economic conditions a questionnaire has been carried out among 354 households in different regions of northern Darfur. By means of 42 questions the following subjects have been covered: the ethnic composition of the population, social conditions, water supply, fire-wood and timber consumption, animal husbandry, cultivation, subsistence production, market economy and infrastructure.

For climatic monitoring we have analysed the available data from 17 climate stations located in the study area. Only three stations (Nyala, El Fasher and El Geneina) provide detailed climatic data, while most of the other stations give mere rain gauges. In many of them, precipitation recording has not been done regularly.

3.1 The Climatic Preconditions of Desertification in Northern Darfur

Northern Darfur is situated within the marginal tropical zone, in which precipitation is concentrated on a short summer period. According to KÖPPEN (1923), the northern half of the area belongs to the BWh-zone (hot dry desert climates), the southern half to the BSh-zone (hot dry steppe climates). TROLL and PAFFEN (1964) set the area into the tropical thorn savanna climates (dry season 7 1/2 - 10 months, including winter). When discussing the role of climate in the process of desertification we shall restrict ourselves mainly to precipitation, its zonal and regional distribution, its seasonality and variability, its concentration as well as its daily distribution. Despite the significance of temperature for the high rate of evapotranspiration in the marginal tropics we shall not deal with temperature in this study for it is a relatively constant factor in that area: The annual mean is about 26° C, the annual amplitude ranges from 7° C to 10° C and the daily fluctuation is about 17° C. Table 6 shows that in the winter months from November to February the mean temperatures in El Fasher (730 m above Sea Level) are fairly low, ranging between 20.5° C and 23.7° C. In March the mean temperature reaches 25.1° C, from April to June it increases rapidly from 28.3° C to 30.5° C. The high temperatures all over the year affect the water balance to a considerable extent.

3.1.1 WATER DEFICIT

As in most regions of the arid and semi-arid zones, the main problem in northern Darfur is the acute deficit in water balance. The greatest part of the province belongs to the desert and semidesert with 10 to 12 arid months. The rest of the region, in the south and west, including the highlands of Jebel Marra, has 8 to 9 arid months and can be considered semi-arid (Figure 7). The prevailing aridity in northern Darfur constitutes the most important precondition for the processes of desertification. An exact monitoring of desertification in this region requires an exact assessment of water deficit and its effects in connection with the different methods of land use.

The precipitation map (Figure 8) shows the zonal order of precipitation in northern Darfur. However, the N - S extension of Jebel Marra massif interrupts the isohyets and makes them bulge to the north. Also, the upheaval of the terrain in the west (up to 1600 m) and the north (about 1000 m) effects an alleviation of the water deficit in those areas by causing the increase of precipitation and the decrease of temperature. The map of water deficit in the Sudan (SATAKOPAN 1965) displays a clear E - W zonation with Jebel Marra as a wetter island (Figure 9).

Thus we find that El Fasher (286 mm) and Nyala (470 mm) have almost similar figures of water deficit (1200 mm and 1119 mm respectively). According to this map, the 800 mm isoline of water deficit runs from north of Wadi Howar southward to El Geneina, and from there to the SE to Juba. This strange NS direction of the water deficit zones, which sets areas of 25 mm and of 1000 mm precipitation on the same isoline, results from the low winter temperatures in the north. The map is constructed according to the method used by THORNTHWAITE (1948) and it is doubtful if this method can be applied without modification in the marginal tropical zone of high seasonality of precipitation. To all who utilize land, whether as pastoralists or as farmers, the Juba area presents a much richer ecosystem than the area north of Wadi Howar.

If we use THORNTHWAITE's method of calculating potential evapotranspiration, water deficit in the study area will range from 500 mm in the west, to 1300 mm in the east. If we use PENMAN's method of calculating potential evaporation on open water sur-

Table 6:

CLIMATIC DATA FROM 17 STATIONS IN NORTHERN DARFUR, 1941 - 1970

(precipitation (P) in mm, temperature (T) in °C)

(Source Meteorological Service Khartoum. 1) 1959 1975

STATION	Alt m	Lat N_o	Long E_o	No. of years	P T	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dez.	Annual average
El Fasher	730	13°38′	25° 2o′	25	P	0	0	1	1	9	16	86	132	35	6	0	0	286
				30	T	20.5	22.1	25.1	28.3	29.9	30.5	28.7	27.1	28	27.5	23.7	20.9	26.1
Katum	1160	14°21′	24° 40′	30	P	0	0	0	1	9	15	86	172	30	3	0	0	316
				3	T	17.9	17.4	22.9	26.2	28	28.3	26.6	24.4	25,3	24.5	22.1	19.1	23.6
Geneina	805	13°29′	22°27′	30	P	0	0	1	3	24	43	168	236	74	10	0	0	559
				14	T	22.3	24.1	26.3	28.9	29.5	29.1	26.7	24.9	25.8	26.2	24.1	22.5	25.9
Malha	ca 900	15° 8′	26°12′	15 [1)]	P	0	0	0	0	1	6	47	96	15	5	0	0	170
Mellit	ca 900	14° 8′	25° 33′	17	P	0	0	0	0	3	9	70	144	34	2	0	0	262
Sileia		14°	22°37′	21	P	0	0	0	2	17	34	127	209	82	18	0	0	489
Kebkabiya	1120	13°39′	24° 5′	28	P	0	0	0	1	7	16	119	197	43	6	0	6	389
Um Keddada	595	13°36′	26°41′	25	P	0	0	0	0	1	22	86	121	28	5	0	0	262
Tawila	890	13°30′	24°54′	14	P	0	0	0	1	1	26	69	143	36	4	0	0	280
Kereinik	795	13°22′	22°54′	18	P	0	0	0	2	16	44	147	215	69	21	0	0	514
Suni	1880	13° 2′	24°25′	23	P	0	0	2	8	31	76	253	328	127	25	0	0	850
Wada'a	ca 650	12°50′	25°45′	19	P	0	0	0	2	15	29	99	159	63	10	0	0	377
Um Hosh		12°45′	26°50′	16	P	0	0	0	37	26	80	152	154	91	15	0	0	555
Habila		12°41′	22°33′	19	P	0	0	3	9	20	81	163	160	119	20	0	0	575
Taweisha		12°17′	26°43′	21	P	0	0	0	1	17	61	105	130	80	23	0	0	417
Nyala	655	12° 4′	24° 53′	30	P	0	0	1	3	21	47	138	167	75	18	0	0	470
				10	T	23.8	24.8	27.3	29.8	29.9	29.3	26.6	25.6	27.0	27.9	26.3	23.7	26.9
Kas	ca 970	12°31′	24°16′	28	P	0	0	0	5	21	83	158	205	92	17	0	0	581

1) 1959 – 1975

Fig.7 Northern Darfur: Aridity and the cultivation dry limit

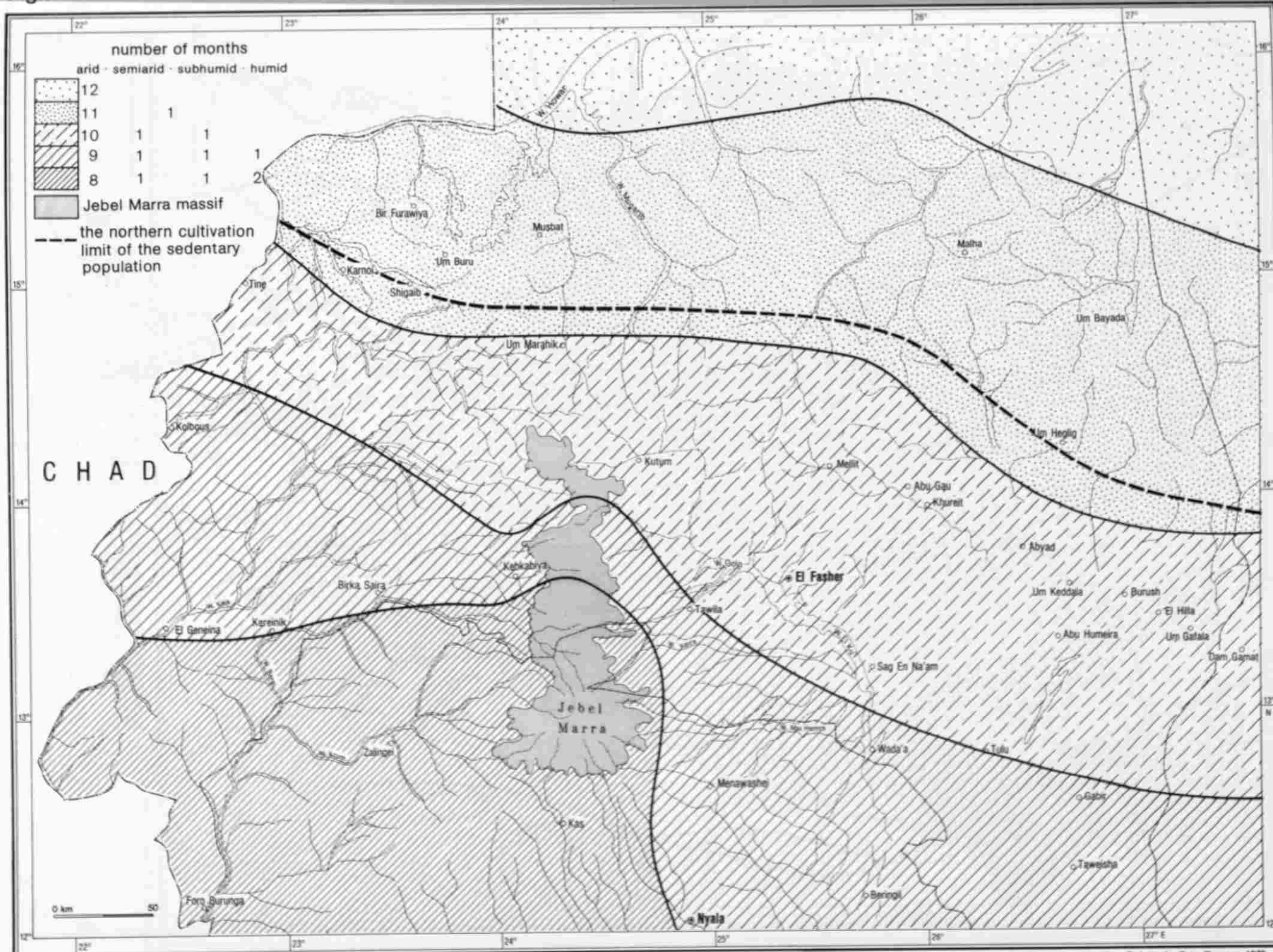


Fig.8 Northern Darfur: Precipitation

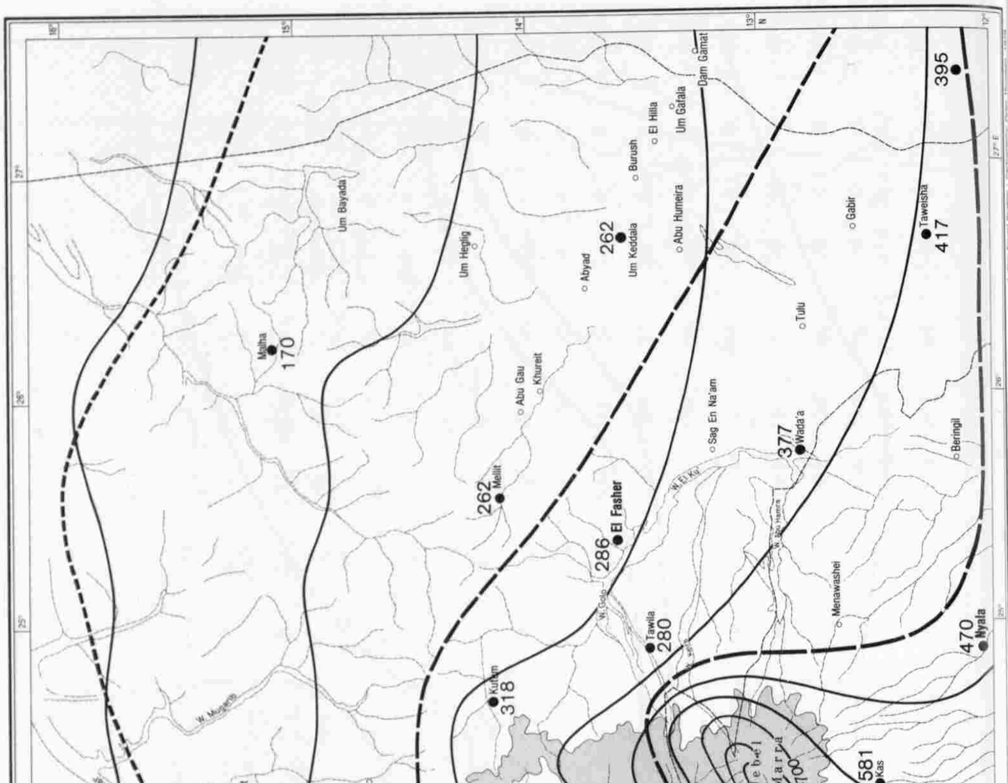
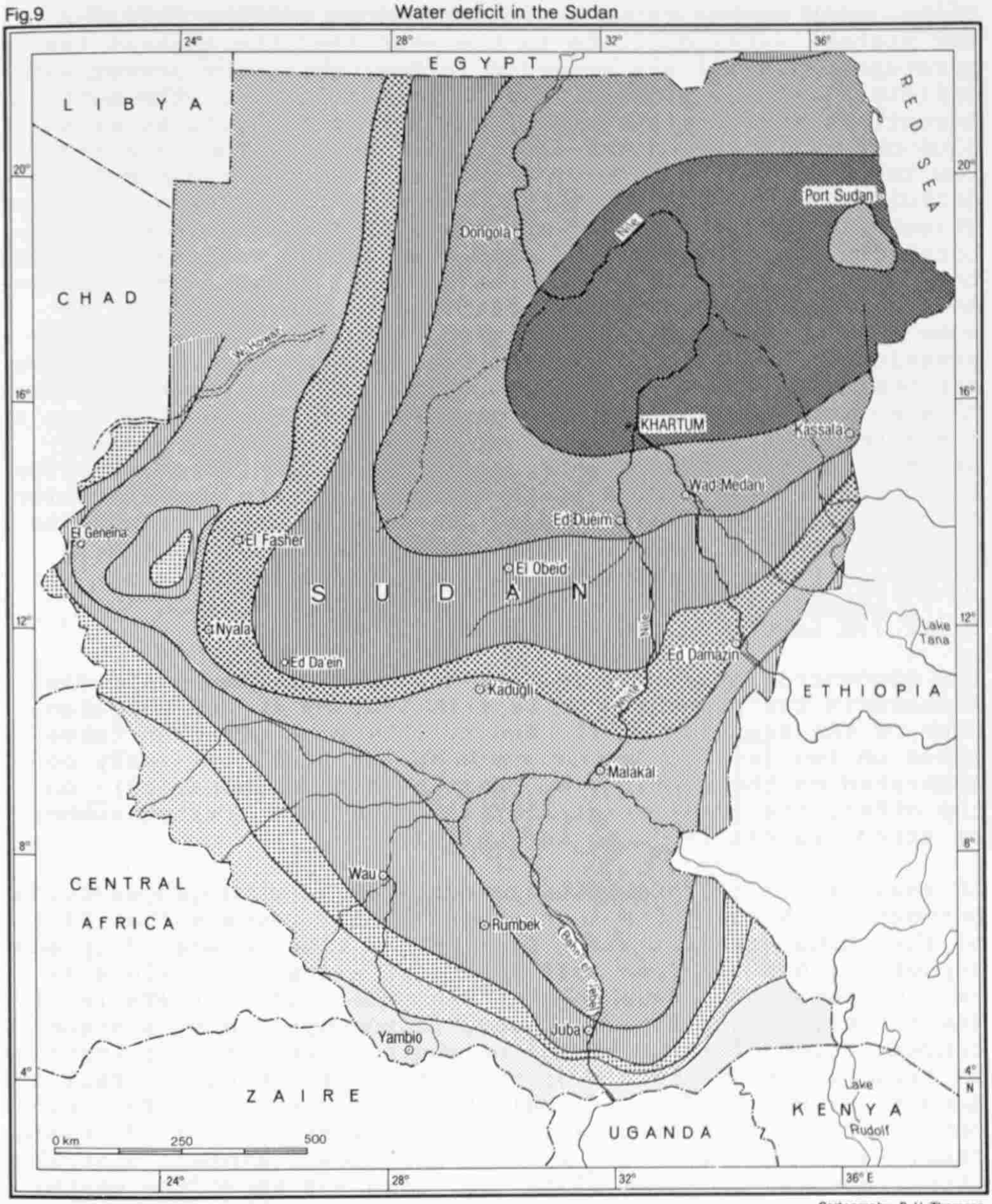


Fig.9 Water deficit in the Sudan



after V. SAZAKOPAN. 1965

Cartography: P. U. Thomsen

0 mm 200 400 600 800 1000 1200 1400 1600 1800

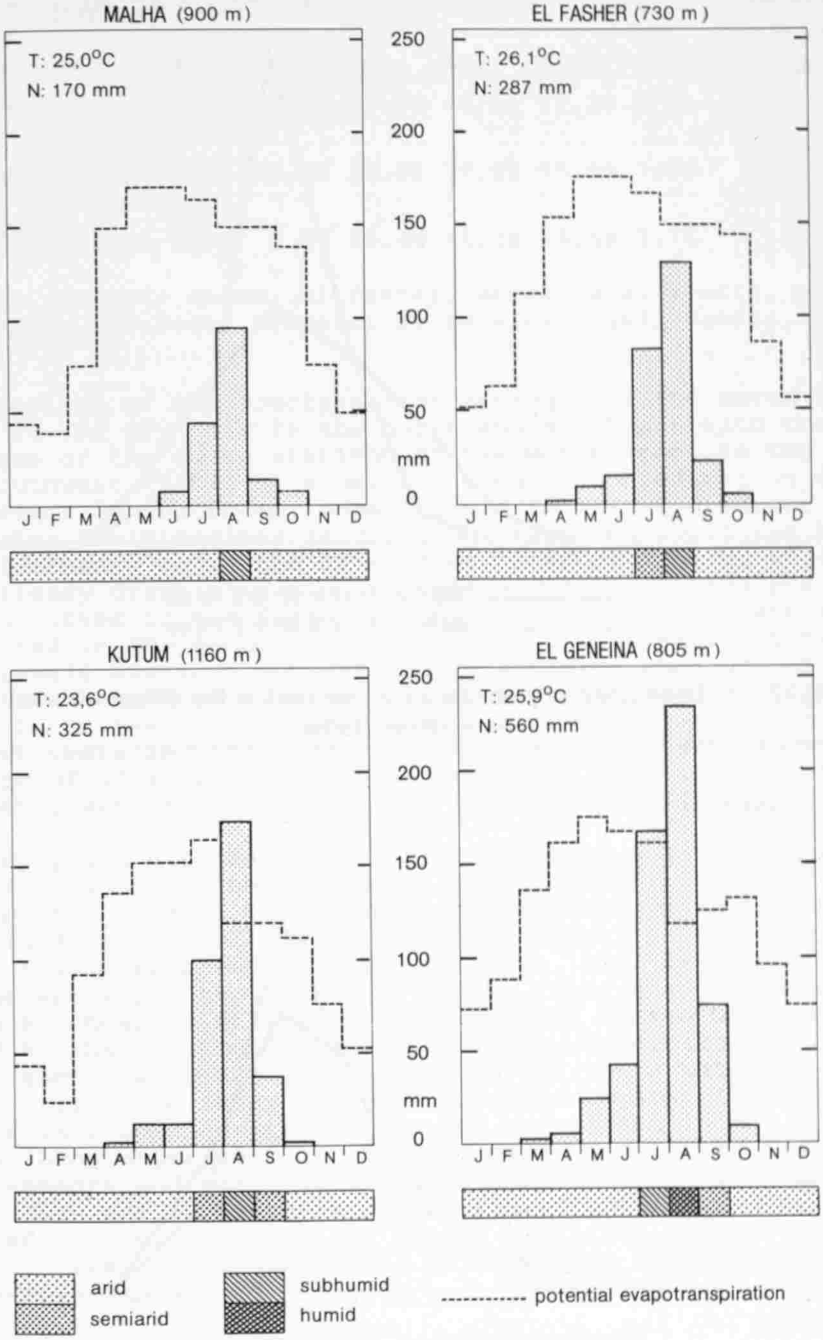
water deficit = evapotranspiration − precipitation faces, much higher rates of water deficit will be obtained. The highest water deficits in the year (and the highest temperatures as well) are recorded in May, while the lowest water deficits (and the highest water surplus) occur in the month of August. In most areas south of the 300 mm isohyet, water surplus occurs in the months of July and August. The relatively low temperatures in January result in a second minimum of water deficit, despite the complete absence of rainfall in that month (Figure 10). This has a remarkably positive influence on pastoralism, especially in the *Jizu* area around *Wadi Howar*. There, the juicy *Jizu* herbs grow during the cool season. The appearance of *Jizu* is, however, conditioned by the occurrence of some rainfalls in the previous wet seasons. Besides, the depression of temperature which causes the increase of relative air humidity reduces the demand of man and livestock for water. This solves the problem which pastoralists permanently face in the Sahelian zone, i.e., lack of drinking water in grazing areas. The influence of water deficit on rain-fed cultivation is considerably modified by the seasonality and concentration of precipitation. These make it possible for the peasants to grow millet in areas of 12 arid months annually, as single rainfall serves as water portions in irrigation farming.

3.1.2 The Concentration of Precipitation

The concentration of precipitation is one of the significant factors in the processes of desertification in the Sahelian zone of the Republic of the Sudan. This concentration takes place on two levels: On the one hand, rainfall is highly concentrated on the summerly wet season (high seasonality); on the other, the total precipitation falls in a limited number of strong rainfalls (high intensity).

An analysis of the precipitation data of 14 rain gauges lying between 12° N and 15° N in northern Darfur reveals that 84 % of the annual precipitation fall in the time between July and September; half of them fall in August alone. July (28.4 %) receives double as much rain as September (14.5 %) (Table 7). The increase of aridity northward is accompanied by a higher concentration of rainfall in the month of August. For instance, in *Malha* (15°8' N) 56.5 % of the annual precipitation fall in August, 27.6 % in July and only 8.2 % in September. This high concentration of precipitation gradually disappears southward. Thus, *Taweisha* (12°17' N) shows a different rainfall distribution from that of *Malha* (15°8' N), some 300 km to the north: In May fall 4.1 %, in June 14.6 %, in July 25.2 %, in August 31.2 %, in September 19.2 % and in October 5.5 % of the annual mean (Figure 11).

Fig.10 Precipitation, evapotranspiration and aridity in northern Darfur



according to the method of Thornthwaite

Fig.11 Distribution of precipitation in per cent in Taweisha and Malha

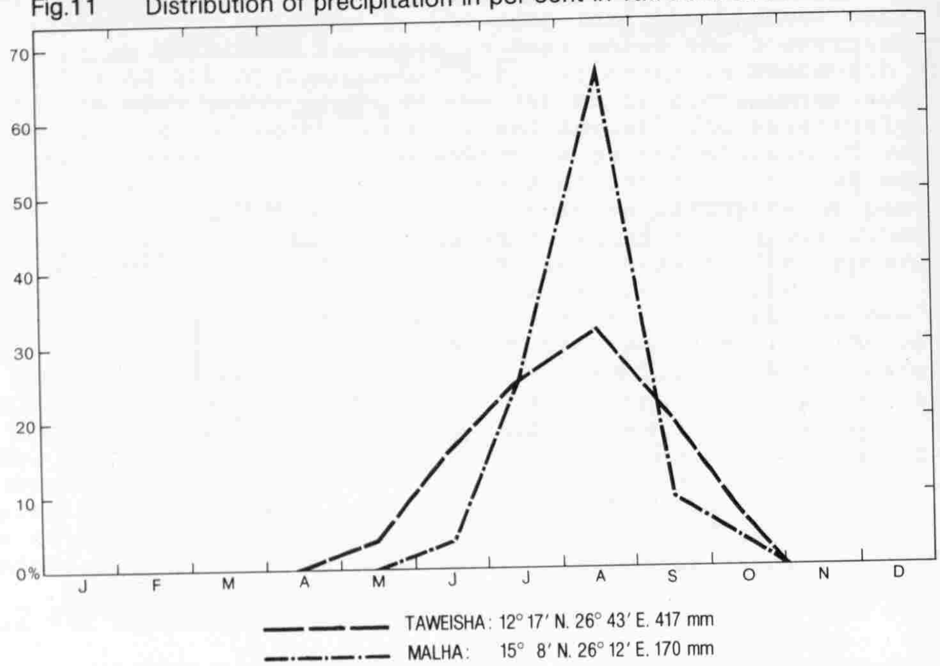


Fig.12 Distribution of precipitation in per cent in the different zones in northern Darfur

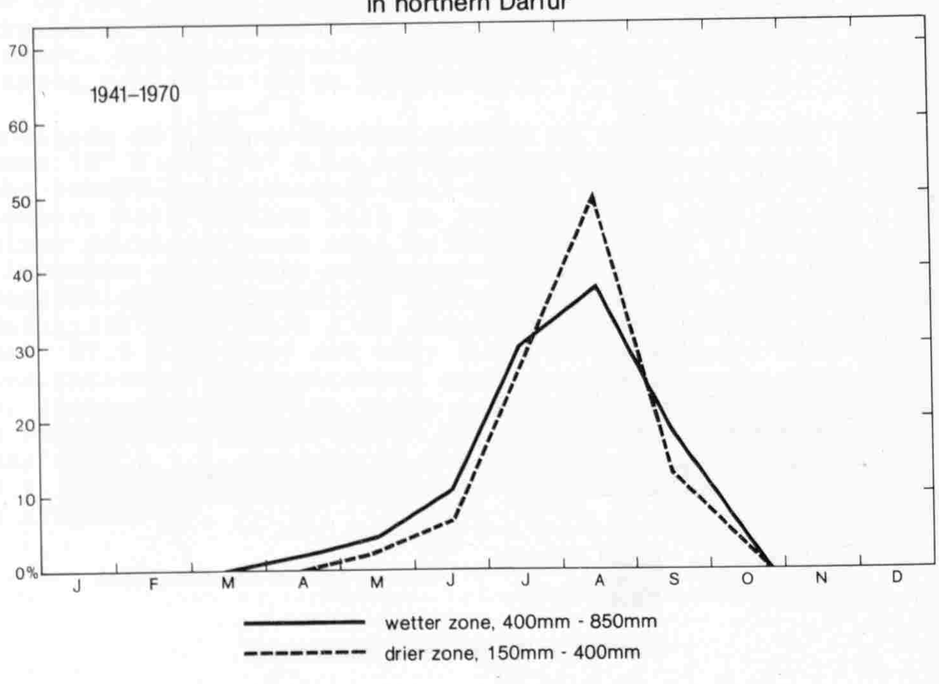


Table 7: Precipitation distribution in 14 stations in northern Darfur (1941 - 1970)

Station	May	June	July	Aug.	Sept.	Oct.	Total of July, Aug. and Sept.
7 dry stations+ (170 - 377 mm)	2.0%	6.3%	27.8%	49.5%	12.3%	2.0&	89.6%
7 wetter stations* (389 - 850 mm)	4.0%	10.0%	29.0%	37.0%	15.5%	3.0%	81.5%
All 14 stations	3.1%	9.0%	28.4%	41.1%	14.5%	2.7%	84.0%

+ *Malha, Mellit, Kutum, El Fasher, Um Keddada, Tawila, Wada'a*
* *Taweisha, Um Hosh, Kreinik, El Geneina, Suni, Habila, Kebkabiya*

A comparison of the precipitation averages of the seven stations in the dry zone in the north and northeast with the averages of the seven stations of the wetter zone in the south and southwest (Table 7) shows the greater concentration of precipitation in the former zone (Figure 12). In the wetter zone, the rains begin earlier (April), but they end about the same time (October) as in the drier zone. BARBOUR (1961 a, p. 44) has already drawn attention to this asymmetry of the precipitation curves in the Sudan. These zonal differences are also reflected in the annual variability of precipitation totals of each single station. This is easily detected when one analyses the distribution of rainfall within the wet years and the dry years in *El Geneina* (Table 8). Both groups of years (the seven wettest years and the seven driest ones since 1928) show a deviation of 37 % from the annual mean (560 mm): the average of the wet years is 765 mm, that of the dry ones 349 mm.

The dry years have an obvious precipitation peak in August with 47.7 % of the total annual precipitation, while July receives only 31.8 %. To the contrary, the wet years have their peak in July with 37.6 % of the total annual precipitation, while August receives only 33.9 %. Here, too, as in the case of the wet zone, the beginning of the rainy season, from May to June, shows relatively higher rainfall in the wet years (16.9 %) than in the dry years (12.6 %). Generally, the rains begin about two weeks earlier in the wet years than in the dry years, i.e., the Inner Tropical Convergence Zone (ITC) reaches higher latitudes earlier in the wet years than in the dry years. Long experience of ethno-climatic monitoring has taught the peasants and pastoralists of western Sudan this climatic rule. They use it in their prediction of precipitation, as reflected in their proverb *"El Kharif el-laiyen min shawagruh baiyen"*, i.e., "The good (wet) rainy season reveals itself in its first rainfalls."

Table 8: Distribution of precipitation (in %) in wet years and in dry years in El Geneina (535 mm)

Years	May	June	July	Aug.	Sept.	Oct.	July - Sept.	Annual Rainfall in mm
The 7 wettest years+	5.1	10.8	37.6	33.9	10.1	1.8	81.6	700 - 850
The 7 driest years*	4.3	7.3	31.8	47.7	7.8	0.5	87.3	200 - 400

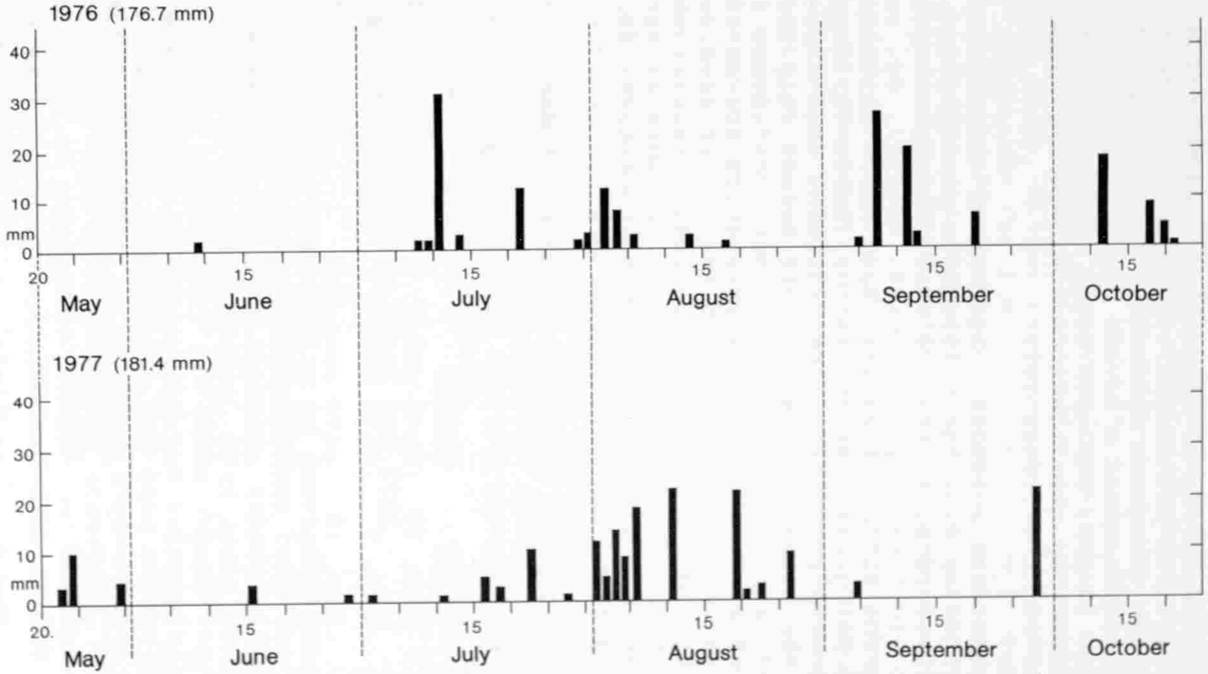
+ 1934, 1946, 1954, 1955, 1961, 1963, 1964
* 1940, 1949, 1967, 1972 - 1975

The second component of precipitation concentration in northern Darfur is the concentration on a few rainy days within the wet season itself. An analysis of the daily rainfalls in El Fasher shows this climatic phenomenon very clearly: 52.5 % of the total annual precipitation fall on 5 single days of an average of 26 mm per day. Of those 5 days, 3 receive 39 % of the total annual precipitation. Such a high concentration of precipitation bears both positive and negative consequences for land utilization. In areas of poor rainfall it becomes possible for the peasant to grow millet (*Pennisetum typhoideum,* Arab. *dukhen*). A diffusion of precipitation over a greater number of rainfalls with longer spans of time in between would make cultivation unthinkable: Due to the high temperatures and the ensuing high evaporation ratios as well as the severe edaphic aridity, weak rainfalls are usually ineffective. For example, the distribution of 120 mm over 24 rainfalls of 5 mm each with intervals of 5 days between the rainfalls would be of little use for millet cultivation. Much more favourable is the distribution of the same amount over 6 rainfalls of 20 mm each, falling with intervals of 10 days.

The distribution of rainfall, however, exhibits high variability, which mars the potentially positive effect of precipitation concentration. The time variability of such strong rainfalls increases the risks of crop cultivation. The sort of millet planted in northern Darfur requires a relatively long growth period of 110 days. (Quicker growing species are less drought resistent.) The critical phase of millet growth is the first half, in which the plant is not yet fully developed. If a drought period of 5 weeks occurs after the seeds have sprouted, the young plants will wither. If such a drought occurs in the middle of the growth period, the plant remains small and ripens prematurely. The natural reaction mechanism of millet in drought is to develop seeds in the first place, which guarantees survival of the kind.

The significance of the distribution of single rainfalls within the wet season for farming can be demonstrated by comparing the years 1976 and 1977 in northern Darfur. Though both years were dry and received only less than 40 % of the mean annual precipitation, in 1977 the millet yields were about four times as much as in 1976. Figure 13 shows that the few rainfalls of

Fig.13 Daily rainfalls in El Fasher during the season of millet cultivation in 1976 and 1977



1977 were concentrated on the most decisive period in millet growth, i.e., from the middle of July to the end of August. In 1976, the case was quite different. From August 6th to September 7th, there occurred a severe drought which dried out the young millet plants. The good rains of September and October could no more help the situation, because the plants had either withered or ripened prematurely.

In the traditional agronomic calendar of central Sudan optimal rain distribution over the cultivation period plays a significant role. According to this calendar the growth period is divided into eight small periods(Arab. *manazil*, sg. *manzel*) of 13 days each. The different *manazil* have names which describe their meteorological characteristics (Table 9). Farmers have their ethnometeorological rules regarding each *manzel*. They disregard the early rains which fall before July (i.e., the rains of *el-haga*^{c}*a* and *el-hana*^{c}*a*). More confidence is laid in the rains of *ed-dira*^{c} (middle July), which are an important criterion for the rest of the wet season. If *ed-dira*^{c} is dry, hopes are laid on the following period, *en-natra*, which marks the full beginning of the wet season. If both *en-natra* and *et-tarfa* are dry, people have to prepare themselves for a severe year of hunger and thirst.

Table 9: The climatic calendar in central Sudan

Winter		Spring	
Manzel	Begin	*Manzel*	Begin
el-ġafar	Oct. 23	*sa*^{c}*d zābeh*	Jan. 22
ez-zabanān	Nov. 5	*sa*^{c}*d bulā*^{c}	Feb. 4
el-iklīl	Nov. 18	*sa*^{c}*d es-sa*^{c}*ūd*	Feb. 17
el-galūb	Dec. 1	*sa*^{c}*d aḫbiya*	March 2
esh-shawla	Dec. 14	*el-farg el-mugaddam*	March 15
en-na^{c}*āyem*	Dec. 27	*el-farg el-mu'aḫḫar*	March 28
el-bulda	Jan. 9	*el-rasha*	Apr. 4

Summer		*Kharīf* (wet season)	
Manzel	Begin	*Manzel*	Begin
en-nitēh	Apr. 23	*en-natra*	July 23
el-bitēn	May 6	*et-tarfa*	Aug. 5
eth-thuraiya	May 19	*el-jabha*	Aug. 18
ed-dabarān	June 1	*el-ḫarasān*	Sept. 1
el-haga^{c}*a*	June 14	*es-sarfa*	Sept. 14
el-hana^{c}*a*	June 27	*el-*^{c}*iwā'*	Sept. 27
ed-dirā^{c}	July 10	*es-simāk*	Oct. 10

As a result of the increasing overpopulation of the marginal zone between Sahara and savanna, the adaptation mechanism developed by the inhabitants to the above-mentioned climatic variability has gradually lost its efficiency. The settlement of nomads together with the northward expansion of the settlement belt of the sedentary cultivators have inevitably led to greater farming risks. Millet is now planted in areas which are climatically unsuitable for its successful growth. Such a land use practice (speculative farming) involves the destruction of the natural vegetation of the area under cultivation. Rapid soil degradation ensues through the aeolian erosion of top soil.

Besides, the fluvial erosion of the bare soil is enhanced by the high intensity and variability of rainfall. Even in the area of the Goz sands (Map 1), gorges of about 1.5 m depth are cut into the millet fields after torrential rainfalls (Photo 6).

Aeolian soil erosion is also enhanced by the occurrence of short drought periods between the single rainfalls within the wet season itself. Especially at the beginning of the cultivation period of millet, the farmers till the fields constantly, thus loosen the soil and destroy the protecting grass and herb cover. The young millet plants, grown in wide rows at distances of 1.4 m to 2.2 m, have only a minute ability to break wind speed at the ground surface. In dry years (e.g., 1972, 1976 and 1982), the cultivated millet fields were extremely bare in the middle of the wet season itself, for the greater part of the plants had withered at a young stage.

3.1.3 RAINFALL VARIABILITY IN PLACE AND TIME

The high local and time variability of precipitation, in northern Darfur, bears far-reaching consequences both for the land use and the ecological balance. However, rainfall fluctuations alone do not lead to desertification. More decisive is the interaction between variability and human impact. In the past, the complete adaptation of human land use to rainfall variability hindered ecological degradation and gave nature a chance of regeneration. The old forms of rational exploitation of natural resources, however, have been gradually abandoned, because of the rapid increase of population in the last few decades. (El Fasher had 26,000 inhabitants in 1956. Today, it has no less than 100,000 inhabitants.)

3.1.3.1 Local Rainfall Variability

The erratic character of rainfall in the Saharan marginal zone is manifested both in the local and time variability of precipitation. Local variability is easily recognized by the high fluctuation of crops within the same area. Neighbouring rain gauges of the same town often reveal quite different levels of precipitation in the same period. Sahel cultivators have tried to adapt themselves to this local variability by cultivating different patches of land at different locations, thus hoping to have luck at one of these spots. There is also an astonishing connection between polygamy and local rainfall variability (Chapter 4.4.2 b).

Moreover, the system used in millet cultivation takes this local variability into account: After the first good rainfalls in July, millet is sown. Later on, only the fields which have received sufficient precipitation are weeded and tended to. Weeding (Arab. *hash*) with a long-handled hack (Arab. *djarraya*), loosens and airs the soil. It also increases the infiltration ratio of rain water.

An investigation carried out by L.HOLY (unpublished) in the Bertiland revealed that in 1975 - 77 90% of the farmers tilled more land than they weeded and tended further on. The relation changes, however, from year to year and is dependent on rainfall fluctuation (Table 10).

Table 10: The relation of the cropped area to the sown one in Duda, and the amount of rainfall

Year	Cropped area/ Sown area	Yield kg/ha	Rainfall in mm El Fasher(Ø 286)	Kutum(Ø 316)
1975	98.5 %	200	136.5	343.6
1976	48.0 %	60	176.7	176.0
1977	27.0 %	?	ca. 200.0	ca. 230.0

The fact that the greater part of the sown areas in 1975 were further tended to and cropped is to be explained by the favourable rainfalls of that year. In Duda itself no rain gauging was made, but the rains there were similar to those of Kutum and unlike those of El Fasher. The relatively good yields of 1975 (200 kg/ha) support this assumption (1976: 60 kg/ha).

The high local rainfall variability is strongly expressed in the amount of rain recorded in El Fasher: 136.5 mm in 1975. This means a deviation of minus 53 % from the annual mean of 286 mm. Our questionnaire has, however, shown that the year 1975 was a fairly good one for most parts of northern Darfur. This is also proved by the fact that the Golo water reservoir, 10 km west of El Fasher, was so full of water in 1975 that it was sufficient for the dry year of 1976 and that water was available there even up to April 1977.

Table 11: Mean standard deviation of precipitation in El Fasher and in El Geneina (in mm)

Station	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
El Fasher													
Precipitation	0	0	0.5	1.0	9.1	16.2	86.0	132.2	35.0	6.0	0	0	286.0
Mean standard deviation	0	0	1.6	3.4	12.2	16.0	51.8	60.2	25.5	7.2	0	0	106.5
El Geneina													
Precipitation	0	0.1	1.3	3.5	24.0	43.0	168.0	236.0	74.0	10.0	0.1	0	560.0
Mean standard deviation	0	0.4	4.6	6.1	32.3	38.9	85.7	64.7	47.6	13.1	0.5	0	119.5

Source: Sudan Meteorological Department, Khartoum 1976

3.1.3.2 Time Variability of Rainfall

The time variability of precipitation manifests itself at various fluctuation levels:

- variability over long periods of more than a decade
- annual fluctuation
- fluctuation of the rainfall of the same month from year to year
- fluctuation of the rainfall of the same pentade from year to year.

In the 62 years, 1917 - 1978, the precipitation of El Fasher shows a variability of 29 %, and a standard mean deviation of 106.5 mm (Table 11). In relation to their mean precipitation the wettest months (July and August) show a lower standard mean deviation than the months of poor precipitation; e.g., August 60.2 mm / 132.2 mm, May 12.2 mm / 9.1 mm.

The maximum of positive variability in El Fasher was reached in 1954: + 123 % - 637.1 mm total rainfall. The minimum negative variability was reached in 1972: - 63 % - 105.9 mm total precipitation. The diffusion of rainfall variability is much wider among the wet years than among the dry years. The occurrence of one or two successive dry years can be easily overbridged by the inhabitants of the Sahel. Drinking water supply is usually secured either by permanent wells or by gasolin water-pumps. There is also a private grain storage practice by which the inhabitants usually store a year's supply of grain. The inhabitants of the sandy Goz in northern Darfur, for instance, store millet in underground shafts called *matmūra* (sing.).

Disastrous effects result when a run of successive dry years occurs. The variability of precipitation in El Fasher (Figure 14) shows that longer runs of dry and of wet years of various lengths often take place.

Dry periods:

1940 - 1944 (5 years)

1947 - 1949 (3 years)

1966 - 1983 (18 years, with two singly occurring average years)

Wet periods:

1919 - 1924 (6 years, interrupted by a dry year)

1927 - 1931 (5 years)

1934 - 1939 (6 years)

1950 - 1954 (5 years, interrupted by a dry year)

Grasses and herbs, annuals as well as perennials, avail themselves of this succession of wet years. For this reason, nomads assess the grazing situation according to the rainfalls of the preceding year and not only according to those of the current one.

The fluctuation of precipitation in El Fasher between 1919 and 1982 (Figure 14) reveals four alternating wet and dry phases (Table 12).

Table 12: Wet and dry phases in El Fasher between 1919 and 1982

Period	duration	wet/dry	annual mean	deviation from long-term mean (286 mm)
1919-1939	21 years	wet	329.3 mm	+ 15.1 %
1940-1949	10 years	dry	218.9 mm	- 23.5 %
1950-1965	16 years	wet	329.2 mm	+ 15.1 %
1966-1983	18 years	dry	201.0 mm	- 29.7 %

Table 12 and Figure 14 show that the long-term annual mean of 286 mm in El Fasher hardly occurs. It, therefore, plays an insignificant role in the land use. During the long wet phase, the farmers and pastoralists quickly become used to a precipitation whose mean lies at about 330 mm, and consider it as normal. With the transition into the dry phase the pendulum abruptly swings strongly to the other side, so that a jump of 110 mm (i.e., 33.3 %) takes place.

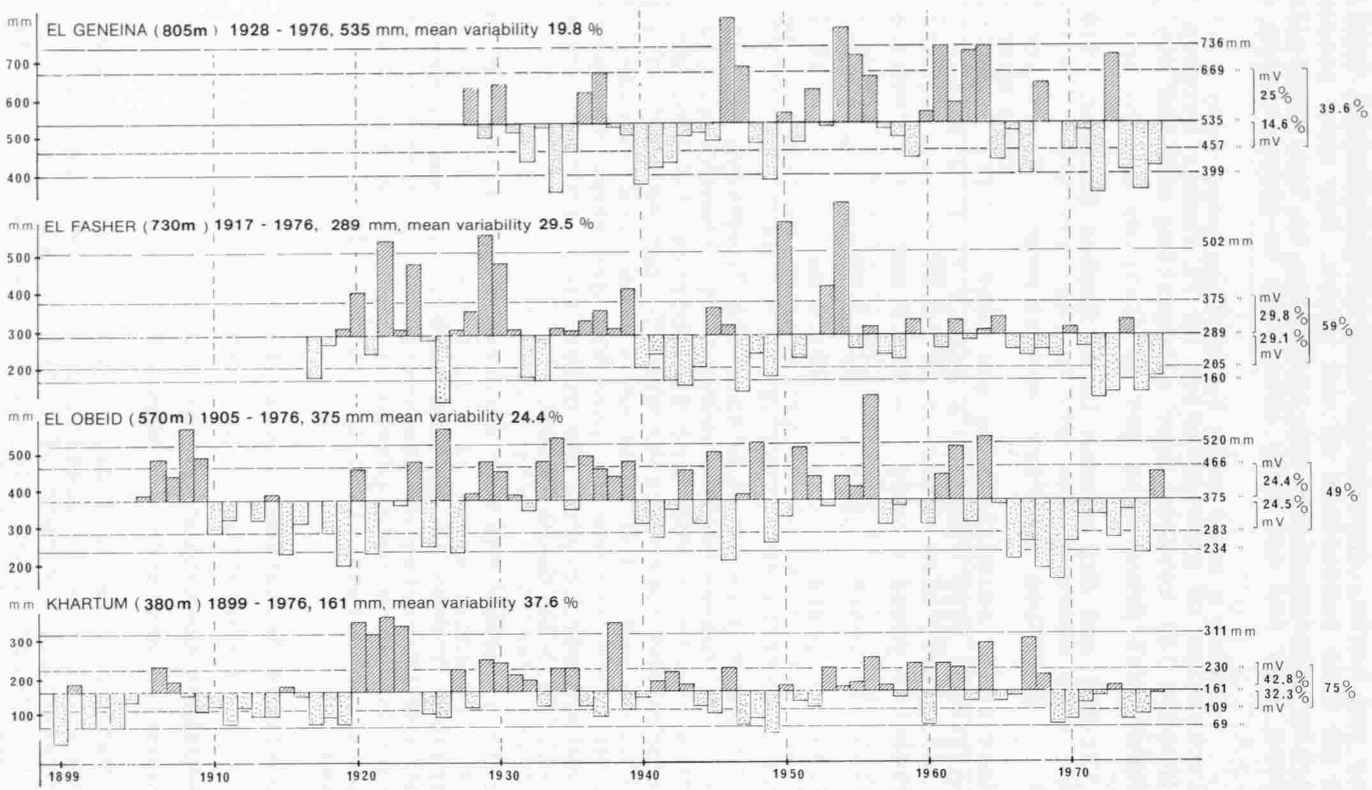
Figure 15 displays the variability of precipitation in El Geneina during short spans of 5 days (pentades). The method used by GRIFFITHS (1959) is applied here with some alteration so as to suit the character of precipitation in northern Darfur. The deviation of the single pentade figures from the mean pentade precipitation between 1936 and 1960 is divided into four categories:

- positive deviation of more than 50 %
- positive deviation of less than 50 %
- negative deviation of less than 50 %
- negative deviation of more than 50 %

The formation of wet and dry runs of pentades is made easier by applying a certain calculating method. Each pentade gets a figure representing the mean of three pentades: the pentade itself, the preceding pentade and the following one. Thus, edaphic humidity or aridity is being taken into account.

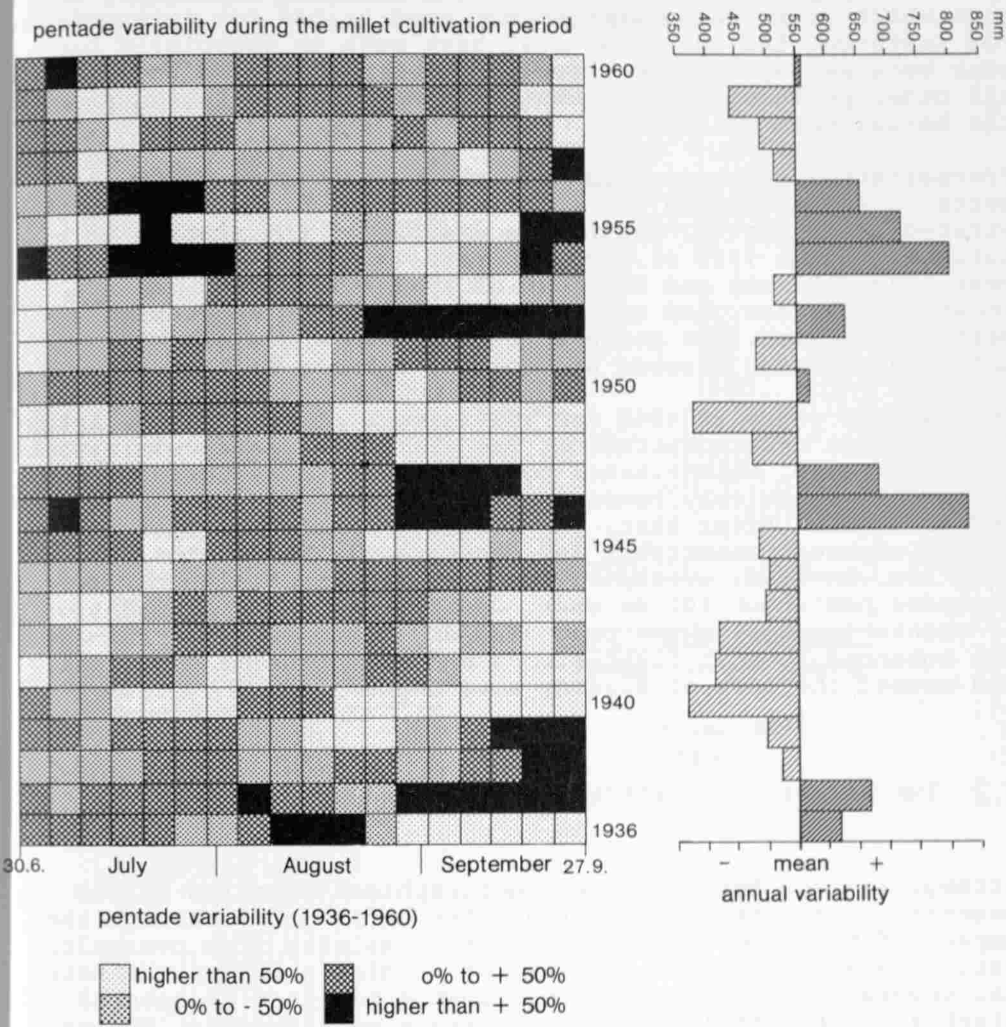
Figure 15 shows that the highest pentade variability during the

Fig.14 Variability of precipitation in the Sahelian zone of the Republic of the Sudan



MENSCHING, H. und F. IBRAHIM, 1978

Fig.15 Variability of precipitation in El Geneina (805m), 1936-1960: 550mm



In order to take into account soil moisture, the average of three successive pentades has been recorded in the middle square; e.g. the average of the pentades A, B, and C has been taken for B.

cultivation period occurs in September. It often lies above 50 %. From the pattern of pentade variability one can easily detect which years were particularly good or bad for agronomists. For instance, the year 1940 must have been an especially bad year because, apart from three positive pentades in the middle, all other pentades show an extremely negative deviation from the annual mean rainfall.

Precipitation diagrams which use the pentade figures can be better correlated with the cultivation period. This is demonstrated by Figure 16, taking the example of the station of Kutum (altitude 1166 m). The wet year 1950 (560 mm), the dry year 1949 (137 mm) and the mean of 1930 - 1960 (325 mm) are shown in pentades, and are correlated with the vegetation period of millet. The pentade mean diagram shows clearly how untypical average figures are for the climate of that zone.

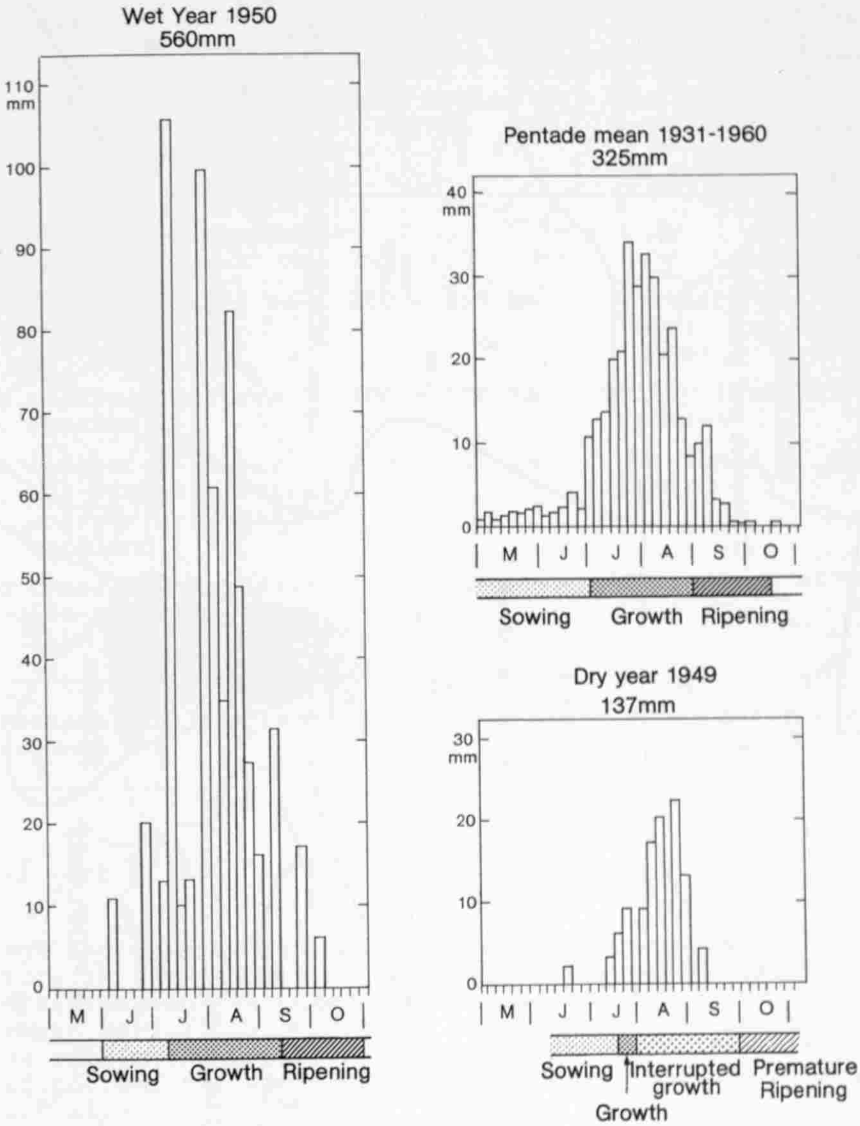
The extreme years of 1949 and 1950 give a picture of the actual distribution of precipitation. The year 1949 was a culmination of a dry phase, which lasted for three years. As the precipitation fell relatively concentrated, millet could grow up to the end of August. After that, practically no rainfall occurred. Millet ripened prematurely and consequently the yields were very low. In 1950, precipitation took a torrential form. Two pentades had about 100 mm each. On account of the degradation of vegetation during the preceding dry years, surface run-off was enhanced so that flash-floods and soil erosion occurred and caused the loss of already sown seeds.

3.2 The Natural Vegetation and its Degradation Forms

Attempt is made here to give a geographical zonation of the vegetation of northern Darfur and its deformation through the impact of man. The degradation forms resulting from overcultivation, overgrazing and clearing of woodlands change the natural vegetation to such an extent that a zonation of natural plant associations is rendered entirely questionable. The main reference for vegetation zonation in the Sudan is work done by JACKSON and HARRISON (1956). Their vegetation survey, however, was carried out thirty years ago. In the meantime, man has strongly reduced the tree-stock of the savanna during a long phase of enhanced desertification. For instance, *Acacia senegal* is now hardly represented in the zone of the *Acacia-senegal* savanna in northern Darfur. More represented there are *Balanites aegyptiaca, Boscia senegalensis, Guiera senegalensis, Sclerocaryea birrea, Acacia raddiana, Commifora africana* and *Acacia mellifera*.

The vegetation zonation of northern Darfur, which is used here (Figure 17) depends on the classifications of JACKSON and HARRISON (1956), LEBON (1965), BARBOUR (1961 a) and IBRAHIM (1980 a

Fig.16
Variability of precipitation and millet cultivation in northern Darfur
(Kutum, 1160m, 14° 21'N, 24°40'E)



Source: IBRAHIM, MENSCHING, 1977

Fig.17 Northern Darfur: Vegetation and carrying capacity in livestock units/km^2 (figures)

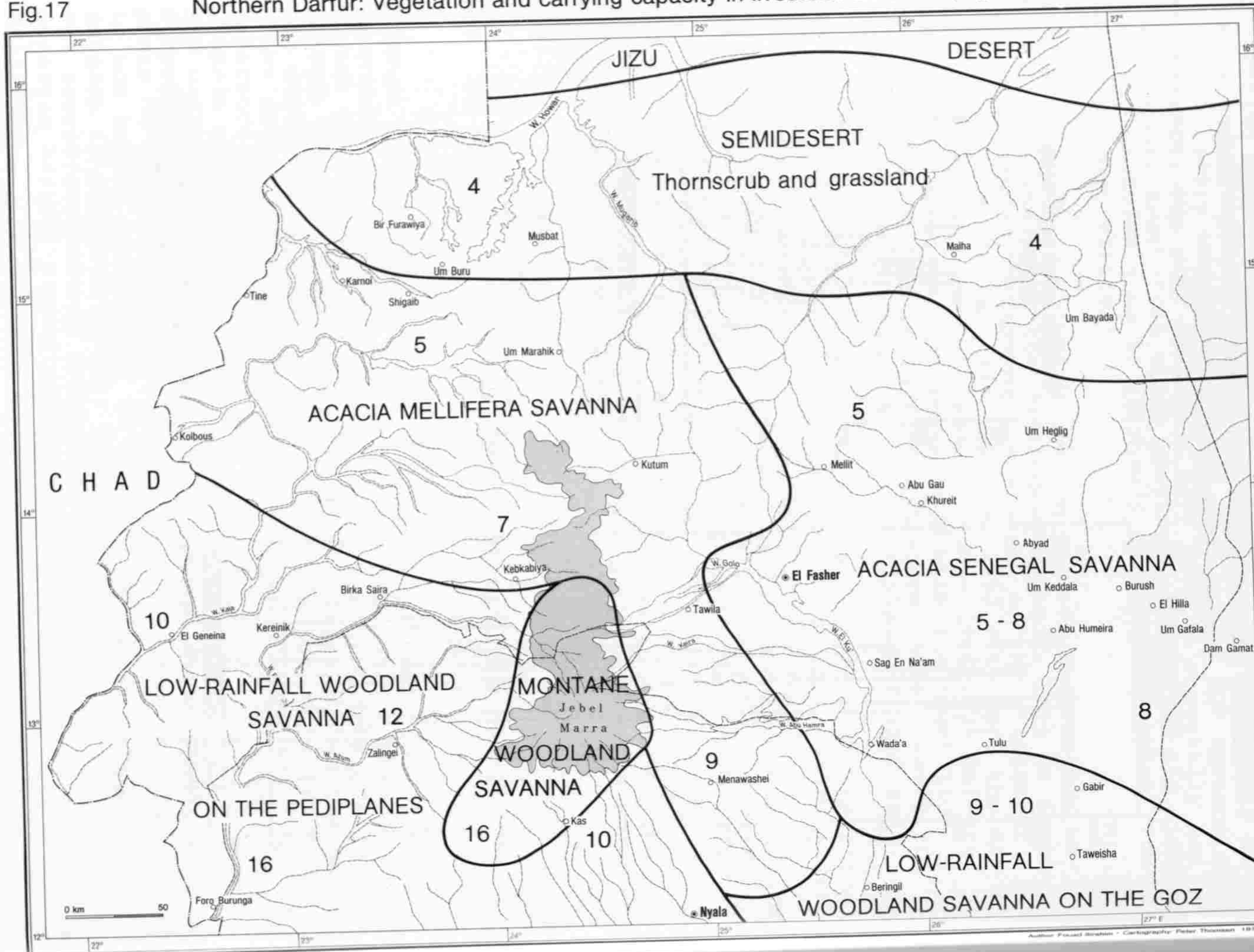


Table 13: Vegetation zones in northern Darfur

Vegetation zone	Precipitation	Area
1 Desert	Less than 80 mm	North of Wadi Howar
2 Semidesert (patch-like thorn-scrub and grassland)	80 - 200 mm	Dar Meidob and northern Dar Zaghawa
3 Low-rainfall woodland-savanna		
a *Acacia-senegal* savanna	200 - 450 mm	Northern Goz sands Berti and Zeyadiya lands)
b *Acacia-mellifera* savanna	200 - 500 mm	Hilly lands of Dar Zaghawa
c *Combretum-Dalbergia-Albizzia-Sericocephala*-savanna-woodland	450 - 650 mm	Goz-sands of eastern Darfur
d *Combretum-Anogeissus*-savanna-woodland	500 - 700 mm	Pediplanes of western Darfur
4 Montane and woodland-savanna	600 - 1000 mm	Jebel Marra massif

3.2.1 The Desert

Though the desert occupies about half of the area of northern Darfur, it is not treated here in detail, because logically no desertification can take place in the desert, especially in northern Darfur where no oases exist. Nevertheless, two areas lying within the desert of northern Darfur are prone to desertification: the vast basin of Wadi Howar and the Jizu area around it.

The Basin of Wadi Howar

Wadi Howar possesses relatively rich flora and fauna. During our survey in October 1976, we could observe some herds of gazelles and ostriches, which are being constantly hunted by the natives there. For hunting, the pastoralists use the *safrug*, a bumerang-like weapon, while soldiers and civil servants use guns. One officer pointed out the horns of a *Tragelaphus Strepsiceros* which he had shot in Wadi Howar (north of Musbat) in the dry year of 1973.

On the partly sandy, partly loamy soils of the Wadi Howar basin is open woodland savanna. Our survey of October 1976 (Figure 18) showed cushion-plants (Arab. *abu rihān*) as ground vegetation, because that year was particularly dry and for that reason, too, we did not encounter pastoralists there. Wadi Howar, which extends for more than 700 km in a SW - NE direction, plays an important role for camel pastoralists. Moreover, for the centuries-old caravan trade, Wadi Howar formed an important stage of the *darb el arbain* (route of the forty days) reaching from Chad to Egypt.

The Jizu Area

Besides Wadi Howar, the Jizu area is a second region with grazing potential within the Darfur desert. The Jizu land extends from the Teiga Plateau to the NW, beyond Wadi Howar far into Chad. As the Jizu herbs and grasses are juicy and belong partly to the succulent species, the animals require no drinking-water. Camel pastoralists from Kordofan and Darfur (Kababīsh, Kawahla, Zeyadiya, Meidōb, Zaghawa, Bedayāt and Rezeigāt) flock into the Jizu belt from October onwards. The Jizu plants grow in the cool season, after the wet season has come to an end, provided that rainfall has brought some moisture. In especially wet years, nomads are able to stay here up till the end of March. With the start of the hot season in April, vegetation becomes drier and sparser, so that the water requirements of the animals increase considerably. Then, nomads embark on their journey to the southwest availing themselves of the wells and water reservoirs in Dar Zaghawa as well as the water pumping stations in Dar Meidob. On the journey to and from the Jizu area, Wadi Howar occupies a key position as a green belt within the Sahara. Its trees and scrubs form a good source for browsing for camels.

The duration of the grazing season in Wadi Howar depends on the amount of precipitation. In dry years, pastoralists remain in the south. According to the information gathered from nomads, Jizu does not grow in the same area every year, but rather "shifts" from year to year; it is said to grow in the same area every fifth year. Despite the inaccuracy which may be entailed in this information, it points clearly to the high variability of precipitation both in time and space.

The following list (Table 14) contains the names of the most important Jizu plants, compiled according to NEWBOLD (1924) and LEBON (1965):

Fig.18 Vegetation profile at the southern margin of Wadi Howar (15° 38′N,24° E)

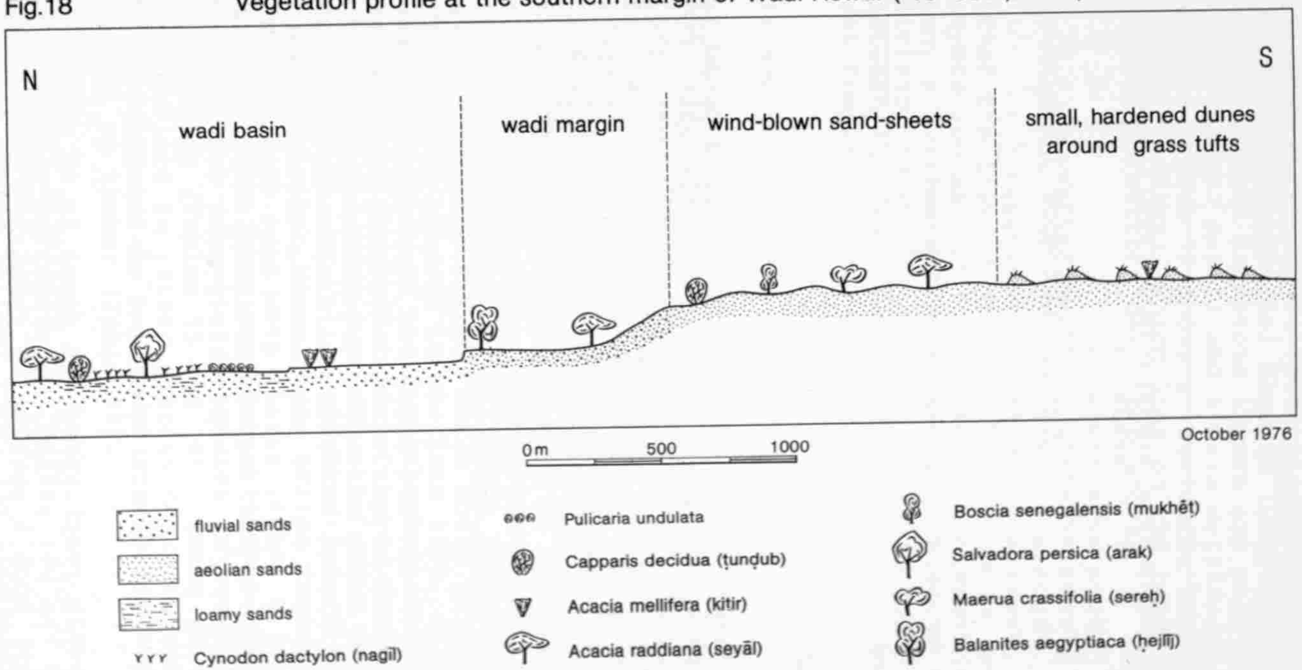


Table 14: Jizu plants

Species		Arabic name
Herbs:	*Indigofera brachteolata (Papilionaceae)*	*derma*
	" arenaria "	*kuschein*
	Crotolaria thebaica "	*natasch*
	Tribulus alatus (Zygophyllaceae)	*guttub*
	Fagonia cretica "	*'agūl*
	Neurada procumbens (Rosaceae)	*sa'adān*
Grasses:	*Triraphis pumilio*	*saleiyan*
	Aristida papposa (A. ciliata)	*nissa*

3.2.2. The Semi-Desert

The semi-desert of northern Darfur forms a broad zone which reaches its widest point of 150 km in the east. Owing to the increase of altitude up to 1000 m in the west, the semi-desert zone is considerably narrower there. The E - W contrast is also underlined by the pedological differences. In the east, predominate the deep Goz sands, in the west the shallower skeletic soils on the crystalline Precambrian Basement Complex.

3.2.2.1 The *Acacia-mellifera* Thornscrub Zone

On the shallow skeletic soils of the northwest prevails *Acacia mellifera* (Arab. *kitir*), which becomes denser in the drainage lines of the pediplains. Grass patches are limited to the aeolian or fluvial sand sheets. In the large wadis, which occur in great numbers in the west, *Acacia albida* (Arab. *harāz*) and *Acacia arabica* (Arab. *garad*) grow more densely, as in the case of Wadi Haraz in Dar Zaghawa and Wadi Garad north of the Berti land.

3.2.2.2 The Semi-Desert Grassland on the Goz

On the largely reactivated Goz dunes in NE Darfur grow short grasses in the wet season, interspersed by single trees (mostly acacias). Such a vegetation formation is still to be found nearly intact in areas of insufficient drinking-water supply (i.e. low human and animal pressure), such as the area of the Um Bayada depression (about 15°N, 27°E) and east of it. The grasses occurring there are mostly *Aristida* species (Arab. *gau*), especially *Aristida plumosa* (Arab. *bayād*). In more intensely grazed areas large patches of *Cenchrus biflorus* (Arab. *ḥaskanīt*, in West Africa: *Cram Cram*) occur. There, tree species are similar to those of the *Acacia-senegal* savanna (Chapter 3.2.3.1). In areas where the Nubian Sandstone layers are near the surface *Commifora africana* (Arab. *gafal*) and *Acacia mellifera* (Arab. *kitir*) predominate. Figure 19 shows a vegetation survey in Wadi Haraz (*Acacia-albida* valley) which lies on the borders between the two semi-desert formations described above.

3.2.3 The Low-Rainfall Woodland-Savanna

The broad belt of the low-rainfall woodland-savanna extends between the isohyets 200 mm and 700 mm. Owing to this wide precipitation span, a further zoning in N-S direction is essential. Another E-W division is conditioned by the morpho-pedological differences between the lower sandy Goz in the east and the higher Basement Complex in the west.

3.2.3.1 *Acacia-senegal* Savanna

This zone extends from the Nile in the east to El Fasher in the west, occupying a belt almost 300 km wide (12°30'N - 15°N). The characteristic tree species there is *Acacia senegal* (Arab. *hashāb*), which is much more strongly represented in Kordofan than in Darfur, a fact which also becomes obvious from the trade figures of gum arabic. In the period 1969 - 1972, thirty times as much gum arabic was sold on the markets of northern Kordofan than on those of northern Darfur (SUDAN GOVERNMENT: International Trade Statistics. Khartoum 1972). The last stocks of *Acacia senegal* occurring on the Goz soils south of Mellit and south of El Fasher were cleared in the late 1970. An attenuation of the *Acacia-senegal* stock is not being practised in Darfur as it is done in Kordofan. The trees can be tapped for gum arabic from the age of five years on, but after ten years production declines rapidly. An economic utilization of *Acacia senegal* requires, therefore, constant attenuation of the tree stock.

Vegetation survey at two locations within the *Acacia-senegal* savanna shows that that name-giving species is scarcely represented in its own zone (Tables 15 and 16) . Owing to the fact that both locations are in rather over-used areas, most of the species which occur there are both unpalatable and hardly useful either as fuel or timber (Table 15).

Though the two surveys displayed in Tables 15 and 16 do not show any *Baobab (Adansonia digitata*, Arab. *tabeldi*), this tree occurs singly or in groups in that zone. The inhabitants of Kordofan and eastern Darfur hollow out the thick stem and use it as a water reservoir. Both IBN BATTUTA in the 14th century and NACHTIGAL in the 19th century reported of this traditional system of water storage.

Fig.19 Vegetation profile in the area of Wadi Haraz, Dar Zaghawa

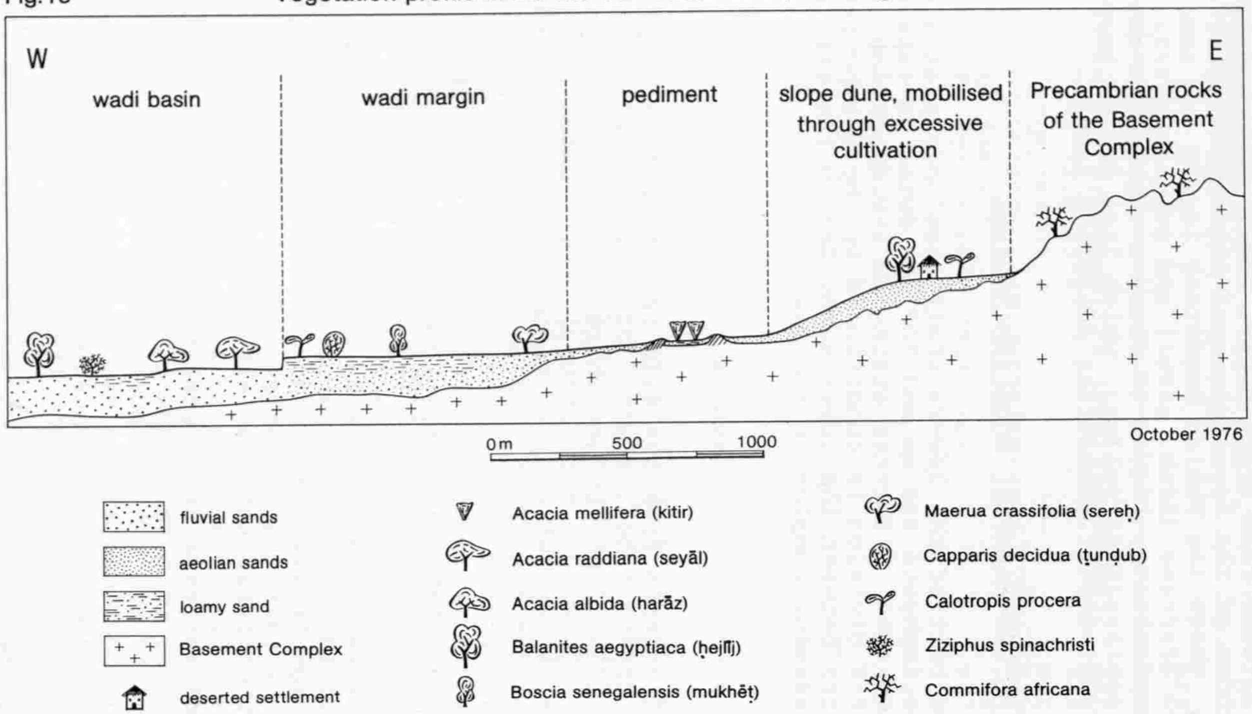


Table 15: Vegetation NW of El Geneina (535 mm) on uncultivated sandy soils (area 10,000 m²)

Species	Arabic name	Number of trees
Albizzia amara (*Albizzia sericocephala*)	*'arad*	22
Combretum cordofanum	*habīl*	20
Guiera senegalensis	*gobbēsh*	13
Boscia "	*mukhēt*	5
Sclerocaryea birrea	*hommēd*	3
	Total	63

Ground vegetation:

A low, thin cover of:

Eragrostis tremula

Cenchrus biflorus

Dactyloctenium aegyptium

among others

Table 16: Vegetation W of Um Keddada (260 mm) on uncultivated sandy soils (area 10,000 m²)

Species	Arabic name	Number of trees
Boscia senegalensis	*mukhēt*	11
Commifora africana	*gafal*	2 - 3
Maerua crassifolia	*sereḥ*	2 - 3
Acacia senegal (old)	*hashāb*	1
Dichrostachys glomerata	*kidād*	1
	Total	ca. 18

Ground vegetation:

Relatively low species of:

Aristida

Cenchrus biflorus

Blepharis

3.2.3.2 The *Acacia-mellifera* Savanna

This vegetation type prevails in the area of Dar Zaghawa and of the eastern pediments of Jebel Marra. Owing to the strong dissection of these areas, there is a constant alteration of species and density at short distances in accordance with the quickly changing morphopedological situation. While the mountain ridges, inselbergs and other rocky outcrops have *Commifora africana* as a characteristic tree, the pediments and pediplains are dominated by *Acacia mellifera, Acacia nubica* and *Acacia raddiana*. Similar to the *Brousse tigrée* on the ironstone in West Africa, the pediments of western Darfur appear striped on the air photos, because *Acacia mellifera* grows more densely on the fluvial deposits on the drainage lines. In the larger, subsequent wadis there is a greater variety of tree species: *Acacia albida, Acacia nilotica, Balanites aegyptiaca, Ziziphus spina christi* and *Capparis decidua*. On the aeolian and fluvial sand-sheets, which have accumulated between the mountain ridges, occur *Boscia senegalensis, Acacia senegal* and *Acacia raddiana*. The density is about 15 trees / ha. The ground vegetation is composed of *Aristida* species and of some herbs, such as *Cassia tora, Cassia occidentalis, Cassia acutifolia* and *Chrozophora brocchiana*.

Figure 20 shows a vegetation profile extending from Wadi Gellaba (E of Kutum) to the neighbouring mountain ridge in the east. Trees which have a higher water requirement grow in the wadi and on the wadi margin where they can avail themselves of the ground water. On the shallow and hard loamy soils grows *Acacia mellifera*.

3.2.3.3 *Combretum-Dalbergia-Albizzia-Sericocephala*-Savanna Woodland on the Goz Soils of East Darfur

This type of vegetation formation, according to the classification made by JACKSON and HARRISON (1956), is found in the study area in central eastern Darfur (Figure 17). The composition of the plant association shows a remarkable decrease of *Acacia* species with the increase of precipitation (450 - 650 mm). Table 17 shows the formation of the species of this zone according to LEBON (1965, p. 31).

A survey made by F. IBRAHIM in October 1981 on a sandy plain, 12 km NE of Babannusa, reveals the dominance of *Dalbergia melanoxylon* (ebony, Sud. Arab. *babannusa*, sing.) and two unpalatable tree species: *Guiera senegalensis* and *Albizzia sericocephala*. The frequency of these three species per 10,000 m² was 260,233 and 173 respectively. This is, however, in a thinly populated area used seasonally by nomadic pastoralists.

Fig.20 Vegetation profile across Wadi Gellaba, east of Kutum

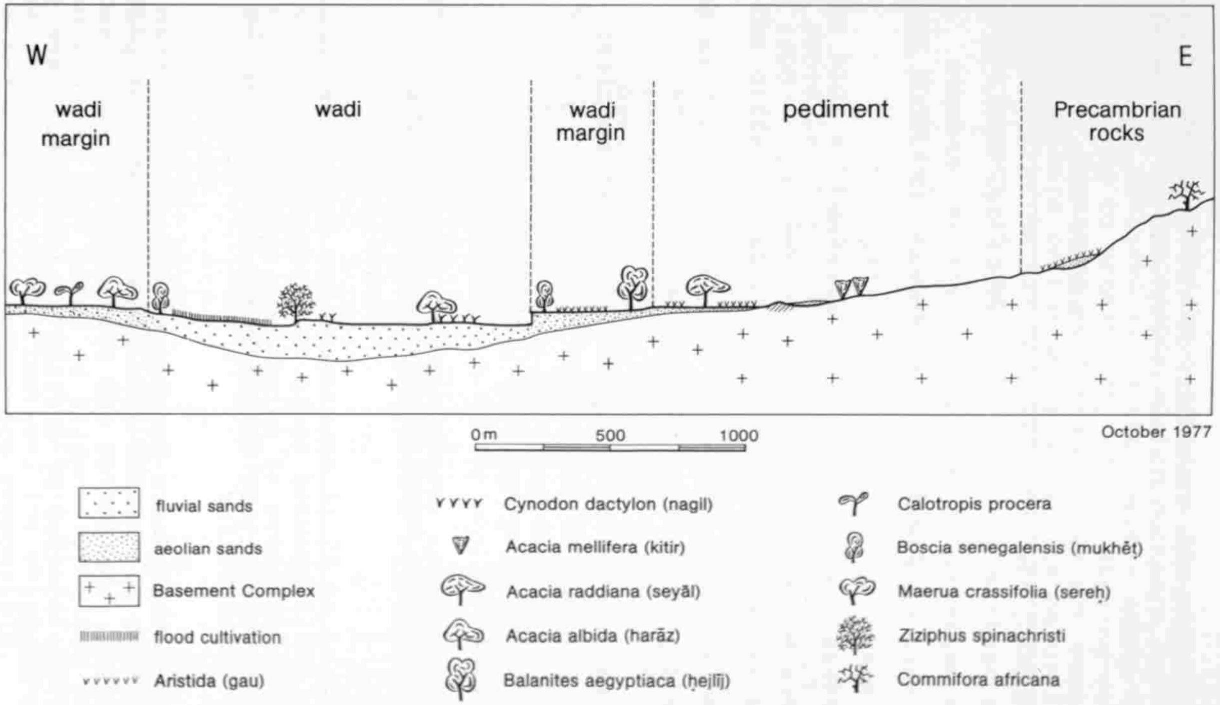


Table 17: Vegetation formation of the *Combretum-cordofanum-Dalbergia-Albizzia-sericocephala*-savanna woodland (LEBON 1965)

Species	Arabic name
Combretum cordofanum	*um dajog, habīl*
Dalbergia melanoxylon (ebony)	*babanus, ebenusa*
Albizzia sericocephala	*'araḍ*
" *amara*	*'araḍ*
Guiera senegalensis	*gobbēsh*
Sclerocarya birrea	*ḥommēḍ*
Commifora pedunculata	*lubān*
Lannea humilis	*leiyūn*
Adansonia digitata	*tebeldi*
The savanna grasses are composed of annual species:	
Aristida pallida	*gau*
Eragrostis tremula	*banu*
Cenchrus biflorus	*ḥaskanit*
In addition, there occur highly palatable herbs:	
Blepharis	*boġēl*

3.2.3.4 *Combretum-Anogeissus*-Savanna Woodland on the Pediplains of West Darfur

West of the Jebel Marra Complex extends the uplifted Basement Complex, which is divided into a great number of pediments, stoney ridges, inselbergs and rock outcrops, intersected by wadis. The pediments combine to build vast pediplains which are alternatively covered by shallow skeletic soils and fluvial sands and clays.

The characteristic trees of this region are *Combretum cordofanum (habīl)* and *Anogeissus leicarpus (sahāb)*. In the wadis, and on the deep and relatively moist soils, occur dense stocks of *Acacia albida (harāz)* and *Ziziphus spina christi (sidir)*. The green leaves and the nutritious pods of *Acacia albida* are particularly liked by browsing animals. A ripe tree produces ca. 135 kg pods annually. The fact that *Acacia albida* carries green leaves in the dry season and its pods ripen towards the end of that season, makes it often the only source of fodder for animal

It is worth mentioning that the conditions for vegetation on the western pediplains are favourable within northern Darfur. Degradation is not as advanced as on the eastern sandy Goz. The reason is that, owing to uncertainty of the dinking-water supply in the dry season, permanent settlemants have not been established in large numbers on the pediplains. The natural regeneration of the vegetation has been able to keep pace with the fairly moderate impact of pastoralists.

3.2.4 MONTANE WOODLAND-SAVANNA OF JEBEL MARRA

Owing to the high altitude of Jebel Marra, reaching a maximum of 3,088 m above lea level, and the resulting increase of precipitation (600 - 1000 mm), a zonation of vegetation can be observed at the different altitudes (LEBON 1965, pp 35 and 91):

Up to 1,800 m: *Cordia abyssinica (gambīl)* and *Ficus*. Extensive sheets of high grasses, especially *Cymbopogon (maḥrēb)*. In the dry season, great savanna fires occur frequently.

1,800 m - 2,300 m: Decrease in the number of trees and dominance of grass species: *Cymbopogon, Adropogon linearis, Themeda triandry*. *Olea laperrini* occurs frequently.

Above 2,300 m: Dwarf shrubs of *Hyparrhenia species* as well as *Blaeria spicata*, associated with *Lavandula stricta*.

Afforestation is limited and amounts to 31,77 ha in the districts of Nyala and Zalingei. In areas between 1,400 m and 2,500 m altitude *Cupressus lusitanica* is preferred for afforestation, while in the piedmont region *Eucalyptus* is planted most frequently.

3.2.5 AZONAL VEGETATION CLASSIFICATION

Like other desert marginal areas, northern Darfur reveals a clear azonal vegetation classification, for which the varying topographic and edaphic conditions are responsible.

3.2.5.1 The Wadi Vegetation

Here there is higher frequency of *Acacia albida, Ziziphus* species, *Balanites aegyptiaca, Capparis decidua, Acacia nilotica* and *Acacia mellifera*. A survey of the wadi vegetation in northern Darfur (300 mm precipitation) is shown in Table 18 .

Table 18: Wadi vegetation between Kutum and Mellit in northern Darfur (ca. 300 mm precipitation)

Species	Arabic name	Number per 10,000 m²
Balanites aegyptiaca	*ḥejlīj*	11
Ziziphus spina christi	*nabag*	7
Boscia senegalensis	*mukhēṭ*	5
Capparis decidua	*tunduḅ*	4
Acacia albida	*ḥarāz*	4
" *raddiana*	*seiyāl*	3
" *mellifera*	*kitir*	3
" *arabica*	*garad*	1
Maerua crassifolia	*sereḥ*	1
	Total	39

On higher locations within the wadi bed, the following ground vegetation was found:

Cynodon dactylon	*abu nagīle*
Dactyloctenium aegyptium	*abu asabi'*
Cassia occidentalis	*kaual*

3.2.5.2 The Goz Vegetation

The fixed old-dune belt (Goz) is the main millet cultivation zone of northern Darfur. Through excessive cultivation the Goz has become the area most stricken by desertification. The tree stock, especially that of *Acacia senegal* and *Maerua crassifolia*, has been largely depleted. A dramatic disappearance of tree species has been observed in the last five years only in Goz Shagra, between El Fasher and Abu Zureiga, after the settlement of the Zaghawa cultivators in that area.

3.2.5.3 The Pediment Vegetation

On the mountain pediments, where merely a thin sediment veil covers the stoney bedrock, grow stocks of shallow-rooted scrubs, mainly *Acacia mellifera* and *Acacia nubica*. Owing to the occurrence of these scrubs in drainage lines they often take the form of "*Brousse tigrée*" known from the laterite vegetation in West Africa.

3.2.5.4 The Mountain Vegetation

Except for Jebel Marra (see above), the vegetation of the mountain ridges, inselbergs, plateaux and outlayers carry a scattered tree population with a predominance of *Commifora* species *(gfal)*. In the vicinity of settlements such mountainous areas are usually stripped of their vegetation and trees are felled for fuel or timber.

3.2.6 USED PLANTS IN NORTHERN DARFUR

In the questionnaire carried out by F. IBRAHIM in Darfur in 1976 - 1977, four questions were put regarding the plant species which are used for fodder, for fuel and for timber. The names of the species were arranged in order according to the frequency in which they were mentioned in the answers. Besides the information on usage, the lists gave a picture of the actual tree composition in the region according to the frequency of their occurrence. For instance, Table 19 shows that *Dalbergia melanoxylon* (ebony) is seldom used in northern Darfur, though it is considered to be the best timber for erecting huts as it is not eaten by termites. The reason for this paradox is that *Dalbergia melanoxylon* occurs seldom in northern Darfur, because it needs higher precipitation. In Tables 20 and 21, the regional differentiation is due to edaphic and climatic variations.

Table 19: Varying degrees of utilization of different tree species in northern Darfur (very often - +++, often - ++, sometimes - +, seldom - -)

Species	Utilization as Timber	Fuel	Fodder
Acacia mellifera (kitir)	+++	+++	++
" *senegal (hashāb)*	+++	++	++
" *raddiana (seiyāl)*	++	++	+
" *arabica (garad)*	++	+	-
" *albida (ḥarāz)*	-	-	+
" *nubica (la'ōt)*	(not mentioned)	-	-
" *seyal (talḥ)*	-	-	-
Ziziphus species *(sidr, nabag)*	+++	+	++
Balanites aegyptiaca (ḥejlij)	++	++	++
Capparis decidua (ṭunḍub)	++	+	+
Guiera senegalensis (ğobbēsh)	++	+	-

Species	Utilization as Timber	Utilization as Fuel	Utilization as Fodder
Albizzia sericocephala ('arad)	–	–	–
Anogeissus schimperi (sahāb)	–	–	–
Boscia senegalensis (mukhēt)	–	–	–
Combretum cordofanum (habīl)	–	–	–
Commifora africana (gafal)	–	–	–
Cordia gharaf (inḍrāb)	+	–	–
Dalbergia melanoxylon (babanūs)	–	–	–
Dichrostachys glomerata (kidād)	–	–	–
Lannea humilis (leiyūn)	+	–	–
Maerua crassifolia (sereḥ)	–		–
Sclerocaryea birrea (hommēd)	–	–	–

Table 20: Tree species in northern Darfur - frequency of utilization for fodder, fuel and timber (all figures in %)

	Acacia mellifera	*Acacia senegal*	*Ziziphus*	*Balanites aegyptiaca*	*Acacia raddiana*	*Capparis decidua*	*Acacia arabica*	*Guiera senegalensis*	Other species
Northern and western regions (mainly pediment areas)	29.0	7.0	12.0	6.5	6.0	2.5	6.0	0.8	30.2
Southern and eastern regions (Goz areas)	20.0	12.0	10.0	9.0	6.5	8.0	4.0	6.6	23.9
Northern Darfur as a whole	23.5	10.0	11.0	8.0	6.3	6.0	5.0	4.5	25.7

Photo 9: In the Sahel, tree stocks become denser in valleys and depressions. *Acacia nilotica* in a wadi near El Fasher (290 mm precipitation), surrounded by Goz dunes, indicates high soil moisture.
August 1976

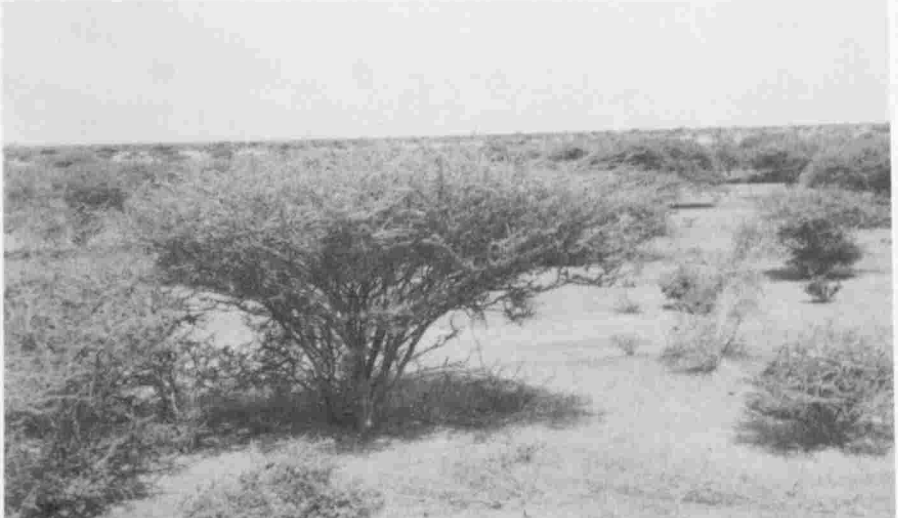


Photo 10: A typical thorn-scrub savanna in NE Kordofan (250 mm precipitation). *Acacia tortilis*.
August 1982

Photo 11: *Acacia-senegal* savanna with a low cover of *Aristida* species.
S of Malha, Darfur (200 mm precipitation). Sept. 1976

Photo 12: *Combretum-Albizzia* savanna in western Darfur.
El Geneina area (500 mm precipitation). Oct. 1977

Photo 13: *Anogeissus-schimperi* savanna in western Darfur (600 mm precipitation). The tree crowns show the effects of branch-cutting for feeding livestock. Oct. 1977

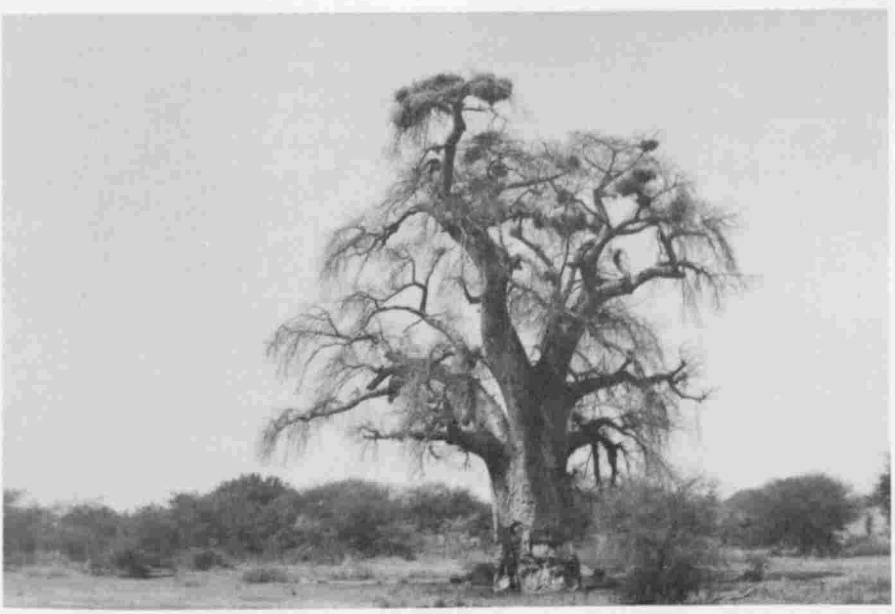


Photo 14: *Adansonia-digitata-Acacia-mellifera* savanna on the pediplains of central Darfur (400 mm precipitation). Dry season 1981

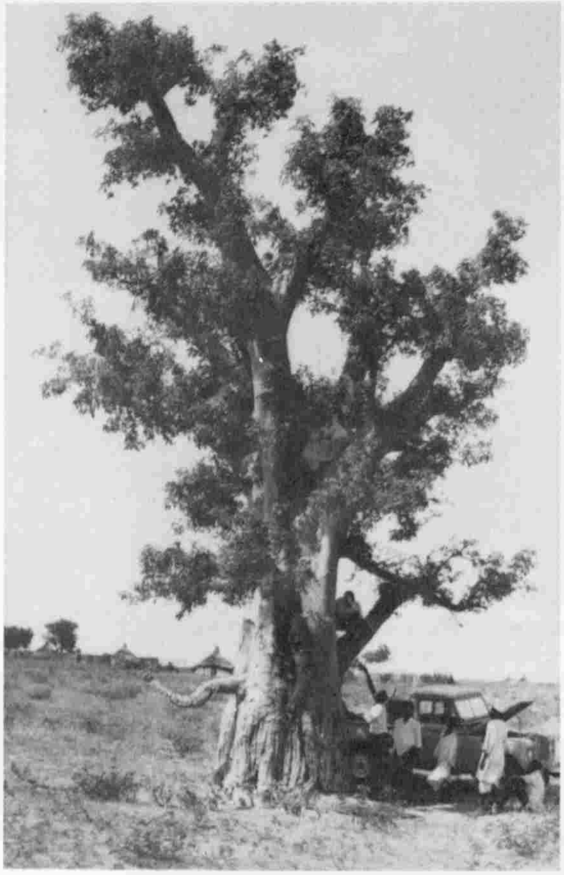


Photo 15:
In areas lacking in available ground-water *Adansonia digitata* stems are hollowed and used as water reservoirs.
El Shagg, S of Um Keddada, eastern Darfur (270 mm precipitation). Sept. 1976

Photo 16:
Acacia albida grows well in the valleys of northern Darfur, where it has access to ground water.
Bir Furawiya (200 mm precipitation) Oct. 1976

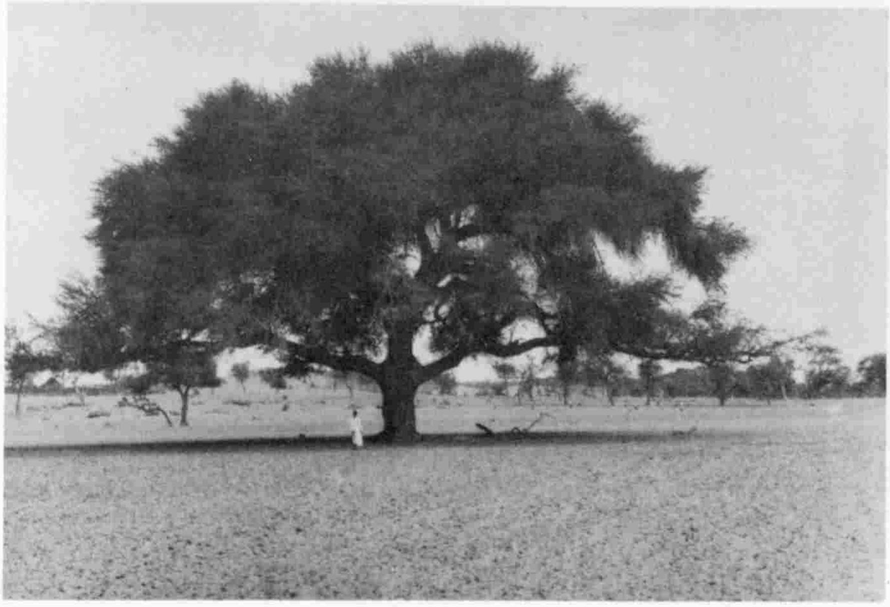


Photo 17: *Aristida* savanna in Sayah, northern Darfur (200 mm precipitation).
Sept. 1977

Photo 18: On moist sites within the thorn-scrub savanna *Cymbopogon* grasses grow densely.
E of El Fasher (280 mm precipitation). Sept. 1976

Table 21: Composition of palatable grasses and herbs in northern Darfur (all figures in %)

	Cenchrus biflorus	*Aristida plumosa*	*Aristida pubifolia*	Other *Aristida* species	*Echinochloa colonom*	*Eragrostis tremula*	*Tephrosia terrestris*	Other species
Northern and western regions (mainly pediment areas)	19.1	14.0	10.4	7.5	8.5	4.7	7.5	28.4
Southern and eastern regions (Goz areas)	24.0	9.6	3.4	15.4	12.0	13.0	4.8	17.8
Northern Darfur as a whole	22.5	6.3	5.7	12.7	10.8	10.2	5.7	26.1

3.3 The Soils (Figure 21)

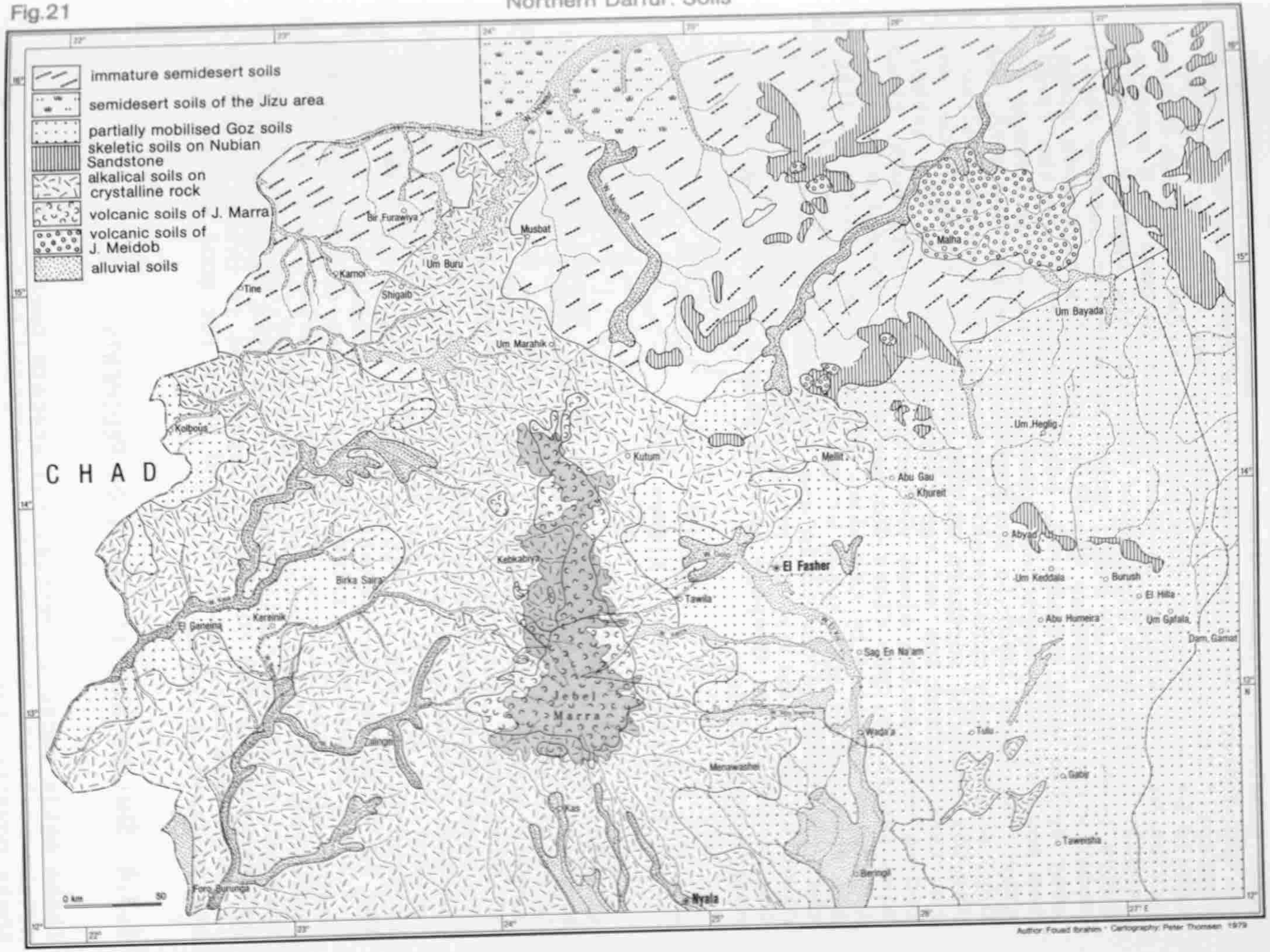
3.3.1 The Semi-Desert Soils

According to LEBON (1965, p. 45) semi-desert soils lie between 14°30'N and 16°N. They are generally immature and vary strongly according to the topography and the mineralogical composition of the substrata. The sandy soils of Wadi Howar, for instance, are much more favourable for vegetation growth than the stoney areas of northern Dar Zaghawa.

3.3.2 The Goz Soils

The Goz soils form a whole zone on the fixed old-dune belt which extends from central Darfur to the Nile. The examined soil samples (IBRAHIM, 1980 a) show that the pH-figure is under 5.5 and that the proportion of organic matter in the Goz soils is very low: the nitrogen content is lower than 500 ppm. In 20 cm depth, the carbon content decreases rapidly from 0.1 % to 0.05 % . L. OLSSON (1983), however, comes to a different conclusion from IBRAHIM (1980 a) in this respect:" ... further

Fig.21 Northern Darfur: Soils



Author: Fouad Ibrahim · Cartography: Peter Thomsen 1979 soil erosion will not affect the carbon available for vegetation as the content 30 cm below surface is almost the same as at the surface." It is astonishing that the Goz soils in Kordofan should be so different from those of Darfur. Further investigation of this subject is needed so as to come to a conclusive result. In the soil profile of the Goz, the upper 3 cm form a loose cover of yellow sand, which is somewhat coarser than the underlying sand because the finer particles have been blown away by the wind (Figure 3). Sometimes, one finds the 10-20 cm top soil slightly enriched with organic matter and hence rather grey. The lower layer is the typical brown-red Goz sand. When dry, Goz sand is considerably hard. The grain-size analyses of the Goz soils of northern Darfur reveal two kinds of Goz soils: the fine-grained Goz and the coarse-grained one. The latter occurs often in the close vicinity of its origin rock, the Nubian Sandstone. The finer Goz has usually covered a longer transport distance by the wind. Figure 22 and Table 22 display the spectrum of both types of Goz soil.It is important to note that fine-grained Goz soils are favourable for vegetation because of their ability to retain moisture for a long time in the root horizon; seepage is much slower than in the coarse-grained Goz soils.

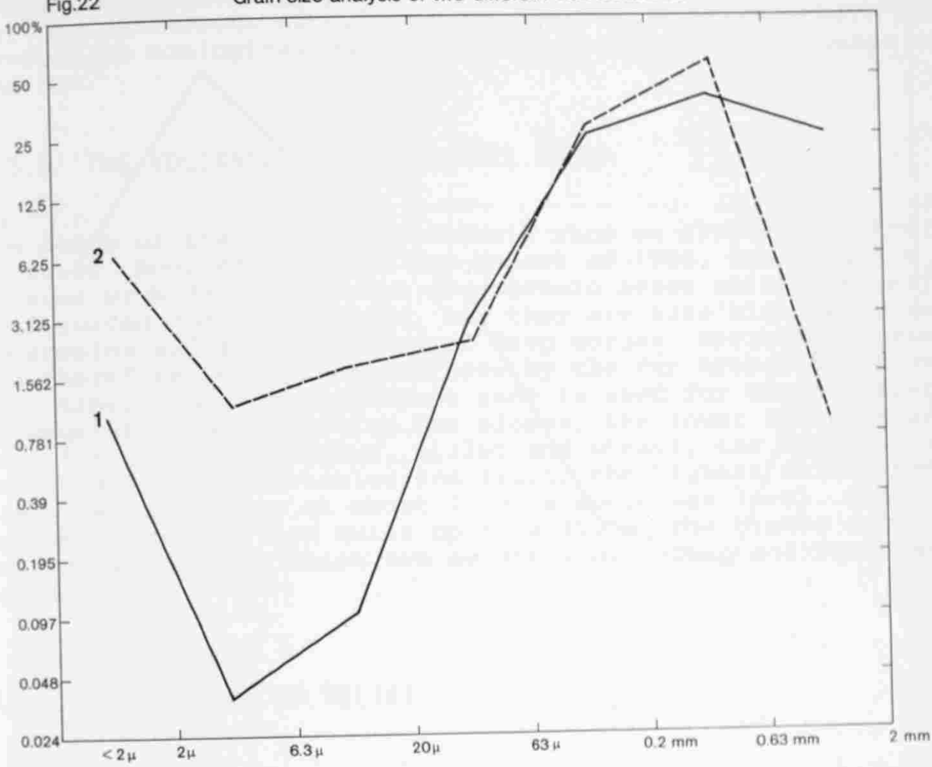
3.3.3 Alluvial Soils (Figure 23)

Alluvial soils occur in the wadi basins. Especially fertile soils are those covering the beds of the wadis springing from Jebel Marra, e.g. Wadi El Ku', Wadi Kaja and Wadi Azum, as they contain part of the volcanic ashes washed out from the slopes of Jebel Marra. The grain-size analyses of the wadis of northern Darfur show a broad differentiation according to the respective catchment area. For instance, the clay content varies between 7 % and 36 %. In the Um-Bayada depression, the clay content is merely 0.5 %, while that of coarse silt (0.02 - 0.063 mm) is 89 %. The electrometric pH-measurement gave 8.5 H_2O and 6.4 KCL (IBRAHIM 1980 a). This soil is non-cracking and has a favourable water balance. The proposed agricultural project has, therefore, promising natural preconditions. Less promising, however, is the economic prospect: the area is infrastructurally inaccessible and the native population is thinly scattered. It can, therefore, build no sound basis for good marketing of agricultural products.

3.3.4 Shallow Skeletic Soils on Pediments

These soils occur in central and western Darfur. They are immature soils which are constantly exposed to erosion. Despite their poverty, they carry a more intact vegetation cover than the soils of the Goz which have been degraded by the strong human and animal impact. The pediments are, therefore, in a

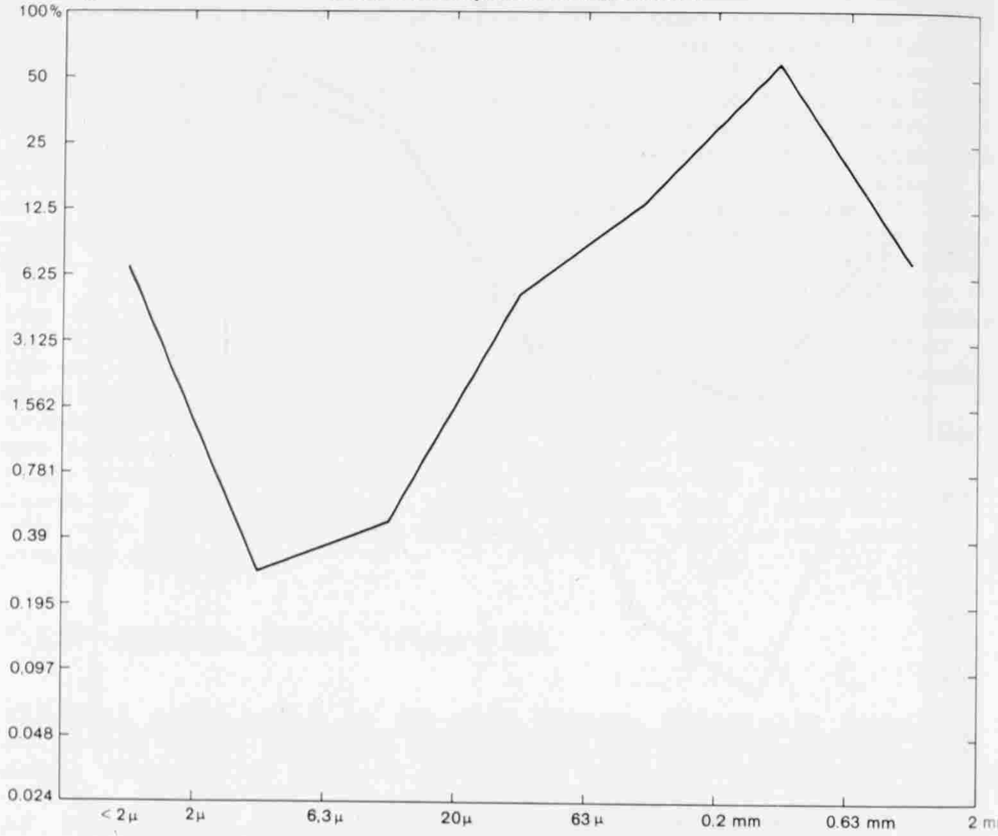
Fig.22 Grain-size analysis of two different Goz sediments



Tab.22: Grain-size analysis of two different Goz sediments

	0.63-2mm	0.2-0.63mm	0.063-0.2mm	20-63μ	6.3-20μ	2-6.3μ	< 2μ
1 Coarse Goz	26.4 %	44.3 %	25.4 %	2.9 %	0.1 %	0.04 %	0.9 %
2 Fine Goz	0.9 %	58.8 %	27.3 %	2.4 %	1.8 %	1 %	7.8 %

Fig.23 Grain-size analysis of wadi sediments



Tab.23: Grain-size analysis of wadi sediments (13 km south of Mellit)

0.63-2mm	0.2-0.63mm	0.063-0.2mm	20-63μ	6.3-20μ	2-6.3μ	< 2μ
8 %	62.9 %	15.7 %	5.2 %	0.5 %	0.3 %	7.4 %

favourable ecological position, because they are less inviting for the settlement of cultivators. So, one can speak here of a reverse of ecological qualities, effected by anthropogenic selection.

3.3.5 The Volcanic Soils of Jebel Marra

The soils of the Jebel Marra massif show an altitude-controlled zonation. According to the FAO Report of 1968, the piedmont is covered with deep sediments of volcanic ashes which are very well suited for cultivation, but they are also highly inclined to erosion and the formation of deep gorges. Terraced farming has therefore been practised here by the Fur tribes for a very long time. Today, the piedmont zone is used for the cultivation of vegetables and fruit on the slopes, the lower terraces are used for cereals (sorghum, millet and wheat), the higher, steeper terraces for vegetables and fruit, the highest cultivated areas (wheat) being at about 2,700 m above sea level. Generally, however, terraces are built up to 2,300 m. The higher zone is covered with tuffs which are severely dissected and form vast badlands.

3.4 The Dynamics of Relief

Relief dynamics are involved in the desertification processes and they provide fairly certain indicators for desertification monitoring. Reference is made here to Chapter 2.2.1.4. Ecological deterioration enhances already existing morphological processes. These include physical soil changes, fluvial and aeolian erosion, transport and accumulation of soils. Such morphodynamic changes often result in hydrological alterations which bear negative consequences for land productivity. The following set of processes are morphodynamic activities triggered off by ecological degradation in northern Darfur. They underlie the same principles explained in Chapter 2.2.1.4:

- The reactivation of the Goz belt
  (Figure 3, Table 3)

- Deflation of top soil
  (Figure 3, Table 3, Figure 4)

- Recent aeolian accumulation as an indicator of desertification processes
  (Figures 28 and 29)

- Slope accumulation

- Accumulation in wind passes
- Accumulation of wind-blown sand-sheets (Figures 28 and 29)
- Formation of *Ziziphus* and *Capparis* dunes (Figure 5, Table 4)
- Sand encroachment onto buildings and fields (Figures 28 and 29)
- Fluvial soil erosion
- Alteration of drainage direction

4. Human Ecology and Desertification in Northern Darfur

Anthropogenic factors are of great relevance to both the causes and the consequences of desertification in northern Darfur. Man triggers off a chain of environmental processes and is ultimately stricken by the ensuing damage. Due to the complex nature of the feed-back mechanism, it becomes difficult to differentiate between causes and effects. In this chapter, the human activities which are closely connected with desertification are studied in more detail with the aim of highlighting the intricate web of interactions between the causes and consequences of this phenomenon.

Data on the population of northern Darfur and the socio-economic conditions prevailing there have been obtained mainly from the results of questionnaires carried out in the area. Thus, 354 households from 206 settlements in the different districts of the province have been investigated. Table 24 shows the regional distribution of the respondents.

Table 24: Distribution of respondents to questionnaire

Region	Settlements	Households
El Fasher area	64	88
N. W. Bertiland	26	53
Gozland in E. Darfur	28	55
Western Darfur	15	17
Jebel Marra	15	29
Dar Zaghawa	49	96
Dar Meidob	9	16
Total	206	354

4.1 Population Structure and Population Development

Despite a low population density of 3.5 inhabitants/km^2 on average northern Darfur may be considered overpopulated. Two reasons can be given for this. On the one hand, the carrying capacity of the land is low, and on the other hand, the population is concentrated on settlements with a permanent water supply. For example, population density in the area of El Fasher (an area of less than 300 mm annual precipitation) amounts to more than 100 inhabitants/km^2. However, desert and semidesert regions in the north are almost uninhabited. The greatest part of the population is concentrated on two main areas, that of El Fasher and that of El Geneina. These two districts embrace almost 70 % of the inhabitants of northern Darfur.

In 1903, the population of Northern Darfur Province was estimated at 130,000, in 1945 at 310,000. The first, and so far most reliable, population census of 1955-1956 recorded 727,929 in Northern Darfur; i.e. 7 % of the total Sudanese population of 10,262,536. According to the second population census of 1973, Northern Darfur had 903,888 inhabitants (cf. Fig. 24). Despite the inaccuracy of these figures, one can estimate the population today (1984) at 1.3 million, which means a tenfold increase since the beginning of the century. At the same time, the agro-ecopotential has been deteriorating through overuse.

4.1.1 Population Structure

Figure 25 shows clearly that the population of Darfur is young: 45.6 % are under 15. The asymmetrical structure of the proportions of males and females in the age group 20-29 years is due to the high migration rate of young men who move from the economically weak region in search of a living in the conurbation Khartoum, the irrigation schemes in the Nile basin or the large mechanized farms in Kassala and Gedaref, while women and children remain at home. For this reason the male population in Darfur (45.8 %) was notably less than the female population in 1973.

In 1973 the majority of the population (74.3 %) were sedentary rural, 15 % were nomadic and 10.7 % urban. Table 25 and Fig. 26 display the classification of the population according to district and mode of living (rural, nomadic, urban).

Table 25: Structure of population of Northern Darfur Province in 1973

District	Urban	Rural	Nomadic	Total	Proportion: District/Prov.
El Fasher	51,932	141,134	13,469	206,535	
	25.2 %	68.3 %	6.5 %	100 %	22.8 %
Northern District	4,762	173,480	50,447	228,689	
	2.1 %	75.9 %	22.0 %	100 %	25.3 %

District	Urban	Rural	Nomadic	Total	Proportion: District/Prov.
Dar Masalit	35,424 9.2 %	278,304 72.1 %	72,228 18.7 %	385,956 100 %	42.7 %
Eastern District	4,693 5.7 %	78,015 94.3 %	- 0 %	82,708 100 %	9.2 %
Total	96,811 10.7 %	670,933 74.23 %	136,144 15.07 %	903,888 100 %	100.0 %

The table indicates some important features:

- The highest rate of urbanisation (25.2 %) occurs in the El Fasher District. The province capital, El Fasher, had 52,000 inhabitants in 1973: today it probably has more than 100,000. The second urban centre in the province is El Geneina, on the borders of Chad, whose population today amounts to that of El Fasher, though it had only 35,400 inhabitants in 1973. An estimated number of 15,000 refugees from Chad have come into the town in the last 2 years. Probably, the number of refugees is even higher, but it is difficult to identify refugees who belong to the same tribes living inside the Sudanese territory (e.g., the Masalit).
- The greatest part of the inhabitants of eastern Darfur (94.3 %) is sedentary rural. The reason is that people, there, live on millet cultivation on the wide-spread sandy soils of the Goz.
- The highest proportion of nomads (22 %) is found in the Northern District. The reason is that rain-fed farming alone cannot guarantee a livelihood in deserts and semideserts.
- The relatively high proportion of nomads (18.7 %) in the Western District of Dar Masalit is due to the favourable grazing resources of the woodlands on the pediplanes on the Basement Complex. Yet, browsers (camels and goats) are compelled to move southwards in the dry season, because of the poverty of water resources on the impermeable crystalline rock.

4.1.2 The Ethnic Structure

The population of northern Darfur is composed of numerous ethnic groups and sub-groups, each possessing its tribal area (dar). The towns and large settlements are inhabited by several tribes, but they usually live in separate quarters. Only in the two big towns, El Fasher and El Geneina, are the tribes beginning to mix. However, the quarters are still called after the major tribes living there.

Fig.24 Population develoment in northern Darfur, 1903-1977

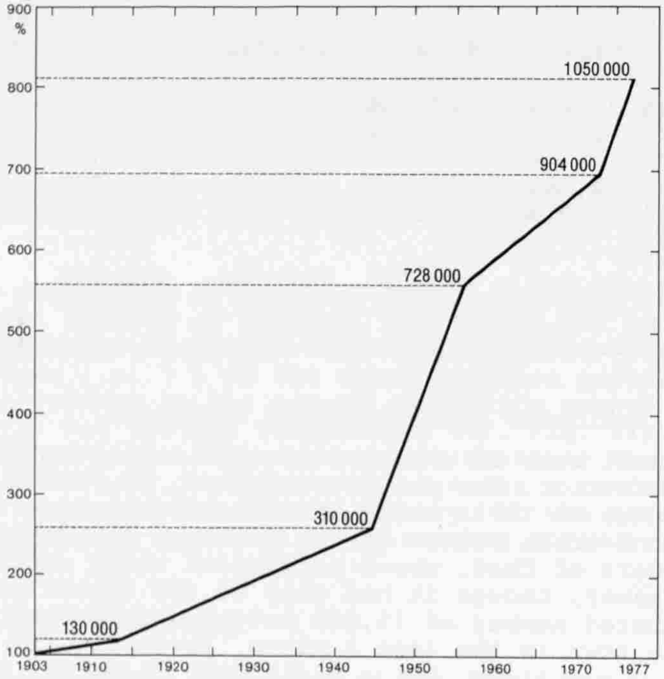


Fig.25 Age Structure of the population of Darfur in 1973

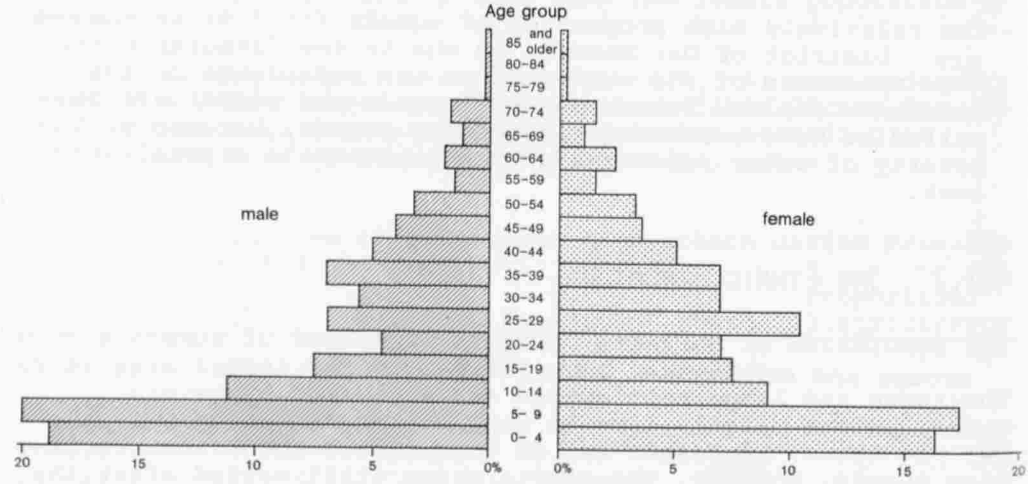
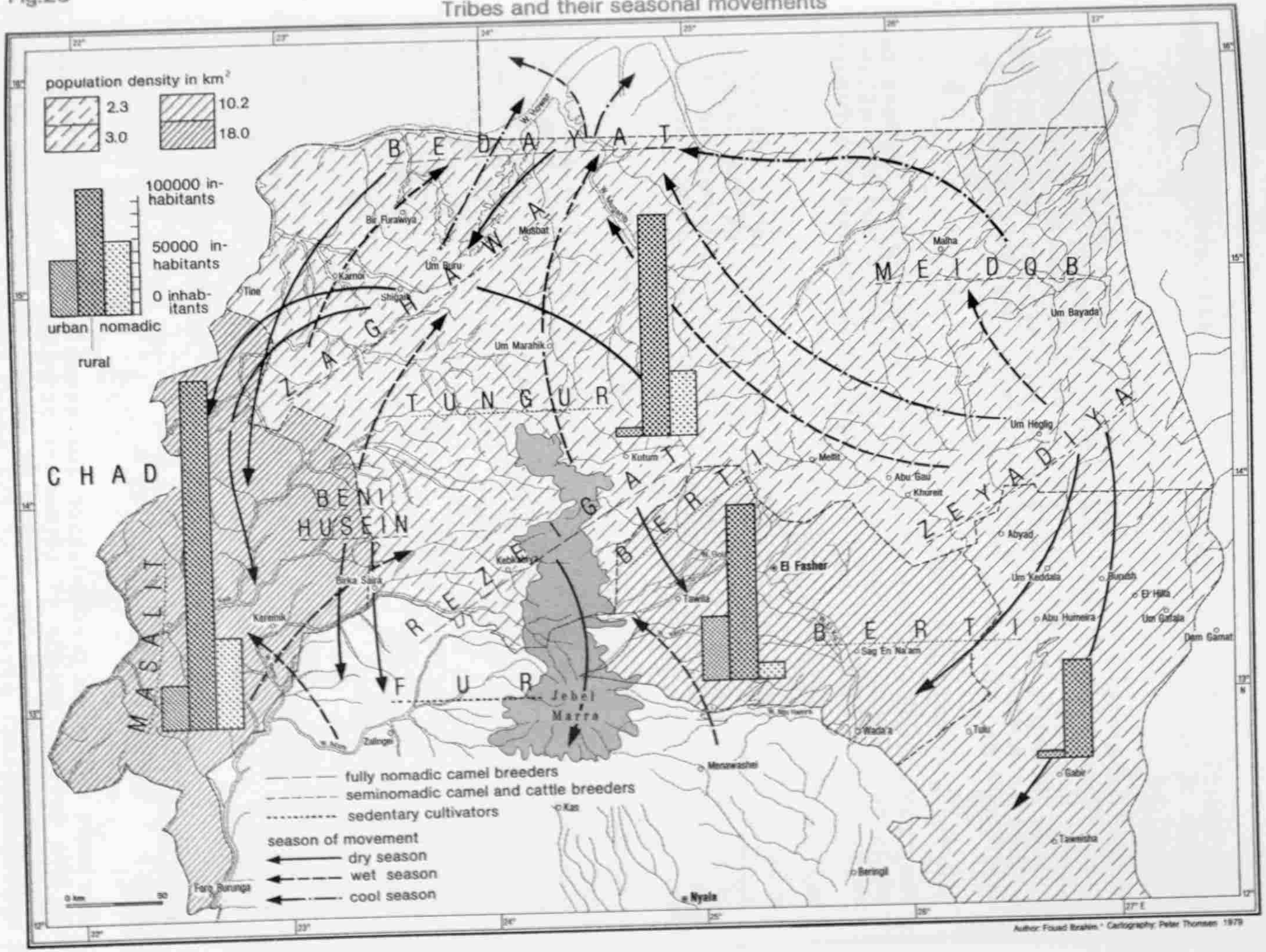


Fig.26

Northern Darfur: Population density and structure in 1973
Tribes and their seasonal movements



One can classify the population ethnically according to their degree of arabization:

The Arabs:

The Arabs are known as nomadic pastoralists. As a result of their former mixing with the natives (probably after taking their women as war booty), they look much darker than other Arabs. However, they speak a very good Arabic. The main Arab tribes in northern Darfur are the Rezeigat, Beni Hussein, Zeiyadiya and the Djawam'a.

The fully arabized groups:

They have entirely lost their native languages which have been replaced by Arabic. They inhabit the Goz zone and are millet cultivators. To these groups belong the Berti and the Tungur.

The partly arabized groups:

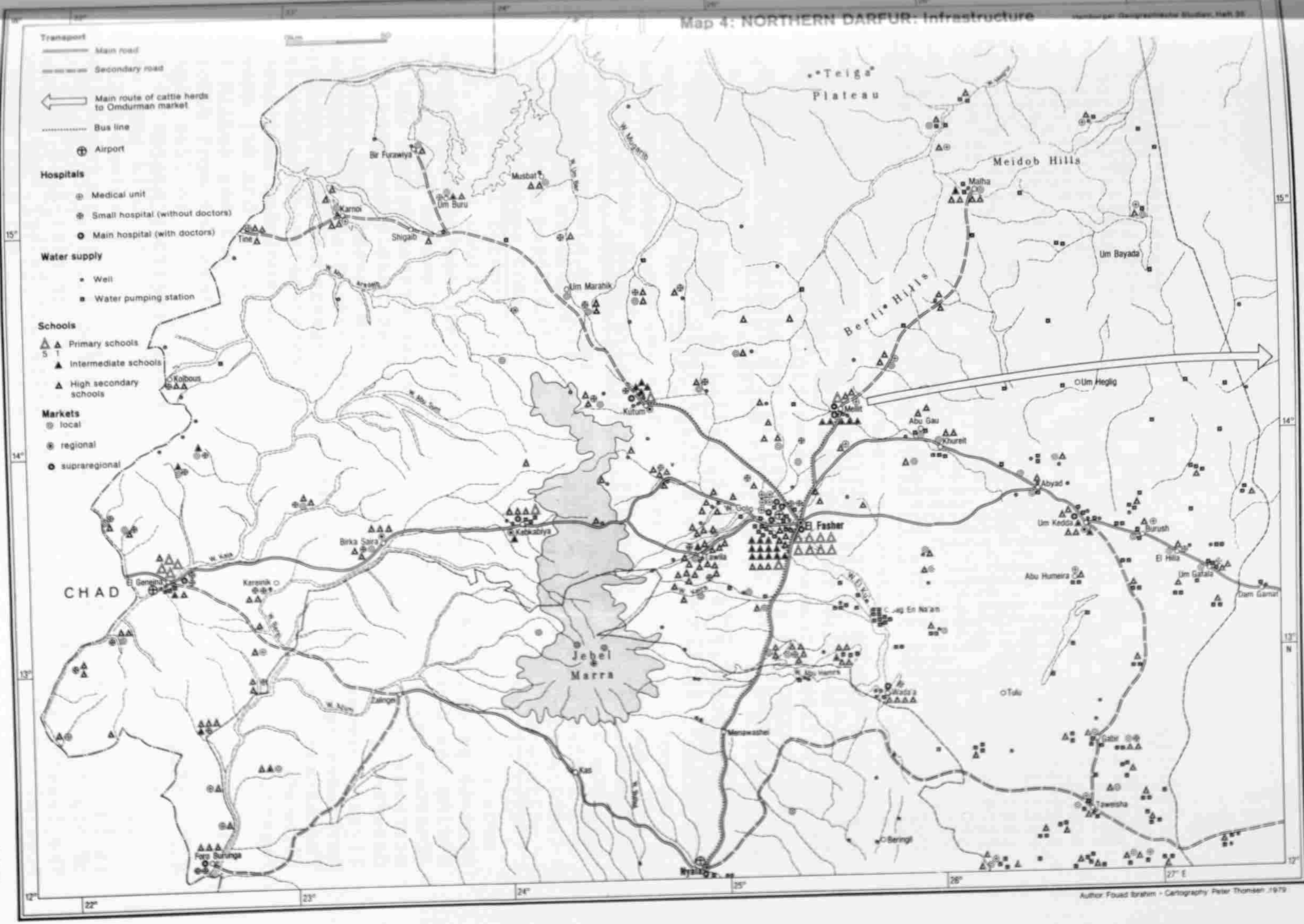
These groups have retained their native languages, but they speak Arabic fluently. They form the majority of the Darfuri. Of these are the Fur and Zaghawa groups, the Meidob and the Masalit. They are mostly settled farmers, but among them there are seminomads and nomads as well.

The non-arabized groups:

They speak very little Arabic and live in isolated areas in Jebel Marra. They are settled cultivators and show little mobility. Generally speaking, women are less arabized than men within the same population group for men have more chance to move about and contact other groups. Figure 26 shows the most important tribes in northern Darfur. Among the largest tribes are the Masalit, who live partly in the Republic of Chad: The same applies to the Zaghawa and the Bedayat in the NW. Apart from the tribes mentioned in Fig. 26, there live smaller groups, such as the Bergid, Bargu, Mima, Kafoot, Tama, Mararit, Kenana and the Asirra. The Fellata who migrated from West Africa a long time ago, are also strongly represented. Some of them were on their pilgrimage route to Mecca, but they settled halfway there in the Sudan. The Fellata belong to the first settlers in some areas of Darfur and actually form the native population. They usually speak no other language than Arabic.

4.1.3 THE SETTLEMENTS (Map 4)

The most decisive precondition for establishing a settlement is the secured supply of permanent drinking water. This is dependent either on the amount of annual precipitation or the hydrogeological structure of the area. Aridity sets the limit of settlements to the north: The farthest permanent settlement is Bir Furawiya, at 15°21'N. In the 1960s a great number of



Map 4: NORTHERN DARFUR: Infrastructure

boreholes were dug in the north and east, where the aquiferous Nubian Sandstone occurs. These boreholes were the centres of new settlements and also the centres of the desertification rings seen on the satellite images. Millet cultivators often spend the wet season scattered on the sandy Goz. After the harvest they return to spend the rest of the year in their central settlement, with permanent water supply. Thus, we find that the population of central settlements fluctuates strongly from season to season. For instance, the population of Mellit (60 km N of El Fasher) increases by 100 % in the dry season (20,000 inhabitants). In the wet season about half of this population lives in the surroundings of Mellit to cultivate the land.

A specific aspect of the settlement development is that the population increase does not mean the increase in inhabitants of the villages themselves. The multiplication happens very often through the establishment of new satellite settlements at a distance of 3-5 km from the mother villages.

Our questionnaire revealed the following dates for the establishment of settlements in northern Darfur (Table 26):

Table 26: Age of settlements in northern Darfur

Date	Before 1900	1900-1950	1950-1970	1970-1973
	61 %	21 %	9.5 %	8.5 %

What is particularly remarkable is the increase of settlements during the drought disaster in 1970-1973. Alone in the area of Abu Zureiga, on Wadi Kej, the Zaghawa who migrated from the north established about 100 settlements at that time. They deserted 475 villages in their tribal land during that period. It is, however, important to note that 39 % of all settlements have been established only since the beginning of the century. The settlements which grew around old water-points, which were formerly used by pastoralists only, are not included in this figure.

4.2 SUBSISTENCE MILLET PRODUCTION AND DESERTIFICATION

It has been proved that excessive rain-fed cultivation is one of the major causes of desertification in the semi-arid zone. The reasons are varied and the processes are rather complex. However, in all cases, three factors are involved: high rainfall variability, high soil vulnerability and unsuitable land use methods. The latter is, in fact, the immediate cause, as the soil and rainfall conditions described are constant components of the natural ecosystems of the arid and semi-arid zones. Man can either use these available natural resources in an adapted manner, which secures their productivity in the long run, or misuse them by unadapted methods to realize high returns in a short time, thereby recklessly destroying the ability of the natural ecosystem to regenerate. Of course, there are social and political pressures as well as financial and technical constraints which force agricultural practices in directions which are far from suitable to the respective natural resources and limits. Here, compromises have to be made, but not at the cost of the next generation. The present generation is in fact following a policy of agricultural strip mining, exhausting all the productivity of soil, while doing nothing for its improvement or even conservation.

The prevalent methods of millet farming enhance desertification in northern Darfur. In order to prepare a field for millet growing the peasants begin by cutting all the trees and clearing all shrubs, herbs and grasses. Though trees neither impede the growth of millet nor compete with it in water demand, peasants assert that trees are gathering places for birds and locusts which eat their millet. Peasants send their children onto the millet fields, especially during the ripening phase to scare birds and locusts by drumming on empty tins. This work would be much more strenuous, if trees were left on the fields to shelter those birds and insects. Preparation for cultivation, therefore, means complete clearance of the natural vegetation till the soil becomes completely bare and vulnerable to erosion. This is usually done several weeks before millet is sown and it takes several weeks more until the plants can render the soil any effective protection. During the growth period of millet, the peasants weed twice. Weeding is absolutely necessary as the indigenous plants are much more adapted to the climatic conditions of the Sahelian zone than millet is. Their roots form a thick net, which has the ability to absorb every drop of rain which seeps through the soil. On the other hand, millet has short roots occupying a relatively small area compared with the considerable height of the plant ranging between 150 and 300 cm. In order to test the different abilities of millet and the indigenous weeds as to their ability to profit from the available soil moisture, we dug holes into the sandy soil of a millet field in northern Darfur (14°15'N, 25°45'E) and similar holes on a neighbouring fallow field of the same kind of soil but having a cover of sparse vegetation with a dominance of low creeping weeds. On the millet field, soil moisture was detected only 10 cm deep, while it occurred at a depth of 100 cm on the fallow field sparsely covered with herbs. It was during the rainy season, and the last rainfall before the test had taken place a week before. Unlike millet, the natural herbs were able to absorb all the soil moisture provided by rain. It is to be remarked that the soil moisture at a depth of 100 cm is common all over that area, even in the dry season.

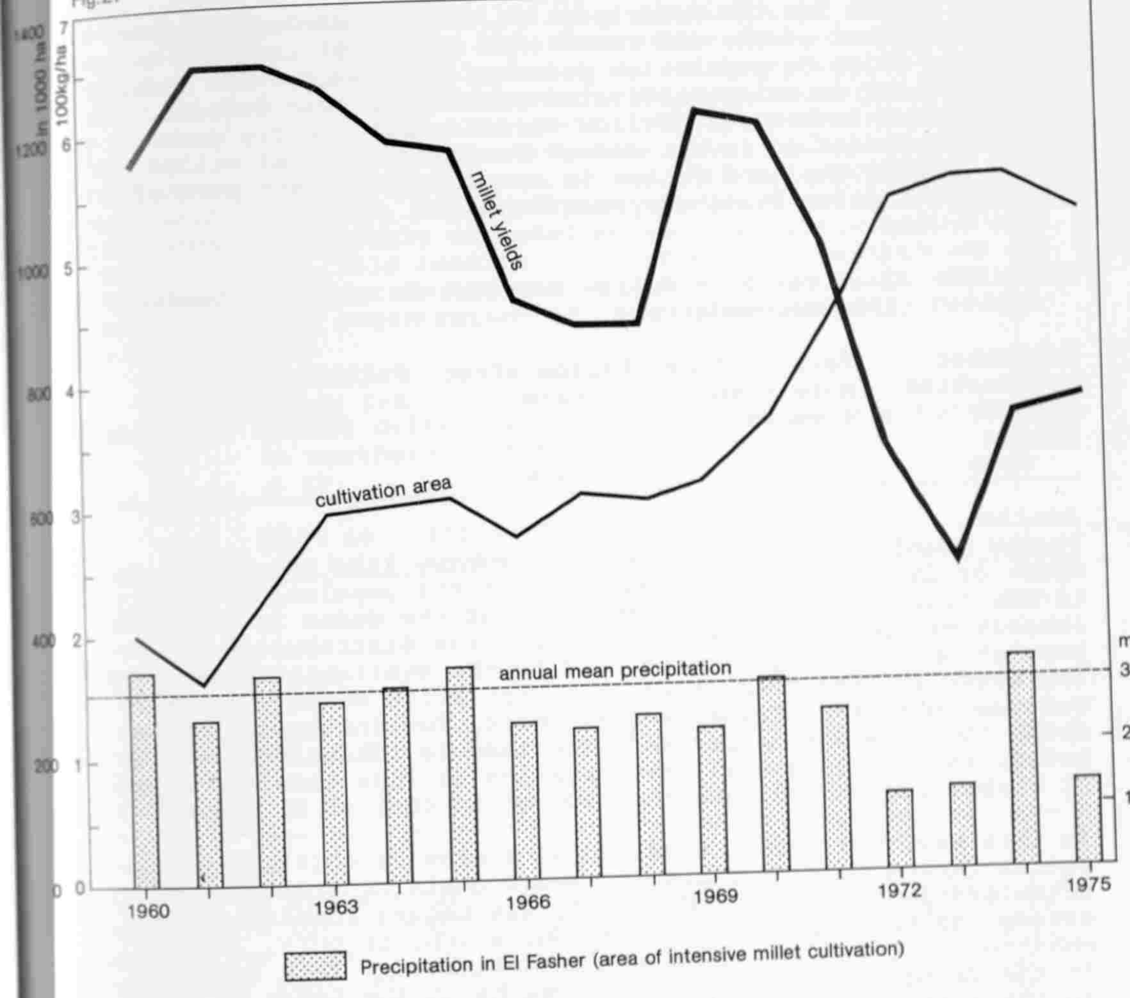
Aware of this rivalry between weeds and millet for moisture the peasants spare no effort to clear their fields of these undesirable herbs and grasses. The process of weeding is done by scratching and loosening the top-soil with a hoe called garraya. This practice, repeated regularly in rain-cultivation areas, results ultimately in the irreversible extinction of the natural vegetation species, which, of course, are much more adapted than crop plants to the arid climatic conditions with the typical recurrence of drought periods. Moreover, the sandy soil, now deprived of its natural plant cover, is exposed to strong deflation, especially during the long dry season of 8 to 10 months. About 200 million tons p. a. of fertile top-soil are reckoned to be blown away from the Sahelian zone into the atmosphere (JUNGE 1977). The amount of atmospheric dust increases every year due to the expansion of cultivation, a fact which can be easily proved, if we study the annual frequency of poor visibility under 1,000 m (cf. Figure 2). The erosion of the fertile top-soil has led to a considerable deterioration of land productivity. That the decrease of the amount of precipitation is only to a limited extent responsible is shown by Figure 27. It is quite apparent that the decrease in production per ha is not directly proportionate to the variability of precipitation (cf. Table 27).

Table 27: Decrease of millet yields in the Sudan from 1960 to 1975

Year	Cultivated area 1,000 ha	Production 1,000 t	Average yield kg/ha	Precipitation mm (El Obeid)
1960	392	226	580	318
1961	334	204	650	447
1962	463	291	650	512
1963	609	374	630	316
1964	599	354	590	540
1965	603	353	580	359
1966	540	352	460	217
1967	605	269	440	267
1968	598	267	440	190
1969	626	385	610	164
1970	723	439	600	261
1971	873	441	500	333
1972	1,070	355	330	332
1973	1,109	281	250	275
1974	1,110	400	370	397
1975	1,055	403	380	232

SOURCE: Yearbook of agricultural statistics, Khartoum, 1974,1976

Fig. 27 Development of millet yields and area of millet cultivation in the Sudan 1960-1975



Another reason for the deterioration of soil productivity is the abandonment of the old rotational system of shifting cultivation. Owing to population pressure in the last few decades the same land is being cultivated year after year without fallow years in-between. Fallow occurs mostly in dry years, when precipitation is not enough for the growth of millet. Thus, leaving the land fallow is compulsory and not part of a soil regeneration farming system (Table 28).

Table 28: Cultivation - fallow rotation in northern Darfur (354 respondants)

Permanent cultivation without fallow	Fallow after more than 4 years	Fallow after 4 years	Fallow after 2-3 years
72 %	7 %	9 %	12 %

It may sound paradoxical in a vast country like the Sudan, to speak of lack of land. One admits that the population density in the Sahelian zone of the Republic of the Sudan is only 3-6 inhabitants per square kilometre, but the distribution of population is strongly restricted by the availability of drinking water all the year round. The population density in the surroundings of El Fasher and El Obeid, for instance, reaches about 100 inhabitants per km^2. The land is intensively cultivated, though the annual precipitation is less than 300 mm in El Fasher region and less than 400 mm in that of El Obeid.

In this way, the sound, traditional system of shifting cultivation turned into land misuse, and a chain of processes of deterioration of land productivity was begun: Population increase led to excessive cultivation, which, in turn, led to enhanced soil erosion and soil impoverishment. This resulted in the decrease of millet yields per ha in the Sudan by half in the last 15 years. To make amends for this, the population, which is constantly increasing at an annual rate of 2.5 %, had to increase the area cultivated with millet, from 392,000 ha in 1960 to 1,055,000 ha in 1975. This expansion of cultivation meant a fresh wave of desertification for the reasons mentioned above.

The average sorghum yield in the Sudan in 1973 was 770 kg per ha (by comparison, the average yields of sorghum in the USA were 3,690 kg and in Egypt 4,170 in the same year). In the northern Sahelian zone, however, where precipitation is less than 300 mm in the annual mean, the yields are much lower. My study in northern Darfur revealed that 50 % of the years are to be considered dry ones, in which the peasants reap either nothing at all or up to only 100 kg/ha. At the same time, the average consumption of millet of a six-membered family amounts to 1,500 kg p. a. (Table 29). This means that the area cultivated by millet per family has to be no less than 15 ha (i. e. about 36 feddans or 29 mokhammas), if subsistence is to be guaranteed. The actual area cultivated by an average family is, however, much smaller and, therefore, the population suffers from chronic undernourishment. It is also characteristic of this arid zone that, especially in dry years, millet cultivation areas are greatly expanded so as to meet the demand of the population. This results in a large-scale destruction of the ecosystem, just in the very years in which it is most vulnerable and its regeneration capability is immensely reduced by the dryness.

Table 29: Millet cultivation plots and consumption per family in northern Darfur

	Plot in ha	Yield kg/ha	Total yield kg	Consumption kg	Deficit kg
Northern Zone (semi-nomads)	2.9	200	580	1,525	945
Southern Zone (settled)	5.8	230	1,330	1,410	80

In order to explain Table 29 it is important to note that the inhabitants of the northern zone are not dependent on millet cultivation solely, but on livestock husbandry as well. However, many families have lost their herds during the latest drought which is still going on and these people have become more dependent on millet production. The yield of 200 kg/ha seems relatively high for the semidesert, but cultivation takes place there mostly in pedologically favourable areas (flood cultivation in wadi basins).

The fact that rain-fed cultivation, especially that of millet, is responsible for desertification in the Sahelian zone can be easily perceived on air and satellite photos. On them, the areas under rain-fed cultivation appear as bare patches within the vegetation of the thornscrub savanna. Soil and vegetation degradation is set off radially from the settlements to form rings or rather stars of desertification. A closer look at these rings in northern Darfur shows recurring forms and degrees of desertification, the nearer one comes to these settlements. A generalised view over these rings of desertification reveals a certain scheme: The outer ring represents the damage caused by tree clearing, overgrazing and excessive browsing; the inner ring is destroyed by excessive cultivation as well as overgrazing (Figure 36).

4.2.1 Desertification as a Result of Excessive Millet Cultivation as Shown by Aerial Photos

By the help of remote sensing we can recognize and control the progress of desertification. Two aerial photos (Photo 19 and Photo 20) of the same area, taken in the same season, but with a span of 14 years in between (1954-1968) are being compared here (Figures 28 and 29). At first sight, the situation is quite apparent: the former cultivation land has been encroached upon by the desert. One should, however, admit that in this area near El Fasher, northern Darfur, Sudan, precipitation in the year 1954 was more than twice as high as in the year 1968, i. e. 637 mm and 248 mm respectively, while the long-term annual mean is 286 mm. This variability, however, is not uncommon in the Sahelian zone. It cannot alone explain the formation of the dune chains, which dominate the photo of 1968. Obviously, nature is not any more capable of recovering the old ecological balance. According to our observations in 1982, i. e. 14 years later, the same desert-like conditions are still prevailing in that area. Millet fields, recognized by their bright geometrical forms, have shrunk to a minimum in the close surroundings of the village (Ghebeishāt, 20 km north of El Fasher).

The bright shades displayed by millet fields on aerial and satellite photos, even during the summerly cultivation period are due to the fact that millet plants are very thinly distributed over the field. The distances measured were between 140 cm and 220 cm. The spaces between the millet stalks are kept quite clear as a result of regular weeding. On the air photos, fallow fields appear darker, because they have a denser cover of herbs and grasses. It may be argued that the shrinkage of cultivation areas would give the soil a chance to regenerate. The rows of newly formed dunes, however, indicate that the soil structure of the old weathered dunes has been destroyed, i. e. the soil lost its stability and the fertile top-soil, which had been developed in some thousands of years, has been deflated and the land is covered by fresh sand dunes and sheets of blown sand of very low productivity.

4.2.2 Overrunning the Agronomic Dry Limit

The example El Fasher area shows clearly that rainfall variability has a great influence on the oscillation of the northern

Photo 19: 1954 - Excessive rain-fed millet cultivation north of El Fasher (280 mm precipitation).
(By courtesy of the Survey Dept., Khartoum)

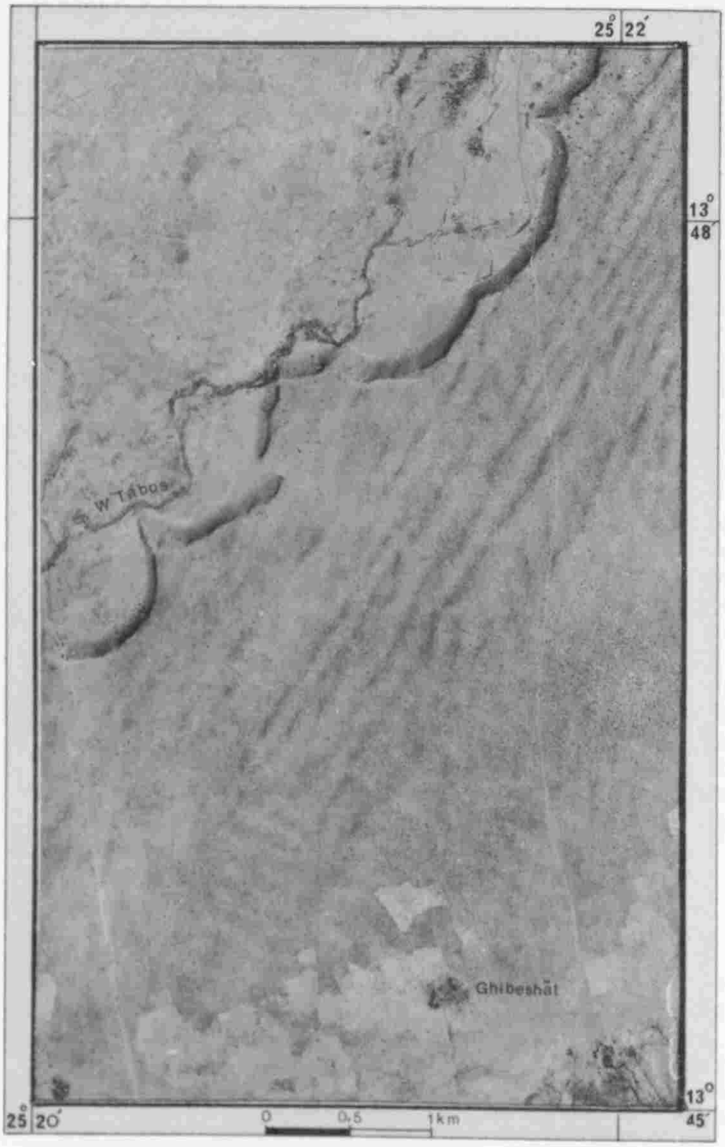
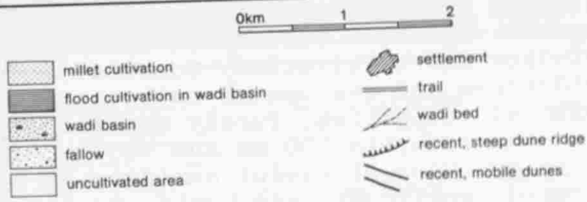


Photo 20: 1968 - Reactivation of the Goz dunes north of El Fasher due to unsuitable land use in a marginal zone (230 mm precipitation).
(By courtesy of the Survey Dept., Khartoum)

Fig.28 North of El Fasher in 1954
Excessive millet cultivation on the Goz

Fig.29 North of El Fasher in 1968
Reactivation of the Goz as a result of overcultivation



limit of rain-fed cultivation in the Sahelian zone. In wet years, the cultivation limit, together with the settlement zone, shifts about 100 km northwards, towards the Sahara. In the dry phases, on the other hand, the cultivation zone withdraws for about 200 km to the south. Figure 30 displays the course of the 200 mm isohyet of the wet year, 1950, and the dry one, 1973. The zone between them is that of high variability which has an extension of 200-400 km from south to north. Because of the broad range of the fluctuation of precipitation between the wet and dry phases, an exact determination of the agronomic dry limit in that zone is extremely difficult. The generally acknowledged determination of the dry limit of rainfed cultivation at 8 arid months is not tenable in the Sahelian zone of the Republic of the Sudan. The front of closely connected areas of millet cultivation goes far beyond that limit and reaches the zone of 10 arid and 2 semi-arid months. Instead of the fictive dry limit of cultivation one can distinguish the following borders: the actual dry limit of rain-fed cultivation, the climatic dry limit (6 arid months annually) and the desertification-hazard limit (500 mm on sandy soils and 600 mm on clayey ones).

Owing to high population pressure a more realistic compromise between the actual limit of rain-fed cultivation (at about 250 mm precipitation) and the ideal climatic dry limit (at about 1,000 mm precipitation) has to be worked out. This could be called "a limit of desertification hazards through rain-fed cultivation". It is the boundary, south of which rational methods of cultivation may be practised without highly endangering the ecological system. Rational methods of land use include the rotation of fallow and cultivation, combinations of tree planting and field-crops and the use of cultivation methods which hinder erosional activities. Purely empirically, this limit lies between the isohyets 500 mm and 600 mm. There, the number of months in the year of useful humidity is four, ranging between semi-arid, semi-humid and humid. South of this limit desertification processes are, of course, possible. But they occur only in places where human and animal pressure is considerably high and land use practices have become excessive and irrational.

At the 1973 Agrarian Conference in El Fasher, a motion was made to forbid cultivation north of the 300 mm isohyet, so as to stop any further deterioration of the natural resources there. Though this recommendation was a basic condition, none of the provinces concerned was able to put it into force as this would mean depriving the inhabitants of that zone of the basis of their existence. This is unthinkable as long as no real alternatives can be offered. In the near future, no such alternatives can be expected either, for it is extremely difficult to find an economic substitute for millet cultivation in that marginal zone. It is often argued that it is not at all profitable to cultivate land in such marginal areas, but one should not

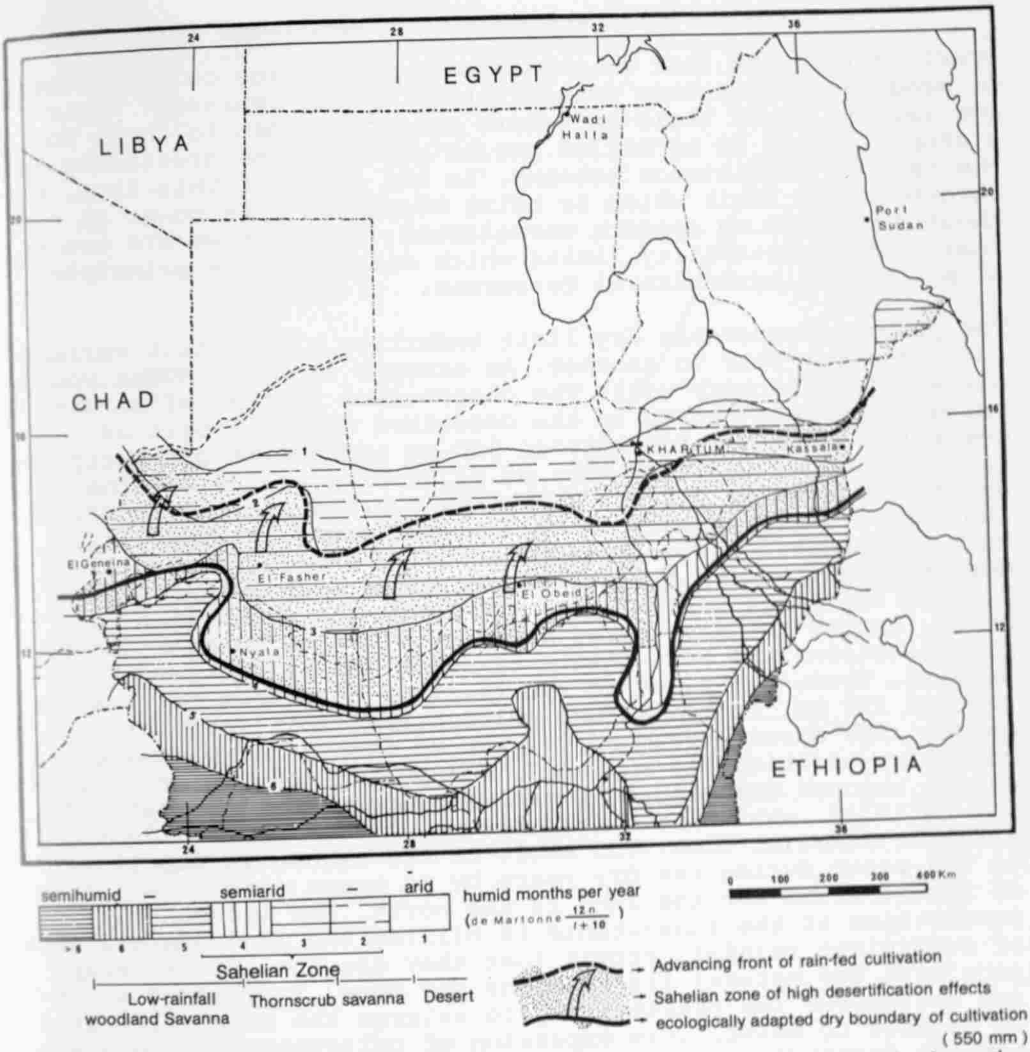


Fig.30 The Sahelian zone of the Republic of the Sudan. The extension of rain-fed cultivation beyond the ecologically adapted agronomic dry boundary.

Source: IBRAHIM, MENSCHING, 1978

overlook the fact that in subsistence production only the costs of seeds are taken into consideration by the peasants. Their own labour, field tools or tenure are of no cost to them. So, a crop yield of 50 kg millet per ha can still be profitable in the case of subsistence economy. In the light of this fact, the agronomic dry limit which is being suggested here to be at about 500 - 600 mm appears unrealistic, too. But we are not in search of profitability limits which disregard the principle of protecting agricultural resources.

The proposed agronomic dry limit underlies also a high variability from one year to another. An example from the Sudan would illustrate this very well. The chosen area is that of El Geneina in western Sudan, in the described marginal belt of desertification hazards between 500 mm and 600 mm of precipitation p. a. The long-term mean of El Geneina is 536 mm, the average maximum is 722 mm, while the average minimum is 382 mm. That signifies that only in 50 % of all years, the marginal belt of desertification hazards actually passes through El Geneina area. During the wet years, whose mean is as much as 722 mm, this belt shifts up to 200 km to the north of El Geneina. During the dry years, however, with 382 mm mean annual precipitation, the belt shifts by about 150 km south of El Geneina. Thus, the swing in the limit of hazardous cultivation reaches 350 km. As the actual cultivation limit, as mentioned before, has already reached the 250 mm isohyet, the damage caused is additionally expanded. Today, the zone of desertification through rain-fed cultivation extends from the latitude 11° to 15° N, embracing a belt 450 km wide, which is identical with the Sahelian zone. The shift of the agronomic dry limit to the south during the dry years by no means signifies a time of regeneration for the land in the north. The increasing persistence of the inhabitants in tilling the land despite lack of sufficient rainfall proves that they are not able to keep pace with the natural fluctuations any more. Instead of shifting southwards the peasants try to enlarge the area cultivated to be able to exist. This expansion of cultivation to counteract the decrease of rainfall works as a catalyst for the processes of desertification. Moreover, it often happens in those dry years, that the crop fails altogether. To buy cereals, the poorer population, which has no animals to sell, are compelled to fell whatever trees they get access to and sell the wood as fuel to get some cash. Figure 31 shows the dramatic increase of millet prices in the years 1973-1977. Thus, wood cutting and the devastation of what is left of the woodlands increase to an alarming degree just in the very years in which the ecosystem is particularly vulnerable.

Fig.31 Increase of millet price in El Geneina between 1973 and 1977

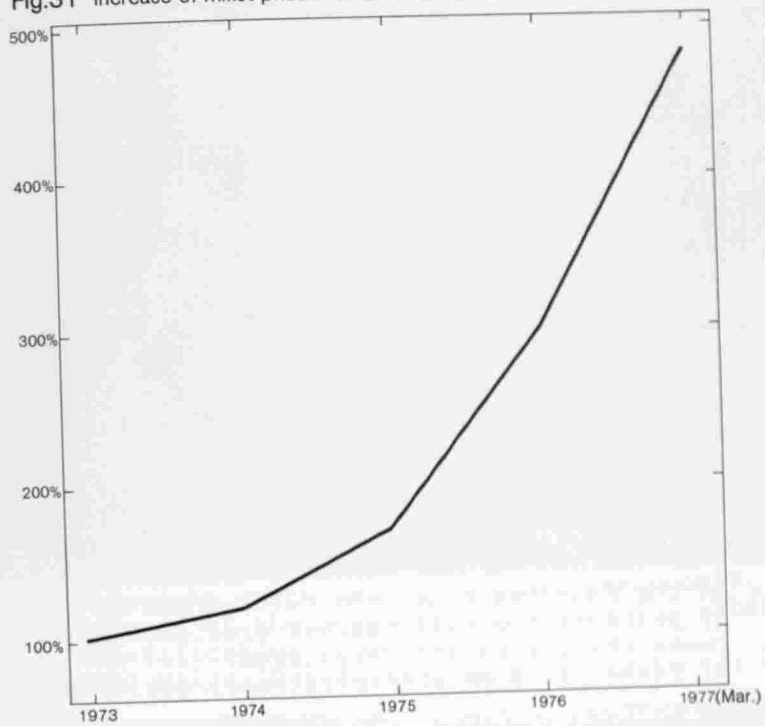


Fig.32 Increase of livestock prices in El Geneina between 1973 and 1977

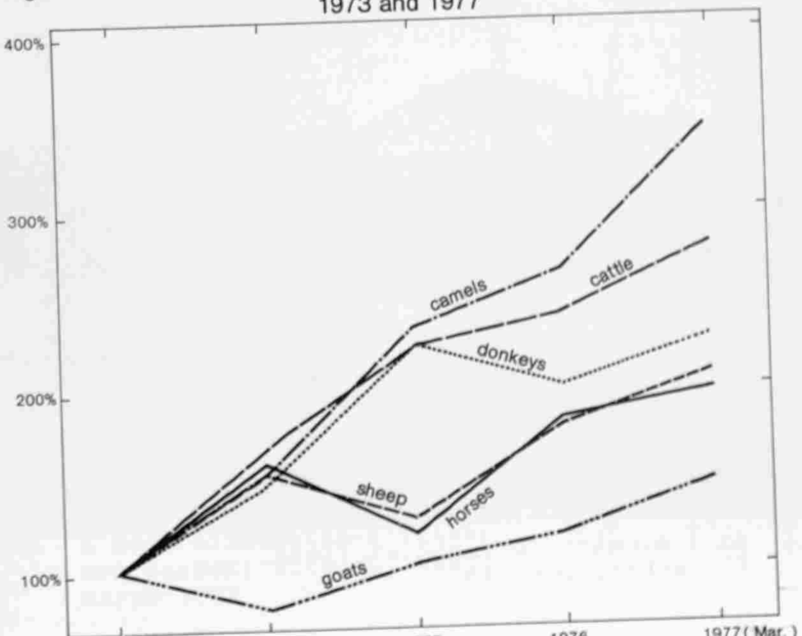


Photo 21: In the Sahelian zone, the cultivation of millet hardly protects the soil against erosion. The spaces between the plants are very large.
El Fasher (290 mm precipitation). Oct. 1981

Photo 22: Soil erosion in a millet field.
El Fasher. Oct. 1977

Photo 23: In drought years farming becomes uneconomic. The persistence of the peasants on cultivation enhances the desertification processes.
Jebel Hilla, Darfur (250 mm precipitation). August 1982

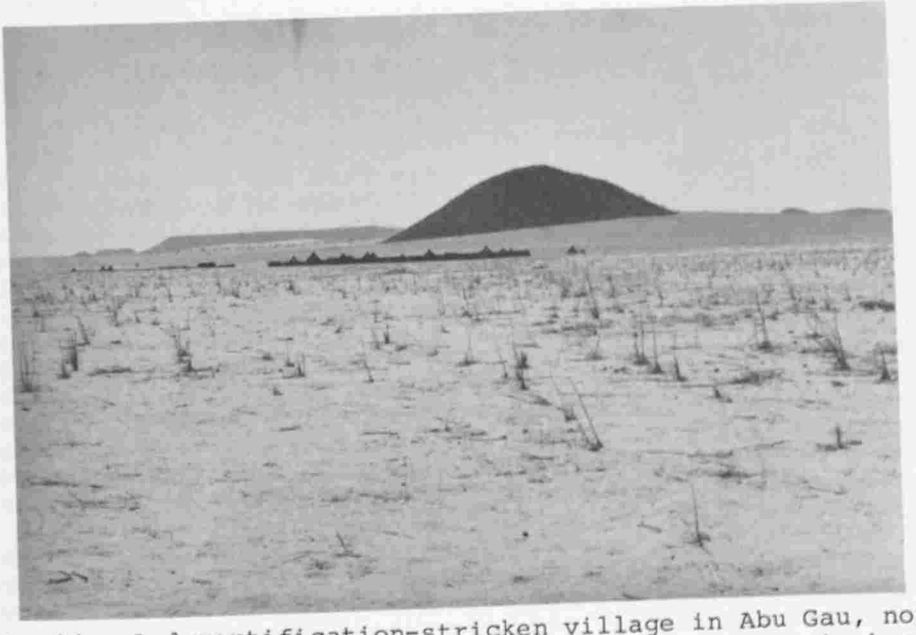


Photo 24: A desertification-stricken village in Abu Gau, northern Darfur, with cultivation at the 250 mm-isohyet.
March 1977

4.3 Pastoralism and the Problem of Overgrazing

The pastoral tribes which live in western Sudan consider themselves as Arabs or non-Arabs, despite the fact that mixed groups constitute the majority. Most Arab ethnic groups there trace their origin back to the two main tribes: the Dja'aliyin and the Djuhaina, which are also represented in other parts of the country. Among these two tribes there are fully nomadic, seminomadic, as well as sedentary groups. Among the groups of non-Arabic origin the most important are the Fur, the Masalit, the Tunjur, the Zaghawa, the Meidob, the Berti, the Nuba and the Fallata (Westerners). Some of them have been so strongly arabized that they have completely lost their tribal language. Highly relevant to the question of identity is Arabism, on the one hand, and Negroism, on the other. Those of mixed origin are exposed to strongly conflicting identities. The possibilities and limits of the economic development of the traditional pastoralism of these tribes are determined both by the tribally conditioned behaviour patterns and the available natural resources. An analysis is being made here of the human and natural assets and alteration of the identity of the peoples concerned. The synergism of the natural, economic, social and political factors in this marginal Saharan zone plays a significant role in this question.

4.3.1 Mobility as a Form of Adaptability to Rainfall Variability

In the Saharan marginal zone, where land use activities reach their northern limit, the phasal fluctuation of precipitation, typical of that zone, is of vital importance. A difference of about 100 mm in the annual mean precipitation causes a shifting of the temporary desert border by more than 100 km to the north during the wet phase, and by more than 100 km to the south in the dry phase. The ability to adapt which the inhabitants of that zone have developed, is expressed by their high degree of mobility. Dry phases of more than 5 years cannot be overcome by mere storage policy. Control of animal numbers and migrations to the southern areas of retreat are the traditional pattern of behaviour during dry phases. It is often presumed that nomads exercise no regulation on their animal stocks. At least in Darfur, however, the case is different. The Meidob pastoralists, for instance, hinder the multiplication of their sheep and goats, in times of drought, by separating males from females. The Rezeigat camel nomads, too, control the pairing of their camels exactly and never leave propagation to pure chance.

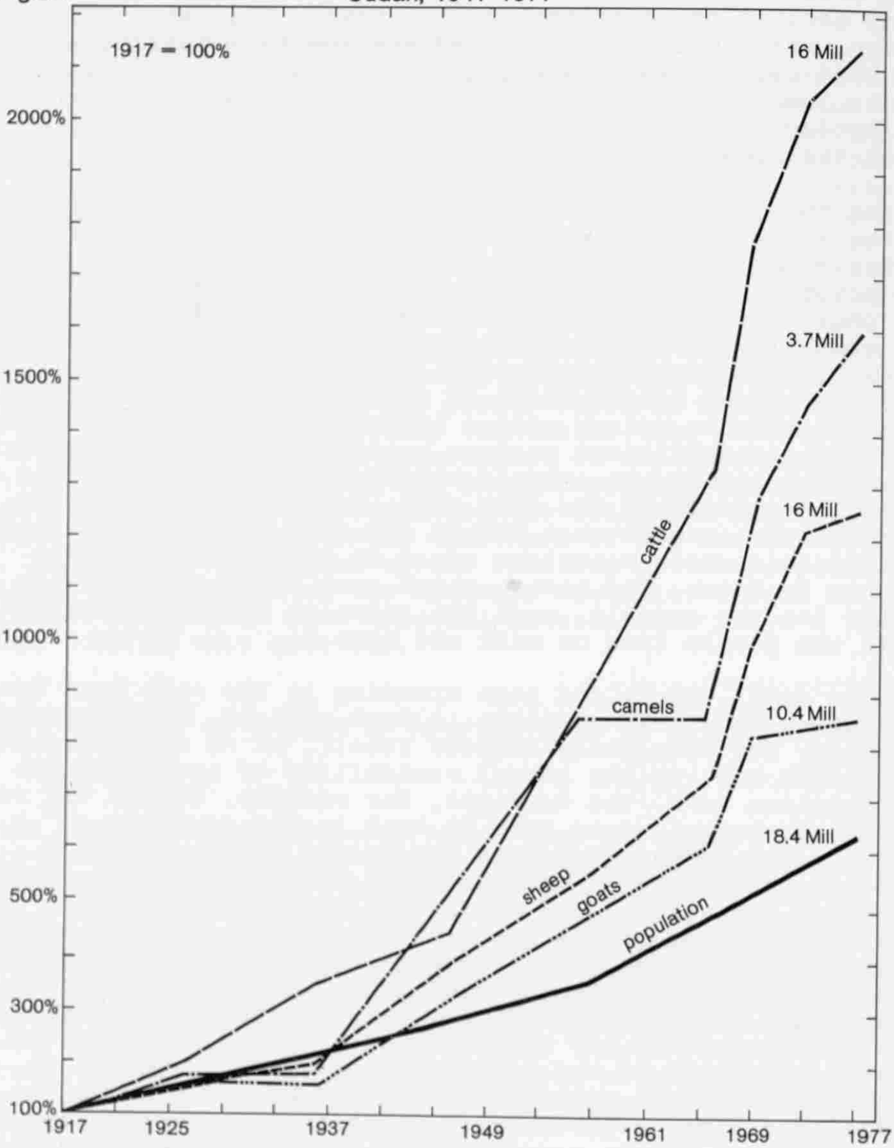
The adaptability mechanism, which the inhabitants have developed over the past centuries is no longer operational today, after decades of rapid population growth. Sedentary animal husbandry, which has only a limited horizon of mobility, and rain-fed cultivation are encroaching upon the nomad grazing lands. These are then forced into extremely marginal areas of low productivity, which results in overgrazing damages, of which the nomads are unjustly accused.

During the favourable wet periods of 1919-1939 and 1950-1965 in the Sudan as in other countries of the Sahelian zone, the number of animals increased extraordinarily (c.f. Figure 33) far beyond the carrying capacity of land. In the succeeding dry phases, the pastures were strongly degraded by overstocking and gradually lost their ability to regenerate. This led ultimately to the drought disasters, which were caused mainly through lack of fodder. Lack of drinking water, which often has dramatic effects, plays only a secondary role in such cases, if there are sufficient pasture possibilities (grasses, herbs, shrubs and trees) the animals require only little water as a rule. The example of the Jizu area, north of Wadi Howar in western Sudan, proves that nomads are able to stay with their animals in certain waterless areas up to half a year from October to March. The herbs, which grow there and serve as fodder for the animals, meet the animals' water requirement, while the people live on milk and meat.

Nomadic camel, sheep and goat breeding is the only land use form which is at all possible in such regions. Nomadic animal husbandry has completely adapted itself, as no other economical system has, to the annual variability of precipitation in the Sahelian zone. The Rezeigat, for example, follow the rain with their animals from Bahr El Arab in the south at 10° N latitude, up to Wadi Howar in the north, as far as 17° N. Although this route is traditionally fixed there are a great number of variational and deviational possibilities. The flexibility of grazing routes displays the highest form of adaptability to the variation in rainfall of that zone. The nomads follow rainfalls at a calculated delay, thus enabling the grasses and herbs to grow before the arrival of the herds and possibly to develop new seeds as well. Figure 34 shows the manifold variants of the movement routes of the nomads in northern Darfur. It reveals their adaptability to both the spatial and time variability of precipitation. Generally, the grazing routes run in a north-south direction and along the available water points (wadis, rahads, hafirs, wells and pumping stations). How far the nomads move northwards and how long they stay in each area depends on the rainfall conditions in that particular season.

In strong contrast to the nomadic activities stands the sedentary animal husbandry, which destroys the same area all the year round. It does not give plants even the shortest break

Fig.33 Develoment of the numbers of population and livestock in the Sudan, 1917-1977



Source: IBRAHIM, MENSCHING, 1977

during which they may grow undisturbed and develop seeds for the next year. Especially in the perimeters of settlements, animal keeping by the sedentary population leads to the complete disappearance of palatable grasses, such as *Cenchrus biflorus, Eragrostis tremula, Echinochloa colonom* and the various *Aristida* species.

At present, many Sahelian states are trying to settle the nomads for political and security reasons. Ecologically this would be disastrous and economically it would signify a great loss. Those who try to convince the nomads that they would be better off if they settled down to a fixed place ignore the fact that almost everywhere in the Sahelian zone nomads are richer than the sedentary peasants. The plea for nomadic pastoral economy by no means implies that it should be left without development, but it should not be the kind of development which leads to its deterioration and final extinction.

4.3.2 Grazing Zones in Northern Darfur

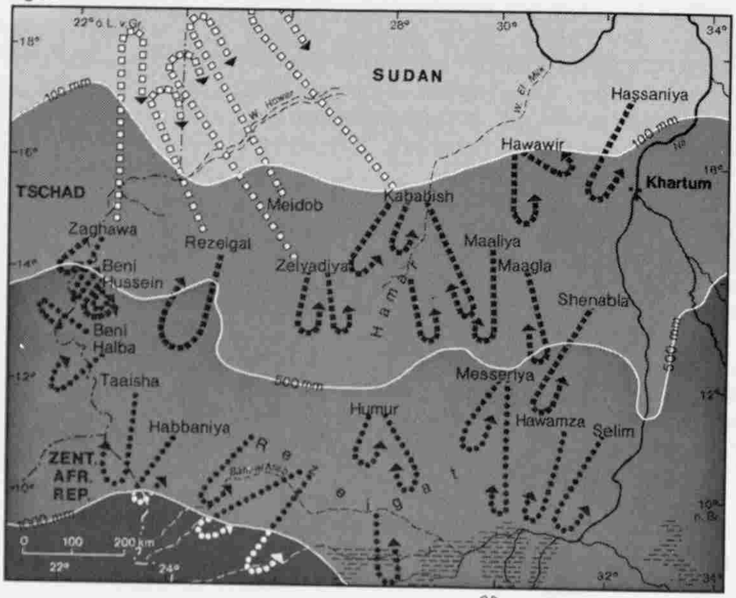
To illustrate the complexty of grazing systems in the Sahelian zone the map of land use of northern Darfur (Map 3) will be briefly discussed in this connection (cf. also Figure 34).

The map divides the region of northern and central Darfur into four grazing zones according to the dominant use during the seasons of the year:

4.3.2.1 All-Year-Round Pastures

These occur in the central zone which coincides with the zone of rain-fed cultivation and the concentration of settlements. All-year-round pastures have been extended in the last decades with the extension of water supply through boreholes. As only 2 to 3 months of the year can be considered humid, adapted grazing is possible solely during these months (July to September). Continuous grazing and browsing has, therefore, severe consequences for the ecological balance. Grasses have been exhausted. Less palatable species, such as *Calotropis procera, Cassia acutifolia, Sesamum alatum* and *Acanthospermum hespidum* have replaced palatable grasses, especially *Aristida* species. The degradation usually takes place in form of concentric rings around settlements. The radius of the overgrazing circle usually covers a day's wandering. Goats, sheep and cattle are taken in the morning by the village boys and brought back in the evening. The most desertified areas are those around water points, for these animals are led there to drink every second day.

Fig.34



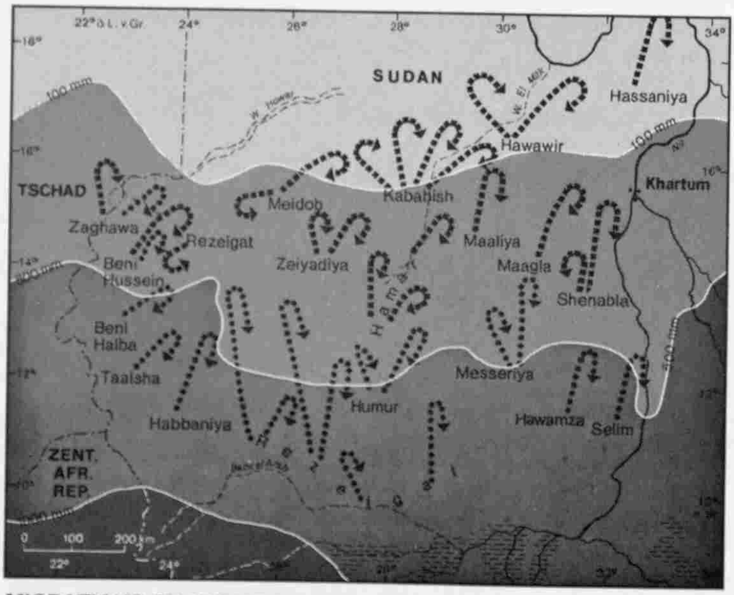
MIGRATIONS OF NOMADS IN WEST SUDAN IN THE WET SEASON

cool season — CAMEL NOMADS

CATTLE NOMADS

Author: F. Ibrahim 1981

Kartographie: M. Tyzenhouse Repro-Arb.: K. Keil



MIGRATIONS OF NOMADS IN WEST SUDAN IN THE DRY SEASON

CAMEL NOMADS

CATTLE NOMADS

Author: F. Ibrahim 1981

Kartographie: M. Tyzenhouse Repro-Arb.: K. Keil

4.3.2.2 Pastures of the Dry Season

These pastures are to be found in the south-western part of the region. There, precipitation ranges between 400 and 800 mm annually. Though rainfall here, too, is extremely seasonal some other physical geographical factors render it possible for herds to spend the dry season there:

- The western forelands of the Jebel Marra massif are hydrologically favourable: some watercourses flow several months in the year. As the prevailing rock is impermeable (Basement Complex) many ponds and shallow wells sustain their water the whole year round. Thus drinking water for man and animal is secured throughout the dry season.
- Owing to the fact that the prevailing soils are skeletic and unfavourable for cultivation, no large-scale clearing of woodland has taken place in that region. For this reason it has become a favourable place for browsing camels. The Rezeigat camel herders especially frequent these pastures regularly in the dry season between November and May.

4.3.2.3 Pastures of the Rainy Season

These are to be found in northern Darfur in the semi-desert between the 100 mm and the 250 mm isohyets. Formerly this zone extended further south but was encroached upon by millet cultivation. Apart from the herds belonging to the tribes living there (Meidob and Zaghawa), the herds of the neighbouring tribes (Rezeigat, Bedayat, Zeiyadiya) frequent these pastures between June and October. Their movements depend, however, on the variation in precipitation: amount, distribution and locality of rainfall. In dry years, many of the neighbouring tribes remain in the south, where they get into conflict with the sedentary cultivators. Indeed, what makes the northern pastures attractive for camel and sheep herders is the fact that they are generally free from cultivation. Moreover, there is a favourable alternation of sandy Goz areas covered with *Aristida* and *Cenchrus biflorus* and wadis rich in trees and shrubs for browsing. Drinking-water is usually available during the rainy season, either in the shallow wells or the seasonal ponds. In dry years, the herds resort to the boreholes dug in the Nubian Sandstone of the Meidob land.

4.3.2.4 Pastures of the Cool Season

These are to be found in Wadi Howar and the Jizu area to the north of the wadi. Apart from the relatively dense tree stock in the great basin of Wadi Howar, the Jizu plants provide pastures during the dry winter months between November and February. The juicy grasses and herbs of the Jizu area, however, do not grow every year in the same manner. In dry years, they do not grow at all and the camel nomads remain in Wadi

Howar or farther south. Though the annual mean of precipitation is less than 100 mm and no drinking-water is available, the herds can spend up to 6 months there in favourable years. The animals get their fodder and moisture from the Jizu plants, while the herders live on milk and meat. The pastures of the cool season are a welcome extension to those of the wet season in the north.

4.3.2.5 Grazing Routes of Nomads and Seminomads (Map 3, Fig. 34)

The routes which the herders follow according to the season of the year are displayed by coloured arrows: The movements in the dry season (orange arrows) are directed southwards. The herds wander along the piedmont of Jebel Marra to the south, turn westwards and stay in the Wadi Azum area till May. With the first showers they go back (violet arrows) taking either the route to the west of Jebel Marra via Kebkabiya or the route to the east via Wada'a and El Fasher. Due to the lack of surface water towards the end of the dry season and at the beginning of the rainy one, the herds are led along Wadi El Ku', where there are several water pumping stations. How far northwards the herds go depends on the condition of the pastures which in turn depends on the amount of rain. Nomads usually possess a very good system of acquiring the latest information about the grazing conditions in the area.

After the end of the rainy season in October, cattle nomads (Baggara) return southwards to spend the dry season there. The Baggara may go as far as Bahr El Arab on the borders of the Dinka land. Camel nomads go either southwards to south-western Darfur or, if they learn of the growth of the Jizu plants, they move northwards (blue arrows), cross Wadi Howar and go as far as the forelands of the Ennedi mountain ranges.

Added to the seasonal movements, there are grazing routes which are not committed to certain seasons (yellow arrows) but are adapted to the occurrence of major wadis or mountain ranges which provide browsing possibilities and drinking water all the year round.

4.3.3 The Problem of Overstocking

A reasonable reorganization of range economy with the aim of a rational management of the available pastures is impossible without carrying out a precise control of the number of animal stocks. The official census is considered by the officials themselves as being unreliable. It is extremely difficult to know the real sizes of the herds, for the owners refuse to give the true figures for fear of being compelled to pay high taxes. Animal statistics are usually compiled from taxation lists which underlie no official control, and are usually made by the chiefs who own most of the animal wealth. Revealing the number of animals by the help of the vaccination figures of the veterinary stations would certainly lead to the refusal of the animal keepers to participate in vaccination campaigns for fear of being highly taxed. Thus trust in government vets would be lost.

More promising is the aerial census, but owing to the high mobility of the herds in the Sahelian zone and the unpredictability of their movements it becomes difficult to select representative samples in a confined area.

Even if one reviews the development of the number of animals according to the official census in this century one is abhorred at the dramatic increase. Figure 33 shows this development in the Republic of the Sudan between the years 1917 - 1977. The human population increased by more than six-fold, the number of cattle rose to twenty-one-fold, that of camels to sixteen-fold, that of sheep to twelve-fold and that of goats to eight-fold. At the same time pastures became smaller and less productive, and the physical condition of the animals suffered respectively.

Every calculation of the degree of stocking is doubtful as long as no reliable census is available. Even the related areas are difficult to determine, for the nomadic annual grazing route embraces more than 500 km while the grazing areas of the sedentary herders are confined to a few square kilometres. Overstocking is best measured by its effects: meagre cattle, minimal milk production (500 g per cow/day), disastrous consequences in drought years and complete destruction of the vegetation cover including tree stock.

The example of Northern Darfur, Sudan, clearly illustrates the difficulties and the gaps met when calculating the degree of overstocking:

- The total area of the province is about 340,000 km^2. Only half of it (170,000 km^2) is suitable for extensive (light) grazing, the rest is desert. Owing to the confined water resources and their distribution only half of this potential grazing land (85,000 km^2) is actually used.
- One has to assume that the real numbers of animals are at least double the figures given in the census.
- The calculation of the animal stock of Northern Darfur in Livestock Standard Units: 1 camel = 1 L.S.U., 1 cow = 0.75 L.S.U., 1 sheep, 1 goat = 0.12 L.S.U. gives the following figures:

Table 30: The numbers of livestock in Northern Darfur in 1976

	Census 1976		taken double	x	L.S.U.	= Total (L.S.U.)
Camel	226,100	x	2	x	1	452,200
Cattle	908,100	x	2	x	0.75	1,362,150
Sheep	1,409,500	x	2	x	0.12	338,280
Goats	1,193,000	x	2	x	0.12	286,320
						2,438,950

- According to a survey done by the author in 1977 embracing 354 households in Northern Darfur the mean size of the herds per household was 10 camels, 7.5 cows, 22.5 sheep and 19.5 goats which equals about 20 L.S.U. Considering that the population was 1 million and that the average size of the households was 6, the total number of livestock could be $\frac{1 \text{ million}}{6} \times 20 = 3{,}333{,}333$ L.S.U.
- According to BOUDET (1975b, p. 30) 100 kg of living animal weight require 1,825 kg plant biomass. To keep a Livestock Standard Unit of 250 kg, 4,562.5 kg of biomass are required $\frac{(1825 \times 250)}{100}$.
- For the Sahelian zone BOUDET (1975a, p. 89) assumes an average annual production of biomass of 1,000 kg dry weight per hectare at the surface. Accordingly, the carrying capacity of the Northern Darfur Province can be calculated as follows:

  $$\frac{8{,}500{,}000 \text{ ha} \cdot 1{,}000 \text{ kg}}{4{,}562.5 \text{ kg}} = 1{,}863{,}014 \text{ L.S.U.}$$

- Therefore, overstocking in that province is as follows:

  2,438,950 L.S.U. - 1,863,014 = 575,936 L.S.U.

  or in %:

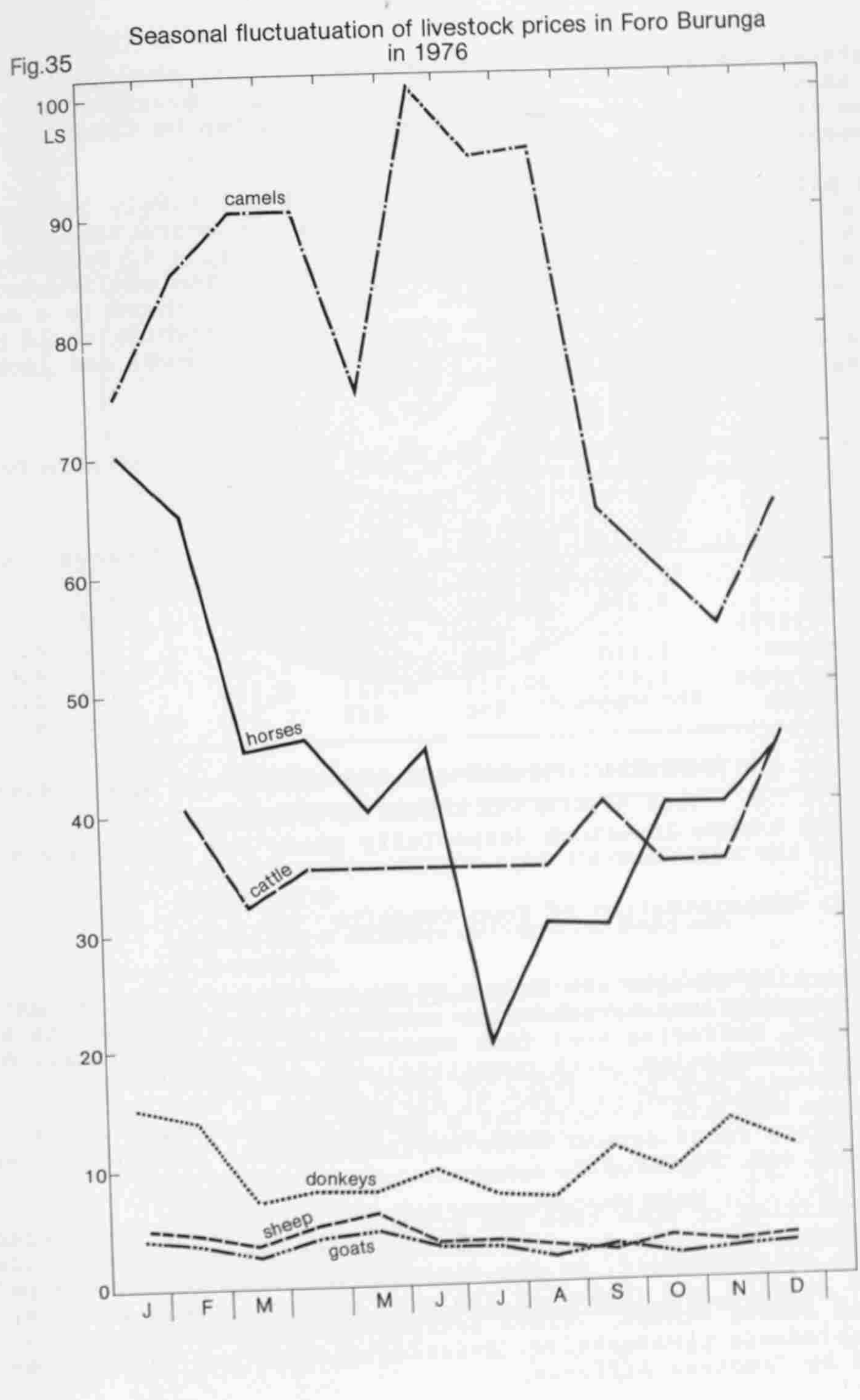
  $$\frac{575{,}936 \cdot 100}{1{,}863{,}014} = 31 \%.$$

If we take the figures mentioned last, overstocking will be much higher:

3,333,333 - 1,863,014 = 1,470,319 L.S.U., or in % $\frac{1{,}470{,}319}{1{,}863{,}014} = 78 \%$.

Another evaluation was done by H. A. MUKHTAR in 1974 (Figure 17). Accordingly, the carrying capacity of the province is estimated at 8 L.S.U. km^2 which means 1,360,000 L.S.U. (170,000 $km^2 \cdot 8$). Thus the overstocking is 79 %.

Fig.35



Seasonal fluctuatuation of livestock prices in Foro Burunga in 1976
100
LS
90
80
70
60
50
40
30
20
10
0
camels
horses
cattle
donkeys
sheep
goats
J
F
M
M
J
J
A
S
O
N
D

Whatever mistakes these estimations may incur, the conditions of animals and pastures clearly reveal a high overstocking degree in the Northern Darfur Province which can be taken as representative of the Sahelian zone.

The sale of animals in northern Darfur is relatively low compared with the number of livestock available (Compare Table 30 with Table 31). The off-take of cattle is only 3 %. Probably this is one of the reasons for the constant rise of livestock prices (cf. Figures 32 and 35). Added to this, there is a remarkable seasonal fluctuation of animal prices which could be related to the rainfall variation, on the one hand, and lack of animal transport means, on the other.

Table 31: Livestock sale on the major markets of northern Darfur in 1976

	Camels	Cattle	Sheep	Goats	Donkeys	Horses
El Fasher	12,100	9,800	13,000	5,200	420	160
Mellit	4,264	3,149	21,462	6,233	905	49
Kutum (1977)	72	144	1,560	2,952	72	ca.100
El Geneina	7,410	8,288	7,480	1,460	1,640	2,030
Foro Burunga	1,433	30,735	6,331	6,124	953	2,241
Um Keddada	45	810	645	360	ca. 70	ca.100
Total	25,324	52,926	50,478	22,329	4,060	4,680

About 30 % more livestock (especially sheep and goats) are sold outside the markets.

SOURCE: Administration of Town Councils

Overstocking damages are most conspicuous where sedentary animal husbandry is exercised. The surroundings of settlements are, therefore, suffering most from the effects of desertification through overgrazing, both quantitatively and qualitatively. After surveying many perimeters of settlements in Darfur, the author has been able to work out a scheme of concentric rings which often recur around these settlements as a result of overstocking (cf. Figure 36).

The qualities of both tree and grass species change considerably the closer one comes towards the centre from which desertification is triggered off. At the distance of about 10 km, the palatable acacias are gradually replaced by unpalatable species, such as *Acacia nubica*, *Guiera senegalensis*, *Albizzia* species and *Leptadenia pyrotechnica*. *Aristida* species are usually replaced by *Cenchrus biflorus*.

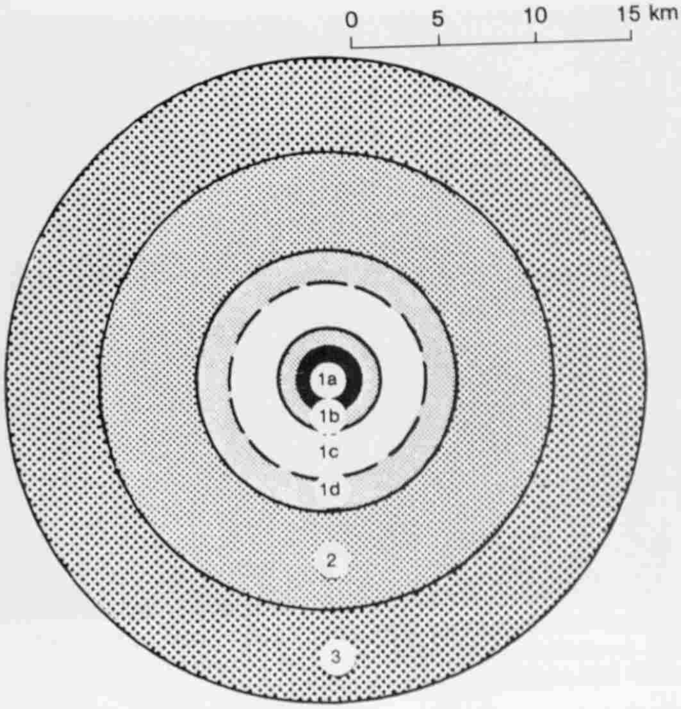


Fig.36 Idealized scheme of desertification in the perimeter of settlements in the Sahelian zone of Darfur, Sudan

The nearer to the centre, the higher the degree of degradation is.

1) Inner ring of excessive cultivation combined with overgrazing
   a) Settlement with old, shade-giving trees (*Balanites aegyptiaca, Acacia raddiana, Ziziphus spina christi, Azadirachta indica*)
   b) Settlement fringes, with unpalatable herbs and shrubs (*Cacia species, Calotropis procera, Guiera senegalensis, Albizzia* species)
   c) Ring of excessive cultivation with no fallow
   d) Ring of cultivation interspersed with fallow. Also overgrazing damages
2) Ring of permanent overgrazing
3) Ring of excessive tree-felling and seasonal overgrazing

Photo 25: Around bore-holes desertification takes place due to the overstocking of the surroundings.
Near El Fasher. March 1977

Photo 26: The supply of permanent water sources incited people to exhaust the pastures and destroy the land.
El Arais, eastern Darfur (250 mm precipitation).
August 1982

Photo 27: Despite the rainy season grasses are missing. *Maerua crassifolia* is deformed by browsing.
Wadi Golo, Darfur (290 mm precipitation). Sept. 1976

Photo 28: Due to overgrazing palatable grasses are replaced by unpalatable herbs.
Um Keddada, Darfur (250 mm precipitation). Sept. 1976

Photo 29: In drought years, fodder has to be bought at high prices to keep livestock alive.
El Fasher. Oct. 1982

Photo 30: Fodder shortage and not lack of drinking water is the actual cause of the Sahel disaster.
N Kordofan (300 mm precipitation). August 1982

Nearer to the settlement the plant density decreases rapidly. Trees are replaced by shrubs which are strongly deformed by browsing animals, such as *Maerua crassifolia*, *Ziziphus spina christi* and *Balanites aegyptiaca*. Closer to the settlement these species become less dense and there is usually a dominance of *Calotropis procera* with some occurrence of *Boscia senegalensis* and *Capparis decidua*. Ground vegetation is dominated by unpalatable herbs, such as *Cacia acutifolia* and *Sesamum alatum*. In the village itself one finds only the protected shade trees, such as *Acacia albida*, *Balanites aegyptiaca*, *Ziziphus mucronata*, *Acacia raddiana* and *Azadirachta indica*.

Desertification effects in the surroundings of settlements and the difficulty to control cattle numbers in order to avoid overstocking, imply that one of the important steps to be taken is to try to achieve evenly distributed grazing all over the area. This could be effected if drinking water facilities were evenly distributed. A rotation of the use of water pumping stations could be used to control grazing activities. Other necessary measures are the improvement of pastures by re-seeding in suitable areas, establishing firelines to check savanna fires, hay making and storage in the rainy season and buying fodder from irrigation areas during the dry season. At the same time, laws have to be issued regulating the rights to use grazing areas by certain groups of the population in order to make animal owners responsible for an improved grazing economy in their respective holdings. Pastures which belong to neither individuals nor to certain tribes are recklessly exploited to the degree of complete destruction. The most important measure and at the same time the one most difficult to realize, is the control of the number of animals to be adapted to the carrying capacity of land. Some form of adapted cattle marketing system must be developed to suit the traditional disposition of the savanna population towards cattle as a symbol of power and riches.

4.4 The Role of Peasant Women in the Process of Desertification

Women peasants in the western region of the Republic of the Sudan are both agents of and sufferers from the processes of desertification. Research done on the problem of desertification in western Sudan, especially in the old stabilized dune belt, Goz, reveals that women there suffer much more from the degradation of pastures and cultivated soils as well as from the disappearance of the original tree stock than men do. Women themselves have actively contributed to this degradation in their desperate attempts to keep their families alive. Nevertheless, all efforts to check the progress of desertification have been so far, made only among the men. For this very reason little is being undertaken to improve the conditions of subsistence production which is mainly practised by women peasants. There is rather a considerable number of afforestation projects, gum arabic plantation projects, cash-crop plantations, mechanized-farming schemes, range-management programmes and various other projects which aim ultimately at improving cash-income. This income flows directly into the pockets of men and only indirectly and to a limited extent towards the subsistence of the peasant family.

4.4.1 Millet Cultivation as Essentially Women's Task in the Goz Belt of Western Sudan

One of the typical scenes in Darfur in the rainy season is that of women peasants doing field-work with their babies tied to their backs. About 90 % of those working on the millet fields are women. Millet is the main source of nutrition for the peasant family in western Sudan, especially in the northern belt, which is endangered and partly already stricken by desertification. Women grind the millet grain, in most cases using the oldest method known: they rub the grain between two stones, kneeling on the ground, holding the upper roundish stone with both hands, rubbing it to and fro on the larger plate-formed stone which is lying on the ground. The flour is used for preparing different kinds of food, such as large, thin flat loaves of bread called kisra. In most cases they do not eat bread at all, but cook a kind of millet pudding called asida. To give it flavour they pour "mulah" on it, which is a sauce made from okra (bamia, weka, ladys' fingers, *Hibiscus aesculentus)*, dried meat (sharmut) and hot spices. This food does not provide the people with proper nourishment, as it lacks the vitamins which should be obtained from fresh vegetables and fruit. Most peasant families eat practically once a day and owing to the shortage of millet towards the end of the dry season the portions diminish gradually.

The Darfur women are well-known for making a thick millet beer which is called marisa or baghu, and is quite nutritious. Though women brew the beer, men consume most of it, for it is considered a men's drink. Though it is forbidden in Islam to consume alcoholic drinks the Fur and the Nuba cannot do without marisa, especially if they are travelling, and are given a goat's skin full of marisa to take with them for food by their wives.

Millet cultivation is looked down upon by men in western Sudan as feminine work, and it is supposed to be degrading for a man to practise it. Lately, this attitude has been slightly modified so that poor men, who are struggling for an existence, accept the idea of doing certain kinds of field-work. They would for instance do some weeding, but no threshing, which is a harder task. Men have also begun to help in sowing by digging the holes, while women follow, planting the grains in these holes. Digging shallow holes into the loose, sandy soil is not, however, exerting work. The case is similar in Jebel Marra where the Fur men in Suni undertake the care of the orange-orchards while women have to cultivate millet, sorghum, tomatoes, onions and garlic, which requires harder work than the irrigating and picking of oranges. What are the reasons which led to the development of such unjust traditions in the distribution of work? Such a discrimination of women in western Sudan is prevalent not only in the agricultural, but also in the urban environment. In Darfur, there is no job, however hard it may be, which women refrain from practising. Women there work in digging wells, and in all types of construction work requiring bodily strength, such as carrying stones, sand and water.

Fetching water from the wells every day, which is traditionally the work of girls and women, is one of the hardest tasks in peasant life. The desertification of land makes this work even harder, for owing to the degradation of the vegetation cover in the higher catchment areas of water courses, these courses have changed their hydrological system in different ways, leading ultimately to the change of surface run-off and the recharge of the shallow ground-water aquifers. Generally the absence of vegetation causes less seepage, more evaporation, quicker runoff, more soil erosion and enhanced sedimentation. The latter process has led to the damming up of the lower courses and the diversion of their direction. These hydromorphological changes have a strong impact on both surface and groundwater supply in the forelands. Some water-reservoirs (hafīr, rahad) are receiving less water than before, thus drying up too early in the dry season compelling women to travel longer distances for their water. Morever, the loss of the vegetation cover enhances soil erosion and with it the silting up of the dug water reservoirs (hafīr), so that they hold much less water than before. The evaporation ratio in shallow hafirs has increased immensely. In the cases in which women depend on the wells in the wadis and in the forelands of mountains a drastic sinking of the ground-water table and the drying up of some wells has been observed, resulting in not only less water for the family but also more work for the women. Moreover, desertification in the catchment areas of wadis which are used as a source of drinking water in the rainy season increases the burden of women, as they used to dig shallow holes (tumad) of about 50 cm depth in those wadis to find water during the rainy season. They use either primitive digging tools or their bare hands, if the soil is sandy and loose, however with the change in the hydrological system of the wadis, women must dig up to three metres to find water. As these tumads are filled up with sediments with every new flood, new ones have to be dug: many wells need to be cleared off the sediments and tree-branches after the floods and the men is this case assist, perhaps because their herds need water to drink.

4.4.2 The Consequences of Rainfall Variability for Women Cultivators

The variability of precipitation which is typical of the Sahelian zone has a far-reaching impact on the lives of women cultivators there:

a) The annual fluctuation of the amount of precipitation and the high variability of the distribution pattern of rainfall within each rainy season leads to difficulty in assessing the crop situation. Women cultivators are thus obliged to clear, till and sow a large area and, some weeks later, decide which parts have received enough rain to make them promising. These parts are then weeded and looked after, until the harvest-time. In dry years even larger areas are cultivated to secure the needed amount of millet for subsistence. Thus, intensified desertification takes place just in the very years in which the natural ability of nature to regenerate itself is impaired by drought. In these cases the amount of work done by women is considerably increased and the contribution to desertification becomes greater.

b) One of the interesting correlations in this respect is that between rainfall variability and polygamy. The questionnaire run in Darfur revealed this strange relationship. When asked how they managed to satisfy their demand of millet or sorghum in a certain dry year (1976) men who had more than one wife almost invariably answered that one of their wives brought in good yields. The explanation of this variation of grain yields within the same season and within the same area is that rainfall in that semi-arid marginal tropical zone reveals high local variability especially at the beginning and at the end of the rainy season. Clouds cluster and produce a heavy afternoon shower, while the sun may be shining two kilometres away. One often notices that two rain-gauges in the same town, a few kilometres apart, give quite different readings of the same day. Generally, men choose their various wives from different villages or different parts of the same village, perhaps to avoid conflicts. Often, each wife remains living in her home village or quarter of origin. Even if the husband were to assemble his wives in one compound, each of them would still have her own millet plot at a considerable distance from those of the other wives. These distances are naturally created, even within the area of the same village, because the newer wife usually procures a plot on the fringes of the village cultivation area, as nearer plots are already occupied by the older villagers. The older wife's plot is usually near the village. This wide distribution of the plots of the same family fits in well with the local variability of rainfall. Polygamy provides more chances of survival for the husband, but not necessarily for the women and children, as mutual help between the different wives of the same man is uncommon, instead, rivalry prevails. Only some indirect help is given to the poorer part of the family by the husband. One should not however overestimate the role of polygamy in rural economy, as the statistical average of men who have more than one wife is only 10 %. In rural areas of western and southern Sudan, the percentage is somewhat higher.The important point is that each wife is made responsible for the livelihood of her part of the family including her husband.

c) The greater consequence of rainfall variability for women cultivators is, however,the compelled migration during the phases of drought. This is mostly relevant to the Zaghawa women of northwestern Darfur. During the recent dry climatic phase begun in 1968, in which precipitation decreased by about 50 % in relation to the foregoing wet phase 1950-1967, women cultivators were obliged to leave their tribal region and migrate southwards during the rainy season to work as millet cultivators in the more humid zone some 200-400 km south of their homeland. On such seasonal migrations women usually take their children with them and form groups, each belonging to one village or area. They cultivate plots of land upon agreement with the owner, who may also provide the seeds. In some cases these migrant women are engaged only for weeding or for both weeding and harvesting, and they guard the crop against grazing animals, scaring birds and locusts by drumming on empty tins.

After reaping and threshing the grain, the working women receive their portion of the yield, which varies from one third to one sixth of the yield. The name of this portion being "ushur" (tenths) may indicate that, in former times, land-labourers used to receive only one tenth of the crop. In any case, land tenure holders are still exploiting women as cheap labour. One must realize that this land, in most cases, belongs actually to the State and those "landlords" have only right of use. They certainly would not have it cultivated, if it were not for the availability of cheap labour. So it is quite an unfair business. At the end of the rainy season, women carry their portion of millet and return with their children to their home-villages.There, they try to feed their families throughout the long dry season of 8 months. The men may occupy themselves by caring for some animals or working at one of the irrigation schemes of the Nile area.

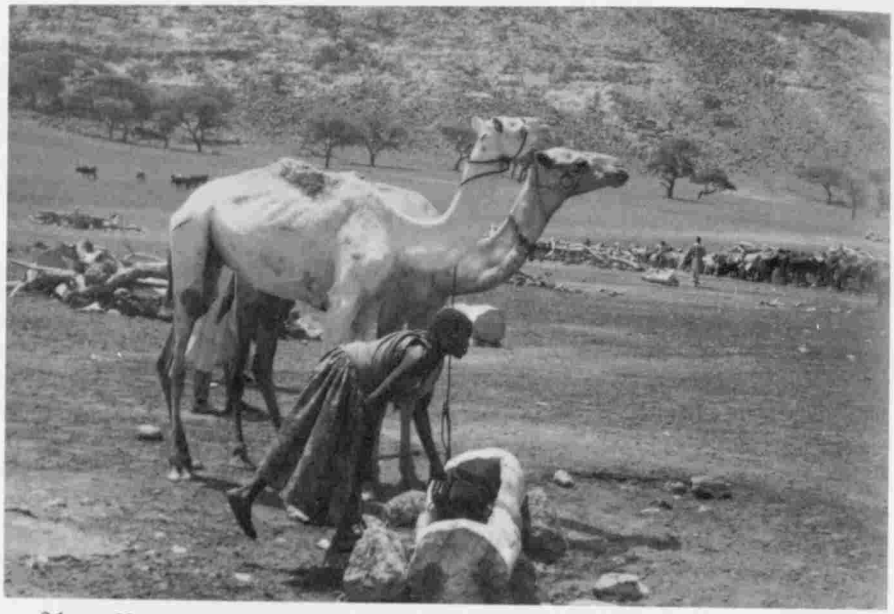


Photo 31: Women are not only responsible for farming, firewood supply, children and household, but they also raise livestock and provide them with water and fodder.
Malha Crater, Darfur. Sept. 1982

Photo 32: With their bare hands girls dig seasonal wells *(tumad)* in Wadi beds.
N of El Geneina. Oct. 1977

Photo 33: Threshing millet (as the whole process of food production) is done by women in western Darfur.
N of El Geneina. Sept. 1977

Photo 34: Wood is indispensable for house construction in Darfur.
El Fasher. Oct. 1977

4.4.3 The New Burden Laid on Women as a Result of the Settlement of Nomads and Semi-Nomads

One of the consequences of desertification is the settlement of nomads and semi-nomads. Settlement, however, brought about more work and more responsibility for women. Sedentary living involves more dependence on cultivation which is traditionally the work of women. In the past nomadic life, women contributed to the livelihood of the family by milking the cattle, making butter, cooking it to conserve it, and selling milk and its different products, at the market. In the rainy season, they used to grow millet or sorghum on a limited scale. The settlement of nomads has been associated with economic and social degradation in most cases, as it was due to the loss of livestock and wealth. This loss rendered men jobless and set most of the burden of caring for the family on the shoulders of the women for the traditional reasons described above. Beside the loss of livestock, the pacification of nomads in the colonial and post-colonial times has contributed to the "unemployment" of the men. Defending tribal pastures and herds against the raids of other tribes was one of the most important tasks of men. With increasing security men have to seek other tasks, but find it difficult to accept sharing farming work with the women.

4.4.4 Possible Ways of Improvement

Considering the fact that women suffer more than men as a result of environmental degradation of the semi-arid zone of the Republic of the Sudan one of the important objectives of combatting desertification and its impact must be to improve the women's situation there. Apart from the recommendations made in the United Nations Plan of Action to Combat Desertification of 1977, further recommendations have to be made and immediately implemented to relieve the heavy burden laid on women in these areas. Many of the projects directed against the causes and consequences of desertification are of technical agrarian nature, which give little or no attention to the flagrant inequality between men and women in the societies in which these projects are being carried out. The following few recommendations are tentatively made as the first step to further suggestions of effective measures to help women in the rural semi-arid environment of the Sudan:

a) Public information media, such as radio, TV, Party information means and schools should teach men how to help their wives and make them realize that it is the man's duty to assume the greater part of the responsibility for feeding his family.

b) Appropriate technological methods of field-work should be developed in order to make the cultivation of land easier and more productive.

c) The prices of millet and sorghum must be controlled on the rural markets to stop the manipulation and exploitation exercised by the merchants. This could be partly achieved by organizing a low-profit making corporation which would undertake the storage of grain in the times of price recession and its marketing when the prices begin to rise.

d) Water supply should be improved, in order to relieve the women's work of fetching water from wells over long distances. Simple technical improvements, such as using hand-pumps or donkeys and camels for drawing water from the wells could be easily introduced, before a final solution could be found.

e) The problem of rural energy should be solved, before it becomes too late, i.e., before the tree stock of the Sahelian zone disappears completely. Intermediate solutions should be found, before oil is explored or solar energy used as all these are long-term solutions. At present, measures could be taken to improve the production, transport and marketing of fire-wood and charcoal. Simple energy-saving ovens should be developed and introduced to replace open fires.

f) In areas prone to or already stricken by desertification alternatives for the cultivation of grain should be found. Handicrafts should be taught to rural women so that they can practise some home-industries, such as making carpets, weaving mats and baskets of straw and palm-leaves, sewing and needle-work. Leather-work from goats' skins should be developed as well.

It is certain that changing traditional attitudes is difficult and requires a long time, but one must start at least by identifying the problem and forcing the people concerned, to recognize it. Though women in rural societies are discriminated against, as amply described above, they are hardly aware of the fact. Even if they realize that they are suffering, they do not perceive the causes and are, therefore, unable to identify any proper solution. Men, on the other hand, are neither interested in knowing the problem nor in solving it. Even if they are principally convinced that something must be done they are not willing to change the traditional order.

When asked why he did not allow his wife to sit and eat with him, a Rezeigat nomad of Western Sudan asserted that his wife would not even dare to drink water in his presence. When asked if he liked his wife at all, he made it clear that liking her and eating with her are completely different subjects. His wife was brought up like that and she herself would never dream of breaking tradition. In fact, it is a great issue to decide whether it is wise at all to interfere with and disturb a traditional society, without offering solid and comprehensive alternatives. Single and isolated changes might be more harmful than no change at all.

4.5 THE DESTRUCTION OF THE TREE STOCKS FOR WINNING TIMBER AND FUEL

The inhabitants of northern Darfur depend almost entirely on wood in meeting their energy requirements and in the building of their huts, fences and enclosures. Figure 37 displays the results of our questionnaire concerning the wood consumption of an average six-member family in northern Darfur.

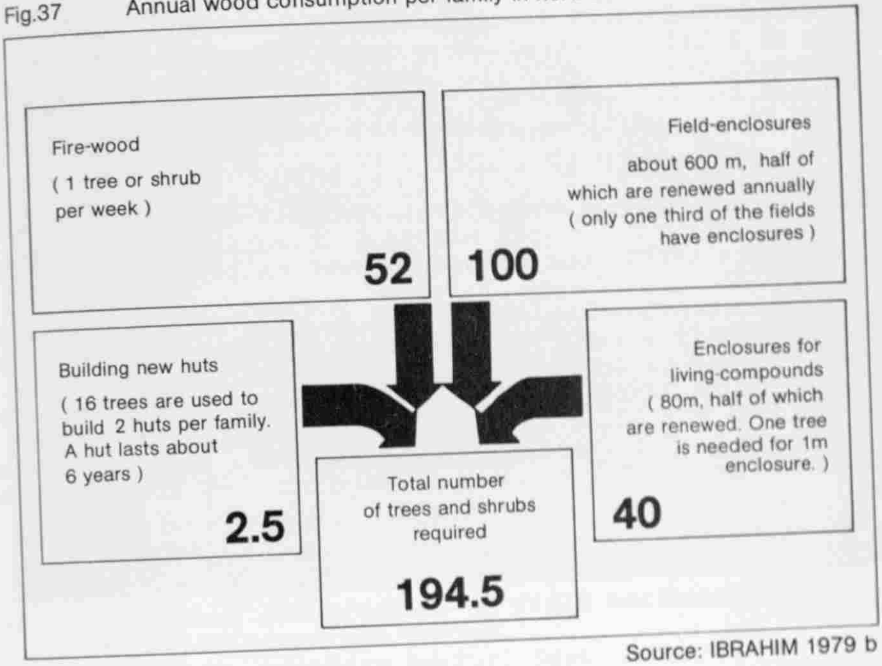
87 % of the inhabitants stated that they obtain wood by felling trees in their near surroundings and in 13 % of the cases, wood is brought from distant areas. The average consumption of firewood is a donkey-load (rahal humar) per family, per week. This is about 50-70 kg wood which can be won by the felling of a middle-sized *Acacia mellifera* and on the market this load costs about as much as the wages of 2.5 days in farming. Despite the high price of wood and its growing scarcity, it is still being used uneconomically. For cooking purposes women often burn one large piece of wood which continues to burn the whole day. Energy-saving ovens, as those known in India or Egypt, are rarely used in the Sudan. Closed mud ovens make use of about 40-50 % of the energy produced, while open fires give only 5 % energy benefit.

Only the urban population of the Sudan uses a simple tin oven (mangad), in which charcoal is burnt. Although the tin oven is not suffciently closed, it wastes less energy than open fires do.

Not only farmers and nomads use wood for fuel, but also the urban population. None of the 30 bakeries of El Fasher use fuel other than wood and gasoline is too expensive to be used for such purposes.

The requirements of timber in northern Darfur are about threefold those of firewood. Annually, about 150 trees or scrubs per family are felled in order to erect the hut (gottia), the surrounding fence (hosh) or the field enclosure (zarība). While huts can last for 6 years on an average, fences and enclosures last no longer than two years, because they are not fixed in the ground and are thus easily destroyed by the animals or the wind.

Fig.37 Annual wood consumption per family in northern Darfur



Source: IBRAHIM 1979 b

An estimated 10 million families in the Sahelian zone make use of 2 billion trees annually. Afforestation activities are, however, very poor in the Sahel. In northern Darfur, trees are planted in the perimeters of El Fasher and Um Keddada as a type of "green belt" to protect the towns from the encroaching sands.

Although in the Sudan laws exist to protect certain tree species and to control charcoal makers in clearing tree-stocks, those laws are rarely obeyed and corruption prevails.

Reducing wood consumption must be given high priority in combatting desertification. Two thirds of the wood used now can be saved, if better construction methods are introduced to make huts and enclosures last longer. In addition, more energy-saving methods should be taught to the population to reduce the consumption of firewood at least by 50 %. Ample extension work must be done in this area, if good results are to be obtained.

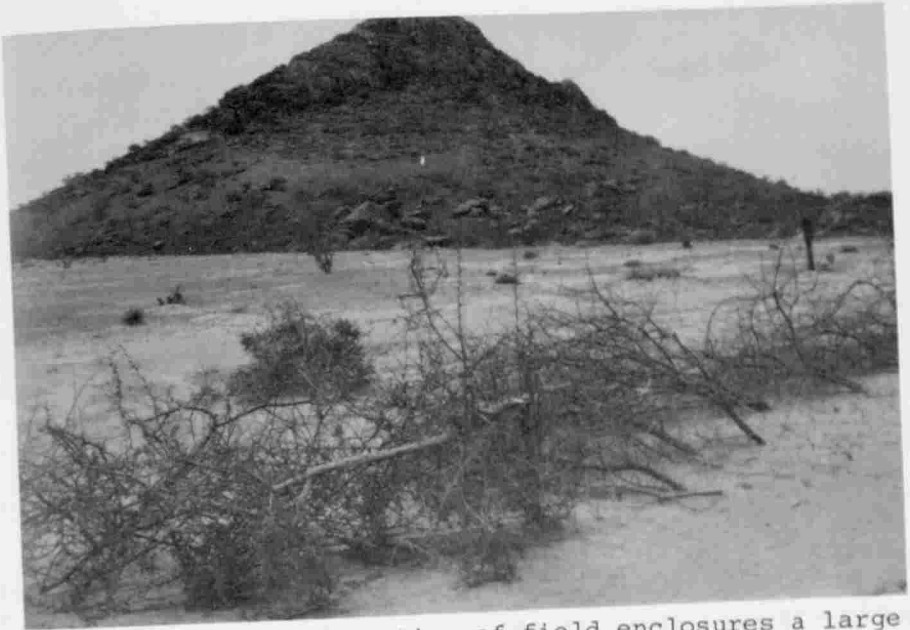


Photo 35: For the construction of field enclosures a large number of trees are felled.
Kafoot, northern Darfur. Sept. 1982

Photo 36: The remaining rest of ebony (*Dalbergia melanoxylon*) in Darfur is being felled for hut construction.
Manawashi, Feb. 1980

Photo 37: Strip-mining is the method of legal and illegal charcoal producers in the Sahelian zone of Darfur.
Manawashi, Oct. 1981

Photo 38: The last trees are being transported to the markets on camel-back. Here, the perimeter of El Fasher is completely desertified.
March 1977

5. Regional Differentiation of Desertification in Northern Darfur

Owing to the ecological variation within northern Darfur and because of the different systems of traditional land use in the different regions, ecological imbalance has reached different degrees from slight to very severe. In this chapter, northern Darfur is divided into 6 ecological-ethnological regions, each of which is examined as to its specific degradation problems.

5.1 JEBEL MARRA AND ITS PIEDMONT

The effects of desertification in the Jebel Marra region vary in degree according to the change of climatic conditions from N to S and from W to E, the hypsometric zonation, the slope inclination and the edaphic variations.

The more humid climate of the higher regions and the southern and western slopes are more favourable for land utilization than the drier climate of the northern and eastern flanks. While the former areas on the weather side receive 600 - 900 mm of mean annual precipitation, the other areas of the leeside receive only 300 - 500 mm. For the whole region of Jebel Marra, however, one has to take into consideration that the last 18 years constituted a long drought phase of about 25 % precipitation deficit. Notwithstanding the worsening climatic conditions the inhabitants intensified land utilization in order to satisfy their growing demands. Especially N and E of the mountain massif desertification damages have taken a large scale. Stress will, therefore, be laid on these areas in this treatise.

The eastern and north-eastern forelands have an elevation of 800 m to 1000 m above S.L. The morphological structure is characterized by several flat-floor consequent wadis separated by Goz accumulations in their lower courses. A little higher the Goz gives way to skeletic pediment surfaces interrupted by inselbergs. The major wadis from N to S are: Wadi Tabos, Wadi Magdub, Wadi Tawila, Wadi Keira (Kej), Wadi Sauda, Wadi Durura, Wadi Abu Hamra and Wadi 'Amer. They follow the inclination towards the E and SE flowing into the large endorheic basin of Wadi El Ku' which flows ultimately into the sea of sands of southern Darfur. Only in exceptionally wet phases can the waters of NE and E Jebel Marra reach the sea through Bahr El Arab and the Nile.

Agriculturally significant are the Goz areas lying between the wadis. These sandy surfaces belong to the western ends of the stabilized old dune belt of the Sahelian zone of the Sudan extending eastwards to the Red Sea Hills. These aeolian sands are here mingled with fine volcanic dust which renders the Goz of the Jebel Marra pediment a particularly consolidated structure, which makes it different from the coarse Goz of the eastern areas dominated by Nubian Sandstone.

The combination of valleys and sandy surfaces renders this area suitable for intensive land use and dense human settlement. While the Goz soils are generally taken under millet cultivation, wadi soils (containing material from the weathered volcanic rocks) are chosen for the growth of sorghum, vegetables and chewing tobacco. The farmers build earthen dams (taras, pl. terūs)in the flat-floor valleys so as to harvest the waters of the seasonal floods. The success or failure of the crop depends on the amount of water trapped behind the taras. Water harvesting, however, has become a highly speculative enterprise in recent years. The reasons of this are complex:

- Both precipitation and run-off have dwindled considerably.
- Water consumption in upstream areas has increased (construction of water reservoirs and irrigation schemes).
- The topography of wadi basins has changed as a result of enhanced aeolian and fluvial deposition. The latter is to be correlated with soil erosion on the higher slopes.

A further reason for the relatively high population density in the foreland of Jebel Marra is the secured water supply. In the wadis there is a large number of permanent traditional wells whose water-table varies between 2 - 6 m below the surface. Boreholes, such as those of Sag En Na'am reach the deeper groundwater layer (30 m). The population of the eastern forelands of Jebel Marra is composed of the Fur, the Berti, the Birgid, the Tungur, the Tama, the Biringa, the Bargo and the Dadinga. The settlements of the Fellata, who came from West Africa are relatively old. Lately, specially after the outbreak of the drought disaster in 1970, more than 100 Zaghawa settlements have been established in that region. This recent phase of agrarian colonisation of these northern tribes is probably responsible for the disappearance of trees and *Aristida* grasses on the Goz in that region. Only patches of *Cenchrus biflorus* appear in the rainy season.

A number of morphodynamic processes has been enhanced by this recent damage of the vegetation cover. Fluvial processes include the dissection of the fringes of the stabilized old dunes and the deepening of wadi beds. The aeolian activities include the deflation of the fine particles in the soils, the formation of wind-blown sand-sheets and *Capparis* dunes in the wadis.

The higher zone of the piedmont (1000 m - 1300 m) is mainly used as pasture for cattle, camels, sheep and goats. Compared with the lower zone, this one has a denser tree stock and more water resources. That is why it is highly frequented by livestock herds of the surrounding settlements as well as by the herds of the Rezeigat nomads (Mahriya, Mahamid, Abu Jallul), who migrate seasonally along the piedmont of the Jebel Marra massif to spend the dry season in the woodland savanna of the southwest. Cultivation is practised mainly within or alongside the wadis where also the larger settlements are located (e.g. Kebkabiya, Kas, Zalingei and Nierteti). Desertification is less severe in this zone than in the lower one. Ecological degradation is to be related here rather to overgrazing than to overcultivation. One of the main causes is also tree-felling for the purpose of supplying fire-wood and timber. Large areas are deforested by illegal charcoal producers. Especially affected by desertification are the perimeters of large settlements.

The next zone is dominated by cultivation terraces which are concentrated within the zone between 1500 m and 1900 m. Terraces reach, however, an elevation of 2700 m. Owing to the difficulty of keeping such terraces on steep slopes, quite a large number of them have been deserted. But this is not caused by the present phase of desertification.

One can roughly identify three zones of cultivation in Jebel Marra. The lowest zone is dominated by irrigated vegetable gardens (tomatoes, okra, chillies, onions and garlic). The middle zone is the millet zone which is also interspersed by tomatoes and chillies as well as by irrigated citrus orchards. The higher zone is a mixed one with a domination of orchards (citrus, mango, juwafa).

Here we have also wheat cultivation. By terracing the slopes soil erosion is subdued and run-off slowed down. Silt layers accumulate on the shallow skeletic soils and the water-balance of the soils is enriched. On the contrary, non-terraced slopes lose their soil layer quickly and are easily subjected to the formation of deep gorges, especially in the loose volcanic ashes.

The Jebel Marra massif is a very old settlement region. It has seen a long history of land utilization including various phases of ecological degradation whenever the Fur population was forced to take refuge in the higher zones during the Arab raids in the forelands (c.f. AHMED 1982).

5.2 DAR ZAGHAWA

Dar Zaghawa is one of the areas of the Republic of the Sudan which has been most stricken by desertification during the latest drought phase. Since 1967 precipitation has been decreasing rapidly. Kutum for instance, which lies at the southern margin of Dar Zaghawa, reveals a precipitation deficit of 42 % between 1967 and 1982, compared with 17 years before (243 mm compared to 345 mm annual mean). The deficit was even greater in Um Buru and Tine, in the centre of Dar Zaghawa (46 % and 69 % respectively). During the years 1950 - 1966, Dar Zaghawa received 250 - 300 mm annual mean precipitation, barely sufficient for the success of millet cultivation which expanded all over the area, during that humid phase. At the same time, the number of animals grew quickly under such relatively good conditions. Dramatic changes took place when precipitation decreased by half in the subsequent drought phase. The greatest loss was recorded among the cattle stock of which two thirds died. The Zaghawa changed from predominantly cattle breeders to predominantly camel breeders. The greater loss, however, was among the millet growers who constitute the poorer level of the Zaghawa. Losing the basis of their existence, they migrated southwards to settle in the more humid zone.

According to an offical report by RIFAI and AHMED (1974) 475 of 804 Zaghawa settlements were deserted during the drought years 1969 - 1973 (Table 32).

Table 32: The Zaghawa distribution during the drought disaster 1973

District	Total No. of Settlements	No. of Deserted Settlements	No. of Families in the Settlements	No. of Families in Pastoral Camps
Tine	113	86	529	172
Karnoi	208	129	251	2,592
Um Buru	110	61	1,163	861
Musbat	87	48	946	986
Um Marahik	90	70	303	205
Dor	106	57	876	954
Other Areas	90	24	1,396	658
Total	804	475	5,464	6,428

Approximate population accordingly: (5,464 + 6,428) x 5 = 59,460

The same report states that the Zaghawa intensified their migration to urban areas during the recent drought phase (Table 33).

Table 33: Migration phases of the Zaghawa

Period of Migration	Per Cent of Total Migrants
Before 1960	30.7
1960 - 1964	11.5
1965 - 1967	8.7
1968 - 1973	49.1

Source: RIFAI et al. (1974)

As a result of the recent wave of migration today most of the Zaghawa live outside their tribal land in NW Darfur. According to RIFAI et al.(1974) the total population of the Zaghawa in 1973 was 148,000, of which only 60,000 lived in Dar Zaghawa, while the remaining 88,000 lived in other parts of Darfur. A considerable number of the Zaghawa live, however, in Khartoum and in other large towns of the Sudan and work there as merchants and labourers. It should be noted that TUBIANA (1977), estimated the number of the Zaghawa in Darfur in 1970 to be 255,000.

Figure 38 shows the destinations of the Zaghawa migrants in the Sudan. Table 34 gives the migration destinations in Darfur, the household numbers of migrants and their proportion of the total number of migrants.

Table 34: Migration destination of the Zaghawa in Darfur

Area	Number of Households Absolute	Per Cent
El Fasher	10,585	55.5
Area between El Fasher and Nyala	3,553	18.7
Nyala	350	1.8
South of Nyala	1,483	7.8

Area	Number of Households Absolute	Per Cent
Ed Da'ein	1,219	6.4
E Darfur	1,642	8.6
W Darfur	223	1.2
Total	19,055	100

Source: RIFAI et al. (1974)

For the Zaghawa, migration does not only mean the loss of their traditional environment and the roots of their identity, but also a socio-economic change. Ninety per cent of the migrants abandoned their semi-nomadic mode of living and livestock-raising and became settled millet farmers in the Goz areas of Darfur. About 10 % live in towns now, where they are well-known as merchants of relatively good educational level. The economic situation of the migrants is better than that of those who remained at home. One of the causes of desertification in Dar Zaghawa is that migrants buy livestock and allow it be raised by their relatives in Dar Zaghawa, leading to overstocking and overgrazing. If this practice were stopped and if animal husbandry were limited to those actually living in Dar Zaghawa, stocking would then be in line with the carrying capacity of the area. The tribal land of Dar Zaghawa is about 40,000 km^2 supporting about 40,000 inhabitants at present. According to MUKHTAR, 1974 (Fig. 17) the carrying capacity in Dar Zaghawa is estimated at 4.6 L.S.U./km^2. This would mean that an average six-membered family can keep a herd of a reasonable size of 23 camels and 40 sheep and goats.

Table 35: Development of livestock numbers in Dar Zaghawa from 1965 to 1974/1975

	1965[1)]	1970[1)]	1974/75[2)]	Increase or Decrease
Cattle	31,830	29,234	10,695	- 66 %
Camels	6,543	7,989	30,778	+ 370 %
Sheep	77,938	86,641	98,000	+ 26 %
Goats	8,976	21,630	68,393	+ 660 %
Horses	1,178	1,076	317	- 73 %
Donkeys	6,217	7,152	9,447	+ 52 %

Sources: 1) TUBIANA, M. J. and J. (1977)
2) District Council, Kutum (1977)

Fig.38 Destinations of the Zaghawa migrants in the last 50 years

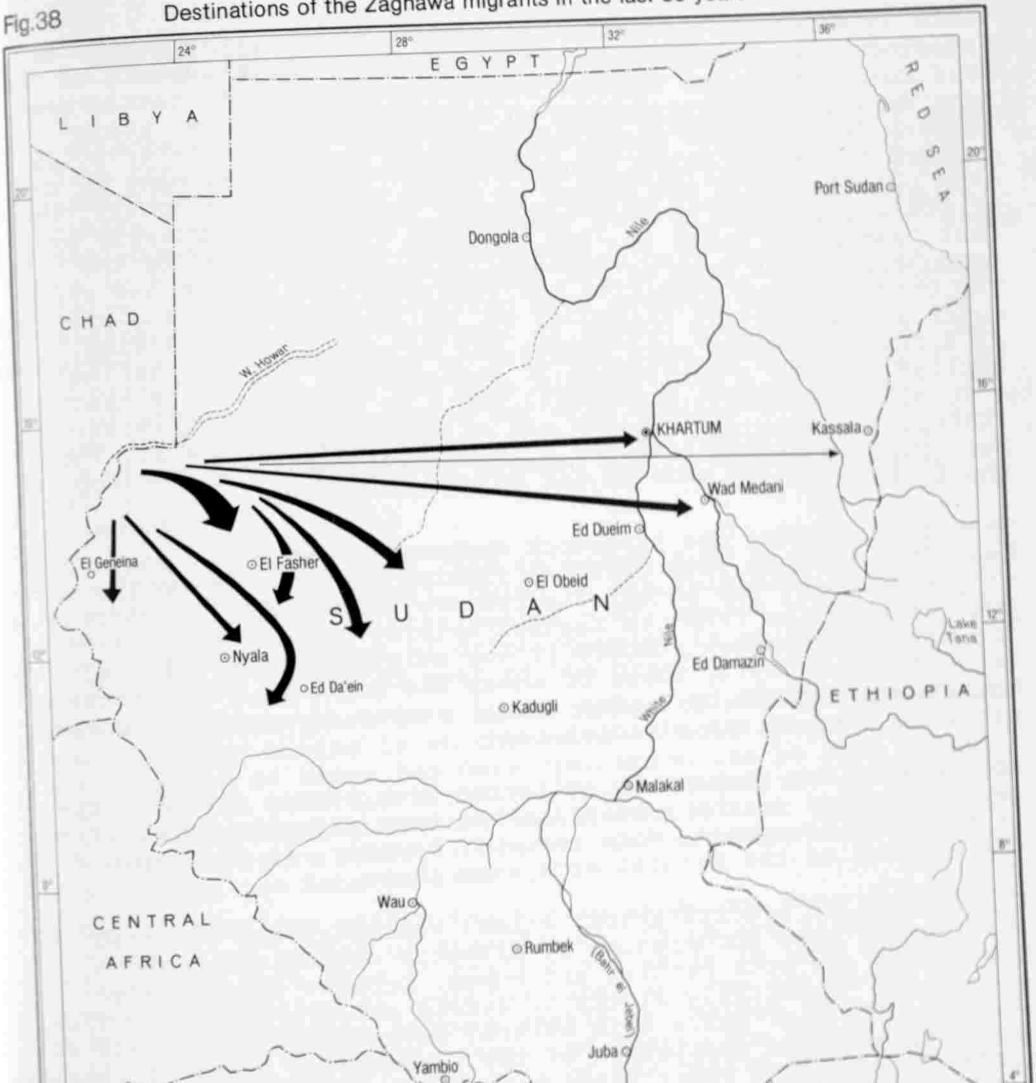


Table 35 shows that despite the severe drought, the number of livestock increased between 1970 and 1974. The structure of the herd composition has however basically changed. As cattle are considerably more vulnerable to drought than camels, their numbers decreased to about one third from 1970 to 1974/75, as opposed to camels which increased by four times as many in the same period. While the number of sheep increased slightly, that of goats increased by more than three times. This clearly proves that camels and goats are considerably more adapted to the drought-stricken area of Dar Zaghawa than are cattle and sheep. The change of the Zaghawa from cattle to camel breeding involves quite a considerable change in identity and mode of living. It is a change towards more mobility in pastoralism, replacing a settled life by a semi-nomadic one. One can appreciate that as a result armed conflicts with the neighbouring camel raising tribes: the Rezeigat (Abu-Jallul and Mahriya) in the SE, the Beni Hussein in the S, the Bedayat in the NW and the Meidob in the E, have followed.

When interpreting the livestock numbers in Table 35, one should bear in mind that such official figures are taken from the taxation registers. The actual figures are much higher. According to oral information from the Zaghawa chiefs, one may get nearer to the actual livestock numbers if one multiplies the official figures of camels by 4, those of sheep and goats by 2 and those of horses and donkeys by 3. The actual number of cattle is comparable to that of the official one.

At present, Dar Zaghawa is suffering from severe drought. The general exodus of the population has been strongly intensified in the last few years. More serious, however, is the rapid deterioration of the natural ecosystem there.

The changes in precipitation, animal husbandry and rain-fed cultivation were accompanied by dramatic ecological changes. The causes are both natural and human. Drought caused large tree stocks, especially stocks of *Acacia mellifera* and *Commifora africana*, to die. While this natural devastation took place on the pediments and pediplanes of the Precambrian Basement Complex, the old dunes were reactivated as a result of excessive rain-fed cultivation and sedentary animal stocks. Rehabilitative measures should aim at the complete conservation of the desertified areas by stopping rain-fed cultivation and controlling sedentary grazing there. Alternatives should be offered by a better management of wadi basins in the southern boundary of Dar Zaghawa, especially in the large wadis of Aradeib and Kaja. Suitable methods of water harvesting could be developed to secure enough water for drinking and the irrigation of a considerable strip of land, and migration should be directed and organized so as to avoid the ecological destruction of the destination areas, as has happened in the area south of El Fasher.

5.3 DAR MEIDOB

The effects of desertification are less pronounced in Dar Meidob than in the other areas of Northern Darfur. Comparison of Dar Zaghawa with Dar Meidob, which lies roughly in the same zone (northern Sahel), provides information on the varying effects of semi-nomadic pastural farming. Most of Dar Meidob still seems to be in a state of ecological balance, only the immediate vicinity of the watering-places and settlements being affected or endangered by overgrazing. We recognize as reasons for the relatively slight danger to the ecological situation in Meidob land primarily the predominance of pasturalism and the confinement of arable farming to a few favourable areas. Although the Meidob land is concentrated in the semi-desert (15° N - 16° N), there are a few favourable factors for pasturalism in this relatively limited region, which has no more moist areas to supplement it.

a) J. Teiga and J. Meidob rise to an altitude of more than 1,000 m above sea level. Owing to the resultant cooling, especially in the winter months - dry season - the grazing animals' requirement of drinking-water is relatively low and the growing period of most of the grazing-plants is longer.

b) In Dar Meidob there is a large number of shallow wadis and sedimentary basins in which, owing to soil advantages, a rich stock of trees has developed which can be used at any time of the year for browsing. A characteristic feature of the cattle-herding Meidob, therefore, is that they do not undertake great seasonal migrations, although they live partly in the Saharan area.

c) Dar Meidob lies within the Nubian Sandstone area which contains large bodies of groundwater. There are 22 deep bore holes and more than 15 traditional wells in this area. The assured supplies of drinking water and the existence of areas of permanent pasture enable the Meidob to keep cattle in addition to camels, sheep and goats. For the Meidob - unlike the Zaghawa - the size of the cattle herds remained unchanged (or possibly increased), despite the disastrous drought from 1969 - 1973 (c.f. Table 36). The traces of this catastrophe are still however visible even today in Dar Meidob. One often comes across withered specimens of *Acacia mellifera* in the countryside, whose death cannot be attributed to man's irresponsibility. This kind of restriction of grazing capacity, however, causes increased pressure upon pasture areas which are not as adversely affected by drought. When the situation became critical, the semi-nomads of the Meidob migrated south at that time, as far as Bahr El Arab.

Table 36: Livestock in Dar Meidob

Source	Camels	Cattle	Sheep	Goats
Taxation Registers (1973)	12,104	7,715	48,880	64,684
Official Report (1973)	40,300	40,300	147,900	94,100
Estimation of a Meidob Chief (1976)	191,000	106,000	320,000	270,000
F. IBRAHIM (1977)	132,000	63,500	377,000	345,000

Table 36 shows that the Meidob are mainly camel breeders. The sizes of their herds are relatively larger than those of other tribes in Northern Darfur. It is worth mentioning that the Meidob number about 45,000 at present (1983): in 1956, they were 22,000. They speak their native language as well as Sudanese Arabic.

5.4 The Zeiyadiya Land

The territory in which the Zeiyadiya (Arabs) live in NE-Darfur extends approximately 450 km in a NS-direction, between 12°N and 16°N. In particularly wet years, the inhabitants migrate with their herds of camels and sheep into the Jizu-area north of Wadi Howar, about 500 km to the northwest. In particularly dry years, they penetrate southward , as far as the railway line. The Zeiyadiya are a group of nomads who are presently in the process of becoming settled. The Zeiyadiya further south have already become settled millet growers and have established a large numer of farming settlements to the east of Mellit and to the north-east of El Fasher. The northern Zeiyadiya, on the other hand, have to this day, remained camel-herding nomads. Their main pasture areas lie in Um Bayada and Wad Mareiga, south-east of the volcanic Jebel Meidob. If one compares vegetation and soils there with those of the Zeiyadiya arable-farming area in the south, one arrives at the same conclusion that although there is much less rainfall in the north than in the south, the ecological situation is better there. The satellite images reveal the farming areas around Khurreit (Koma) and Abu Gau (Abu Kau) as white patches completely void of vegetation.

An example of the many Zeiyadiya groups who are in the transitional stage between arable farming and nomadic cattle-herding are the Zeiyadiya of Um Hejelija (Um Heglig) - a scattered settlement, comprising approximately 100 households. In the rainy season the women on the Goz grow some millet, while the men, the younger ones in particular, roam about with the herds of sheep and camels, in search of fodder and water. When the first rain (rashāsh) begins to fall in June, they move south as far as Et Taweisha, Haskanita and as far as the railway line. As this part of eastern Darfur is the old-dune belt (Goz), there are hardly any pools of water (rahad) for watering the animals. The pastoral route, therefore, follows the water pumping stations (donki) Gaber, Abu Humeira and Um Keddada. This migration southward at the start of the rainy season lasts only until August; the semi-nomads then return to Um Hejelija and then travel immediately northwards to J. Teganor, En Nasub, Um Bayada and Wad Mereiga. In September they return southwards and spend the dry season near the water pumping station Abu Humeira. In especially favourable years when the Jizu-area offers good grazing, the Zeiyadiya spend the winter months there.

Although the Zeiyadiya semi-nomads cover great distances on their migration - about 700 km in a year - considerable damage is done by overgrazing during their fairly long stay around the water pumping stations.

5.5 Dar Masalit

Dar Masalit represents the most important region in the Northern Darfur Province, where 43 % (386,000) of the population of the whole province live. Western Darfur notably possesses the best natural resources in the province.

The international boundary between the Republic of the Sudan and the Republic of Chad runs through the middle of the Masalit tribal land. The Masalit generally cross the borders without hindrances, as they always did in the past, however in recent years, civil war in Chad caused the flow of 12,000 Chad refugees into Dar Masalit, bringing insecurity into the border area, and making exchange across the borders difficult.

The Masalit are sedentary farmers and live in about 4,000 small settlements, with 65 Omdias - small rural administrative units. Each household cultivates about 2 hectares - enough to meet its annual requirement of millet (ca. 1,500 kg). A household also possesses a small herd of livestock (Table 37).

Table 37: Livestock numbers in Dar Masalit (1976, according to official vaccinations)

	Cattle	Camels (rough estimation)	Sheep	Goats
Total	471,346	100,000	340,476	280,823
Per household	6	1.3	4.4	3.6

Pastures are relatively well distributed in Dar Masalit, due to the dense drainage net, which has developed on the impermeable crystalline rock of the Basement Complex. Though run-off is only periodic or episodic, it is sufficient to recharge ground water in wadi beds, which is tapped by the traditional wells and shallow holes.

Desertification in Dar Masalit is strongest in the sandy areas around El Geneina. Excessive millet cultivation together with overstocking is responsible for ecological degradation. Though the annual mean precipitation in El Geneina is 535 mm, rain-fed cultivation seems to be ecologically unadapted there.

5.6 The Berti Land

The Berti land extends from the Berti Hills in central northern Darfur eastwards, down to the borders of Kordofan. The Berti are millet cultivators on the sandy soils of the Goz belt. They also keep small herds of sheep and goats and some have small herds of cattle. The natural vegetation is an *Acacia-senegal* savanna. Short *Aristida* species cover the ground in the short wet season and in degraded areas, *Cenchrus biflorus* has replaced *Aristida*. In more degraded areas unpalatable herbs are the only remaining species available. The most desertified areas are those of Mellit, Khurreit (Koma), and Abu Gau. Further to the east, desertification is concentrated in the areas of Abyad, El Arais, Um Keddada, Jebel Hilla, and Abu Humeira. The cause of the degradation is the construction of deep bore-holes in the aquifer Nubian Sandstone of eastern Darfur. This has intensified settlement combined with intensive rain-fed cultivation.

5.7 El Fasher Region

The concentration of population in El Fasher, the capital of Darfur Region, has led to severe desertification damages in the surroundings of the town. Apparently, this was already the case in the time of NACHTIGAL (1874), for he reported on the treelessness of the perimeter of El Fasher. The situation must have drastically worsened in the last few decades, because elderly people report that they used to go hunting in the forests around El Fasher. Today, there is neither wild life nor tree stock worth mentioning in that area.

This degradation cannot be simply due to the recent drought phase: for such phases are proved to have happened in the past without causing such a devastation of the ecosystem. The main cause of desertification here is strong human pressure. In 1956, El Fasher had only 26,000 inhabitants, today their number ranges between 100,000 and 150,000. The economy is based on both farming and animal husbandry. Considering the fact that in that area the precipitation mean of the last 17 years is about 200 m (cf. Table 12), such a concentration of excessive land utilization must have had severe negative consequences on the natural resources. The area of El Fasher appears as a white patch (vegetationless) on the LANDSAT imagery.

The inhabitants of the town of El Fasher face many problems which are directly related to the problems of drought and desertification:

- The water supply in the dry season is disastrous. Drinking-water is provided mainly by the Golo reservoir. This is, however, strongly exposed to the hazard of siltation and the insecurity of run-off. Ground-water is available in limited amounts in the vicinity of the town (Goz Esh Shagra) and rich aquifer layers are found in Sag En Na'am, 40 km to the south, but at present, it is considered too expensive to install water-pipes and water-lifting stations along such a distance.
- The supply of millet, the main source of nutrition in Darfur, is very poor before the harvest time and millet prices reach their highest in the wet season, two months before the new harvest. In 1984 , the millet price for 100 kg reached about US $ 60, which is more than the monthly wages of an average worker. An average household requires not less than 100 kg millet per month. It is obvious, therefore, that most of the town inhabitants are under-fed.

Photo 39: Berti Hills in the NE, part of Dar Zaghawa in the NW, Wadi El Ku' in the middle, Jebel Marra massif in the W, the pediplains of Nyala in the S.
LANDSAT, Band 7, February 1976

Fig.39 **EL FASHER AREA: Desertification as a consequence of excessive millet cultivation in the arid zone of the Sudan**

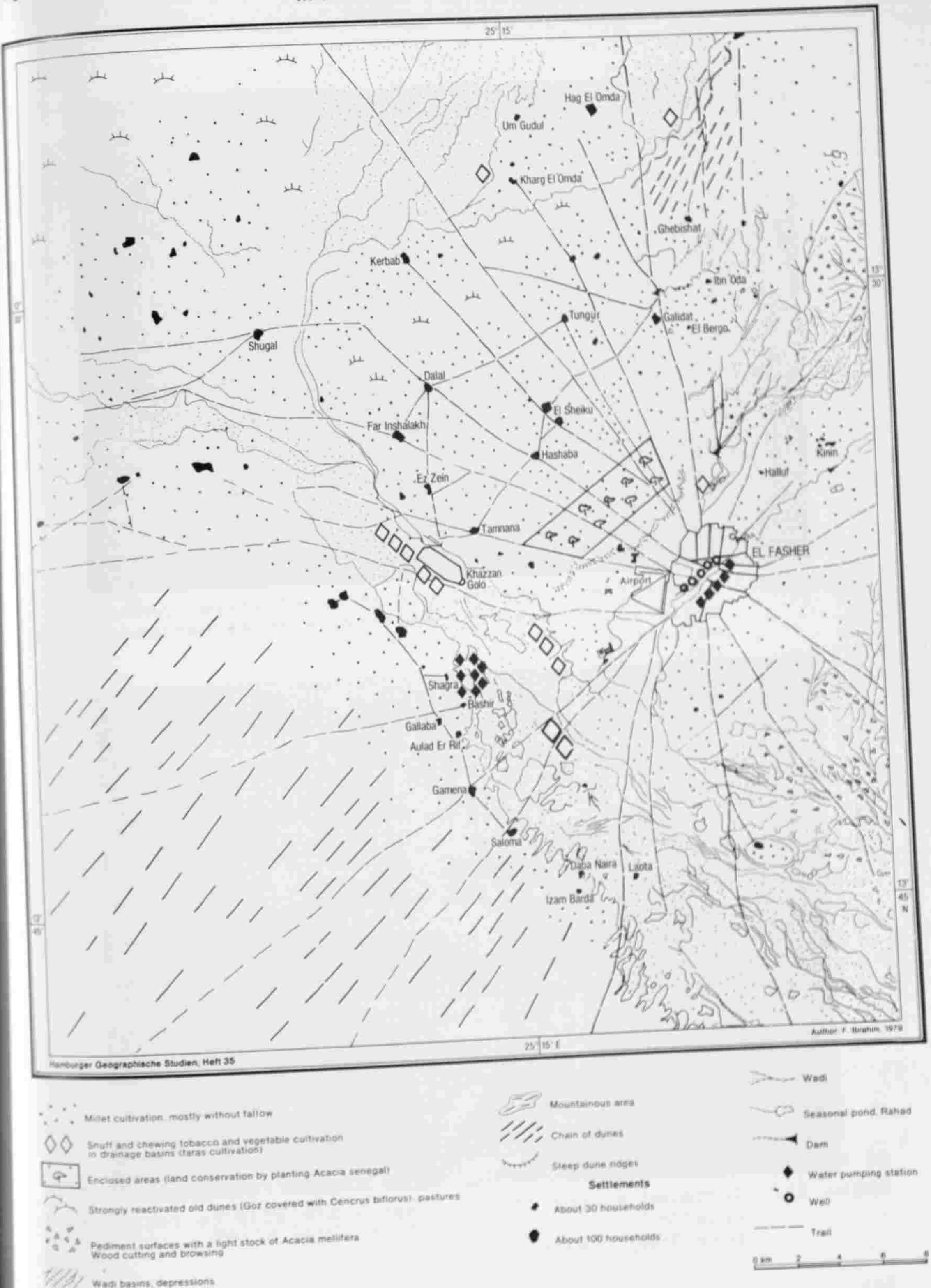


Photo 40: Severely dissected slopes of Jebel Marra. Anthropogenic impact has enhanced formation of badlands in the vulnerable tuffs.
Oct. 1981

Photo 41: Terraced slopes of Jebel Marra are able to resist soil erosion.
Tora Tonga. March 1981

Photo 42: During the drought disaster 1970 - 1973, 475 settlements were deserted in Dar Zaghawa.
Um Haraz. Oct. 1976

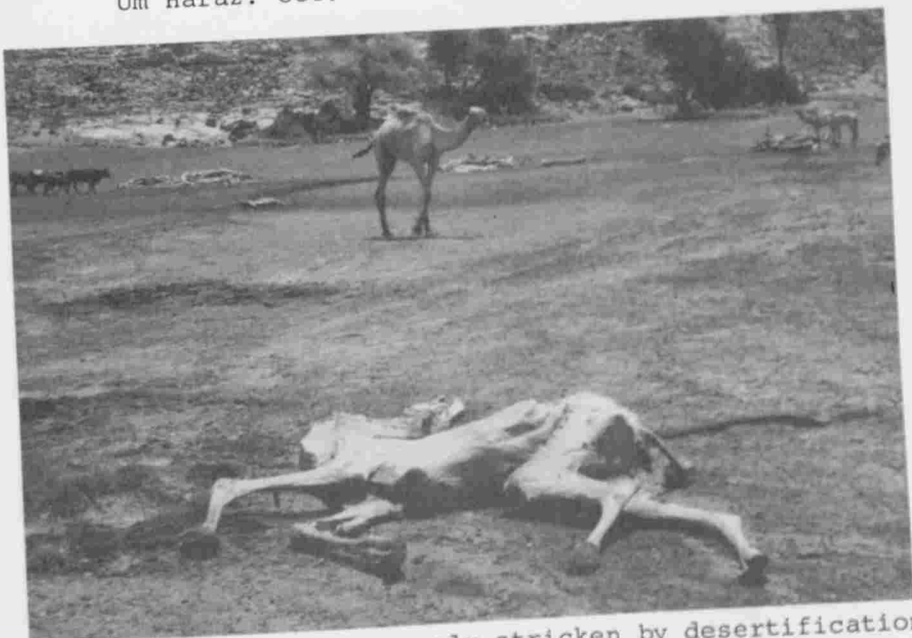


Photo 43: Livestock is severely stricken by desertification in Dar Meidob.
Malha Crater, Sept. 1982

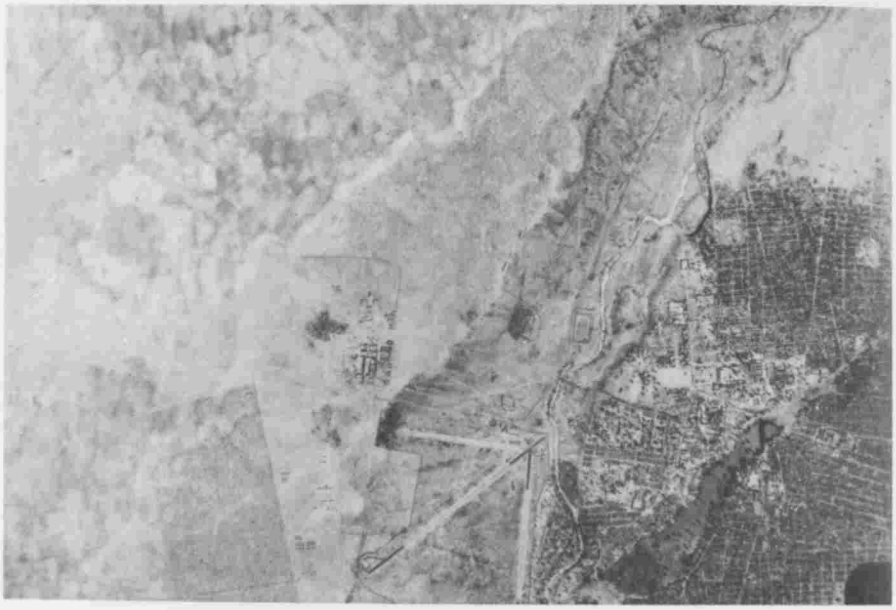


Photo 44: The W perimeter of El Fasher in 1968. Tree stock is completely depleted, the Goz sands are reactivated by excessive cultivation.
(By courtesy of the Survey Dept., Khartoum)

Photo 45: El Fasher is a central place for nomads and farmers. Its seasonal lake is of great importance.
Oct. 1977

Photo 46: Although El Fasher is a large town, the inhabitants practise cultivation within their compounds.
Sept. 1977

Photo 47: The surroundings of El Fasher are completely cultivated although the rainfall mean for the last 18 years is 200 mm.
Sept. 1977

6. Measures of Combatting Desertification in the Sahelian Zone

6.1 The U. N. "Plan of Action to Combat Desertification"

An ambitious "Plan of Action to Combat Desertification" was prepared by the UN World Conference on Desertification in Nairobi, 1977, and was passed by the UN General Assembly in New York. Since then little has been done to realize that plan, for the countries stricken by desertification have neither the funds nor the technology required to implement the recommendations. In the developed countries recent economic problems have restricted assistence on the ecological problem in developing countries. In addition to these reasons, there prevails among decision-makers the idea that desertification control is not an issue of high priority. Even those who propagate desertification control and rehabilitation projects conceive them on a narrow scale for spotwise improvement and are more pilot-projects than development programmes. A successful plan to combat desertification in the Sahel has to be comprehensive. All recommended measures should aim at a balance between land exploitation and the ability of plants and soils to regenerate. The following measures are tentatively suggested.

- Preparation of land use plans based on precise knowledge of the soil productivity and the dominant socioeconomic conditions
- Gradual substitution of rain-fed cultivation beyond the climatically-controlled agronomic dry limit by regulated animal husbandry. This measure should be taken according to a well-conceived plan and the change should bring about economic advantages to the population, otherwise co-operation cannot be expected.
- Improving livestock husbandry through a controlled use of the pastures. For each area, the maximum number of animals (in L.S.U.: Livestock Standard Units) should be fixed according to its carrying capacity and this number should not be exceeded. At the same time, methods of improving pastures, such as re-seeding, should be used. New pastures could be made accessible through ensuring the supply of drinking-water. The rotation of the use of water pumping stations can provide a method of grazing-rotation. Through improving the infrastructural conditions, such as veterinary service, marketing facilities, transport means and the processing of animal products, animal husbandry can become much more economic than it is at present. As a transitional measure water-points, fodder places and veterinary stations could be

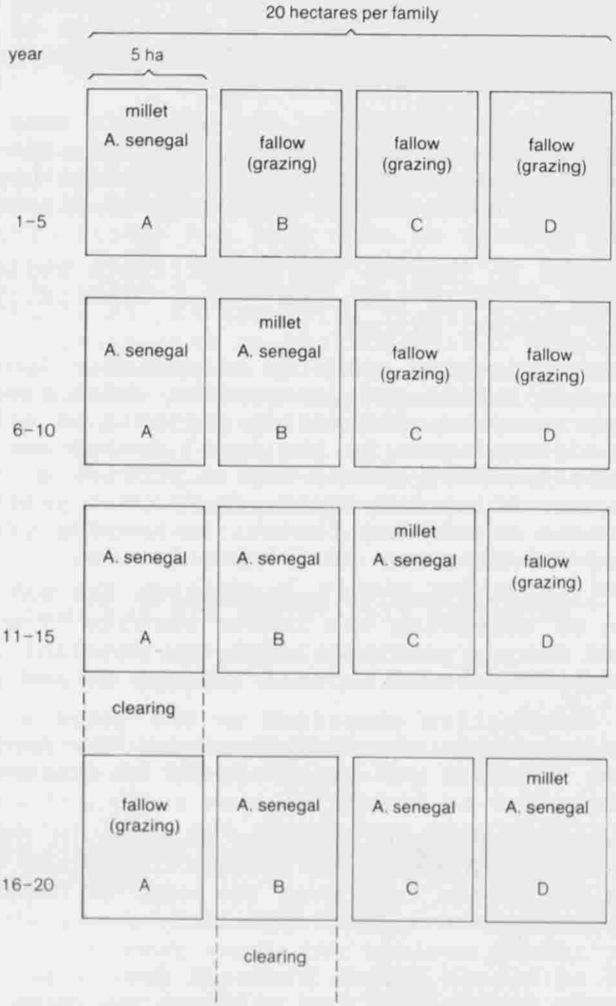
established on the main routes on which livestock is herded to the market centres.

- Controlling wood-cutting, planting trees in settlement perimeters by the inhabitants themselves, introducing new agro-forestry methods, for instance that of combining millet with gum arabic (cf. Fig. 40), known in some parts of Kordofan, and finally using energy-saving charcoal-ovens instead of the commonly used open wood-fires.
- Promoting the exchange between the northern zone of nomadic livestock-breeding and the southern zone of rain-fed cultivation through the improvement of infrastructure and enlarging the market function of the central places in the transitional zone.
- Taking measures to improve and rehabilitate soils and vegetation in the strongly affected areas, especially in the perimeter of central places.
- Establishing irrigation projects at suitable locations, for example in wadi basins and depressions which have rich ground-water reserves. Irrigation projects in arid areas have to be adjusted more to the local demand and less to the European markets. They should aim at providing the region with fresh vegetables and fruit. In drought years, they should act as a regulating factor, in keeping grain prices within the purchase power of the population.
- Developing labour-intensive manufactures and handicrafts with the purpose of absorbing the labour surplus from agricultural areas. As far as possible local raw material (e.g., wood, leather and wool) should be used (Photos 48 and 49).
- Organizing informative campaigns on the dangers of desertification and possible remedial measures. The co-operation of politicians, teachers and tribal heads is extremely necessary in this respect.
- Establishing research and training centres in the affected areas in order to investigate specific problems and to train local teams which can take over the work of desertification control in their native environments.

6.2 Relevant Development Recommendations for the Sahel

So far, considerable attention has been paid by international organizations to Saharan encroachment onto the northern belt of the Sudan-Sahel zone. There, the damages have been most apparent and thus have been reported upon in a dramatic manner in the world press.

Fig.40 Combined cultivation of millet and gum arabic *(Acacia senegal)* on the old dune belt of the Sahel (rainfall: 300-400 mm).



Five years after planting *A. senegal* tapping begins.
Starting from the 16th year this rotational system functions properly.

For subsistence 5 ha of millet and 5 ha pasture are sufficient. Clearing 5 ha of *A. senegal* would help to cover a good part of fire-wood requirements.
10 ha for winning gum arabic serve as cash resource.

Source: F. Ibrahim . Desertification . Hagemann / Düsseldorf 1979

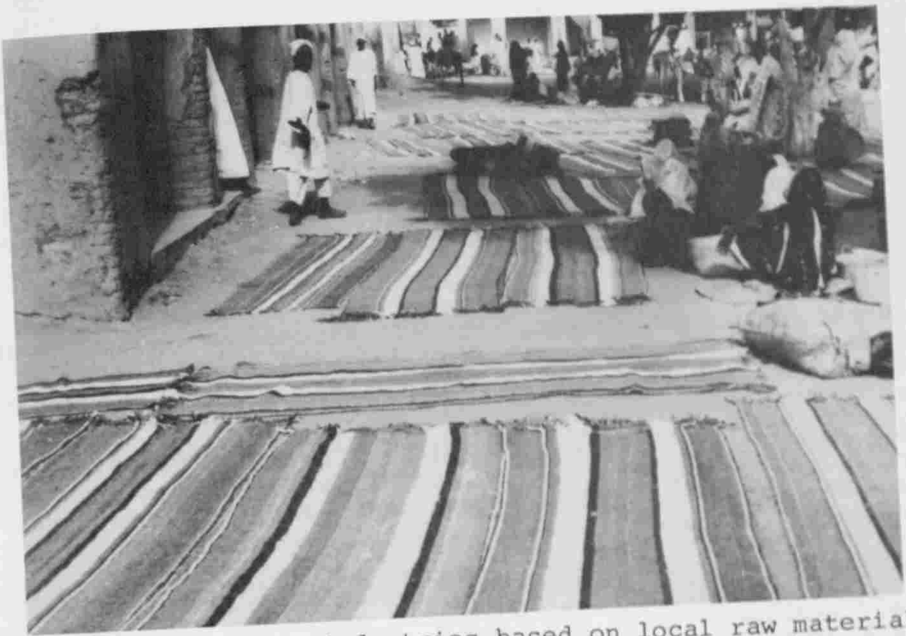


Photo 48: Local home industries based on local raw materials may offer an alternative for land use in the arid zone. Carpet weavers in Mellit, Darfur. Oct. 1977

Photo 49: Leather handicraft is a promising employment for rural population.
Mellit. Oct. 1977

In the meantime, more serious desertification processes however, have been running stealthily in the southern belt of the Sahel where the human and animal populations are considerably higher than along the Saharan margin. The fact that the southern Sahel has not yet shown the typical pictures of "desert encroachment", such as sand dune movement, renders the normal observer or journalist unable to realize the great urgency of combatting desertification in that zone.

High priority should, therefore, be given to research-work which endeavours to identify the most adapted methods of monitoring, controlling and combatting desertification in the southern Sahelian belt (lying between 11°N and 14°N). A number of arguments also support this approach:

- There are still vast areas within the southern Sahel which are in relatively good ecological conditions. These areas must be immediately surveyed and put under controlled use, before it is too late to take any effective measures.
- It is much more economic to protect and rehabilitate ecologically favourable areas than to try to retrieve areas already swallowed up by the Sahara. Taking into consideration the slowness and inefficacy of the rehabilitation measures taken since the UN Conference on Desertification in Nairobi in 1977, there is good reason to fear that while we are involved in a desperate battle at the desert front in the northern Sahel, the interior Sudan-Sahel belt is becoming stealthily desertified. It would be much wiser, therefore, to withdraw the front of combatting desertification about 200 km southwards.
- The majority of the Sahelian population live in the southern belt. The fact that anti-desertification measures are essential to the development strategy in the Sahel makes it necessary to direct more research-work in that belt of higher population density.
- Out of the broad spectrum of the research-work required to be done in the Sahelian zone three main fields should be given higher priority:

6.2.1 Surveying the Natural and the Socio-Economic Conditions in the Sahel

The most important precondition for monitoring desertification in the Sahel is to carry out a detailed inventory of the natural potential and the socio-economic conditions currently existing there. At present, there is a severe lack of reliable maps of a reasonable scale of the Sahel. All development projects trying to rehabilitate and improve the natural resources are confronted with this lack of useful maps. The existing topographic maps are out of date (60 - 70 years old) and provide only limited information on the ecological potential and its present utilization.

A survey of the Sahelian zone which extends from 11°N to 16°N has to be carried out. This embraces a belt of 450 km breadth and about 6,000 km length (2,700,000 km^2). The suggested maps should be of a scale of 1 : 500,000. This scale is large enough to enable the identification of the relevant characteristics of ecology and human activitiy. At the same time, it is small enough to render it possible to accomplish the survey within a relatively short time. The expected number of map areas is 34. The total number of thematical maps would be 102.

The three thematic maps which should be produced by the survey are:

6.2.1.1 Map of Ecological Units

This map should provide basic information on the natural resources of the different ecological areas within the Sahelian zone, including the climatic characteristics, pedological specifications, hydrological and relief conditions as well as vegetation density and plant-associations. The map should also show the status of desertification, i.e., the kind of degradation and its degree in the different areas.

6.2.1.2 Map of Present Land Use

This map should show the various land use systems, their intensity and productivity. These systems embrace traditional rainfed cultivation, mechanized farming, irrigated cultivation, nomadic pastoralism and sedentary animal husbandry as well as forest economy.

6.2.1.3 Map of Population, Settlements and Infrastructure

This map should display the distribution of ethnic groups, density of population, settlements of different sizes, roads, railroads and other means of communication, schools, waterpoints, hospitals, veterinary stations, markets, factories and other important infrastructure. For the last map ground data collection is indispensable while the first two maps may depend on the filtering of satellite imagery and some ground check. If available, air photos should be also made use of.

6.2.2 Research-Work on Adapted Methods of Resource Management in the Sahel

The objective of such studies is to find out and experiment on the optimal methods of resource management in areas prone to desertification in tropical Africa receiving from 200 mm to 700 mm annual mean precipitation. The idea behind such research-work is the plausible assumption that traditional methods of land use are most adapted to the climatic and edaphic conditions in drylands. Owing to the recent increase in population and animal pressure on the limited natural resources, these methods have lost their former adaptability. Here, studies as well as experiments (in form of pilot projects) are required to identify feasible solutions. On the one hand, traditional methods should be improved to be more productive and less destructive. On the other, human and animal pressure should be lessened in marginal areas either by migration to more productive areas or vocational diversion towards handicraft and small industry. Four fields of research and experimentation are proposed in this respect:

6.2.2.1 Adapted Rain-Fed Cultivation on Small Holdings

Traditional small holdings of rain-fed cultivation (millet, sorghum, ground-nuts, sesame) in the different locations and different ethnic groups within the Sahel should be investigated as to their adaptability to the arid conditions. Reasons for suitability or unsuitability of a certain land use method should be identified. The socio-economic consequences of desertification on the small holdings are to be studied in order to determine the human indicators of negative environmental changes. The problems of subsistence agriculture with limited market production are to be highlighted. Adapted systems of land use involving crop rotation, cultivation-fallow rotation, agro-forestry and farming combined with livestock husbandry are to be identified.

6.2.2.2 Adapted Pastoralism

The objective is to recognize the adapted and less adapted pastoral activities currently practised in the Sahelian zone. The various systems of livestock management among nomads, semi-nomads and sedentary groups are to be studied to enable one to develop feasible measures of improvement. Detailed studies on the carrying capacity of pastures in the different ecological units are required prior to controlling grazing. At the same time, methods of rehabilitating pastures by re-seeding and rotational grazing (e.g., through the rotation of water supply) should be worked out. This research-work is to be complemented by socio-economic studies on the changing economic and social conditions of pastoral economy under the present degradation of grazing resources.

6.2.2.3 Adapted Wood Economy

The limited wood resources of the Sahel are being threatened by increased depletion. Under the prevailing arid conditions, afforestation is not only expensive but also proceeds at a very slow pace. Research-work should be carried out, in order to discover and test more adapted methods of wood economy. The objective is to reduce the consumption of firewood and building timber to a tolerable amount. Study and experimentation should tackle the following activities:

- developing energy-saving ovens
- developing energy-saving cooking-methods
- developing energy-saving charcoal production
- developing practical alternatives for wood
- developing wood-saving constructing-methods
- finding alternatives for field-enclosures and kraals
- experimenting with tree plantations in village perimeters
- experimenting with new methods of agro-forestry, such as combining millet with *Acacia senegal* or sorghum with *Acacia albida* (cf. Figure 40).

6.2.2.4 Adapted Methods of Surface-Water Harvesting

One of the major problems in the arid zone is the concentration of rainfall on a short time of the year, while 6 - 11 months remain dry. The high intensity and concentration of precipitation results in the loss of the greater part of the water through flash-floods, seepage and evaporation. Not only does this effect a shortage of drinking-water in more than 6 months of the year, but it also leads to desertification around permanent water-points, where a concentration of human and animal population is usually found.

Improving the methods of surface-water harvesting would bring about some ecological advantages. It would make it possible to open new grounds for grazing and rain-fed cultivation which to-day cannot be effected for lack of drinking-water. This would lessen the strain on the overused areas. Better water management would also secure water surplus for irrigated cultivation in edaphically favourable areas. This would be a good alternative to destructive farming in marginal areas.

Although surface-water harvesting has been practised in the Mediterranean region since the Roman times, it is little known in the Sudan-Sahel zone. Feasibility studies should be carried out so as to discover the best adapted methods of surface-water harvesting in that zone.

Some of the problems which confront the research worker are:

- defining the catchment areas of surface-water harvesting by means of geomorphological surveys
- finding methods of protecting the catchment areas against deforestation and erosion damages
- finding methods to lessen seepage and evaporation losses
- finding methods to slow down the silting up of water reservoirs
- solving the problem of pollution of water reservoirs
- solving the problem of conflicting rights of water use among the inhabitants of large drainage basins

6.2.3 Research on Desertification Education

In order to be able to combat desertification effectively, educative measures should be directed to the problems of arid land management and the deterioration of natural resources as a result of land misuse in the Sahelian zone. Such public education should be conducted at all levels from the primary level to the adult one.

No studies exist, however, on the method of teaching the subject of desertification within the syllabuses of the relevant school subjects: Geography, Biology, Environmental Education. There is urgent need, therefore, for research-work done in that field, for none of the teachers of the above-mentioned subjects has either adequate knowledge of desertification nor knows how to teach that subject to others. Research-work on the methodology of teaching desertification will have to concentrate on the following activities:

a) developing curricula on desertification as an integral part of Biology, Geography and Environmental Education

b) devising learning units on desertification and resource management in arid lands for learners at all levels

c) writing text books for the use of teachers and learners using recent scientific findings on relevant subjects such as:

   - land carrying capacity
   - animal husbandry and livestock-marketing
   - nomads and their settlement
   - overcultivation on the sandy soils
   - excessive tree-felling and its consequences
   - traditional and modern land use methods

d) devising audiovisual aids and testing their efficiency:
   - producing series of commented slides on the different subjects of resource management in drylands
   - designing commented posters showing the above-mentioned subjects for use in areas where slide projection is impossible
   - designing radio and TV programmes on the problem of desertification

e) devising programmes for training African experts for extension work on the field of desertification.

Though the above-mentioned suggestions go beyond research-work and extend to development activities, they should be considered as research-work, for this field is completely new and there are hardly any experts available to carry out development work on desertification education at the present time.

6.3 MEASURES UNDERTAKEN IN THE REPUBLIC OF THE SUDAN

Already in 1942 the Sudan government formed a commission to investigate desert encroachment on the irrigated lands on the Nile and rain-fed areas. The commission came to the following results:

- Desert encroachment has been caused by the impact of man on arid and semi-arid lands.
- The desert marginal zone has expanded southwards into the most active economic regions of the Sudan.
- Some indicators of this are diminishing productivity of both cultivated land and pastures, the increasing desettlement of the population and the increase of tribal conflicts on the issues of nomadic routes and the usage rights of water and land.
- The situation is enhanced by the people's misuse of land in the form of overgrazing, mass cutting of woods for building purposes and fuel supply, overgrazing, savanna-fires and shifting cultivation.

Some of the important measures taken by the Sudan government in the last 40 years to combat desertification are summarized as:

6.3.1 LEGISLATIONS

In 1944 the Land Use Law was issued to regulate land tenures and land use systems in order to ensure a rational use of land.

One of the hard blows against the good management of local natural resources was the abolition of the "people's administration system" with its Nazir, Omda and Sheikh. The Council Officers who are imposed by the Government are unable to win the co-operation of the people.

In 1956, immediately after independence, the "Rural Water Corporation" was legislatively established to supply the population of rural areas with water for human and animal use. It is to be regretted that this corporation was dissolved in 1976 - 1977. Thus, comprehensive rural development became more difficult to realize.

Many other laws regulating cultivation and pastures have been issued both by the central and the local authorities.

The establishment of the Regional Ministries of Agriculture, Food and Natural Resources has institutionalized the task of conservation of soil, vegetation and water.

A presidential decree for the formation of a supra-ministerial commission for natural resources is expected this year. The Regional Ministers of Agriculture and Natural Resources of the affected Regions are protesting that they are not being involved in the initial discussion on this legislation.

Recently, the law of the "National Committee for Man, Environment and Development" has been issued.

6.3.2 Studies and Surveys

Many regional studies and surveys by national and foreign teams have been carried out over the semi-arid zone of the Sudan. A great supply of reports and maps (geological, hydrological, soil, vegetation and land use maps) is already available. A new plan of action against desertification should make a synthesis of this bulk of work from the new point of view.

6.3.3 Training and Research

Over forty years the University of Khartoum has graduated a large number of experts of agriculture, veterinary sciences, geography, geology, hydrology, botany, topography, meteorology, social sciences, etc. With little additional training an efficient staff of experts can be qualified to tackle the problems of desertification. It is advisable, however, to pay some attention to the training of unacademic field-workers to be sent to and stationed at smaller towns in the affected zone.

The Institute of Environmental Studies at the University of Khartoum was established in 1978. One of its main research tasks is the subject of desertification. Research-work in the field of natural resources is very active in the Sudan. Many scientists at the University of Khartoum are conducting research-work in the different regions of the Sudan. The Agricultural Research Corporation is a well-equipped research institution with about 15 stations in the different vegetational zones. The National Council for Research co-ordinates research in the whole country and it has adopted the latest programme of desert encroachment control.

6.3.4 Pilot Projects

- Town perimeters in selected rural areas have been established and controlled for the last 20 years.
- Green belts have been planted on the fringes of Khartoum and other towns. Experiences won there can be made use of in similar projects.
- Afforestation and sand dune fixation have been carried out in different parts of the country.
- A pilot farm has been established in Ghazala Gawazat 25 years ago to test the relationship between the ecosystem and its use by man and animal.
- Several areas in western Sudan have been fenced for the conservation of natural vegetation and to test the ability for natural regeneration in the savanna zone.
- Control of firewood and charcoal production is the aim of combined projects between the Forestry Department and the Ministry of Commerce.
- Desert sheep pilot projects.
- Firelines pilot projects.

6.3.5 The Most Recent Projects

The Desert Encroachment Control and Rehabilitation Programme (DECARP):
This project consists of nine parts which would cost a total of about 26 million US $. Five sub-projects aim at establishing provincial development centres in the provinces affected by desertification: Northern Kordofan, Southern Kordofan, Northern Darfur, Southern Darfur, Nile and Northern Provinces. In addition to the general tasks each centre has specific activities to carry out. Further sub-projects are: Evaluation and Mapping of Natural Resources and Desert Encroachment Monitoring, Stock Route Improvement and Feasibility Study for the Establishment

of a Wildlife Reserve. The DECARP has produced several documents on the problem of desertification.

Few of the suggested projects have actually started, owing to the difficulty in soliciting funds. Though the majority of the projects contained in DECARP are well worked out, some are less practicable. Several projects and some sub-projects were proposed and in later years, a number of projects were dropped and a few new ones were introduced. At present, the project titles according to the list of priority of the Ministry of Agriculture and Irrigation and the United Nations Sudano-Sahelian Office (UNSO) are:

- Support to the National Desertification Control Coordinating Unit
- Restocking of the Gum Arabic Belt
- Management of Grazing Resources Around Permanent Water Supplies
- Application of Water Harvesting
- Gardud Soil Improvement
- Fireline Construction in Western Sudan
- Sand Dunes Fixation and Reclamation
- Integrated Village Development
- Rehabilitation of Severely Degraded Rangelands
- Public Education Campaign for Desertification Control

Progress has been made in the implementation of the first four projects. A feasibility study for the establishment of a series of multi-purpose tree-plantations to resolve the Khartoum energy-crisis has also been completed.

DECARP-projects have been modified to be more practicable. A second review is, however, needed to enable them to deal more directly with combatting desertification. These projects, in fact, were conceived in 1974, three years before the UN Conference on Desertification in Nairobi in 1977. At that early stage the perception of the problem of desertification and its causes was incomplete. The general view was that the desert (Sahara) was encroaching onto the savanna and irrigated areas in the Nile basin mainly as a natural phenomenon, i.e., due to climatic changes. Thus these projects concentrated locally on the Saharan marginal zone and thematically on combatting drought and sand movement as well as rehabilitating desertified areas. After the UN Nairobi Conference on Desertification, it became clear that this kind of ecological deterioration of savanna land results from land misuse.

For the above-mentioned reason the projects of combatting desertification should have a comprehensive approach of land use. One must get away from thinking in departments: Forestry, Range, Cultivation, Water Supply, Wild Life, etc. A comprehensive reorganisation of land use should be implemented in the project areas in order to provide examples of proper land use for the inhabitants of the zone prone to ecological degradation.

6.3.6 BILATERAL MEASURES: THE EXAMPLE OF THE SUDAN - LOWER SAXONY (F.R.G.) JOINT DEVELOPMENT PROGRAMME

In addition to the efforts made by national and UN organisations to combat desertification in the Sudan, there is a considerable number of desertification-related development projects in the Sahelian zone of the Sudan which are conceived on a bilateral basis. As it would go beyond the scope of this study to report and comment on all these projects, the example of the joint development programme between Lower Saxony (F.R.G.) and the Sudan will be selected and dealt with here.

Being the Region of the Sudan which is most stricken by desertification, Darfur has received particular interest from Lower Saxony. Many of the development measures listed below are being implemented in Darfur.

Owing to the deterioration of living-conditions as a result of a preceding ecological degradation in the rural areas of the Sahelian zone of the Sudan, measures of ecological rehabilitation are accompanied by both short and middle termed development measures so as to improve the very bad conditions under which the population of these areas live. According to the principle of self-help small dams will be constructed to supply people and animals with drinking-water from seasonal water-courses in Darfur, wherein the local population will participate by labour force. In areas where ground-water is accessible at a suitable depth, 50 hand-pumps will be installed in villages in Darfur for the supply of drinking-water.

In the energy sector, the development projects aim at using energy-saving methods in the brick and cement industries and in bakeries. In the field of veterinary medicine research is promoted in cooperation between the University of Khartoum and the University of Hannover with the aim of developing vaccination serum won from the areas of later application. In the field of human medicine there is a stress on the training of nurses and midwives as well as the use of adapted technology.

Vocational training and the establishment of small industries in rural areas are being promoted so as to lessen pressure on the limited agricultural resources. The transfer of know-how is also being intensified in the fields of forestry, geology and cartography. The latter field is particularly important as the necessary topographic and thematic maps of the Sudan are either lacking or in an unsatisfactory condition. For a better organization of land use and a proper exploitation of the mining resources of the country reliable thematic maps have to be made.

The development work of Lower Saxony is directed to crisis areas, favours small projects with adapted technology and self-helping implementation methods, concentrates on training and education and puts the whole work in a frame of partnership with Sudanese institutions. Specially noteworthy is the direct cooperation between Darfur and Lower Saxony without the direct intervention of the central governments of both Sudan and F.R. Germany. This may lessen the danger of manipulating development help through international politics.

Summary

The spread of desert conditions south of the Sahara into the thorn-scrub savanna and the low-rainfall woodland-savanna during the last few decades is a phenomenon of ecological imbalance which is known as desertification. This process of the creeping destruction of the quasi-natural ecosystem of the Sahelian zone has been caused by a synergism of human and natural factors: i.e., the rapid increase of human and animal populations and the simultaneous occurrence of a long drought phase which began in 1968 and has lasted up till now (1984). In the first two chapters, the author deals with the general aspects of this kind of ecological imbalance, the processes which are triggered off as well as with the methods of monitoring desertification in the Sahelian zone. The main part of the book tackles the results of a field-study on desertification in northern Darfur in the Republic of the Sudan.

The aim of this field-study is to assess the physical and anthropogenic complex of the processes of desertification in northern Darfur which is a part of the Sahelian zone. The ecological and socio-economical factors are analysed, the consequences for the ecosystem and for man himself are displayed and feasible measures to combat desertification are being discussed. Stress is laid on the regional differences within the area of study. To attain the above-mentioned aims a survey of the present ecological potential of the region and its use and misuse by man has been carried out. The dynamics of the desertification process, which is launched through the impact of man is analysed.

Climatic data are assessed in order to find out the degree of the effect of water deficit, variability and intensity of precipitation as well as short-term climatic fluctuations on rain-fed cultivation and animal husbandry, both sedentary and nomadic. The investigation of climate in northern Darfur has proved that aridity is an important precondition for enhancing the process of desertification. And though the natural ecosystem has fully adapted itself to the arid conditions, they render the quick regeneration, under the persistence of man's impact, very difficult. For in the natural ecosystem far-reaching anthropogenic destruction of soil and vegetation is not provided for. A further, even more decisive climatic factor is the variability of precipitation. Although it is, like aridity, a principal character of the climatic pattern of the arid and semiarid zones, disastrous effects can be avoided, only if land use takes full consideration of this variability. This requires a great deal of mobility, which is possible only for

nomadic animal husbandry. The vegetation cover of northern Darfur has been surveyed, so that a local differentiation of the quantitative and qualitative degradation of vegetation can be made. Overstocking in that area could be estimated between 30 and 80 %. The geological structure plays a significant part therein: The areas of the Basement Complex are less affected by desertification damages than the areas of the Nubian Sandstone Series. Owing to the occurrence of groundwater in the layers of the Nubian Sandstone, water supply is secured in that area. This leads to permanent grazing and overstocking while in the area of the Basement Complex seasonal grazing is dominant on the basis of seasonal ponds (rahad, fula) and the water reservoirs (ḥafīr, khazzān).

The study of the morphodynamic processes which are related to desertification shows that the most active part takes place within the Goz belt extending from El Fasher region eastwards to Kordofan. The deflation of top-soil and the accumulation of sands in form of recently formed dunes are both indicators and agents of the current processes of desertification on the Goz dunes. Eolian activity has resulted from the destruction of the vegetation cover through overgrazing, deforestation and rain-fed cultivation. It is evident that the regeneration of the plant cover is greatly impeded by the reactivation of old stabilized dunes which means continuous deflation and accumulation of sand masses.

The anthropogenic aspects of desertification in the studied region have been investigated, among others, by means of a questionnaire which was carried out among 350 households, scattered over more than 200 settlements. Thus one was able to make a quantitative assessment of the cultivated area, millet production and consumption, water supply problems, the consumption of firewood and building timber and the infrastructural situation: medical care, educational services, administrative structure, transport problems and marketing facilities.

The most far-reaching impact on the natural resources of the savanna is effected by rain-fed cultivation beyond the climatically adapted agronomic dry limit. The most serious damages in northern Darfur are not caused by the nomadic animal husbandry, but by the combination of rain-fed cultivation and sedentary animal breeding. As the latter is practised in the surroundings of settlements, where soil is also exhausted through cultivation, a concentration of desertification phenomena is to be noticed there. A further deterioration of the ecological resources in the farther surroundings of settlements is caused by the clearing of the tree-stock, for the inhabitants require great amounts of wood for building and cooking purposes.

One of the outcomes of the evaluation of the gained information is a map of desertification in the area. It shows the following:

a. About *15 %* of the area of northern and central Darfur are *highly affected* by desertification. These lie within the cultivated Goz belt and in the overpopulated land of Dar Zaghawa.

b. About *30 %* of the region are *moderately affected by desertification*. These areas lie also in the above-mentioned zones but are under less population pressure.

c. About *35 %* are *highly exposed to desertification hazards*. These are more or less grazing lands with scattered millet cultivation.

d. About *20 %* are *less exposed to desertification hazards*. These include the less intensively used seasonal pastures in Dar Meidob and the climatically favourable region in the southwest.

The ecological damages caused by desertification lead to a drastic narrowing of the basis of existence of the population of northern Darfur. As the population usually practises a subsistence economy, any degradation of land use resources should threaten its very existence. The mobile population groups abandon the desertified areas, while the others (women, children and older people) stick to their native homes even unto starvation.

Under the influence of a permanent deterioration of the situation the solution of the problems becomes more and more difficult. This applies both to the ecological and to the social spheres. Methods of combatting desertification in northern Darfur are being discussed in the conclusion. They apply to many parts in the west of the Sudan. All recommended measures aim at a reorganization of land use so that the equilibrium between the utilization and the regeneration of the natural resources can be recovered. In order to realize this aim the following measures have to be taken:

1) Preparation of land use plans based on a precise knowledge of the soil productivity and the dominant socio-economic conditions

2) Gradual substitution of rain-fed cultivation beyond the climatically controlled agronomic dry limit by regulated animal husbandry. This measure should be taken according to a well-conceived plan. The change should bring about economic advantages to the population, otherwise its co-operation is not to be expected.

3) Improving livestock husbandry through a controlled use of the pastures. For each area, the maximum number of animals (in L.S.U.: Livestock Standard Units) should be fixed

according to its carrying capacity. This number should not be exceeded. At the same time, methods of improving pastures, such as reseeding, should be used. New pastures could be made accessible through ensuring the supply with drinking water. The rotation of the use of water pumping stations can provide a method of grazing rotation. Through improving the infrastructural conditions, such as veterinary service, marketing facilities, transport means and the processing of animal products animal husbandry can become much more economic than it is at present. As a transitional measure water-points, fodder places and veterinary stations could be established on the main routes on which livestock is driven on hoof from Darfur to the market of Omdurman.

4) Controlling wood cutting, planting trees in settlement perimeters by the inhabitants themselves, introducing new agro-forestry methods, as for instance that of combining millet with gum arabic and finally using energy-saving charcoal-ovens instead of the commonly used open wood-fires.

5) Promoting the exchange between the northern zone of nomadic livestock-breeding and the southern zone of rain-fed cultivation through the improvement of infrastructure and enlarging the market function of the central places in the transitional zone (Um Keddada, Mellit, El Fasher, Kutum, Kebkabiya, Saraf Umra, El Geneina).

6) Taking measures to improve and rehabilitate soils and vegetation in the strongly affected areas, especially in the perimeter of Um Keddada, Khurreit (Koma), El Fasher, Abu Zureiga, Mellit, Kutum, Um Buru, Bir Furawiya and Karnoi.

7) Establishing irrigation projects at suitable locations, as for example in wadi basins and depressions which have rich ground-water reserves. The irrigation project of Sag En Naam has to adjust itself more to the local demand and less to the European markets. It should help to provide the region with fresh vegetables and fruit. In drought years, it should act as a regulating factor, in order to keep millet prices within the purchase power of the population. The whole scheme should be handed over to private hands working on an economic basis.

8) Developing labour-intensive manufactures and handicrafts with the purpose of absorbing the labour surplus from agricultural areas. Wood, leather and wool can serve as local raw materials.

9) Organizing enlightenment campaigns on the dangers of desertification and possible remedial measures. Here, the

cooperation of politicians, teachers and tribal heads is most necessary.

10) Establishing research and training centres in the affected areas in order to investigate specific problems and to train local teams which can take over the work of desertification control in their native environments.

Whether it would be possible to carry out these measures to combat desertification in northern Darfur depends, to a considerable extent, on the political powers in the country. Both the Darfuri and the local decision-makers show great willingness to participate in carrying out the measures of rehabilitation. They lack, however, both the suitable plans and the financial means to realize them. The natural resources of northern Darfur are seriously endangered and if no preventive and corrective measures are taken soon to rescue the ecosystems from complete deterioration, the proper time will be missed for good.

LIST OF THE BOTANIC AND ARABIC NAMES OF THE PLANT SPECIES MENTIONED IN THE TEXT

Acacia albida - ḥarāz
A. arabica - garad (sunut)
A. mellifera - kitir
A. nilotica - sunut (garad)
A. nubica - laʿōt
A. raddiana - seiyāl
A. senegal (gum arabic) - hashāb
A. seyal - taliḥ
A. tortilis - samar (seyāl)
Acanthospermum hespidum - ḥorāb hausa
Adansonia digitata - tebeldi
Aeluropus lagopoides - nadjīla
Albizzia amara - ʿarad
Albizzia sericocephala - ʿarad
Andropogon linearis
Anogeissus leicarpus - saḥāb
Anogeissus schimperi - saḥāb
Aristida - gau
Aristida mutabilis - dubelab
A. pallida (A. Sieberana)
A. pubifolia - kurēb
Azadirachta indica - nīm
Balanites aegyptiaca - ḥijlīj (lālōb)
Blaeria spicata
Blepharis persica (linariifolia) - boǧēl
Barassus aethiopum - delēb
Boscia senegalensis - muḫḫēt
Cadaba rotundifolia - kurmut
Calotropis procera - ʿushar
Capparis decidua - tundub
Capparis spinosa - tundub
Cassia tora - kaual, ḥarīsha
C. occidentalis - kaual, surēb, sene

C. acutifolia - sene sene
Cenchrus biflorus - ḥaskanīt
Chrozophora brocchiana - ᶜargesi
Combretum cordofanum - habīl
Commifora africana - gafal
Commifora pedunculata - lubān
Corchorus olitorius - muluḫiya
Cordia abyssinica - gambil, indrāb
Cordia gharaf - indrāb
Crotalaria thebaica - natash
Cupressus lusitanica
Cymbopogon nervatus - nāl
Cymbopogon proximus - maḫrēb (marḫabēb)
Cynodon dactylon - nadjile (abu nadjile)
Dactyloctenium aegyptium - abu asabiᶜ, kiriāb
Dalbergia melanoxylon (babanūs, abanūs)
Dichrostachys glomerata - kidād
Echinochloa colonom - dafra
Eragrostis tremula - banu
Eucalyptus species -kafūr
Euphorbia abyssinica - shadjar as-sim
Fagonia cretica - ᶜagūl
Ficus sycamorus - gemmēz
Grewia tonax - geddēm
Guiera senegalensis - ġobbēsh
Hibiscus aesculentus - bamia (wēka, darrāba)
Hyparrhenia species
Hyphaene thebaica - dōm
Indigofera arenaria - kushein
Indigofera brachteolata - derma
Khaya senegalensis - ḥomra
Lannea humilis - leiyūn
Lavandula stricta
Leptadenia pyrotechnica - maraḫ
Maerua crassifolia - sereḥ
Neurada procumbens - saᶜdan

Olea laperrini

Panicum turgidum - tumām

Pennisetum typhoideum - duḫen

Pistacia atlantica

Prosopis africana - Abu surūg

Phoenix dactylifera

Rhynchosia minima - adān el-fār

Salvadora persica - arāk

Sclerocaryea birrea - ḥommēd

Sesamum alatum - semsem el-djamal

Sesamum orientale - semsem

Sida cordifolia - niada

Solanum dubium - djubbīn

Sorghum verticilliflorum - marēg

Sorghum vulgare - durra

Stipagrostis papposa - nissa

Stipagrostis plumosa - baiyād, Um sumeima

Stirga hermonthica - būda

Themeda triandra

Trianthema pentandra - rba^c (raba^{c}a)

Tribulus alatus

Tribulus terrestris - drēssa

Tripogon minimus - guttub

Triraphis pumilio - saleiyan

Ziziphus mucronata - nabage

Ziziphus mauritiana - nabage

Ziziphus spina christi - sidir, nabage

References

ABAYAZID, O. M. (1975): Prospects of fuel and energy in the Sudan. National Council of Research, Khartoum.

ABU SIN, M. E. (1982): A change in strategy of animal herding among nomads of the Butana - Eastern Sudan. In: G. HEINRITZ (ed.): Problems of agricultural development in the Sudan. Forum 2. Göttingen. 87-104.

ADAMS, M. E. (1975): A development plan for semi-arid areas in western Sudan. Experimental Agric. 2.4, 277-287.

AHMED, A. A. (1982): Land use history of Jebel Marra, Sudan. Geojournal, 6.1, 6 14.

AHMED, A. M. (ed.): (1976): Some aspects of pastoral nomadism in the Sudan. Khartoum. 219 pp.

AL AZHARIA JAHN, S. (1981): Traditional water purification in tropical developing countries. GTZ. Eschborn. 276 pp.

AL TUNISI, M. b. U. (1789-1857) (1965): Tashḥiz alazhān bisīrat bilad al-arab wal-sudan. Cairo.

AL TUNISI, M. b. U. (1789-1857) (no date): Voyage au Darfour. Transl. by Dr. Perron. 1st edn. 1845. Paris.

ALAM EL DIN, I. O. (1968): The Qoz, a geomorphological analysis of sandy western Sudan. Diss. Univ. Los Angeles Calif.

ANAYA GARDUNO, M. (1977): Technology and desertification. In: Secr. UN Conf. Desertification (ed.): Desertification, its causes and consequences. Nairobi, Kenya, Oxford (asf.), Frankfurt. 319-448.

ANDREW, G. (1944a): Memorandum on desert creep. Soil conservation committee, Sudan Gov. Khartoum.

ANDREW, G. (1944b): Notes on quaternary climate in the Sudan. In: Rep. Soil Conserv. Com. App. 25, 145-157.

ANDREWS, F. W. (1954): The vegetation of the Sudan. In: Agric. Sudan. In: J. D. TOTHILL (ed.) 3rd edn. London. 32-61.

ARKELL, A. J. (1951/52): History of Darfur, A. D. 1200-1700. In: S.N.R. 32 (1951), 1-2, 37-70, 207-238 and 33, (1952), 1-2, 129-153, 244-275.

ARKELL, A. J. (1955): A history of the Sudan to 1921. London.

ASAD, T. (1964): Seasonal movements of the Kababish Arabs of northern Kordofan. S.N.R. 45, 48-58.

ASAD, T. (1970): The Kababish Arabs. Hurst, London. 263 pp.

BABIKER, A. A. (1982): Urbanization and desertification in the Sudan. In: Geojournal 6.1, 69-76.

BABIKER, A. A. (1983): Agricultural land use and deterioration of wood resources in Nuba Mountains, Province of Southern Kordofan. In: At-Tasaḥḥur, vol. I. Khartoum. 1-4.

BABIKER, A. A., ABDU, A. S. (1981): Rural energy and the environment. In: D. BAXTER (ed.): Women and the environment. I. E. S. Khartoum. 86-91.

BAKE, G. (1981): Physisch- und kulturgeographische Grundlagen der Desertifikation in Südwest-Sizilien. In: K. GIESSNER, H.-G. WAGNER (eds.): Geographische Probleme in Trockenräumen der Erde. Würzburg. (Würzb. Geogr. Arb. 53) 51-72.

BAKHIT, A. M. A., IBRAHIM, F. N. (1982): Geomorphological aspects of the process of desertification in western Sudan. In: Geojournal 6.1, 19-24.

BAKHIT, A. M. A. (1983): Desertification, rehabilitation and conservation: the case of western Sudan. In: At-Tasaḥḥur, vol. I. Khartoum. 5-9.

BALFOUR-PAUL, H. G. (1955): History and antiquities of Darfur. Khartoum.

BARBOUR, K. M. (1950): The Wadi Azum from Zalingei to Murnei. In: S.N.R. 31, 105-128.

BARBOUR, K. M. (1954): The Wadi Azum. In: Geogr. J. 120, 174-182.

BARBOUR, K. M. (1961a): The Republic of the Sudan, a regional geography. London.

BARBOUR, K. M. (1961b): Population, land and water in central Sudan. In: K. M. BARBOUR, R. M. PROTHERO (eds.): Essays on African population. London. 137-156.

BARDAI (1967-1971): Arbeitsberichte aus der Forschungsstation Bardai/Tibesti. Berlin. (Berliner Geogr. Abh.) 5, 8, 9, 10.

BARTH, F. (1967): Economic spheres in Darfur. In: R. FIRTH (ed.): Themes in economic anthropology. London, New York. 149-174.

BARTH, H. K. (1977): Der Geokomplex Sahel. Untersuchungen zur Landschaftsökologie im Sahel Malis als Grundlage agrar- und weidewirtschaftl. Entwicklungsplanung. Tübingen. 234 pp. (Tübinger Geogr. Stud. 71).

BARTHA, R. (1970): Futterpflanzen in der Sahelzone Afrikas. Afr. Stud. 48.

BAUMER, M. (1968): Ecologie et aménagement des pâturages au Kordofan. Montpellier. 56 pp.

BAUMER, M. (1975): Noms vernaculaires Soudanais utiles á l'écologiste. Paris. 127 pp.

BAYOUMI, A. A. (1974): Forest bibliography of the Sudan up to 1973. Khartoum. 159 pp.

BAYOUMI, M. S. et al. (1977): Guide lines towards development of nomadism in the Sudan. In: M. A. EL HASSAN (ed): Growth, employment and equity. Khartoum. 96-155.

BEATON, A. C. (1948): The fur. In: S.N.R. 29, 1-39.

BHALOTRA, Y. P. R. (1963): Meteorology of the Sudan. Sudan Meteor. Serv. Mem. 6. Khartoum. 33 pp.

BORN, M. (1965): Zentralkordofan. Bauern u. Nomaden in Savannengebieten des Sudan. Marburg. 252 pp. (Marburger Geogr. Schr. 25). 251 pp.

BOUDET, G. (1972): Désertification de l'Afrique tropicale sèche. In: Andansonia. Ser. 2.12, 505-524.

BOUDET, G. (1975a): Improvement of pastures and livestock exploitation in the Sahel. In: The Sahel. Ecological approaches to land use. MAB Tech. Notes 1 (Paris), 89-97.

BOUDET, G. (1975b): Pastures and livestock in the Sahel. In: The Sahel. Ecological approaches to land use. MAB Tech. Notes 1 (Paris), 29-34.

BREHM, A. E. (1983): Brehms Reisen im Sudan, 1847 bis 1852. H. ARNDT (ed.): Erdmann. Wels/Oberösterreich. 412 pp.

BUTZER, K. W. (1958): Studien zum vor- und frühgeschichtlichen Landschaftswandel der Sahara. Wiesbaden (Akad. Wiss. Lit. u. Abh. Math.-Nat.-Wiss. KL. 1).

BUTZER, K. W. (1961): Climatic change in arid regions since the pliocene. Arid Zone Res. 17, 35-64.

BUURSINK, J. (1971): Soils of central Sudan. Diss. Univ. Utrecht.

CATINOT, R. (1973): Contribution a l'Etude de la désertification de l'Afrique tropicale sèche. B.F.T. 184. Paris.

CATINOT, R. (1974): Contribution du forestier à la lutte contre la désertification en zones sèches. B.F.T. 155, Paris. 3-13.

CHARNEY, J. G. (1975): Dynamics of deserts and drought in the Sahel. In: Q. J. R. Met. Soc. 101, 193-202.

CHARREAU, C. (1972): Problêmes posés par l'utilisation agricole des sols tropicaux par des cultures annuelles. Agron. Trop. Ser. Agron. génér. Et. techn. 27, 905-929.

CUNNISON, I. (1966): Baggara Arabs. Power and the lineage in a Sudanese nomad tribe. Oxford. 224 pp.

DAGHER, J. A. (1968): Sudanese bibliography. Arabic sources, 1875-1967. Beirut.

DALBY, R., HARRISON CHURCH, R. J. (eds.): Drought in Africa. School of Oriental and African Studies. London.

DELWAULLE, J. C. (1973a): Désertification de l'Afrique au sud du Sahara. B.F.T. 149, 3-20.

DELWAULLE, J. C. (1973b): Résultats de six ans d'observations sur l'érosion au Niger. B.F.T. 150, 15-36.

DELWAULLE, J. C. (1975): Le rôle du forestier dans l'aménagement du Sahel. B.F.T. 160, 3-22.

DELWAULLE, J. C., ROEDERER (1973): Le bois de feu à Niamey. B.F.T. 152, 55-60.

ECKHOLM, E. (1975): Desertification, a world problem. In: Ambio 4, 137-145.

ECKHOLM, E. (1977): The shrinking forests. In: Focus 28, No. 1, 12-16.

ECKHOLM, E., BROWN, L. R. (1977): The spreading deserts. In: Focus 28, No. 1, 1-11.

EDMONDS, J. M. (1942): The distribution of the Kordofan sand (Anglo-Egyptian Sudan). In: Geolog. Mag. 79, 18-30.

EL AMIN, H. M. (1973): Sudan acacias. Forest Research Institute. Bulletin No. 1. Khartoum. 64 pp.

EL MUBARAK, E. M. (1964): Die politische Geschichte Darfurs (in Arab.). Khartoum.

EL NASRI, A. (1962): A bibliography of the Sudan, 1938-1958. Oxford.

EL-TOM, M. A. (1975): The rains of the Sudan. Khartoum Univ. Press. Khartoum. 100 pp.

ENSOR, S. F. (1881): Incidents on a journey through Nubia to Darfoor. London.

FAIRBRIDGE, R. W. (1963): Nile sedimentation above Wadi Halfa during the last 20 000 years. In: Kush 11, 96-197.

FALKNER, F. R. (1938): Die Trockengrenze des Regenfeldbaus in Afrika. In: Peterm. geogr. Mitt. 84, 209-214.

FALKNER, F. R. (1939): Beiträge zur Agrargeographie der afrikanischen Trockengebiete. Stuttgart (Geogr. Abh., Reihe 3, H. 11).

GIESSNER, K. (1981): Die Jungquartäre Klimageschichte der Sahara - Stand und Vergleich der bisherigen Forschungsergebnisse. In: K. GIESSNER, H.-G. WAGNER (eds.): Geographische Probleme in Trockenräumen der Erde. Würzburg. 111-127 (Würzburger Geogr. Arbeiten, 53).

GIFFARD, P.-L. (1975): Les gommiers, essences de reboisement pour les régions Saheliennes. In: B.F.T. 161, 3-21.

GLANTZ, M. H. (1977): Desertification. Boulder Colorado. 346 pp.

GREENE, H. (1954): Soils of the Anglo-Egyptian Sudan. In: J. D. TOTHILL (ed.): Agriculture in the Sudan. 3rd edn. London. 144-175.

GROVE, A. T., WARREN, A. (1968): Quaternary landforms and climate on the south side of the Sahara. In: Geogr. J. 134, 194-208.

FAO (1968): Land and water resources of the Jebel Marra area. FAO/SF, 48 SUD, 17. Rome.

FAO/UNEP (1978): Ecological management of arid and semi-arid rangelands of Africa, the Near and Middle East (EMASAR phase II). Vol. 8, Sudan (G. BONDET et al).

HAGEDORN, H. GIESSNER, K., WEISE, O., BUSCHE, D., GRUNERT, G. (1977): Dune stabilization, GTZ. Eschborn. 400 pp.

HALWAGY, R. (1962a): The impact of man on semi-desert vegetation in the Sudan. In: J. Ecol. 50, 263-273.

HALWAGY, R. (1962b): The incidence of biotic factors in northern Sudan. In: Oikos 13, 97-117.

HAMMER DIGERNES, T. (1977): Wood for fuel. Energy crisis implying desertification. Geogr. Inst. Univ. Bergen. 124 pp.

HANEY, A., PAYLORE, P. (eds.) (1976): Desertification, problems, perspectives. Tucson. Ariz.

HARE, F. K. (1977): Climate and desertification. In: Desertification, its causes and consequences. UN Conf. on Desertification, Nairobi, Oxford, Frankfurt. 63-167.

HARRISON CHURCH, R. J. (1976): Strategy for redevelopment of the Sahel. In: Problems in the development and conservation of desert and semidesert land. Pre-Congress Symp. K 26, July 20-26, 1976. Ashkhabad. 175-178.

HASSAN, M. H. (1974): An illustrated guide to the plants of Erkowit. Khartoum Univ. Press. Khartoum. 106 pp.

HASSAN, Y. F. (1973): The Arabs and the Sudan. Khartoum. 298 pp.

HEINRITZ, G. (ed.) (1982): Problems of agricultural development in the Sudan. Forum 2. Göttingen. 123 pp.

HELLDEN, U. (1978): Evaluation of Landsat - 2 imagery for desertification studies in northern Kordofan, Sudan. Rapporter och Notiser 38. Lund.

HELLDEN, U. (1981): Satellite data for regional studies of desertification. Lunds Univers. Naturgeogr. Inst. Rapporter och Notiser 50. Lund. 20 pp.

HELLDEN, U., OLSSON, K. (1982): The potential of Landsat MSS data for wood resources monitoring (Sudan). Lunds Univers. Naturgeogr. Inst. Rapporter och Notiser 52. Lund. 35 pp.

HERZOG, R. (1955): Die Hawawir, eine Berbergruppe in der Bajuda-Wüste. Berlin (Mitt. Inst. f. Orientforschung 3).

HERZOG, R. (1956): Veränderungen und Auflösungserscheinungen im nordafrikanischen Nomadentum. Paideuma 6. Frankfurt/M.

HERZOG, R. (1957): Die Nubier. Untersuchungen und Beobachtungen zur Gruppengliederung, Gesellschaftsform und Wirtschaftsweise. Völkerkundl. Forschungen 2. Berlin.

HERZOG, R. (1963a): Seßhaftwerden von Nomaden. Köln, Opladen (Forschungsber. d. Landes NRW. 1238).

HERZOG, R. (1963b): Der Verfall alter Karawanenrouten zwischen dem Sudan und Ägypten. 25. Intern. Orientalistenkongreß. 5. Moscow.

HOLY, L. (1974): Neighbours and kinsmen - a study of the Berti people of Darfur. London. 186 pp.

HOROWITZ, M. (1979): The sociology of pastoralism and African livestock projects. US AID, P.E.D.P. 6. Inst. f. Dev. Anthrop. Binghampton. New York. 102 pp.

HUNTING, TECH. SERVICES LTD (1974): Southern Darfur land-use planning survey. London.

HUNTING TECH. SERVICES LTD (1974): Savannah Development Project - Phase II. Annex 3: Livestock and range resources. London.

HUNTING TECH. SERVICES LTD (1977): Agricultural development in the Jebel Marra area. London.

IBN BATTUTA, M. J. (1914): Tuḥfat al-nuzzār fi gharāib al-amsār. Vol. 1.2 1st edn. 1893. Paris.

IBN BATTUTA, M. J. (1958): The travels of Ibn Battuta, A. D. 1325-1354. Vol. III. Transl. by GIBB, H.A.R. Cambridge.

IBN KHALDUN, A. M. (1956-61): al-'Ibar wa-diwān al-mubtadā wal-khabar. Vol. 1-7. Beirut.

IBRAHIM, F. (1978a): Millet cultivation as a major cause of desertification in Darfur and Kordofan, Sudan. In: Regional IGU Conf. Vol. 1. Lagos. 1-4.

IBRAHIM, F. (1978b): Anthropogenic causes of desertification in western Sudan. In: Geojournal 2, 243-254.

IBRAHIM, F. (1978c): Desertification, ein weltweites Problem. Eine Auswertung der UN-Konferenz über Desertification in Nairobi 1977. In: Geogr. Rundschau 30, 104-107.

IBRAHIM, F. (1978d): The problem of desertification in the Republic of the Sudan with special reference to Northern Darfur Province. Khartoum Univ. Press. Khartoum. 54 pp. (SRC. Monograph Series 8).

IBRAHIM, F. (1979a): Die Konurbation Khartoum. In: Geogr. Rundschau 31, 363-371.

IBRAHIM, F. (1979b): Desertification. A world-wide problem. Series of transparencies. Information material, Hagemann. Düsseldorf. 48 pp.

IBRAHIM, F. (1980a): Desertification in Nord-Darfur - Untersuchungen zur Gefährdung des Naturpotentials durch nicht angepaßte Landnutzungsmethoden in der Sahelzone der Republik

Sudan. Hamburg. 175 pp. (Hamburger Geogr. Studien 35).

IBRAHIM, F. (1980b): Sudan, Land und Bevölkerung. In: Republik Sudan-Staat. Politik. Wirtschaft. Hamburg. 1-15. (Mitteilungen des Deutschen Orientinstituts 14).

IBRAHIM, F. (1981a): El Fasher und sein Umland. In: Geographische Probleme in Trockenräumen der Erde. Würzburger Geographische Arbeiten, Würzburg. 129-157.

IBRAHIM, F. (1981b): Role of women in desertification in western Sudan. In: Environmental Research Paper Series, Nr. 2 IES. University of Khartoum. 99-106 (And in: Geojournal 6.1, 25-30).

IBRAHIM, F. (1981c): Training and education within the Integrated Project on Arid Lands in northern Kenya. In: IPAL Technical Report Number F-1. MAB. UNESCO. Nairobi. 127-194.

IBRAHIM, F. (ed.): (1982a): The Nile Countries, Egypt and the Sudan - Social and Environmental Problems of Development. Geojournal 6.1.

IBRAHIM, F. (1982b): Erosion. In: Enzyklopädie Naturwissenschaft und Technik. Jahresband 1982. Landsberg. 161-166.

IBRAHIM, F. (1982c): Desertifikation. In: Enzyklopädie Naturwissenschaft und Technik. Jahresband 1982. Landsberg. 603-620.

IBRAHIM, F. (1982d): Monitoring and controlling ecological degradation in the arid zone of the Republic of the Sudan. In: Scientific Reviews on Arid Zone Research. Vol. 1. Jodhpur/India. 53-85.

IBRAHIM, F. (1982e): The ecological problems of irrigated cultivation in Egypt. In: MENSCHING, H. (ed.): Problems of the management of irrigated land. IGU. Hamburg 1982. 61-70.

IBRAHIM, F. (1983): The role of nomadism in the process of desertification in western Sudan. In: Applied Geogr. and Development, Vol. 22. Tübingen. 46-57.

IBRAHIM, F. (1983): Cultural geographical causes of desertification - case studies in the central Tunisian steppes and the Sahelian zone of the Sudan. In: WIRTH, E. (ed.): German Geographical Research in the Middle East (Arabic). Erlanger Geogr. Arb. Sonderb. 14. Erlangen/Beirut 1983. 80-103.

IBRAHIM, F. (ed.) (1983, 1984): Sudan Journal of Desertification. UNSO. Khartoum. New York.

IBRAHIM, F. (1983): The fight against the desert. In: Development and Cooperation (D+C), P 12/6. (Bonn), 9-11.

IBRAHIM, F. (1984): Savannenökosysteme. In: Geowissenschaften in unserer Zeit.

IBRAHIM, F. (1984): The problem of overstocking and ecological degradation in the Republic of the Sudan. In: Sudan Journal of Desertification, Vol. 2. UNSO Khartoum/New York, 12-20.

JACKSON, I. J. (1977): Climate, water and agriculture in the tropics. London, New York.

JACKSON, J. K. (1957): Changes in the climate and vegetation of Sudan. In: S.N.R. 38, 47-66.

JACKSON, J. K., HARRISON, M. N. (1956): Ecological classification of the vegetation of the Sudan. Forest Bull., New Ser. 2. Khartoum.

JACKSON, J. K., SHAWKI, M. K. (1950): Shifting cultivation in the Sudan. In: S.N.R. 31, 210-222.

JAEGER, F. (1943): Trocknet Afrika aus? In: Geogr. Zeitschr. 49, 1-19.

JÄKEL, D. (1977): Preliminary account of studies on the development and distribution of precipitation in the Sahel and adjoining areas. In: Applied Sciences and Development, Vol. 10. Tübingen, 81-95.

JÄTZOLD, R. (1970): Ein Beitrag zur Klassifikation des Agrarklimas der Tropen (mit Beispielen aus Ostafrika). In: H. BLUME, K. H. SCHRÖDER (eds.): Beiträge zur Geographie der Tropen und Subtropen. Tübingen. 57-69 (Tübinger geographische Studien 34, Sonderband 3).

JÄTZOLD, R. (1976): Climatic, man-made and game-made deserts in East Africa. In: Problems in the development and conservation of desert and semidesert land. Pre-Congress Symp. K 26, July 20-26, 1976. Ashkhabad. 155-159.

JÄTZOLD, R. (1982): Farm management handbook of Kenya. Vol. II, Part A: West Kenya. Trier. 397 pp.

JÄTZOLD, R. (1983): Farm management handbook of Kenya. Vol. II, Part B: Central Kenya. Trier. 739 pp.

JÄTZOLD, R. (1983): Farm management handbook of Kenya. Vol. II, Part C: East Kenya. Trier. 411 pp.

JANKE, B. (1973): Naturpotential und Landnutzung im Nigertal bei Niamey/Rep. Niger. Hannover. 189 pp. (Jahrb. d. Geogr. Ges. zu Hannover. Jb. f. 1972).

JEFFERSON, J. H. K. (1953): Soil conservation in the Sudan. Development and projects. Khartoum.

JEFFERSON, J. H. K. (1954): Hafirs or development by surface water supplies in the Sudan. In: Tropical Agriculture 31, 95-108.

KEWITT, T. N. (1950): Goz soils of the Anglo-Egyptian Sudan and shifting cultivation on the clay-plains of the central Sudan. Khartoum. (Ministry of Agriculture, Research Div. Memoir No. 14).

JOHNSON, D. L. (1974): Changing patterns of pastoral nomadism in North Africa. In: HOYLE (ed.): Spatial aspects of development. Wiley. 147-166.

JOHNSON, D. L. (1977a): The human dimensions of desertification. In: Economic Geography, Vol. 53, No. 4, Oct. 1977, 317-321.

JOHNSON, D. L. (1977b): Pastoral nomadism in the Sahel zone. In: K. W. DEUTSCH (ed.): Eco-social systems and eco-politics. UNESCO, Paris. 169-185.

JOHNSON, D. L. (1977c): Concepts of systems analysis in relation to desertification. In: The Science Associations' Nairobi Seminar on Desertification, Aug. 21-25. Agenda and Supporting Documents. Nairobi.

JOHNSON, D. L. (1977d): The human face of desertification. Economic Geography, Vol. 53, No. 4, Oct. 1977, Clark Univ. Worcester, Mass. USA, 317-436.

JOHNSON, D. L. (1980a): Desertification and nomadic pastoral development. In: E. T. BARTLETT, N. DYSON-HUDSON (eds.): The man and the biospere program in grazing lands. Washington, D. C. 75-86.

JOHNSON, D. L. (1980b): "UNCOD, combatting desertification, and the pastoral nomad." In: Commission on nomadic peoples. I.U.A.E.S. Mc Gill University. Montreal. 6-10.

JOHNSON, D. L. (1980c): Pastoralism: Some alternative futures. In: L. BERRY, W. KATES (eds.): Making the most of the least: alternative ways to development. New York. 77-93.

JOHNSON, D. L. (1981): The effect of climate fluctuations on human populations: two hypotheses. In: T. M. L. WIGLEY, INGRAM, FARMER (eds.): Climate and history. Cambridge. 479-513.

JUNGE, C. (1977): The importance of mineral dust as an atmospheric constituent. Preprint to the workshop on Saharan dust. Gothenburg.

KASSAS, M. (1955): Rainfall and vegetation belts in arid North-East Africa. In: Arid Zone Research 5, 49-57.

KASSAS, M. (1970): Desertification versus potential for recovery in circum-Saharan territories. In: H. DREGNE (ed.): Arid Lands in Transition. Washington, D. C. 1970. 123-142.

KASSAS, M., IMAN, M. (1954): The wadi-bed ecosystem. In: J. Ecol. 42, 424-441.

KATES, R. W., JOHNSON, D. L., JOHNSON-HARING, K. (1977): Population, society and desertification. In: Desertification, its causes and consequences. Secr. of the UN Conf. on Desertification, Nairobi, Kenya, Oxford, Frankfurt. 261-317.

KHOGALI, M. M. (1977): The physical and human factors that contributed to the development of trade and migration routes of central bilad al-Sudan. Paper pres. on the 3rd Internat. Conf. on Central Bilad al-Sudan. Khartoum.

KHOGALI, M. M. (1978): Western Sudanese migrants to Khashm El-Girba agricultural region. A case study. Paper pres. on the IGU Population Preconf. Symp. Zaria, Nigeria.

KHOGALI, M. M. (1980): Sedentarization of nomads in the north and central Sudan. Ph. D. Thesis. University of Khartoum.

KLEINSORGE, H., ZSCHEKED, J. G. (1958): Geologic-hydrologic research in the arid and semi-arid zone of the western Sudan. Hannover.

KÖPPEN, W. (1923): Die Klimate der Erde. Berlin-Leipzig.

KRINGS, Th. F. (1980): Kulturgeographischer Wandel in der Kontaktzone von Nomaden und Bauern im Sahel von Obervolta. Hamburg. 144 pp. (Hamburger Geogr. Studien 36).

KÜRCHHOFF, D. (1906): Alte und neue Handelsstraßen und Handelsmittelpunkte in Nordost-Afrika. In: Geogr. Zeitschr. 12, 277-291 and 326-339.

LAMPEN, G. D. (1928): A short account of Meidob. In: S.N.R. 11, 55-62.

LAMPREY, H. F. (1977-1980): IPAL Technical Reports. UNESCO. MAB. Nairobi.

LAND (1974): use planning survey in southern Darfur. Ed. by

Hunting Technical Services, Overseas Development Admin. Sudan, Ministry of Agriculture. London.

Arid LANDS (1966): A geographical appraisal. Ed. by E. S. HILLS. London.

LANDSBERG, H. E. (1976): The definition and determination of climatic changes, fluctuations and outlooks. In: R. J. KOPEK (ed.): Atmospheric quality and climatic change. Chapel Hill, N. C., 52-64 (Studies in Geography. 9).

LAPANOUSE, J. (1802): Mémoire sur les caravanes du Darfour et du Sennaar. Paris.

LAUER, W. (1952): Humide and aride Jahreszeiten in Afrika und Südamerika und ihre Beziehung zu den Vegetationsgürteln. In: Studien zur Klima- und Vegetationskunde der Tropen. Bonn. 15-98 (Bonner geographische Abhandlungen 9).

LAUER, W. (1975): Vom Wesen der Tropen. Klimaökologische Studien zum Inhalt und zur Abgrenzung eines irdischen Landschaftsgürtels. Wiesbaden. (Akad. d. Wiss. u. d. Lit., Abh. d. math.-naturwiss. Klasse 3).

LEBON, J. H. G. (1965): Land use in Sudan. Bude, Cornwall. (World Land Use Survey Monogr. 4).

LEBON, J. H. G., ROBERTSON, V. C. (1961): The Jebel Marra, Darfur, and its region. In: Geogr. J. 127, 30-49.

LE HOUEROU, H. N. (1974): Deterioration of the ecological equilibrium in the arid zones of North Africa. Rome (mimeo).

LIVING (1977): with the desert. In: Ekistics 43, 242-324.

LOUIS, H. (1973): Fortschritte und Fragwürdigkeiten in neueren Arbeiten zur Analyse fluvialer Landformung besonders in den Tropen. Z. f. Geomorphologie 17, 1, 1-42.

LUNDHOLM, B. (1975): Environmental monitoring needs in Africa. In: P. RICHARDS (ed.): African Environment. Special Report 1. London, 9-24.

LUSIGI, W. I. (1980-1983): IPAL Technical reports. UNESCO. MAB. Nairobi.

LYNES, R. N. (1921): Notes on the natural history of Jebel Marra. Khartoum (S.N.R. 4, Pt. 2).

MAB (1974): Impact of human activities and land use practices on grazing lands. Rep. Series 25. Paris.

MAB (1977): Map of the distribution of arid regions. Technical Notes 7, UNESCO. Paris.

MABBUTT, J. A. (1976): Physiographic setting as an indication of inherent resistance to desertification. In: Problems in the development and conservation of desert and semidesert land. Pre-Congress Symp. K 26, July 20-26, 1976. Ashkhabad. 189-197.

MABBUTT, J. A., BERKOWICZ, S. M. (1980) (eds.): The threatened lands. 24th I.G.U. Congress Tokyo. Kensington NSW Australia. 153 pp.

MAC MICHAEL, H. A. (1912): The tribes of northern and central Kordofan. London. Repr. 1967.

MAC MICHAEL, H. A. (1920): The Tungur-Fur of Dar Furnung. In: S.N.R. 3, 24-32.

MAC MICHAEL, H. A. (1922): A history of the Arabs in the Sudan, and some account of the people who preceded them and of the tribes inhabiting Darfur. Vol. 1.2. Cambridge.

MAC MICHAEL, H. A. (1955): The Sudan. London, New York.

MANSHARD, W. (1960): Ein Vorschlag zur Gliederung und Benennung von Vegetationsformationen in Afrika südlich der Sahara. In: Geograph. Taschenbuch 1960/61, 454-463.

MANSHARD, W. (1962): Der Ablauf der Regenzeiten in Westafrika, dargestellt an Beispielen aus Ghana. In: H. UHLIG, W. MANSHARD, A. GERSTENHAUER: Beiträge zur Geographie tropischer und subtropischer Entwicklungsländer. Indien-Westafrika-Mexiko. Gießen. 47-81 (Gießener geographische Schriften 2).

MARNO, E. (1873): Sudanesische Märkte. In: Mitt. d. K. u. K. Geogr. Ges. Wien 16, 487-490.

MASON-BEY, A. (1880): Dar-For. In: Peterm. Geogr. Mitt. 26, 377-381.

MATHER, D. B. (1956): Migration in the Sudan. In: R. W. STEEL, C. A. FISHER: Geographical essays on British tropical lands. London. 115-143.

MAYDELL, H.-J. von (1974): Aufgaben und Möglichkeiten der Forstwirtschaft in der Sahelzone. In: Afrika Spectrum 9, 291-307.

MAYDELL, H.-J. von (1975): Pflanzungen mit Acacia albida - ein Beitrag zur Entwicklung der Landnutzung in der Sahelzone. In: Entwicklung und ländlicher Raum 9, 15-16.

MAYDELL, H.-J. von (1977): The contribution of forestry to regional development in the Sahel. In: Applied Sciences and Development. Vol. 10. Tübingen, 164-174.

MAYDELL, H.-J. von (1978): Tree and shrub species for agroforestry systems in the Sahelian zone of Africa. In: Plant Research and Development, Vol. 7 (Tübingen), 44-59.

MAYDELL, H.-J. von (1979): Agroforestry - a combination of agricultural, sylvicultural and pastoral land-use. In: Plant Research and Development, Vol. 9 (Tübingen), 17-23.

MAYDELL, H.-J. von (1982): Möglichkeiten zur Erhöhung der humanökologischen Tragfähigkeit durch agroforstliche Maßnahmen in semiariden Gebieten tropischer und subtropischer Gebirge. In: Gießener Beiträge zur Entwicklungsforschung, Reihe 1, Bd. 8, 121-130.

MAYDELL, H.-J. von (1983): Agroforstwirtschaft: Beiträge von Bäumen und Sträuchern zur Nahrungsmittelversorgung in den Tropen. In: Der Tropenlandwirt, Zeitschr. f. d. Landw. in den Tropen und Subtropen 84, 157-167.

MECKELEIN, W. (1959): Forschungen in der zentralen Sahara. Bd. 1: Klimageomorphologie. Braunschweig. 181 pp.

MECKELEIN, W. (1973): Climatic-geomorphological zones and land utilization in the coastal desert of the North Sahara. In: D. H. K. AMIRAN and A. W. WILSON (eds.): Coastal deserts. Tucson, Ariz. 159-165.

MECKELEIN, W. (1977): Probleme der Oasenkolonisation in der libyschen Wüste Ägyptens. Mannheim. 445-458 (Mannheimer Geogr. Arbeiten 1).

MECKELEIN, W. (1980) (ed.): Desertification in extremely arid environments. Stuttgart. 203 pp. (Stuttgarter Geogr. Studien 95).

MENSCHING, H. (1974a): Landforms as a dynamic expression of climatic factors in the Sahara and Sahel - a critical discussion. In: Zeitschr. Geomorph., Suppl. 20, 168-177.

MENSCHING, H. (1974b): Die Sahelzone Afrikas. Ursachen und Konsequenzen der Dürrekatastrophe. In: Afrika Spectrum 9, 241-259.

MENSCHING, H. (1974c): Aktuelle Morphodynamik im afrikanischen Sahel. In: H. POSER (ed.): Geomorphologische Prozesse und Prozeßkombinationen in der Gegenwart. 22-38. (Abh. der Akademie der Wiss. in Göttingen).

MENSCHING, H. (1975a): Die Sahelzone - Ursachen und Konsequenzen der Dürrekatastrophe in Afrika. In: Umschau in Wiss. u. Techn. 75, 305-308.

MENSCHING, H. (1975b): Climato-hydrological aspects of the potential of the natural resources in the Sahel zone of West Africa. In: Geoscientific Studies and the Potential of the Natural Environment. Köln, München, 77-82.

MENSCHING, H. (1978a): Die Wüste schreitet voran. In: Umschau in Wiss. u. Techn. 78, 99-106.

MENSCHING, H. (1978b): Desertification and its impact on the ecosystem of the Sahelian zone. In: Regional I.G.U. Conf. 1. (Lagos). 5-8.

MENSCHING, H. (1978c): Anthropogene Einwirkungen auf das morphodynamische Prozeßgefüge in der Sahelzone Afrikas. In: Tagungsbericht und wissenschaftl. Abhandl. 41. Deutscher Geographentag Mainz 1977. Wiesbaden. 407-416.

MENSCHING, H. (1978d): Inselberge, Pedimente und Rumpfflächen im Sudan (Republik). Ein Beitr. zur morphogenet. Sequenz in den ariden Subtropen u. Tropen Afrikas. In: Zeitschr. Geomorph. Suppl. 30, 1-19.

MENSCHING, H. (1978e): Zur Geomorphologie des Jebel Marra (Darfur/Sudan). In: Beiträge zur Quartär- und Landschaftsforschung. Festschr. f. J. FINK. Wien. 333-344.

MENSCHING, H. (1980a): Ein komplexes Phänomen der Degradierung und Zerstörung des marginaltropischen Ökosystems in der Sahelzone Afrikas. In: Geomethodica 5. Basel, 17-40.

MENSCHING, H. (1980b): Desertification in a mountain region: The Jebel Marra/Sudan. In: J. A. MABBUTT, S. M. BERKOWICZ (eds.): The threatened drylands. 24th I.G.U. Congress Tokyo. Kensington NSW Australia. 29-32.

MENSCHING, H. (1980c): The Sahelian zone and the problems of desertification. In: A. A. BALKEMA (ed.): Palaeo-ecology of Africa and the surrounding islands. Vol. 12. Rotterdam. 257-266.

MENSCHING, H., K. GIESSNER, G. STUCKMANN (1970): Sudan - Sahel - Sahara. Hannover. (Jahrb. d. Geogr. Ges. zu Hannover. Jb. f. 1969). 219 pp.

MENSCHING, H., F. IBRAHIM (1975): Desertification in the steppe region of North Africa. In: A. T. GROVE (ed.): Proceedings of the Cambridge Meeting on Desertification, I.G.U. Cambridge. 65-67 (mimeo).

MENSCHING, H., IBRAHIM, F. (1976a): Notes towards the definition and geographical analysis of the problem of desertification in and around arid lands. In: Problems in the development and conservation of desert and semidesert land. Pre-Congress Symp. K 26, July 20 - 26, 1976. Ashkhabad. 207-216.

MENSCHING, H., IBRAHIM, F. (1976b): Desertification im zentraltunesischen Steppengebiet. In: Nachr. d. Akad. d. Wiss. Göttingen. 2. Math.-phys. Kl. 8, 99-118.

MENSCHING, H., IBRAHIM, F. (1976c): Das Problem der Desertifikation. In: Geogr. Zeitschr. 64, 81-93.

MENSCHING, H., IBRAHIM, F. (1977): The problem of desertification in and around arid lands, with two contributions on the anthropogenic destruction of land use potential and a discussion of measures for rehabilitation. In: Applied Sciences and Development. Vol. 10. Tübingen, 7-43.

MENSCHING, H., IBRAHIM, F. (1978): Desertification in der Sahelzone der Republik Sudan. In: Afrika Spectrum 13, 5-20.

MENSCHING, H., IBRAHIM, F. (1979): Zur Kartenbeilage Desertification. In: Geogr. Rundschau 31, 355-356.

MENSCHING, H., IBRAHIM, F. (1980): Mapping desertification in the Sudan - a methodological approach. In: J. A. MABBUTT, S. M. BERKOWICZ (eds.): The threatened drylands. 24th I.G.U. Congress, Tokyo. Kensington, NSW Australia. 19-28.

MENSCHING, H., HAARMANN, V. (1982) (eds.): Problems of the management of irrigated land in areas of traditional and modern cultivation. I.G.U. Hamburg. 174 pp.

MICHON, P. (1973): Le Sahara avance-t-il vers le sud? In: B.F.T. 150, 3-14.

MONOD, T. (1959): Parts respectives de l'homme et des phénomènes naturels dans la dégradation du paysage et le déclin des civilisations à travers le monde méditerranéen. In: 7e Réunion de IUCN 1, 31-69.

MONOD, T. (1975) (ed.): Pastoralism in tropical Africa. 13th Intern. Afr. Seminar, Niamey. London.

MORAL, P. (1964): Essai sur les régions pluviothermiques de l'Afrique de l'ouest. Annales de Geogr., 400, 73, Paris.

MORTIMORE, M. J. (1977): Changes in the agrarian structure in Dagacheri village, Kano State, Nigeria. Rome: FAO

MUKHTAR, H. A. (1974): Weidegebiete im Sudan. Algier (in Arabic).

NACHTIGAL, G. (1889): Sahara und Sudan. T. 3: Wadai und Dar-For. Leipzig.

NEWBOLD, D. (1924): A desert odyssey of a thousand miles. In: S.N.R. 7, 43-92.

NICHOLSON, S. E. (1976): A climatic chronology for Africa. Synthesis of geological, historical and meteorological information and data. Diss. Madison. Wisc.

NOVIKOFF, G. (1975): The desertification of range lands and cereal cultivated lands in presaharian Tunisia. In: G. NOVIKOFF, F. H. WAGNER, D. SKOURI (eds.): Tunisian Presaharan Project. Report 3. Logan, Utah, 163-169.

NOVIKOFF, G., WAGNER, F. H., HAJEJE, M. S. (1976): Tunisian Presaharan Project. Report 5. Joint MAB and US Internat. Biol. Programme. Logan, Utah.

OESTERDIEKHOFF, P., WOHLMUTH (1983) (eds.): The development perspectives of the Democratic Republic of Sudan. IFO-Inst. München, Afr. Sud. 109. Weltforum München, Köln, London, 339 pp.

O'FAHEY, R. S. (1980): State and society in Darfur. Hurst. London. 210 pp.

O'FAHEY, R. S., MUAHMMAD, A. G. (1972): Documents from Dar Fur. Fasc. 1. Bergen.

O'FAHEY, R. S., SPAULDING, J. L. (1974): Kingdoms of the Sudan. London. 235 pp.

OLIVER, J. (1969): Problems of determining evapotranspiration in the semi-arid tropics illustrated with references to the Sudan. In: J. Trop. Geogr. 28, 64-74.

OLSSON, L. (1983): Desertification or climate. Lund Studies in Geography No. 6. Univ. of Lund. 36 pp.

OLSSON, L., STERN, M. (1981): Large area data sampling for remote sensing. Lunds Univ. Naturgeogr. Inst. Rapporter och Notiser 49. 57 pp.

OTTERMAN, J. (1974): Baring high albedo soils by overgrazing. A hypothesized desertification mechanism. In: Science 186, 531-533.

PENMAN, H. L. (1956): Evaporation. An introductory survey. In: Netherlands J. Agric. Sci. 4, 8-29.

PFUND, J. (1876/77): Reisebriefe aus Kordofan und Dar-Fur. In:

L. FRIEDERICHSEN (ed.): Mitt. d. Geogr. Ges. in Hamburg 2, 121-305.

QUÉZEL, P. (1969): Flore et végétation des plateaux du Darfur nord occidental et du Jébel Gourgeil. Paris. 146 pp.

RAMSAY, D. M. (1950): The forest ecology of central Darfur. Khartoum (Forest Bull., New Ser. 1)

RAPP, A. (1974): A review of desertization in Africa. Water, vegetation and man. Stockholm (SIES. Report 1).

RAPP, A. (1975): Soil erosion and sedimentation in Tanzania and Lesotho. In: Ambio 4, 154-163.

RAPP, A., HELLDEN, U. (1979): Research on environmental monitoring methods for land use planning in African drylands. Lunds Univers. Naturgeogr. Inst. Rapporter och Notiser 42, Lund. 124 pp.

RATH, U. C. W. (1956): Rainfall and agriculture in the Sudan. Khartoum.

RIFAI, A. M., AHMED, A. R. (1974): Die Dürre in Nord-Darfur und ihre Auswirkungen auf den Stamm der Zaghawa. Official report. El Fasher (in Arab.).

RIFAI, A. M.et al (1973): Infrastruktur in Nord-Darfur und die sozioökonomische Situation der Meidob (in Arab.). El Fasher.

SATAKOPAN, V. (1965): Water balance in the Sudan. Khartoum (Sudan Meteorological Service. Memoir 5)

SCHIFFERS, H. (1971/73) (ed.): Die Sahara und ihre Randgebiete. Bd. 1-3. München (Afrika-Studien 60-62).

SCHMIDT-LORENZ, R. (1971): Die Böden. In: P. von BLANCKENBURG, H.-D. CREMER (eds.): Handbuch der Landwirtschaft und Ernährung in den Entwicklungsländern. Vol. 2. Pflanzliche u. tierische Produktion in den Tropen u. Subtropen. Stuttgart, 44-80.

SCHOLZ, F., JANZEN, J. (1982) (eds.): Nomadismus - ein Entwicklungsproblem? Berlin. 247 pp. (Abh. d. Geogr. Inst. Bd. 33. Anthropogeographie).

SCHULTZE, J. H. (1963): Der Ost-Sudan. Entwicklungsland zwischen Wüste und Regenwald. Berlin. (Abh. d. 1. Geogr. Inst. d. FU Berlin 7).

SCHULTZE, J. H. (1966): Wasserwirtschaft und Wasserhaushalt im Ost-Sudan. In: Nova Acta Leopoldina, N. F. 31, No. 176, 89-105.

SCHWEINFURTH, G. (1878): Im Herzen von Afrika. Leipzig.

SHAWKI, M. K., MUSNAD, H. (1964): The green belt south of Khartoum. Khartoum (Forest Bull. 7).

SLATIN, R. (1876): Baggara und Nubaner. Stuttgart. (Das Ausland 49).

SLATIN, R. (1896): Fire and the sword in the Sudan. London.

SOEFFING, H. (1979): Veränderungen in der Siedlungsweise bei den For im Jebel Marra. Veröff. aus dem Übersee-Museum Bremen. Reihe F, Bremer Afrika Archiv, Bd. 6, Bremen. 286 pp.

SOIL EROSION (1963) by wind and measures for its control on agricultural lands. Rome. (FAO Agricultural Development Paper 71).

STEBBING, E. P. (1935): The encroaching Sahara. The threat to the west African colonies. In: Geogr. J. 85, 506-524.

STEBBING, E. P. (1937): The threat of the Sahara. London. (J. Royal Afr. Soc., Suppl. zu Bd. 36).

STEBBING, E. P. (1938): The man-made desert in Africa. London. (J. Royal Afr. Soc., Suppl. zu Bd. 37).

STEBBING, E. P. (1953): The creeping desert in the Sudan and elsewhere in Africa, 15-30 degrees latitude. Khartoum.

LÄNDERBERICHT SUDAN (1976). Statist. Bundesamt Wiesbaden (ed.). Mainz. (Statistik des Auslands).

SUDAN-Almanac (1948) 1903 - 1942. London.

SUDAN Government (1944) (ed.): The report of the soil conservation committee. Khartoum.

SUDAN GOVERNMENT (1960/62) (ed.): First population census of Sudan 1955/56. Vols. 1 and 2. Khartoum.

SUDAN GOVERNMENT (ed.): Internal statistics 1960-1964 and 1967-1972.

SUDAN GOVERNMENT (ed.): Agricultural statistics 1962/63, 1967/68, 1968/69, 1969/70, 1974, 1975, 1976. Khartoum.

SUDAN GOVERNMENT (1966a) (ed.): Population and housing survey - El Fasher. Khartoum.

SUDAN GOVERNMENT (1966b) (ed.): Population and housing survey - El Geneina. Khartoum.

SUDAN GOVERNMENT (1968) (ed.): Population and housing survey - - Darfur province, urban areas. Khartoum.

SUDAN GOVERNMENT (1973) (ed.): Statistical yearbook 1973. Khartoum.

SUDAN GOVERNMENT (1976) (ed.): Internal trade statistics and price indices 1973-1975. Khartoum.

SUDAN GOVERNMENT (1977) (ed.): The Sudan experience in the field of desert encroachment control and rehabilitation. Paper presented on the UN Conf. on Desertification. Nairobi.

SUDAN GOVERNMENT (1982) (ed.): Renewable energy assessment for the Sudan. Ministry of Energy and Mining. Khartoum. 67 pp.

THORNTHWAITE, C. W. (1948): An approach toward a rational classification of climate. In: Geograph. Rev. 38, 55-94.

TRICART, J. (1959): Geomorphologie dynamique de la moyenne vallée du Niger (Soudan). In: Annales de Geogr., 368, 333-343.

TROLL, C., PAFFEN, K. H. (1964): Karte der Jahreszeiten-Klimate der Erde. In: Erdkunde 1, 5-28 und Karte.

TRUMBLE, H. C., WOODROFFE, K. (1954): The influence of climatic factors on the reaction of desert shrubs to grazing sheep. In: J. L. CLOUDSLEY-THOMPSON (ed.): Biology of Deserts. London, 129-147.

TUBIANA, M.-J., TUBIANA, J. (1977): The Zaghawa from an ecological perspective. Rotterdam. 119 pp.

UNEP (1980): Energy and environment in East Africa. Energy Report Series 3-80. Nairobi. 405 pp.

UNEP (1981): The environmental impacts of production and use of energy. Reports I-IV. Energy Report Series. Nairobi.

UNESCO (1963): Nomades et nomadisme au Sahara. Recherches sur la zone aride 19. Paris.

UNESCO (1975): The Sahel. Ecological approaches to land use. Paris (MAB Technical Notes).

UNESCO (1979): Tropical grazing land ecosystems. Paris. 655 pp.

UNESCO (1980): Case studies on desertification. Ed. by J. A. MABUTT, C. FLORET. Paris. 279 pp.

UNITED NATIONS (1977a): Conference on Desertification, Nairobi.

Desertification, its cuases and consequences. Pergamon Press. Oxford/Frankfurt.

UNITED NATIONS (1977b): Transitional green belt in North Africa. A/Conf. 74/25. Nairobi.

UNITED NATIONS (1977c): Conference on Desertification, Nairobi. Transitional project on management of livestock and range-lands to combat desertification in the Sudano-Sahelian regions (Solar). A/Conf. 77/26. Nairobi.

UNITED NATIONS (1977d): World map of desertification, 1:25 Mio. A/Conf. 74/2. Nairobi.

UNITED NATIONS (1977e): World maps: Status of desertification. Climate aridity index. Aridity and drought probability. 1:25 Mio. A/Conf. 74/31. Nairobi.

UNITED NATIONS (1977f): Plan of action to combat desertification. A/Conf. 74/L. 36. Nairobi.

UNSO (1981): Desertification control and range management. New York.

VOS, A. de (1975): Africa - the devastated continent? Man's impact on the ecology of Africa. Den Haag. (Monographiae Biologicae 26).

WALLEN, C. C. (1967): Aridity definitions and their applicability. In: Geografiska Annaler, Ser. A. 49, 367-384.

WALTHER, E. G., NICHOLSON, S. E. (1977): Using climatic and crop data to combat desertification. In: The Science Associations' Nairobi Seminar on Desertification, Aug. 21-25. Agenda and supporting documents. Nairobi. 1-23.

WARREN, A. (1966): The Goz region of Kordofan. Diss. Cambridge.

WARREN, A. (1970): Dune trends and their implications in the central Sudan. In: Zeitschr. Geomorph., Suppl. 10, 154-180.

WARREN, A., MAIZELS, J. K. (1977): Ecological change and desertification. In: Desertification, its causes and consequences. Pergamon Press. Oxford/Frankfurt. 169-260.

WEICKER, M. (1982): Die Beziehungen zwischen Nomaden und Bauern im senegalesischen Sahel. Bayreuther Geowissenschaftl. Arbeiten. Bd. 4. Bayreuth. 168 pp.

WHITEMAN, A. J. (1971): The geology of the Sudan Republic. Oxford.

WICKENS, G. E. (1962): Savanna development in the Sudan. Plant ecology. Rome.

WICKENS, G. E. (1970): A brief note on the early history of Jabal Marra and the recently discovered Tora city of Kebeleh. In: S.N.R. 51, 147-151.

WIDSTRAND, C. G. (1975): The rationale of nomad economy. In: Ambio 4, 146-153.

WILSON, R. T. (1960): Wildlife in northern Darfur, Sudan, a review of its distribution and status in the recent past and at present. In: Biol. Conserv. 17, 85-101.

WILSON, R. T. (1978): The "Gizu" winter grazing in the south Libyan desert. In: Journ. Arid Environments 1, 325-342.

WIRTH, E. (1983) (ed.): German geographical research in the Middle East. (Arabic). Erlangen/Beirut 1983. 600 pp.

WORRALL, G. A. (1960): Patchiness in vegetation in the northern Sudan. In: J. Ecol. 48, 107-115.

WORRALL, G. A. (1961): A brief account of the soils of the Sudan. In: Africa Soils 6, 63-81.

WHO (1975) (ed.): Drought and agriculture. Techn. Note 138. Genf.

ZURBUCHEN, J. (1884): Reise nach Chartum, durch Kordofan und Darfur, 1879. Tagebuchblätter. In: Peterm. Geogr. Mitt. 30, 443-454.

FURTHER SOURCES

Maps

1 : 4,000,000:	Sudan, Topo. N.S. 624.4, 1976
1 : 2,000,000:	El Fasher, Africa, 14, 2201, Topo. Center, Washington, D. C.
1 : 2,000,000:	Geological Map, 2 sheets, British Government, 1975
1 : 1,000,000:	World Map, ND 34, Abéché World Map, ND 35, El Fasher
1 : 250,000:	Sudan Survey, Khartoum, No.: 44 M 53 D, 54 A, 54 B ND-35-H, 54 E, 54 F

53 K, ND-35-L, 54 I, ND-35-J
54 L, 54 M, 54 N

Air Photos
Survey Department, Khartum 1954, 1960, 1968

Satellite Imagery
ERTS, NASA, 1972, 1973, 1975, 1976; Bands 4, 5, 7

Photos, Figures and Maps: by the author

ABBREVIATIONS

B.F.T.	Bois et Forêts des Tropiques
FAO	Food and Agriculture Organization of the UN
I.G.U.	International Geographical Union
I.U.C.N	International Union for Conservation of Nature and Natural Resources
MAB	Man and Biosphere
mimeo	mimeographed
SIES	Secretary for International Ecology, Stockholm
S.N.R	Sudan Notes and Records
SRC	Studies and Research Centre
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization

2

lluviale Tone und Sande in Wadis und Abflußbecken
lluvial clay and sand in wadis and drainage basins

lugsanddecken
Vind-blown sandsheets

oz: festgelegte, stellenweise anthropogen reaktivierte Dünensande
oz: fixed, at places anthropogenetically reactivated dune sands

ertiäres bis rezentes vulkanisches Gestein (Basalte, Konglomerate, Tuffe)
ertiary to recent volcanic rocks (basalt, conglomerate, tuff)

ubischer Sandstein (im Becken von Wadi El Ku' bis 900 m Mächtigkeit)
ubian Sandstone (in the basin of Wadi El Ku' up to 900 m thickness)

asement Complex (präkambrische Gneise, Schiefer und Quarzite sowie paläozo

Bayreuther Geowissenschaftliche Arbeiten

Band 1: Versch. Verf.: Geowissenschaftliche Beiträge über Oberfranken. 1980. 230 Seiten, 28 Tabellen, 35 Abbildungen und 32 Karten. DM 34,—

Band 2: Jürgen Weber: Der Unternehmer als Entscheidungsträger regionaler Arbeitsmärkte. Eine Analyse über industrielle und handwerkliche Strukturen in Oberfranken, ihre Determinanten und Auswirkungen auf die regionalen Arbeitsmärkte. 1981. 160 Seiten, 18 Tabellen, 18 Abbildungen und 12 Karten. DM 32,—

Band 3: Wolfgang Thomas: Entwicklung eines Immisionsmeßsystems für PCA, Chlorkohlenwasserstoffe und Spurenmetalle mittels epiphytischer Moose – angewandt auf den Raum Bayern. 1981. 142 Seiten, 25 Tabellen, 35 Abbildungen. DM 33,80

Band 4: Martin Weicker: Die Beziehungen zwischen Nomaden und Bauern im senegalesischen Sahel. Eine konflikttheoretische Analyse. 1982. 170 Seiten, 10 Tabellen, 12 Abbildungen. DM 42,—

Band 5: Philipp Hümmer: Siedlungsstrukturen und sozialräumliche Beziehungsmuster in der ländlichen Türkei, das tertiäre Hügelland der Çukurova als Aktionsraum altbäuerlicher und ehemals nomadischer Bevölkerung. 1984. 132 Seiten, 1 Tabelle, 22 Abbildungen. DM 49,—

Band 6: Ecological Imbalance in the Republic of the Sudan, with Reference to Desertification in Darfur. 1984. 215 Seiten, 37 Tabellen, 40 Figuren, 49 Fotos, 4 Karten im Anhang. DM 32,—

In Vorbereitung:

Wieland Lippoldmüller: Populationsökologie von Cirsium vulgare Ten (Speerdistel).