

UNITED NATIONS EDUCATIONAL,  
SCIENTIFIC AND CULTURAL ORGANIZATION

Major Project on Scientific Research on Arid Lands

Department of Natural Sciences

REPORT ON ARID ZONE RESEARCH IN THE SUDAN

by

Frank Dixey,  
formerly Director of British Overseas Geological Surveys  
and

G. Aubert,  
Chef de la Section des Sols, O.R.S.T.O.M.

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Proposals for an Arid Zone Research Institute in the Sudan.

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APPENDIX

Proposals for an Arid Zone Research Institute in the Sudan.

I - a) Terms of reference and organization of the mission

We were sent on mission by UNESCO, at the request of the Government of the Republic of the Sudan, to ascertain what scientific research is needed on arid zone problems in this country, to make proposals for organizing such research and to indicate what, in our opinion and in that of the competent local authorities, appear to be the best means of solving these problems and developing this arid zone.

In this connexion, we contacted the persons responsible in the relevant sections of Unesco, in Paris and of FAO, in Rome, before proceeding to the Sudan, where we had two jobs to do: firstly, to discuss the problem of investigating and exploiting the arid zone with the competent authorities in the Government, the university and other bodies; and secondly, to study this zone at first-hand and obtain a better grasp of its problems in order to suggest the more practical ways of solving them, taking account of what has already been done in this country, and of the plans already made for the future.

In Paris, on 3 January 1961, we met Professor V. Kovda, Director of the Natural Sciences Department of Unesco, and his colleague, Mr. Batisse, Chief of the Division of Studies related to Natural Resources.

At FAO in Rome, on 4 January 1961, we talked to Mr. SCHICKELE, Director of the Division of Land and Water Development; Mr. de VAJDA, in charge of UN Special Fund Projects for this Division; Messrs. DABELL, Chief of Section, and BRAMAO, de MEREDIEU, DUDAL and LEMOS, specialists in the same Division; Messrs. FRANCOIS and METRO, of the Division of Forestry and Forest Products; Messrs. D.E. DEKKER and de BRICHAMBAUT of the Division of Plant Production and Protection; and a specialist from the Division of Animal Production and Health.

In this way, we had very full details, before leaving for the Sudan, of all that these two organizations were doing and had already done on the "Arid zone of the Sudan", of their plans for the future and of the extent to which they could expand research on these lines.

We used this information as a basis in drawing up our proposals.

On 13 February, on our return from the Sudan, we submitted our proposals to Mr. Batisse at Unesco; besides discussing them with various other members of the Organization, including Mr. RODERICK - in the absence of Professor Kovda - Mrs. GRIVET, of the Division of Technological Sciences, and Mr. KARAM of the Bureau of Relations with Member States.

On 5 January, we were met at the airport at Khartoum by Sayed HASSAN AHMED YOUSSEF, Secretary General of the Sudanese National Commission for Unesco; and by Sayed SAED ABDELRAHMAN, of the Department of Land Use and Rural Water Development, a former pupil of one of the members of our mission.

We stayed in Khartoum from 5 to 10 January.

During our stay there we met, in addition to the persons already mentioned :

from the Ministry of Education: H.E. Sayed ZIADA ARBAB, Minister of Education; Sayed ABD EL ALIM TAHA, Director of Education; Sayed MANDOUR, Assistant Director of Cultural Relations.

from the Ministry of Agriculture: Sayed YACOUB EL HILU and Sayed AHMED ABDALLA OSMAN, of the Planning and Projects Department.

from the Department of Land Use and Rural Water Development: Sayed A.R. BAYOUMI, Director of Department; Sayed MAGDOUB EL BANA, Deputy Director; Sayed ABBAS ABD EL MAGID, Engineer in the Land Use section.

from the Ministry of Animal Resources: Dr. IBRAHIM M. KHALIL, Director of the Ministry; Sayed M<sup>d</sup> ALI MIHEIMIED, Assistant Director; Sayed AMIN ABDALLAH EL KARIB, Director of the Research Division; and Sayed MUSTAFA MOHAMMED BAASHER, Chief Engineer of the Section for the organization of pastureland.

from various other Ministries: Sayed YAHIA ABD EL MAGID, Chief Hydrologist, the chief government Meteorologist, and Sayed ABDEL LATIF, Assistant Director of the Geology Service.

from the University of Khartoum, Faculty of Agronomy: Dr. ASHOUR, Professor of Plant Biology and Dr. DROVER, Professor of Soil Science; Faculty of Veterinary Science: Dr. NAZEER, the Dean; Faculty of Sciences: Dr. J.L. CLOUDSLEY-THOMPSON, Professor of Zoology, Dr. G. WHITEMAN, Professor of Geology.

from Technical Cooperation Missions: M.G. FARUQUI, Representative of the United Nations; Mr. RAO, Head of the Unesco Mission and Mr. STENCELEN and Dr. KADHIM, experts from the same Mission; Mr. SHIRNAME, Head of the FAO Mission and Mr. RAMSAY and Dr. BASU, of the same Mission.

Then at Khartoum on 30 and 31 January, after our trip to the West (Kordofan and Darfur) we met the following:

from the Ministry of Agriculture: Sayed SHAWKI, Director of Forests, Sayed WADI HABASCHI, Director of Agriculture.

from the Ministry of Public Works: Sayed MAHMOUD AHMED ABDALLAH, Chief of the Geology Service.

from the Faculty of Sciences of the University: Dr. LEBON, Professor of Geography and Mr. BERRY, Lecturer in Geomorphology; Dr. K.N. MACLEAY, Professor of Botany, Dean of the Faculty of Sciences.

from the Faculty of Letters: Professor I.G. CUNNISON, Professor of Social Anthropology.

from the Wad Medani Centre of Agronomic Research: Dr. W.T.H. WILLIAMSON, of the Soils Section and Mr. VINCK, Soil Chemist.

from the I.C.A. (U.S.A. Technical Cooperation Organ): Mr. I. WALKER, Mr. JACKSON and Mr. F. OLVER.

In the period from 10 to 29 January 1961, we visited first Kordofan, then Darfur.

At El Obeid, we were received by the Military Governor (Government?) Miralai ZEIN EL ABDIN HASSAN EL TAYEB, and by the Governor of the Province, Sayed ABDALLAH MOHAMMED EL AMIN.

There we met the Vice-Governor, Sayed AMIN SHAZALI, also Dr. AHMED MAGDOUB ABDOUIN, Provincial Veterinary Surgeon; Sayed GAAPAR HASSAN, Engineer in the Land Use Section; Mr. GUNNAR POULSEN, Warden of Forests; Sayed BAYOUMI, Forestry Engineer; Mr. P.N. VIDAL-HALL, Forestry expert in charge of gum problems; and Mr. BAUMER, Chief of the Pasturage Section for Kordofan.

During our trip, we also met the Commissar of the Bara district; and at Lagowa, the chief agricultural engineer for the province of Kordofan.

At El Fasher, we were received by the military and civil governors. Also by the Commissar of the El Fasher district, and his assistant; the agricultural engineer, and the engineer of the veterinary services; and we met Sayed SAED ABD EL RAHMAN, engineer in the Land Use Service; Sayed WADI TALLA SAED, assistant at the Experimental Station for Improvement of pastures and live-stock at Gazal Gawazet.

At Kutum, thanks to the assistance of the District Commissar, we were able to meet two local chiefs.

During the period from 1 to 8 February, we toured the Red Sea province.

At Port-Sudan, we were received by the Governor of the Kassala Province, and by Sayed SALIM MOHAMMED TAHIR, Commissar General of Port Sudan. We were also able to meet Sayed ALI HAMID, District Commissar, the engineer of the Land Use Department of the Kassala Province and Mr. TRAMONTINI, Hydraulic Engineer of the Department of Land Use and Rural Water Development.

When visiting or passing through Khartoum, El Obeid, El Fasher and Port Sudan, various meetings were arranged for us:

At El Obeid and Port Sudan, a meeting of the Provincial Land Use Bureau; at El Fasher, a meeting of the Land Use Bureau and of the Mellit Committee; at Khartoum, a meeting of the Sudanese National Commission for Unesco, sub-commission for study of the Arid Zone.

At these meetings and interviews, we heard the views of the leading Sudanese authorities on the problem of arid zone research in this country; and were able, also, to state and discuss our own views.

Apart from this we were able, thanks to the help we received from various authorities and from the Land Use department in particular, to make extremely useful tours of various parts of the country. The places we saw were as follows:

- 11 to 20 January, in Kordofan: El Obeid, Bara, Hamrat el Wuz, Sodiri, Um Badr, Mazrub, El Obeid.

El Obeid, Abu Zabad, Lagowa, Lac Keilak, Um Shuheita, Tira Mandi, Es Semeiha, Um Kuvaba, El Obeid.

- from 23 to 29 January, in Darfur: El Fasher, Mellit, Malla, El Fasher.

El Fasher, Kabkabyia, Sirief, Abu Gidad, Kabkabyia, Kutum, El Fasher.

- on 2 and 3 February, around Port Sudan, first in the Khor Arbat Valley then in the Khor Sallum and Gvob valleys.

- from 4 to 7 February, Port Sudan, Mohammed Quol, Geweit mines, Solala, Khor Odib, Adar Awibe, Dalween, Mohammed Quol, Port Sudan.

On these tours, we were accompanied by various Sudanese engineers and foreign experts:

- Sayed ABEAS ABD EL MAGID organized all our tours with the greatest care and efficiency. He remained with us whilst we toured the various provinces. On our tour of Kordofan, we were also accompanied by Messrs. M. BAUMER and M. POULSEN; in Darfur, by Sayed SAED ABD EL RAHMAN and the Agricultural Engineer; in the Red Sea Province, by Sayed ALI HAMID, the engineer of the Land Use Service, also by Dr. BASU and Mr. TRAMONTINI. All these persons helped us unstintingly and gave us the benefit of their exhaustive knowledge of the regions visited; and much of the information contained in this report was provided by them, whilst the opinions expressed in the report crystallized from the discussions we held with them.

We would like to express our deep gratitude to all these people, and to all those who helped us by their advice and devoted services.

## 2. NOTES ON CERTAIN REGIONS OF THE ARID ZONE IN THE SUDAN

We were very fortunate in being able to make extensive trips through certain typical regions of the Sudan accompanied by officials, engineers and experts having a through knowledge of local problems. And we were able to meet and discuss these problems, on the spot, with local

and regional officials, administrators and chiefs.

This report contains the observations we made in the course of our journeys. They do not claim to constitute a description of the arid zone of the Sudan; and they deal only with certain regions: Kordofan, Darfur and the part of the province of Kassala which lies along the Red Sea coast. Moreover, our trips were too short in relation to the size of the area covered.

As against this, the areas visited were chosen by the heads of the relevant departments (in particular Sayed Bayoumi) as being highly characteristic of the area as a whole; so that the observations we were able to make provided the basis for the recommendations given later in the report.

#### 1. KORDOFAN and DARFUR

The regions we visited in these two provinces fall into two sharply differentiated parts:

- In the North,

Northern Kordofan, mainly sandy, with a few rocky jebels, crossed by several depressions and valleys where the soil is more compact; and Northern Darfur which is sandy, but with mountain chains and large hills;

- In the South,

Southern Kordofan, consisting of a wide clayey plain to the east of the Nube mountains and a plateau of fine light loam soils, intersected by valleys and clayey plains, to the west of these mountains; and Southern Darfur, comprising a vast clayey plain.

The line dividing these two regions is very clearly marked in part of the zone: in Kordofan, it runs south of Umur Ruwaba, Es Jemeiha; in Darfur, south and south-west of El Fasher; elsewhere, it is less clearly defined: it passes south of El Obeid and Er Rahad, north of Abu Sabad.

#### A. - THE NORTHERN ZONE

##### - Climate and vegetation

The climate of this zone is arid. In the area to the north of the one which we visited, up to the 15th parallel, approximately, i.e. Hamrat el Wuz in Kordofan and Malha in Darfur, it is actually sub-desert and desert. In the south, on the other hand, the climate is only semi-arid.

The seasons are very clearly differentiated: a short rainy season, often with very heavy and irregular rainfall, from July to September; and a very dry season from October to June.

The annual rainfall in this zone is very small:

Hamrat el Wuz ..... 145 mm      El Obeid ..... 388 mm

Sodiri .....	230 mm	Um Ruwaba .....	397 mm
Umm Badir .....	245 mm	En Nahud .....	424 mm
Mazrub .....	274 mm	Malha .....	approx. 200 mm
Bara .....	312 mm	Kutum .....	340 mm
Abu Zabad .....	442 mm	Kabkabyia .....	400 mm
El Lagowa .....	690 mm	El Fasher .....	403 mm
		Es Sirief .....	443 mm

Temperatures are high: with an annual average temperature of 26.1 at El Fasher; 26.6 at El Obeid; 26.9 at En Nahud. Absolute maximum temperatures may rise to from 45-46° between April and August; minimum temperatures of 0° may be recorded in January and February.

During most of the year, the figure for atmospheric humidity is low. There are very violent winds throughout the whole of the year, but more especially during the dry season, from October to the end of May, when they blow from the north often causing sand-storms. During the rainy season, sand winds are less violent, but may occur nevertheless.

In that part of the northern zone which we saw, the vegetation is of two types: pseudo-steppe in the northern parts, savanna further south.

The pseudo-steppe vegetation consists mainly of Gramineae: Schoenefeldia gracilis, Ctenium elegans, Aristida pallida and A. funiculata, Brachiaria sp., Panicum turgidum; but there are abundant Leptadenia spartium and a few species of trees - mainly Acacia raddiana and Balanites aegyptiaca - and here and there, Boscia senegalensis.

In the low-lying parts, plains, valleys and hollows, there are also other species of Aristida (A. adscensionis, for instance and, above all A. luorinata) Cymbopogon - such as Cymbopogon proximus and C. nervatus - Cyperus and Capparis. In places where the soil has been degraded by hydromorphia, or the vegetation itself has been despoiled by fire or over-grazing, Blepharis sp. (and in particular Blepharis linariifolia) becomes more prevalent.

The savanna, too, takes various forms. The most common is a fairly open tree formation, consisting mainly of Acacia senegal with occasional Acacia raddiana and also, in the most humid parts, Acacia albida, Balanites aegyptiaca, Maerna crassifolia, Dobera glabra and, very rarely, Salvadora persica. In some places, Acacia mellifera and Acacia orphoto are more prevalent, interspersed with Boscia senegalensis; then again, in compact zones such as are to be found in certain valleys of the Darfur province between Kabkabya and Sirief, the main type of vegetation is A. Seyal. In very sandy zones, the main type may be Guiera senegalensis. In places where the sand retains the humidity to a depth of at least several metres, Faidherbia albida will grow.

In the hilly areas, particularly in the Darfur province, Maeria sp. is more prevalent, growing even on very stony soil; whilst in damper or cooler parts, Albizzia sericocephala, Anogeissus Schimperii, Bauhinia rufescens, and Tamarindus indica are to be found.

The herbacious vegetation is likewise very varied, but consists mainly of various types of Aristida and Pennisetum, Cenchrus biflorus and Cenchrus prieurii, Dactyloctenium, Aegyptium, Eragrostis sp., Indigofera sp., Cassia sp., Blepharis. Certain hills in the Darfur province, in particular, are covered almost exclusively with Aristida.

In some places as for instance ground villages or water points - El Fasher, Mellit, Kutum, Abu Gidad in Darfur; or Gebita, Bara, Abouzaima, Um Bard, etc. in Kordofan - the vegetation is very degraded and eventually disappears altogether, leaving the bare soil exposed to the vagaries of the weather and in particular, the ravages of the wind. There are very extensive areas where this process, though already occurring, is not as far advanced: the woody or arboraceous species are still fairly well preserved, though already badly despoiled by the herds; but the grass growing between them has all disappeared except just round the trees, which afford some protection against the deprivations of grazing animals. There are still a few herbaceous plants to be found here and there, but most of them are species of little nutritive value, such as Cenchrus, Aristida, Blepharis, and so on.

On some jebels, where the position affords protection against destruction by fire or grazing herds, a slightly different type of vegetation, similar to that of rather more humid zones, is still to be found.

- Rocks and soils

Kordofan

In all this northern part of the region which we toured, sands predominate, very markedly. Their aspect varies from zone to zone; they may take the form of large slightly undulating plateaux of quartz sands; or rows of flattened, blunted dunes; or a combination of the two - a vast sandy plain or low-lying plateau surmounted by dune hillocks. We were unable to ascertain whether this in fact represented two different types of formation, one superimposed on the other; or a single formation, with the top re-moulded by the wind.

Generally speaking, these dune formations, survivals of an era more arid than the present one, are now fixed. But the sands may be set in movement again owing to the destruction of the vegetation by man and the animals he brings in his wake, a phenomenon which may be either purely local and on a very small scale, or much more general and extensive as, for instance, in the Kheiron region, some 15-18 km. north-north-west of Bara.

In some places, as at Bara, there are lacustrine calcareous formations.

These sand formations are broken by rows of hills and heavy loam or clay patches.

The hills form ranges running either S.W.-N.E. or N-S. They are formed mainly of acid rocks, with granites and gneiss predominating; although there are also syenites and rhyolites as in the Jebel Abu Hadid, north of Shershar or even, now and again, pyroxene or amphibole schists or dolerites, as in the region East of Um Badr. The quartz seams are particularly extensive in some of these ranges, impregnating the whole of the massif, and forming remarkably jagged ridges which cut up the stretches of sand. Here and there, as for instance to the south and east of El Obeid, some fine pegmatites are to be found.

At the foot of these hills, colluvial accumulations of pebbles have formed, some of them very large, and extending far out onto the plain, where they have been remoulded by the action of water.

The sand sometimes extends very high up the sides of the hills, indicating the action of very strong winds in the past. In places there are signs of winds beginning to blow again, probably after a long interval, covering the northern slopes of the hills with a thick layer of sand, and laying those on the east and west bare.

In many depressions and low-lying areas, there are deposits containing a higher proportion of loam or even definitely clayey in character. These deposits are to be found in the areas between dunes or in some depressions of the sandy plateaux. They may also form wide plains, like the ranges of hills, with which they appear to be connected (Sherhar and Sodiri plains, for instance, and others).

These plains are sometimes sprinkled with pebbles and shingle, often blunted or even slightly rounded, showing that they were carried there by water, usually from fairly nearby. Elsewhere, they are still jagged and sharp, in which case they merely constitute the debris of underlying rocky massifs which are in some cases actually visible on the surface.

On the other hand, some of the pebbles and gravel come merely from the soil and consist of ferruginous concretions or calcareous nodules.

In some low-lying zones calcareous elements consisting probably of weathering products of the calcic minerals of the rocks in some of the nearby hills, are to be found in the form of powdery lacustrine lime, or even lime crust, as at Shershar and at El Qaa, near El Quleit, a few kilometres east-south-east of Mazrub, and so on. In this last place, as at several others, the depression in which these substances are found, stretching roughly north-south, ends abruptly at the foot of a steep ridge, running in the direction south-east - north-west, of finest acid metamorphic rock. On the other side the sands extend right up to the foot of the

ridge, in parts even up the slopes.

Elsewhere, calcic elements appear only in the form of nodules in certain types of more or less hydromorphic soils.

Throughout the whole of the zone we toured the most widespread type of soil on top of the sand, is brown steppe soil. It has a low organic matter content, but it extends fairly deep, often down to from 60 to 70 cm. It has a peculiar structure, and its only protection against wind or water erosion is its vegetation cover.

In parts, particularly in the area between Um Badr and Mazrum, brown soils give way to reddish-brown ones. West of Sodiri, the division between these two soil types is governed by the texture of the under-lying layer, as was observed in Senegal, Mali and elsewhere: reddish-brown soils will be found on sand or light loam, brown soils where the character of the underlying layer is more definitely loam. As we go south, brown and reddish brown soils on sand give place to ferruginous tropical soils, unleached or only slightly leached. These soils sometimes resemble the "Dior" soils of the North-Central region of Senegal; they are particularly mature in type near the Jebel Abu-Sinun, north-west of El Obeid.

Northwards, on the contrary, brown soils give place to Sierozems, which are poorer in organic matter, and likewise weakly structured. There are very typical Sierozems already 50 km. to the north of Bara and, above all, between Shershar and Hamrat el Wuz, as well as in certain areas of strongly dunar morphology, some fifty kilometres to the east of Sodiri, for example.

These are cases when Sierozems give place, as a result of extreme degradation, to sub-desert or even desert dunes (north of Bara, for instance, and in the vicinity of numerous towns and villages).

On top of heavy loam or light silt deposits, brown soils are usually to be found; but they show a marked hydromorphic tendency, often containing large quantities of very hard ferruginous nodules, or calcic nodules, as for instance near Shershar.

In certain areas, above all towards the south, this tendency is accentuated and we find veritable hydromorphic soils resembling Tirs soils in varying degrees, and containing nodules. We find this for instance in certain depressions in the vicinity of Girgil or Mazrub; and a similar type of soil is observed on extensive, low-lying plains, flooded at intervals, fairly far to the north of El Obeid - at Shershar, for instance, or in the Abu Zaima depression (Wadi El Milk valley).

Fairly hydromorphic brown soil on top of heavy loam or clay often shows serious erosion, even on slight slopes. There is a very typical example of this in the area round Sodiri.

At some points, a very marked accumulation of limestone, by pedological processes, seems to have occurred, and we find a veritable lime crust, as at Quleit. Elsewhere, as in the Shershar plain, it is difficult to see exactly what it is - a soil with a lime crust, or thin, colluvial-type deposits on top of lacustrine or swamp-formed lime.

There are frequent instances, in depressions, of these clayey, hydro-morphic soils having surface horizons with diffuse structure, reminiscent of alkali soils. This occurs at the foot of various jebels north of Shershar.

Skeletal soils are to be found covering most of the hills; and also on the heaps of pebbles to be found forming numerous small patches on some of the plains.

Elsewhere, these pebbles and gravels constitute a thin superficial deposit, or the residue of sweet erosion, and merely represent certain phases in the formation of the soils described above - brown soils in particular.

These soils, in the whole of this zone, are frequently eroded by either wind or water - a point to which we shall return later.

Another interesting point: in numerous parts of this region, a fossil soil is to be seen underneath the present soil, probably a tropical ferruginous soil, slightly leached.

Elsewhere, the fossil soil appears to have been modified in the upper horizons only. Such is the case, for example, in the area between Bara and Sodiri, where the upper part of the profile, to a depth of about 45 cm., consists of brown steppe soil, whilst the lower part, consisting of tropical ferruginous soil, may be slightly leached.

This may indicate a change in the climate. In fact, the region is said formerly to have had a damper climate, which is said to have become dryer, comparatively recently; although that may be several thousands of years ago.

### Darfur

The region we toured in Darfur includes a vast high tableland around Kabkabyia, and mountain massifs. The tableland forms the watershed between the river Chad on the one side, and the Nile on the other. The basement rocks are covered over, in most parts, not only by weathering products but, on top of them, by sandy deposits, lavishly sprinkled with heaps of pebbles and gravel. They are intersected by several parallel ridges, due to the presence of rocks offering greater resistance to atmospheric decomposition.

On the north-east and south-east, this tableland merges into the vast sandy plains which border the highest massifs (Mounts Wana, Tabago, Furung, etc.).

Ultrabasic volcanic rocks pierce the sandy cover of these plains here and there, forming small, very low jebels such as those 50 km. to the west of El Fasher.

The hill ranges and mountains are formed by the basement rocks, usually metamorphic rocks (schists or gneiss), sometimes also of syenites, diorites, or rhyolites, or even of more basic rocks, such as dolerites.

Especially in the north and east of this zone, the basement rocks are covered by Nubian sandstone, varying in type - very sandy, conglomeratic, or again, extremely fine, almost quartz-like. Underneath the sandstone, the metamorphic rocks are in some cases strongly weathered and covered with a ferruginous layer varying in thickness. Some fine examples of this phenomenon are to be found about 100 km. west of El Fasher, or again, 50 km. west of Kutum.

These sandstones are in turn covered by layers of basaltic rocks, forming the high tablelands very typical of the area. These basaltic rocks are particularly common in the region west of Kutum or again, in the Tagabo mountains and at Malha.

The character of the sand on the great plain appears to be roughly the same, in the Darfur and Kordofan provinces. In parts, to the north and north-east of El Fasher, for instance, they are strongly dunal in formation; sometimes they are even in movement, as a result of human and animal intervention; we saw examples of this at Mellit, Kutum and Abu Gidad.

In the zone we described above, in the Kordofan province, the alluvial deposits in the existing valleys were not important. This is not true in Darfur, where the rivers are numerous, and the valleys wide: such as Wadi el Ku, Wadi Kutum, Wadi Azum, Wadi Delgo, Wadi Terai, etc. Their alluvial deposits form series of terraces, of various types ranging from heavy loam to fine sandy or even, in places, very pebbly.

In some of the valleys in the hilly zone, more especially east of Kabkabiya, the materials brought down by solifluction form heaps of pebbles, gravel and fine particles nearer to heavy loam than clay in character, which seems prevailing in this region, or perhaps a little damper.

Lastly, there are certain depressions like those north-east of Kabkabiya or at Malha, where there are deposits of carbonates, limestone and even carbonate of soda. Between El Fasher and Kabkabiya, some 100 km. from the former, there is a very fine example of lacustrine lime, several decimetres thick.

As in the Kordofan province, brown steppe soils are preponderant, especially on top of the sands and heavy loams, in that part of the Darfur province which we toured. A clear example of this is to be found along the banks of the Khor Kolo-Koloyat, south of Mellit. The soil itself is about 65 to 70 cm. thick and, except for the first 12 centimetres, is brown, sandy, slightly humiferous and only slightly structured.

On top of coarser sands, the soil becomes slightly reddish in colour, falling into the reddish-brown soil category, as between Mellit and Malha. This soil is very seriously degraded by wind erosion, the herbaceous vegetation has been ravaged by over-grazing as protection provided by the existing acacia trees is entirely inadequate.

Brown soils are also fairly common in this region, on the vast sandy tablelands, slightly undulating or characterized by flattened dunes, stretching to the north and west of El Fasher; but they, again, are eroded. On plains composed of more compact loams, these brown soils become hydromorphic, and are enriched by small ferruginous concretions and calcareous nodules.

In certain zones, mainly towards the south, in the vicinity of El Fasher and east of Kabkabiya, but also at Kutum and near Serief, we find soil of the tropical ferruginous type, either non- or slightly leached.

On the alluvium and colluvium in the valley, the soils are immature, but their type varies from place to place, falling into either the brown steppe or the tropical ferruginous category.

A very fine example of soil sequence, based partly on age, is to be found in the plain 60 km. west-north-west of Kabkabiya in the direction of Sirief. Near Khor, the soil is immature and little developed on top of fine sandy non-calcareous alluvia: but on the plain itself, only a few hundred metres away, we find immature tropical ferruginous soil, also of the fine sandy type and slightly reddish, especially at a depth of from 25 to 47 cm. Slightly further west, on a gentle slope, the soil is tropical ferruginous, slightly leached and eroded, frequently right down to the claypan. Then lastly, further west still, we find a very special type of soil, on top of amphibole gneiss, namely a brown tropical ferruginous soil which is very important throughout this region. It is difficult to tell, after the short trip we made, whether this soil - which is good farming soil when neither too pebbly nor too much eroded, fairly humiferous and rich in basic substances, calcium in particular - was produced by present climatic conditions or whether, on the contrary, it was formed in a past, more humid climate. In the latter case the soil would belong to the brown entrophic tropical fossil soil type.

It may be noted in this connection that there are to be found in this region, between Kabkabiya and Sirief, on top of gneiss and underneath more recent alluvial or colluvial deposits, remnants of a fossil tropical ferruginous soil which appears to be fairly leached. This

certainly indicates that the climate in the past was more humid than at present.

On the basaltic tablelands very fine black soils, fairly well structured, albeit a trifle compact, are to be found. We had no time to make a proper study of them; but they must have some of the characteristics of both tropical ferruginous and hydromorphic soils.

Hydromorphic soils are very extensive not only on the clayey plains - as at Abu Gidad and at various places between El Fasher and Mellit - but also on the amphibole gneiss and rocks of the old tableland to the west of Kabkabiya, rich in ferro-magnesian minerals. They are more or less humiferous at the surface and characterised mainly by their fairly loose structure, high degree of compactness and abundant ferruginous and manganiferous concretions; also, more rarely, by the presence of calcareous nodules. At some points, their characteristics are definitely those of Tirs or "dark hot-region soil" (belonging to the more general category of Vertisols).

Both alluvial and colluvial soils and skeletal soils are far more widespread in this part of Darfur than in that part of the Kordofan region which we have described above: so are skeletal soils.

#### Land Use

In all this northern section of both Kordofan and Darfur, as far as we were able to observe, the extent to which the land can be utilized depends mainly on available water supplies.

Water is obtained from wells and borings, from a few large pools or from hafirs.

Our investigation of the wells and borings was very superficial. It appears that some of them are located, according to the traditional method, over underground water-courses which are not visible on the surface, or in hollows or valleys; over more diffuse water-tables, or again at certain "vantage" points such as localized water-accumulation zones along the edge of a small sandy plateau or dune, above a clay bed, as for instance in certain villages north of Mellit. Amongst the hills and mounts of Darfur, some wells are located over the fracture lines of geological faults, as at Hara to the east north-east of Kabkabiya, or in the hills some hundred kilometres west of el Fasher, on the Kabkabiya track.

The wells are as a rule not very deep; the borings go deeper.

Large pools, the traditional assembly point of large herds, are few and far between in these parts. The largest we saw were those at Um Badr in Kordofan, caused by a chain of dunes damming a valley; and the one at Mellit, in Darfur, a kind of artificial lake formed by the dam built across the narrow gorge where the valley cuts through the granite massif.

The "hafirs" are artificial reservoirs for collecting and storing rain and run-off water.

In view of the character of the soils in this area, often very sandy, these hafirs are not very numerous, although they are to be found here and there in small hollows on plateaux, at various points such as Faragallah, north of El Obeid where the unsuitable nature of the earth reduces their usefulness; or again, on the compact, heavy loam or clay soils of certain hollows or valleys, as at Mazrub, near El Fasher or Umm Marahi, 30 km. to the north of this last town.

Wherever there is a water point of any size, or whatever type it may be, large numbers of people and cattle will inevitably collect. As a general rule, the land surrounding these points is not particularly suitable for producing food and fodder, with the result that both the vegetation and subsequently the soil in these areas is frequently seriously degraded. On sandy soils, the wind causes the formation of veritable dunes; on soils of a more compact type, disastrous water erosion may occur, even on very slight slopes.

In all areas around or within a short distance of water points, use is made of the gum-trees or natural pasturage and, especially in the less arid parts, small areas are planted with crops.

During the past few decades the gum plantations have, it seems, shifted southwards and shrunk in area owing, apparently, to the increase in the size of herds (due to the application of sanitary measures) and the consequent extension of their grazing land. Another contributory factor has been the increase in the number of water points, which has resulted in exposing patches of savanna land, hitherto intact, to danger of destruction either by grazing herds or, in the dry season, by fire. This leads to the growth of more young grass to replace the old-burnt-down tufts.

Steps should be taken to replace plantations of Acacias when they grow too old. It is advantageous to place the area under cultivation for several years, provided that the clearing is not done too drastically and the roots are left in; also the land must not be left under cultivation too long, as this will harm the roots which remain in the ground and which will, later, throw out new shoots.

The most rational way of utilizing certain very arid zones where even gum trees will not thrive is to use them for grazing camels. This applies to the whole of this zone.

It is important, however, not to despoil the natural vegetation and to make sure that all the various herbaceous species are maintained, especially the perennials.

The best way of doing this is to arrange to use the pastures round each water point in rotation, or to close down water points in turn before they run out, according to the condition of the surrounding vegetation; and to draw up, as it were, a rota for the use of the water points by certain herds:

Problems of human psychology, of course, crop here: for there are old traditions governing the moving of flocks or grazing places. Thus a coordinated policy would have to be worked out, but that would require a more intimate knowledge of the area.

The cultivation of crops (sorghum and sesame, millet or groundnuts) should be confined to sufficiently irrigated areas, where the vegetation normally grows again; and the clearance should be done by methods which do not preclude following the land at some future date.

In practice, unfortunately, according to our observations, these precautions are seldom observed, with the result that both vegetation and soils are being degraded at an ever-increasing tempo.

The land round certain towns or villages or in the vicinity of water points is being denuded, and the sand is starting to move again, leading the formation of desert soils and shifting dunes. At some places we have already mentioned, this process has already assumed major proportions; at others, all that has happened so far is that microdunes or nebkhas have formed round dessicated clumps of vegetation, or sand has piled up alongside hedges or lines of grass. In other places, but very frequently (north of El Fasher, south of Mellit, near Mazrub, in some zones 10 km. east of Es Semeiha, around Umm Ruwaba, Hamrat el Wuz, etc.) the only effect of wind erosion on cultivated fields or young fallow lands is to form dunar micro-furrows measuring a few centimetres, due to the shifting and accumulation of the sandy particles in the surface horizon of the soil after destruction or removal of its organic matter.

In certain places, even in this zone, the erosion of the soil is due to water. This is not as common as wind erosion, but it may nevertheless occur when there is no vegetation to protect the soil, owing to its unstable structure, at any rate on the surface. It is mainly a case of sheet erosion. The most striking examples of this are found in the Darfur province.

The process of degradation is even more marked when it comes to the vegetation. In both Kordofan and Darfun, the size of the areas where herbaceous vegetation is extremely scanty or confined merely to those species which resist best to animal grazing is startling.

## B - SOUTHERN ZONE

The arid part of Kordofan and Darfur is to be found in regions further to the south than those briefly described above. This southern belt, where the climate is semi-arid rather than arid in the true sense of the word, extends roughly from a line running through Umm Ruwaba, Er Rahad, El Obeid, north of En Nahud and El Fasher, on the northern side (i.e. between the 13th and 14th parallels), down to Rashad, El Lagowa and north of Jebel in the south. The climatic conditions are similar to those in the northern zone, but the air is less dry and the rainfall heavier - 500 mm. and over, as shown by the figures given at the beginning of this chapter.

This belt may be divided into three parts: the vast clayey plains east of the Nuba mountains in Kordofan, and south and south-west of El Fasher in Darfur; a region of steep hills and mountains north of the Nuba mountains and the Kordofan mountains; and a low tableland of fine loamy sands dotted with clayey depressions, stretching from west of the Nuba mountains to south-east of El Fasher.

### 1. The clayey plain - environmental conditions

On top of fluviatile-type clays there have formed, since relatively ancient times, black soils similar to the Tirs soils in Morocco, the Regur soils in India, etc.; they are very dark in colour on the southern edges of this belt, more brown-coloured in the north. These are hydromorphic soils, with temporary surface hydromorphia. They usually contain small calcareous granules and always a large number of ferruginous concretions, though these are seldom large. They are very dry and hard in summer with dessication joints a metre and more deep; but in the rainy season they are swollen and waterlogged. "Gilgai" relief, so common in this type of soil, appeared as far as we could see to be fairly rare. In the top 5-7 cm. appears a horizon of argillaceous sand or arenaceous clay of granular nuciform texture, but deeper down the soils are very compact and have a looser structure.

Whenever they are on a slope - which is rare in view of the markedly plane topography - they erode easily.

The vegetation consists of savanna of varying density, with Acacia mellifera, Acacia hebecladoides, some Acacia campylacantha and Acacia seyal, Albizzia sericocephala, Cadaba glandulosa, Balanites aegyptiaca, Capparis sp., Boscia senegalensis in certain places; and there is a herbaceous cover consisting mainly of Hyparrhenia and Setaria, together with Blepharis and above all, Blepharis maderaspatensis.

Throughout this zone, the water-table is deep, the water sometimes saline, and there is little surface water. Hafirs can be constructed whenever the topography is suitable; but there are still very few of them.

The monotony of these vast plains is broken by a few rare, light sand or light loam patches of alluvial origin, and several jebels striking roughly north-south, mainly near the Nuba mountains and in the south of this zone. Petrographically they are gneissic with quartz and pegmatite seams, or amphibolitic, the latter being more common.

#### Use of the land

Whilst the land on these vast plains is chemically very fertile, its physical properties are poor. In the zone under consideration, however, the main obstacle to the utilization of the land is the excessive dryness of the climate, uneven distribution of the rainfall (a short rainy season, followed by long months with no rain at all) and a shortage of water points for men and cattle.

Generally speaking, there is little farming. The main crop is sorghum; cotton is not grown on a large scale, except towards the south or, in zones where extra water can be supplied in the form of irrigation or flooding (round Es Semeiha and Er Rahad).

Elsewhere these vast plains are used for extensive stock-breeding, at any rate in those parts not too far away from water supplies. The vegetation here remains green longer than in the sandy land nearby, but it does not make its appearance until a later stage in the rainy season. At the height of the rainy season the zone becomes impassable, being complete waterlogged or even flooded.

## 2. The Nuba Mountains

Though the Nuba mountains lie within the zone with which we are dealing, the climate in the northern sector does not seem to be semi-arid in the strict sense of the term. The rainfall figure rises sharply here but there is a certain edaphic aridity owing to the steepness of the slopes and the extremely pebbly nature of the soils. The few hills we observed, both amongst the Nuba mountains and in the Jebel Kordofan, are mainly granitic with a few pegmatites and numerous quartz seams. It was not until further south that we observed rocks of a more basic character.

The vegetation consists of fairly sparse savanna thinned out by frequent fires, comprising Acacia spp., Combretum hartmannianum, Boswellia papyrifera, Cenchrus biflorus, Hyparrhenia spp., etc.

Very little use is made of the land here, except for certain patches of detritus at the foot of the mountains or on the damper colluvia beyond those patches where the land is fairly rich. Here sorghum, tobacco and occasionally vegetables are grown.

Further south, however, the hard-working Naba, traditionally a farming people, who have taken refuge on the jebels, have taken advantage of the more abundant rainfall and have contrived, despite unfavourable topographical and soil conditions, to do some very successful terrace farming.

### 3. The low fine-sand tableland - rocks and soils

Extending from west of the Nuba Mountains to the vast clayey plain south-east of El Fasher is a large low-lying tableland, or large plain with fine sandy or light loam soils. This zone is very flat, except along the banks of several rivers or hollows, such as the one near Sarata.

The prevailing type of soil here is tropical ferruginous, only slightly leached except in iron oxides, and frequently resembling certain of the Dior soils of Senegal. In some places where the sand is coarser, the soil seems to be more strongly leached, but this phenomenon is never very accentuated, even in the southernmost sector of this belt.

The plain is broken by a few jebels of granite with quartz seams, and a few quartz wrinkles.

The deposits in the valleys and depressions are either heavy loam or clayey and the soils are hydromorphic in varying degrees; --brown soils with calcareous nodules, for instance, reminiscent of the Mourcis and Dians of the Niger Valley. These soils are compact, containing small grains of sub-rounded quartzous sands and, at least in one part of the profile, numerous small ferruginous concretions and also often calcareous nodules and granules. For the first few centimetres, the structure of the soil is nuciform, fine polyedral; it then becomes polyedral, coarser and more compact, slightly prismatic; and often prismatic lower down.

At a few rare points - as for instance a little to the south of the Wadi Shellengo, the structure, fine in the surface horizon, thickens and becomes nuciform and gritty lower down.

Further south (Wadi el Far) there are black soils in the valleys, similar to those described in speaking of the large clayey plains.

They are sometimes covered with recent alluvia, indicating that at least the beginning of their formation must date very far back. They appear, despite this, not only to maintain their character in the present climate, but even to be continuing to evolve on approximately the same lines - though they tend, perhaps, to become browner rather than more melanized.

At several places to the south of El Obeid and between Umm Sumeina and Thuwei, we noted the existence of ancient, leached tropical ferruginous soil.

Between Abu, Zabad and Saata, there are remnants of an ancient, stripped cuirasse.

#### Vegetation

The sandy plateau is covered with savanna, the composition of which varies from place to place but which, by and large, consists of Combretum cordofanum and Caculatum, Anogneissus schimperi, Dalbergia melanoxyllum, Commiphora africana, Lannea humilis, Scelerocarya birrea, Albizzia sericocephala, Terminalia brownii, Terminalia laxiflora, a few Boscia senegalensis and a cover of grasses, mostly very degraded, consisting mainly of Aristida spp. and Blepharis spp.

In certain parts - south of Abu Zabad or El Odaya, for instance - there are a few patches of sparse savanna consisting of Acacia senegalensis probably planted there.

On compact soils, Gramineae are more abundant: Aristida mutabilis, A. hordacea, Ctenium elegans. The trees and bushes in these parts are Acacia mellifera, Acacia seyal and Acacia hebecladoides, Balanites aegyptiaca, Boscia senegalensis, Anogeissus schimperi, Albizzia sericocephala and Dichrostachys glomerata.

#### Utilization of the land

The water supply throughout this zone comes mainly from wells and boring, some of which go down very deep; there are a few natural pools and hafirs, except further south where topographical and soil conditions are such as to make them common.

Here, as in the northern zone, stock-breeding is very important. To a large extent flocks are moved from place to place.

Crops are grown on the sands in large areas round water points - important centres such as Abu Haraz or Abu Zabad - or in the vicinity of borings made fairly recently, as at Er Saata and Zarqua. The most common crops are sorghum and millet and a few leguminous crops.

On the compact soils in the depressions and valleys some cotton has been cultivated, but the rainfall is not heavy enough for good results to be obtained.

It is in this zone that the Abu Zabad mechanized farming sector has been organized. The fields have been well laid out, in parallel strips at right-angles to the direction of the wind; but the strips are too wide (80m.) and the wind-breaks too narrow (15-20 m), too low, and, most important of all, too thinly sown. With the rainfall as low as it is here, the millet, groundnut and sesame crops are sown too thinly to afford adequate protection to the soil. The result is that though there is a strip 20-25 m. wide along the northern edge of each field where the

soil is not too badly degraded, all the rest of the field is badly eroded and sand piles up alongside the wind-breaks on the south edge. Harvests are poor.

In some of the fields there were signs of incipient water-gullying. There is also very strong wind erosion because the vegetation has been destroyed by too many herds all concentrated in the vicinity of the water source. Round Zarqua and Es Saata, for instance, the vegetation has been despoiled in this way over an area of several square kilometers; and the same process seems to be occurring, extremely fast, alongside the new railway line.

It is surprising also to see sheet erosion in the midst of the country, far from any inhabited centre, in zones through which herds pass or where they graze. A typical example of this phenomenon is to be found north-east of Abu Zabaq; and there are many others, south-west of Abu Haraz, for example, half-way between there and Saata, or east of Umm Defeis.

In all these cases the herbaceous vegetation is very impoverished or non-existent; the soil is eroded and there are patches where the iron oxide layer, normally found at a depth of some 20 centimetres, appears on the surface under a covering of coarse quartzous sand, which is all that remains of the top horizons. This layer, as it hardens, becomes more and more impermeable to water, thus increasing the wash and so further extending this phenomenon. And since the quantity of water entering the soil is thereby decreased, the trees and bushes die for lack of nourishment.

Unless measures are taken to stop it, this process of degradation must inevitably go on spreading endlessly.

## II RED SEA ZONE

In the course of our visit to the area, we were fortunate enough to be able to spend a week in the Red Sea Province where, thanks to the help we received from everyone, we were able to get an idea of some of the problems raised by the development of this extremely arid area. We went along the coast, plain and up into the hills north and south of Port Sudan; and even went on a trip lasting several days which took us further into the mountain chain and into the Khor Odib basin.

Our observations, (though they are, we are perfectly aware, incomplete and far too hasty) on this region, which is completely different from the two preceding ones, are given below:

### Geomorphology

In the Red Sea area we saw something of the major geomorphological features, in that along the scarp of the plateau there ran an erosion surface in the form of a broad bench with which the inland valleys were accordant, which was represented seawards on the roughly-accordant summit

levels of the residual hills of basement rocks: there was also, as along the upper Khor Gwob, for example, a lower well-planed basement surface that dipped down seawards beneath the great accumulation of debris, at least superficially pebbly, forming the older part of the coastal plain. The main stage of this accumulation had aggraded the valleys emerging from the foot-hills, and at least partially buried many of the residual hills, so that it was possible to travel continuously along aggraded valleys and intermont plains from one river system to the next on the one widespread aggraded surface, with only occasionally having to cross a low col of solid rocks.

On the coastal plain north of Port Sudan there are remnants of a marine calcareous formation, possibly of miocene age, resting directly on an eroded surface of basement rocks, the sediments have a general seaward dip, but locally they were faulted and tilted prior to the aggradation of the extensive gravel plain surrounding them.

Near the coast is abundant evidence of recent oscillations of sea level relative to the land; uplift of the coast in at least two stages of very late geological age has brought up the lagoon floors the coral reefs to form respectively wide bare saline flats, extending back several miles from the sea, and low ridge marking the former fringing and isolated coral reefs. On the margin of one such lagoon, 19 miles by road north of Solala, an early Stone Age site was observed. There is room for much further study of the extent and age relations of the erosion surfaces, the main aggraded coastal plain, the principal river terraces, the raised beaches, and the aggraded upper valleys and the lower submerged valleys.

In and near the Khor Arbaat delta fixed dunes are becoming mobile owing to removal of their vegetational cover, and small fresh barchans were seen, as well as certain low ridges that may be related to lunettes.

The Khor Arbaat, Sollum and Gwob deltas were observed, as well as the highly-cultivated flood plain of the Khor Odib. The deltas, as well as certain of the aggraded valleys within the foothills, are worthy of greater study from the point of view of ground-water supplies; in the deltas it may be possible to find ground waters that would lead to a more stable form of agriculture than the flash irrigation practised or proposed. The lesser floods could in many cases be used for flash irrigation, but the extreme irregularity of the rainfall and of stream flow would make it difficult or impossible to use economically all the waters of the exceptionally heavy floods.

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Climate

The rainfall on the coastal plain is very small and very concentrated. It decreases from north to south. The mean figures are as follows:

Suakin: 149mm. Port Sudan: 110mm. Dalween: approx 50mm.

On the hills and inland plains, the amount of rainfall varies very much from place to place depending mainly on the exposure, but on the whole it is slightly more abundant - 126mm. for instance, at the Geweit Mines. A large part of the rain falls in July, August and September, though there is also some rain in November and December. This probably accounts for the remarkably luxuriant vegetation to be found in parts of the Khor Sofaya valley which are not over-grazed, on fairly sandy or light loam soils.

For all this, the arid nature of this region constitutes the main obstacle to its development.

### Vegetation

The vegetation appears to comprise certain species which are characteristic of arid tropical Africa, together with others more usually to be found in the arid parts of North Africa. We are not sufficiently specialist in this field to be able to give more information about this important part of the zone we toured.

We did, however, notice at least three different types of vegetation in different parts of the region, as follows:

a) savanna with Acacia tortilis prevailing, also Acacia flava, Cappari aphylla and Gramineae such as Panicum turgidum; and various types of Aristida (A. hordesia), Cymbopogon sp. and so on; This type of vegetation is to be found on the plains, a little south of Mohammed Quol for instance but it is more common on the hills or on the inland plains - south of Geweit mines and south of Sofaya.

b) Sparse steppe comprising several types of shrubs, most of them those such as Acacia tortilis, Acacia flava, a few rare Acacia albida, Balanites aegyptiaca, Callotropis procera; various Gramineae such as Panicum turgidum, Aristida adsencionis, A. hordesia, A. mutabilis; and herbaceous species such as Aerva tomentosa and Euphorbia spp.

In some places Leptadenia spartium is to be found; at others, especially in the flood zones of the Khors, there are more species of Gramineae, they are more plentiful with Dactyloctenium sp., Brachyaria sp. and Echinochloa in addition to the species enumerated above.

This type of vegetation also often includes halophytes: Suaeda maritima, Salsola spp., Dicellaea retriflexa.

c) Vegetation consisting mainly of halophytes. This is to be found at certain points on the light loam plain, as for instance to the south of Port Sudan; on saline clays, former aggraded lagoons, as for instance Mohammed Quol; and in several points of the inland valleys, where the saline elements are the result of the weathering of rocks rich in sodium.

minerals, such as the green schists to the north-west of the Geweit mines. In these places Salvadora persica grows in abundance.

### Soils

Generally speaking, the soils of this region are not very mature, in view of the climatic conditions in which they were formed and in which they still exist.

The soils on the coastal plain both south and north of Port Sudan, as well as those on the inland plains, belong to the category of sub-desert grey woils, slightly humiferous to a depth of from 15 to 20cm., and very weakly structured. They are as a rule of the fine sand or light loam type; though there are a few places, as for instance near the Khor Sallum Valley, where their profile is slightly more developed, resembling the profile of a sierozem soil.

Then in the valleys of the Khors, the soils formed on recent fluviatile deposits, are of the alluvial type, heavy loam or light silt and very weakly structured. These soils have no real horizons, but rather a succession of beds of river deposits.

The slopes stretching from the foot of the hills onto the plains and, to an even greater extent the inland plains between the hills, are scattered with large quantities of pebbles and stones not as a rule worn smooth; and covered, except the most recent ones, with a film of metal oxides deposited there by evaporation. This is known as "desert varnish", although in fact formed in a climate which is arid but not desert.

An interesting point: the stone implements found by one of our party (Dr. Dixey) between Khor Eit and Solala, north of Port Sudan, had been first weathered and then covered with this "varnish".

Over large areas these gravel heaps are comparable to lithosols or lithic soils. But these two types of soil are even more widespread on aggraded coral reefs or actually on the hills which, however, are often not covered with soil at all.

In certain parts these deposits of small pebbles or gravel, spreading over wide areas of the plains, have the appearance of regs.

Other types of soil almost equally skeletal are of eolian origin: nebkhas north of Port Sudan and round Sofaya; barkhans round Port Sudan; lunettes in the coastal zone 20 to 25 km. further north. The first two at any rate appear to have resulted indirectly from human activities; the last may be sub-recent. A last category comprises the salt soils, for instance in certain inland valleys like those north of the Geweit mines, or in the coastal area (north of Port Sudan, south of Suakim). This category includes alkaline saline soils (Solonchaks) or even soils with a saline crust.

### Utilization of the land

In these very unfavourable climatic conditions the extent to which this land, anyway infertile, can be used is extremely limited.

There is very little dry farming (millet) even to the south of Port Sudan, and it is only possible on fine sand or light loam soil not excessively permeable and having a sufficiently low wilting point.

Irrigated farming in the true sense of the term is likewise limited, since the necessary dams, reservoirs and borings are still few in number; moreover, the salinity of the water-table often represents an obstacle (Khor Arbaat); although the flood waters, on the contrary, are very useful in the deltas of Khors (Arbaat, Sallom, Gwob), and in some of the inland plains (Sofaya, Onib). The area where the flood waters are partially regulated by a system of small dams and earth dikes already measures some thousands of hectares, and could be further extended.

Another type of plant which can be grown where water can be supplied is the date-palm, which is able to draw its sustenance, through its roots, direct from the water-table and can stand a fairly high degree of salinity (as for instance in the area between Sofaya and the Geweit mines).

Stock-breeding is an essential feature of the economy of this region; though it ought in fact to be strictly limited in view of the scantiness of the herbaceous vegetation. In this region, as in the Darfur and Kordofan provinces, there are unfortunately frequent signs of over-grazing patches bare of grass and in particular of Graminacea, due to changes neither in the soil nor in the water-table; tufts of Panicum turgidum nibbled down right to the root; certain plants with their root system much more developed than the part above ground; and so on. Examples of over-grazing abound in the whole of the coastal plain, but more particularly to the north of Port Sudan: north of the flood zone of the Khor Arbaat, north of Khor Eit and south of Mohammed Quol.

In this arid zone, water erosion cannot constitute much danger; although there are a few traces of such erosion in ravines and rills and - more seldom - of sheet erosion on the slopes at the foot of hills.

Wind erosion, on the other hand, is very prevalent, particularly on the coastal plain and in places where the vegetation is despoiled by over-pasturing or owing to the soils being too saline.

In view of the arid climate and unfavourable soil conditions in this region (pebbly, large patches of regs, saline soils), it is not easy to see how the land can be made to produce more than at present.

Certain technical measures could, however, probably be taken: extension of flood plain cultivation - sorghum in particular - in the flood zones of the principal Khors, at least in parts where the soil is heavy loam or loam; cultivation of date-palms in areas where the water-table is not too saline, and close to the surface; cultivation of irrigated crops (market gardening or fruit) by making borings, which should wherever possible be located upstream from underground dams or below works designed to permit the recharge of the water-table; introduction of rice crops in the coastal flood zone, even where the ground is slightly saline; more extensive utilization of the "underflow" waters in the large Khors; construction of large numbers of dams across the Khors, in order to hold the silt brought down by the floods and help the flood water to infiltrate so as to increase the number of small patches suitable for crop cultivation or affording better pasture. In addition, steps could be taken to adapt cultivated (sorghum, crops for fodder) better to existing conditions, and introduce other crops; give them better protection against pests (this applies especially to sorghum); regulate grazing so as to enable the vegetation to grow better; experiment with artificial rain, perhaps; use solar energy to cook with very simple domestic implements, so as to reduce the danger of forest fires; combat the shifting of the dunes around Port Sudan using methods similar to those successfully applied, for instance, in Pakistan, where two kinds of measures were taken in order to provide cover for the soil - first, small artificial dams were built and secondly, various species of vegetation were planted, including both creeping plants and shrubs with deeper root systems.

However, a great deal more technical research will have to be done before farming in the region can be improved (we give details, below of some of the research that will have to be done); and it will not be possible except if human conditions are favourable, and certain social problems can be solved.

3. THE PROBLEMS TO BE SOLVED  
BASIC RESEARCH AND APPLIED RESEARCH

General

As a foundation for many branches of scientific work a number of base maps are required, as in topography, geology, geomorphology, pedology, phytogeography, hydrology and hydrogeology; in addition, particularly where land use problems are important, integrated surveys of rocks, land forms, soils, vegetation, etc., are needed. This mapping is, however, a long term operation and, with the moderate facilities likely to be available, useful results are most likely to be achieved by working on a priority basis the areas scheduled for development.

It has to be borne in mind that in recent years a very large number of surveys of limited areas, or examination of particular problems, have been made by international experts of various kinds, and wherever possible the recommendations made should be implemented as soon as staff can be made available.

Geology

The main requirements in geology appear to be to achieve publication as early as possible of the 1:250,000 maps and relative reports already completed or nearly so, and to map on a larger scale, such as 1:100,000, when the relative topographical maps are available, and to describe in greater detail the more important development areas.

While geology in relation to other branches of science concerned with short-term needs such as hydrology and hydrogeology, geomorphology, pedology, etc. requires prior consideration, systematic basic geological mapping on a long-term pattern should also be carried out; with a view to mineral development, for example, this should be on a reconnaissance scale in the more isolated areas, such as the northern part of the Sudan and in greater detail in the more accessible parts of the country and where the rocks are well exposed, as in the Port Sudan area and the escarpment country leading up to the plateau. Furthermore, given a suitable geological background, such as the rocks of the basement complex, mineral deposits are more likely to be discovered in the course of detailed mapping, for open reconnaissance mapping may well fail to disclose mineral that are in fact present. Known mineral deposits of promise should of course be carefully examined and mapped, as in the case of the iron-ore mica, and wollastonite deposits recently reported on by the Geological Survey, and any lesser indications of minerals revealed by mapping should also be carefully followed up; it is on the basis of reports of this nature that mining companies are attracted to mineralized areas to make their own more detailed investigations.

### Geomorphology

Very little information on the geomorphology of the Sudan has so far been published, although latterly the Geography Department of the University has carried out some detailed mapping in the Red Sea area, where results of great interest have been obtained, and has worked also in the west of the Nile area and elsewhere on the plateau.

Geomorphological studies in the Sudan can be regarded as concerned on the one hand with the older geomorphological history of the country relating to the older surfaces of erosion and their remnants, and, on the other hand, with the events of recent geological times and of the present day, for which the major geomorphological features provide the topographic background. The latter aspects of geomorphology, referring to the details of surface forms and their origin, are of fundamental importance for the study of soils, plant ecology, hydrology and hydrogeology, and various other matters related to the general problems of land use and land management. Thus geomorphology is concerned with erosion platforms and terraces, river development, the infilling or aggradation of valleys, the occurrence of surface waters and of ground water, erosion by wind and water, sheet erosion and gully erosion, soil creep, the deposition of sediments on land and in shallow waters, shore line features and relative movements of land and sea, and many other land forms and processes.

It reveals also recent climatic changes, as in the presence of fixed or moving sand-dunes, in the association of lacustrine sediments with older or younger wind-blown sands, variations in the regimes of streams, etc. These features indicate trends of climatic change that may be of importance in relation to current land use.

The problems of desert creep, the formation and movement of sand-dunes, which in some parts of the Sudan are advancing at the rate of 1 to 3 metres per year on the agricultural land or oases, and are sometimes blocking old stream courses, all come within the province of geomorphology. Again, in various parts of Kordofan and Darfur Provinces, for example, some areas are subject to persistent wind erosion, resulting in the exposure of great expanses of bare rock or rubbly surface debris, while near by the sand may be piled high on the northern flanks of jebels; these and many other geomorphological features are deserving of closer study with a view to a better understanding and control of natural processes affecting the use of the land.

### Hydrology

For purposes of agriculture, irrigation and water supply generally it is important that the number of rain gauges and stream discharge stations in the Sudan be considerably increased; moreover, since for many purposes the intensity of precipitation is more important than the total precipitation, it is most desirable that automatic rain-gauges be established wherever possible. The need for increasing the network of

stations is the greater because of the great variation of the precipitation, both from one locality to another and from season to season.

From the point of view of both surface and underground waters additional information is needed on the rates of infiltration of rain-water, and, particularly for the construction and maintenance of hafirs and dams, more investigation is required into evaporation losses and their prevention; into leakage problems, and into the prevention of pollution; in all these matters it is important to keep in touch with relative research stations elsewhere and to experiment with their results under local conditions. For information on the prevention of evaporation losses reference should be made to the recent Unesco/ICID publication entitled "Worldwide Survey of Experiments and Results on the Prevention of Evaporation Losses from Reservoirs".

Applications for new hafirs and dams are referred to the Provincial Land Use Boards, who take into account not only the demand for water but also the effect that the provision of such water points may have on grazing and soil erosion problems; in many cases the land is so overstocked that the provision of new water points can do nothing but cause additional harm to the land, and in others it is important to ensure that there will be adequate control of stock numbers and of grazing before the new water points can be approved.

As regards the desalination or conversion of saline waters, it is understood that the United Nations has in hand the preparation of a publication that will aim at presenting the costs of conversion by various methods in many countries under a wide range of local conditions of geography, energy supply, general economics, etc.

Apart from the L.U. and R.W.D. Department, the Geological Survey and the Chief Hydrologist of the Ministry of Irrigation, it is understood that there are various other Departments and authorities directly concerned with the investigation and production of water supplies, both surface and underground; for reasons of economy and efficiency, and of avoiding duplication of effort, as well as of making the best use of the services of the specialists available, it is clearly most desirable that these activities should be properly co-ordinated under a small but active water board suited to local conditions.

### Hydrogeology

Within the last few years, as mentioned earlier in this report, at least 5 expert missions have reported on water supply conditions in the Sudan, most of them being concerned directly or indirectly with groundwater supplies; those reports have reviewed the general conditions, the need for water, and the means of providing it, as well as any special investigations required, both from the short-term and the long-term point of view. It is not necessary therefore to refer at this stage to more than a few of the more salient features of the general problem of hydrogeology. A number of the recommendations of the latest report, that on the Potable Water Supply in the Republic of the Sudan, prepared for

the International Co-operation Administration in 1959, are being put into effect in so far as availability of staff and equipment will permit. For example, certain heavy duty rotary drills have been provided, which permit of drilling to as much as 1,000 feet, and two experienced water-supply geologists have been selected to assist respectively the Geological Survey and the L.U. and R.W.D. Department in their ground-water problems, and a geophysical team is expected to arrive shortly to investigate, amongst other matters, the depth to the basement rocks beneath the cover of Nubian sandstone in areas west of El Obeid.

One of the foremost needs in hydrogeology is to publish as early as possible in the form of maps and reports the large amount of information that has been accumulated to date. It is understood that Mr. Karkanis, formerly of the Geological Survey, is engaged in the compilation of a memoir covering the hydrogeological activities of the past 50 years, and a work of this nature may be expected to be of permanent value to all concerned with the ground-water problems of the Sudan.

For a number of years the Geological Survey has included in its published Annual Report a table of bore-holes constructed, giving details of depth, standing water level, yield, formations penetrated, etc., and for the purposes of permanence of record and ease of access it is to be hoped that this practice will be continued by the Department or Departments now responsible for water-boring.

Ground-water development has now reached the stage where greater information is required on the quantitative aspects of ground-water. For example, it is necessary to know not only where water recurs but also in what quantity, and in addition more information is required on the quantities of recharge of ground-water bodies under different conditions. In these matters essential information is given by systematic observation of bore-hole water levels and of yields under test, as well as the geophysical logging of bore-holes for the aquifer factors of porosity, transmissibility, etc., and on this information can be based estimates of safe yield of the bore-holes, the volume of ground-water available for use, and the probable permanence of the supply. Exploration drilling, for which provision has recently been made, and observation bore-holes are of special value for these investigations. In development operations the yields of bore-holes are sometimes quoted on the basis of very inadequate tests, and in order that the supplies should be long maintained it is important that the safe yields should be carefully established and not exceeded.

All these matters, as well as the rapid testing of the quality of bore-hole waters by field methods, are much more easily and efficiently conducted when the geological and engineering aspects of drilling are closely integrated.

An additional study of some importance to the Sudan is that of the hydrogeology of the Nile Valley, with special reference to the subterranean waters of the Nile in the semi-arid regions, and it is under-

stood that the University has such an investigation under consideration.

There is scope also for more systematic and detailed examination, by geological, geophysical and drilling methods, of the possible occurrence of ground-water bodies in the areas of natural recharge by streams, as in the alluvial fans of coarse materials formed where mountain streams debouch on to plains, as in western Darfur, in the valleys .. extensively aggraded or infilled by coarse sediments, as on the inner margin of the Red Sea coastal plain, and in the deltas of streams that occasionally reach the sea but more frequently lose themselves in the coarser sediments at the apexes of the deltas, again as in the Red Sea area.

In the Khor Arbait delta, for example, north of Port Sudan in which great quantities of water are absorbed first from stream flow and later from sub-surface flow, two shallow bores of about 30 m. in depth were put down several years ago, and gave inconclusive results; but the area should be further examined by an exploration party equipped with suitable light drilling and geophysical equipment, and the same remark would apply to other deltas such as those of the Khor Sollum and Khor Gwob; in all these deltas ground water is much needed for the establishment of a more settled form of agriculture.

Suitable aggraded inland valleys need to be similarly investigated, and we were informed of one valley in which useful supplies of water had been found in this way by a mining company.

As regards the annual programme of new bore-holes required in the Sudan, we were informed that such a programme is drawn up by the Land Use and Water Development Ward, which refers its recommendations to the Geological Survey for advice on the feasibility of getting water at the required points. The Geological Survey reports on the basis of information already available or of new investigations as required, and it will be greatly assisted in this task, and in its general investigation of ground waters, by the exploration drills now made available.

As in the case of the development of surface supplies, it is important that new bore-holes should be sited not only in relation to water demand but also with regard to proper land use and control, so as to avoid the risk of extending still further the evils of over-grazing and soil erosion by providing new water supplies.

With reference to the development of ground-water supplies, general reference should be made to the recent publication by the UN Water Resources Development Centre on "Large Scale Ground-Water Development". This paper discusses, amongst other matters, the questions of the systematic stages of ground-water development, with particular reference to the part played by hydrogeological investigation, the indispensability of close association of geological and engineering advice and control in drilling operations, bore-hole maintenance, economic matters, co-ordinated control of water operations generally, and the proper supervision of field operations whereby close contact is maintained with field staff and their technical needs adequately and promptly met - with matters of the greatest interest and importance to the Sudan.

## Soils

In the development of the arid zone in the Sudan, the part played by soils and vegetation differs slightly from that of the other features of the environment - rocks, types of terrain, and water - the main problems in relation to which we have already outlined.

It is essential that we should know not only the various types of soil and how they are distributed; but also the extent to which it is possible to utilize and preserve them. All prospection and mapping work must be done in collaboration with the Land Use and Agronomic Research departments. Some of the problems involved are complex and pertain rather to the science of agronomy than to the study of soils of vegetation.

Various studies of the soils of the Sudan have already been made; but with the exception of those pertaining to the actual Valley of the Nile, which is not covered by this report, they are not very widely known.

The study of these soils is, however, of absorbing interest. In all the parts we visited, we recognized a great variety of soil types, ranging from tropical ferruginous to desert. Some soils of the hydromorphic category (black soils) or Vertisols are to be found over very wide areas and in very different climatic conditions (more especially in Kordofan), so that it is possible to give a precise definition of the basic features of the soil type they represent.<sup>(1)</sup>

The same applies to various types of soils on basalt and basic volcanic rocks, which have been very thoroughly studied in humid tropical climates, but much less thoroughly in arid tropical climates. A study of fossil soils, of which we have quoted several examples in the foregoing pages, should also provide new data about possible variations of climate and ecological conditions in this part of Africa over the past millenia or tens of millenia.

A general cartographical survey of these soils covering the whole of the arid zone would be extremely useful, but it need not be very detailed, at least to begin with, except in the case of a few carefully selected areas which will have to be fully and completely mapped, i.e. the north and centre of Kordofan (sandy and clayey plains); the El Fasher, Kutum, Mellit and Malha zones, and the valleys along the northern edge of these hills, in Darfur; and the Red Zea zone (Khor Arbaat, Khor Sallom, Khor Odib).

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(1) The authors, either classify them as hydromorphic or calcomagnesi-morphic, sub-category hydromorphic, or else put them in a category apart.

A detailed study of their physical properties (structure, permeability, water-retention), also of the fertility level of some of the most typical soils will need to be made: sandy brown soils in the Kordofan and Darfur provinces; hydromorphic brown soils with nodules, brown Tirs soils and black soils east of the Nuba mountains and south-west of El Fasher; alluvial soils in Darfur; immature soils on the deltas and inland plains of the Red Sea region.

This study should devote special attention to the physical properties of the soils, which are very important as regards their utilization, and should lead to the elaboration of methods of treating the soils (amelioration, working them and so on) in such a way as to increase water infiltration, increase their ability to retain water useful for plants (natural or cultivated) and improve their water profile. Technically speaking this is in our opinion one of the most urgent problems to be investigated; in the case of the irrigated soils of the Gezira, this has already been done.

In combination with the surveys already undertaken throughout the world by Unesco and FAO, it will be possible to study both the composition of the organic matter contained in these arid zone soils and their genesis (biological aspect).

The arid zone of the Sudan provides a particularly good subject for a survey of this kind in that the evolution of this organic matter can be compared in good drainage conditions and with various types of hydromorphia also with various kinds of vegetational cover.

To conserve the soils of this region the first step will have to be to combat wind erosion.

The detailed survey should include a study of the nature and extent of wind erosion, and of how it is influenced by environmental conditions including in particular the soil cover. Whilst the effects of wind erosion on sandy soils are fairly well known, the same is not true for clayey soils. We still have to find out, for instance, what intensity it is capable of attaining. The soils of the Kassala Province or of certain areas in Darfur or East Kordofan provide excellent material for this kind of research.

On the strength of the results obtained it will be possible to determine the best methods for protecting soils against this kind of degradation which will probably include appropriate types of farming or way of preserving the vegetational cover.

Even in the case of sandy soils, various experiments will have to be made for adapting the traditional methods of combating wind erosion (fixing the dunes) to the problems of various specific areas, such as Port Sudan, Kheiran, round Mellit and Kutum.

Since the degree of soil erosion — both wind and water — is greatly influenced by the type of vegetation growing on the soil, a detailed study of erosion on soils covered with different species of vegetation and grazed to varying extents will have to be made.

There is little water erosion except at a few places in Darfur and to the south-west of El Obeid.

### Vegetation

The surveys to be carried out in the arid zone in the Sudan should be designed to complete the investigations already made on the species and groups of vegetation growing there.

This work should be done in close collaboration with the specialists on these subjects in the Faculty of Science and Agronomy, the Departments of Agriculture and Forestry, the Department of Land Use and the Ministry of Animal Production.

It would be very useful to make a general chart of the vegetation groups throughout the zone, supplemented by detailed maps of each individual sector.

Ecological studies should also be made of the resistance of plants to drought and — in particular in the Red Sea area — to salt.

The capacity to resist drought is particularly noteworthy in the plants of the "Gizu" Resistance to drought might also be studied — as to both degree of drought and type of drought — for a number of specially important plants: Acacias, such as Acacia albida and Acacia flava, graminaceous and leguminous grasses; and the fodder plants in the most arid zones.

Tests on salt resistance could also be made on graminaceous plants such as lucerne, for example, which grow along the shores of the Red Sea, forming useful pasture.

One of the main problems in developing stockbreeding and farming in these arid zones is to adapt the vegetation growing on the various types of soils and protect them against the particular dangers to which they are exposed — grazing, fires, wood-felling.

Phytodynamic research will therefore have to be carried out, with special reference to the degree of pasturing, the extent and frequency of fires, the use of the crop rotation system and the length of the cycle, and the development of mechanical farming methods. Important points to be studied include the respective proportions of annual and perennial Graminaceae, the ability of ligneous species to grow again and the characteristics of the various types of vegetation in relation to fodder production and to the protection they afford the soil against erosion at all stages of their growth.

It is possible that this research may indicate that certain plants are particularly useful and should therefore be more widely developed; whilst certain others should be introduced into the area.

Some of this research has already been started, for instance in Kordofan, by the Department for the Reorganization of Grazing Land of the Ministry of Animal Production. It should be stressed once again that all work must be done in the closest possible collaboration with this Department.

The research work necessary in order to ensure the best possible use of the vegetation will also have to include a biochemical study of the nutritive value of the main fodder plants already in the region or recently introduced; and of the medicinal value of certain species. For those species which have already proved their value, research will concentrate on methods of improving their quality and methods of cultivation; whereas for those not so well known the aim will be to determine their beneficial qualities. These investigations can only be undertaken with the collaboration of the specialized laboratories which exist at the University and in certain countries such as England and France.

We shall not deal here with research to be carried out on cultivated plants - selection, protection, productivity. This work has already been begun by the various sections of the Ministry of Agriculture, and covers the selection of varieties of millet and sorghum, and secondarily, of sesame, groundnuts and cotton, their resistance to drought and the possibilities they offer for improvement of their nutritive or industrial value and also, in some cases, resistance to disease. This, and the selection of new species to be introduced, forms part of the regular work of the Ministry. The scientific bodies concerned with the study of the arid zone must work in close cooperation with this Ministry; their main job will be to provide the basic research data.

We shall not deal, either, with the problems of the improvement of Acacias and the development of ligneous species for fuel; these are already being studied by the Department of Forestry.

We should like, nevertheless, to mention how important it is, in our view, to develop the cultivation of certain crops: date palms which may draw their water supply from the watertable of the inland plains on the other side of the hills along the Red Sea coast; fruit trees and market gardening which may be watered at some places in Kordofan and in certain valleys or at the foot of patches of colluvium in Darfur; cotton and perhaps also maize which, by ploughing more deeply and building up wide raised ridges, may be grown in the wettest parts of the zone, for instance on the clayey land east of the Nuba mountains.

### Fauna

The study of the fauna of the arid zone of the Sudan likewise falls into four sections, as follows:

- a) making an inventory of the fauna, in collaboration with professors and research workers in the corresponding laboratories at the University; surveys will have to be made in order to complete the data at present available on existing types of fauna and possibilities of using them.
- b) carrying out ecological research on the feeding of certain wild animals, such as gazelle, guinea-fowl; the feeding and watering of these animals in the dry season, and the drought resistance of certain domestic animals - ovines and bovines - the Sudanese species of which appear to be remarkably well adapted to the difficult conditions prevailing in this region.
- c) evolution of natural fauna in relation to the condition of the vegetation, the frequency and seasons of bush fires, and the size of the areas under crops.
- d) feeding and evolution of the main domestic species in relation to methods of breeding (moving of flocks) and availability of water and food supplies (stages of evolution and degradation of the vegetation on which they feed). This last feature has already been investigated in some measure by the experts of the Ministry of Animal Production; so that all that remains to be done is to pursue this work further, if possible.

As regards research on the protection of animals against disease, this has already been very efficiently organized in the Sudan; and little more remains to be done in this line.

### Agronomic Problems

We have already mentioned most of these in the foregoing pages, and indicated the steps being taken by the appropriate technical sections of the ministries to carry out the necessary research. There are, however, some agronomic problems not specifically related to any one of the problems studied, but rather to the whole.

In arid zones even less than in more temperate zones is it possible to consider separately agricultural, silvicultural or pastoral development. The studies of crops, forestry and pasture should be highly developed in all the regions which have sufficient rainfall: a period of several years under crops when animals will be pastured on the fields after the harvest to feed on plant residues, straw and hay, followed by several years under fallow, used for pasture until a fresh growth of Acacia senegalensis has developed sufficiently; finally customary forestry use of "gum tree orchards" for several years until gum-production begins to fall.

Research on alternating crops with forest fallow could be continued, and the crops planted in rows or in quincunx formation. The patches of natural vegetation left to serve as wind-breaks must either be sufficiently high and thick to serve this purpose, or else artificially improved.

### Social Studies

Although we had many discussions on this subject in the course of our mission in the Sudan, and despite the extremely interesting information which certain persons such as Professor Ian Cunnisson provided us, it is more difficult in this field than in the preceding ones to outline a research programme designed to promote the development of the region.

All we can do is to indicate the main lines of research, stressing certain particularly important trends and objectives.

For all this human problems are vital and must be solved before it is possible to make the improvements in such matters as farming techniques, pasturing and so on which are obviously technically desirable.

There is room for a great deal of research in the field of human physiology - mechanism of resistance to heat and drought, acquisition and transmission of the requisite characteristics and so on, but this kind of research does not need to be given priority in the present scheme, since highly qualified bodies in various countries, including France, England, the USA and USSR are already working on it.

As against this, attention does need to be given to research on social anthropology amongst the peoples of the Sudan. A start has already been made in this direction, mainly by university professors; relating to both the demographic and special features and feeding habits of each group and also to their traditional farming and pasturing methods; and it is of urgent importance that this work should be further developed. Certain of their traditional methods could perhaps be changed with a view to opening up the region more fully; but others may be found to be fundamentally correct and should as such, be maintained. In any case it is essential to study them and discover the reasons underlying them. The tribes to be given top priority in this respect should, we think, include the Beya, Kababish and Furs and the sedentary Hamish.

It is clear from the outset that the research recommended will show that it is necessary, from the technical standpoint, to introduce certain changes in local farming and grazing traditions. These changes will inevitably cause social and economic repercussions which must, where possible, be studied in advance. As an example we give below some of the changes proposed, and their probable repercussions:

- partial sedentarization of some of the tribes; this will have economic repercussions and affect hygiene and education;

- alteration of the migration routes of nomads in relation to the condition of the water points, and the state of the land and vegetation

cover; this will make it possible to use the water points in turn and to establish a general system of rotation, using land for crops, forest and grazing successively;

- limitation of the size of herds of camel and even of ovines and bovines, resulting in a very substantial decrease in the numbers of caprines;
- limitation of crops in the most arid regions (rainfall less than 300 mm), as a means of protecting the vegetational cover of the soil;
- change of farming methods in the more humid regions, with a view to conforming more closely to the rotation principle, fundamental to all agriculture, and greatly extending the vegetational zones kept in reserve or forbidden for grazing.
- introduction of new farming and grazing methods, etc.

All these changes will have economic repercussions which may even, in certain cases, reduce their practicability. Conversely, prevailing economic conditions (price and market policies in particular) may sometimes facilitate such changes, or make it easier to introduce them on a larger scale. Hence, the economic aspect too will have to be studied.

Lengthy though it is, this account of the problems to be solved and the research necessary to this end is still far from complete. We have nevertheless given an outline of the principal measures to be taken in order to develop the zone in question more fully.

#### 4. CURRENT RESEARCH AND INVESTIGATION

In the course of our contacts with the Ministries and Departments and with the University we were enabled to see and hear something of the considerable amount of scientific work recently achieved and in progress, and it is possible to give here only the following few illustrative examples from the large amount of information we gathered.

During our visit there was held at Khartoum the conference of the Ministry of Agriculture, held every two years, at which are laid down the lines of the research programme for the succeeding two years. The Ministry maintains its well-known Agricultural Research Institute at Wad Medani in the Gezira; it is concerned mainly with problems of irrigation and pursues research in the following branches: soil science, agronomy and plant physiology, botany and plant physiology, entomology, zoology (birds), and cotton breeding. It maintains also a research station north of Khartoum, and others outside the arid areas. The Ministry is devoting

much attention also to investigations relating to the new Roseires and Rashman el Girba dam schemes.

The Annual Reports of the Forestry Department include a section describing its activities in research and education, as well as its international expert aid and fellowships. One of the Department's more important research activities relates to gum production.

In the Animal Production Department one of the four Divisions is devoted to research, and the problems at present under investigation include rotational grazing, grassland and forest fires, desert creep, bush clearance, and relative water problems; the Division is also working on various animal improvement schemes, and hopes to assist in establishing dairy and poultry farming within reach of the principal towns. In this Division and elsewhere the Department is devoting much attention to research on animal diseases, with special reference to pleuropneumonia, in cooperation with the UN Special Fund and ICA. They intend to build a main biochemical laboratory for research in connection with animal health and animal breeding.

Research activities in general are however greatly hampered by a shortage of technical men to assist the research staff.

Veterinary science is served also by the new Sudan Journal of Veterinary Science and Animal Husbandry.

The Department of Land Use and Rural Water Development submitted to the Unesco General Symposium on Arid Zone Problems, held at Paris in May, 1960, a report on activities in the Sudan related to arid zone research and future plans. It describes the Department's Arid Zone Land Use Planning Project, with special reference to a 5-year study of the central part of Kordofan Province, a study of mechanized agriculture, and an investigation into evaporation and seepage losses.

The Department is constructing an average of 50 water points a year with a view to the development of rural areas, and it is carrying out investigations into flood frequencies and volume in deltaic and other areas. The Ministry of Irrigation and Hydro-Electric Power maintains a large number of river-gauging stations along the Nile and its main tributaries, and it has recently carried out a detailed hydrological investigation of an area of 12,000 square miles in the Jebel Marra, as described in a report to the Association of Scientific Hydrology at Helsinki in 1960. The Sudan Meteorological Service is engaged not only on normal meteorological observations but also on measurements of solar radiation and of wind velocity, of special interest in the arid areas, and on evaporation control experiments, concerning which it has recently issued Technical Note No. 1

The Geological Survey Department is in process of building up its staff with a view to increased activity in its main tasks of geological mapping, mineral investigation and hydrogeological study and advice. It has 8 geological sheets on a scale of 1:250,000 awaiting publication, it has recently issued reports on iron ore, mica and wollastonite, and its office and field staff are constantly engaged on duties relating to the investigation and development of ground-water supplies. The oil possibilities of parts of the coastal plain north of Port Sudan are being investigated by an Italian oil company.

On all sides we were informed of the overwhelming importance of the water problem in the rural areas; this was not always a matter of the need for increased water supplies but of better distribution and better co-ordination with land-use activities, so as to reduce the prevalent evil effects of overstocking, overgrazing, soil erosion, etc.

The Technical Departments have prepared 7-year development programmes in which provision is made for the conduct of researches related to their work; the L.U. and R.W.D. Department, for example, has prepared a 7-year plan for soil and land use survey which would cover a considerable part of the arid lands, and would be conducted by teams of soil surveyors, plant ecologists and related specialists.

Throughout our interviews we were impressed by the uniformity of the view that far more basic research, as in soil surveys, plant and animal ecology, hydrology, etc., is required as a basis for applied research, and that improved facilities are needed for the issue and distribution of the results of scientific work. Furthermore, investigation at all levels is held up by the shortage of technical staff, and there is widespread need of increased scientific and technical training in order to put into effect the expert knowledge that is being provided in many fields.

We were very favourably impressed by many of the younger scientific and technical staff who showed considerable readiness to co-operate in their duties, particularly at the Provincial level.

There has recently been formed a local co-operating committee on the Unesco Major Project on Scientific Research in Arid Lands, with the objects of enlisting public support of studies of arid lands and of promoting an appreciation of the significance of such studies. Most of the Technical Departments, the University and other bodies, are represented on this committee, which, however, owing to staff shortage and other matters, had not yet reached the stage of implementing its functions.

At the Agricultural, Veterinary and Science Faculties at the University we found not only general agreement as to the importance and urgency of basic research in the arid areas, but also that the

University had itself drafted proposals for a University Arid Zone Research Unit which were under active consideration and had already received promise of financial support. The proposed scheme sets forth the urgency of Arid Zone Research in the Sudan, the organization of the Unit, the constitution of an advisory board, the estimated capital and recurrent expenditure, and the programmes of research to be pursued in botany, geography, geomorphology, geology, palynology, carbon-14 datings, hydrogeology, zoology and social science.

Moreover, the University has also recently assisted in the setting up of a Hydrobiological Research Unit, and it is hoped that the relationships of the Arid Zone Research Unit to the University will be similar to those already established for the Hydrobiological Research Unit.

In addition, the University Departments have themselves recently carried out a number of arid zone investigations in various fields, including the functions and distribution of hafirs, land use mapping on the scale of 1:250:000, the geomorphology of the Red Sea coastal area and of Khartoum Province, and the social role of cattle and other anthropological studies amongst certain nomadic tribes. In addition the Department of Agriculture has carried out a number of investigations relating especially to arid areas, including particularly research in soil science (nitrogen dynamics) and some aspects agro-physiology. The Department of Veterinary Science in conducting research, especially on animal nutrition in arid areas, in cooperation with the Department of Animal Production of the Government and with the Rockefeller Foundation.

The Ninth Annual Conference of the Sudan Philosophical Society, held in January 1961, was devoted to surveying for development in the Sudan. The papers presented related largely to arid zone problems, and they were contributed by the University and by the Government Departments; they dealt with topographic survey, photogrammetry, land use and land use mapping, ground-water problems, and the importance of maps in relation to development.

#### International Aid to the Sudan

In matters related directly or indirectly to the object of our Mission, the Government of the Sudan has received technical aid from numerous U.N. organizations and other bodies; these aid organizations and the subjects on which they have given assistance include the following.

1. U.N.T.A.A.
  - (a) Programme of Ground-Water Investigation for the Anglo-Egyptian Sudan. R.A. Waite.  
U.S.G.S. 1955.

Gives recommendations regarding ground-water investigation and the organization required for this.

- (b) Experts in Economic Planning
- (c) Chief Engineer, L.U. and R.W.D. Department, under "Opex" Plan.

2. Special Fund - Schemes and Projects

Already approved : 6

- (a) Regional pleuropneumonia research station, for requirements of Animal Production Department and FAO.
- (b) Locust survey
- (c) Hides and skins.

Under consideration:-

- (d) Forest research and teaching institute.
- (e) Kordofan land use survey
- (f) Soil surveys in equatoria.

3. Economic Commission for Africa

- (a) Economic planning
- (b) Public administration.

4. FAO

- (a) A programme of Ground-water Investigation, Report No. 875, L. Mazurczak, 1958.  
Discusses geological mapping in relation to ground-water investigation, regional ground-water investigations, and a programme of field operations.
- (b) Organization and Programme for Land and Water Utilization, Report No. 439. C.R. Enlow, 1955.  
Discusses land and water utilization, rural water development, and recommends subjects for research.
- (c) Land and Water Conservation and Land Utilization. Report No. 1085 M.F. Williams, 1959  
Discusses requirements for a conservation programme, reports on specific land problems, and recommends the setting-up of a Land Use and Rural Water Development Department.
- (d) Rural Surface Water Development. Report No. 1272. J.P. Dumoulin, 1960  
Discusses the construction and maintenance of hafirs and dams,

and various irrigation projects, including those of the Khor Arbaat, Khor Sollum and Khor Goeb deltas, and of Khor Odib.

Recommends the formation of committees in every Province to examine requests for hafirs.

- (e) Livestock Improvement  
Report No. 626. J. Hammond, 1959

Discusses the introduction of dairy cattle, the development of mixed farming and beef production, and sheep, and recommends measures for improvement.

- (f) Grassland Improvement and Pasture Development  
Report No. 913 P.P. Bonnemaïson, 1958.

After a general study of the problems of the grazing lands and of pasture and fodder production, he stresses the need of bioclimatic studies for the main grazing areas, of ecological studies, and of trials on carrying capacity and grazing management. Great care has to be given to the training of junior staff in the field of plant ecology, and to propaganda and education on grazing and pasture problems.

- (g) FAO has provided a land use expert to the L.U. and R.W.D. Department, as well as experts on a wide range of other subjects, including forestry, wood technology, hides and skins, forestry, economics, statistics, rice, date processing and packing, marketing and rural credit, vaccine production and water-boring.

#### 4. UNESCO

Experts in the following branches have been provided:-

- (a) Science training of secondary school teachers.
- (b) Science education
- (c) Rural community training
- (d) Mass education
- (e) Low-cost building of schools, etc.
- (f) Archaeological studies
- (g) Education planning.

5. WMO

- (a) Agrometeorologists
- (b) Meteorological instrument specialists.

6. WHO

Various experts on malaria control, rural health centres, etc.

7. ILO

- (a) Vocational training institute
- (b) Manpower survey.

8. USOM and ICA

The United States Overseas Mission to the Sudan commenced operation in the spring of 1958, and since that time has provided or is arranging for aid of various kinds under the heads of health, animal resources, agriculture, irrigation, forestry, cartographic surveys and map production, highway development, rural water development, technical education, audio-visual training aids, telecommunications and equipment for agriculture, industry, etc. These activities are described in the publication "Progress through co-operation" issued by USOM (Sudan), November 1, 1960.

In various directions provision is made for the research necessary to achieve the desired ends. For example, the project entitled Agriculture Development will provide help to the research centres in testing new crops, especially those now imported such as tea and sugar, and in increasing the production of those now grown; moreover, assistance is given to the Extension Service in making information on the results obtained available to farmers. In addition, economic feasibility studies of mineral deposits are to be undertaken.

Contracts are being signed as required for Engineer Consultant Services, and one company, the Tudor Engineering Company, has already made a number of reports on such matters as rural water supply, a sugar industry, a jute industry, a sewerage system for Khartoum North, and radio communications.

The rural water-supply report, issued in 1959, was entitled "Report on Potable Water Supply in the Republic of the Sudan". It discusses groundwater geology, groundwater development and surface water development, and recommends the sending of Sudanese staff to the USA for technical training; the purchase of 3 heavy-duty rotary drills, geophysical surveys, the commencement of a groundwater inventory, and a long-range study of the groundwater situation; and research on hafir lining. It stresses the importance of

the close association of geological and drilling knowledge in drilling operations, and the effective supervision of these operations.

A considerable number of the recommendations made in the report are now being implemented, including particularly the training of staff, the provision of heavy-duty drills, the provision of two hydro-geologists to advise the Geological Survey, and the L.U. and R.W.D. Department, and a team for groundwater geophysical surveys in the En Nahud area and elsewhere.

9. French Bi-Lateral Aid (IFCT)

- (a) A range management officer, attached to the Animal Production Department, is stationed in El Obeid. He is a soil scientist and plant ecologist, and he is carrying out studies relating to the improvement of grazing.
- (b) A mission of two French archaeologists is working in the Nile Valley south of Wadi Halfa.

5. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS - GENERAL PROBLEMS

1. Shortage of Scientific and Technical Staff

In all aspects of basic and applied science there is a great shortage of scientific and technical staff, which makes it difficult for the country to gain as much advantage as it should from the expert advice it is receiving in many fields. Moreover, the shortage of technical assistance reduces the value of the services of the scientific staff, who have to spend much of their time on duties that could be performed by men of lesser rank. To remedy this position requires a long-term policy of training science teachers, increased science teaching in the later stages of school life, and greater provision for technical schools and university training. In addition, the conditions of service in the scientific departments needs to be such as not only to attract but also to retain the best men. Much additional training is accordingly required at technical graduate and research levels, with provision for suitable men to progress from one to the other.

We were informed, for example, that in range management there are only 6 technical assistants to 8 scientific officers, of whom 2 are still in the USA, whereas the proportion should be about 40 to 6.

Moreover, there is urgent need for courses of instruction in range management, and indeed in all problems relating to the arid zone; this

could perhaps be best achieved within the Agricultural Institute, which could possibly provide a section specializing in such problems in the last year of study. Such instruction would doubtless improve recruitment to the relative services, and would also provide better career prospects for men interested in such activities.

See Recommendation 1

## 2. Basic Research

Much basic research is required as a basis for the applied research necessary for the proper use of the land, and the development of its resources; in addition, much information already gathered needs to be made available for use in the form of reports and maps. The coverage of topographic maps on the scale of 1:100,000 needs to be greatly extended as a basis for scientific work, as well as maps of larger scale, or air-photo mosaics of various kinds, in areas requiring closer study. The coverage of geological maps on the current scale of 1:250,000 needs to be extended, and the maps already prepared for printing should be issued as soon as possible, not only because of the demand for their geological data but also for the hydrological and hydrogeological information they provide; mapping on the scale of 1:100,000 or, if possible of 1:50,000 scale is desirable in many areas in which development is in hand or proposed. Soils and vegetation mapping is also urgently needed. Moreover, much basic information is required in respect to geomorphology, soils, vegetation, hydrology, climate, microclimate, land use, etc., and in many areas it is important that integrated surveys be undertaken in these branches in view of the close inter-relationships existing between them.

See Recommendation 2

## 3. Applied Research

In view of the gross over-stocking of many areas, the over-cultivation of others and the effects of uncontrolled grass burning, all leading to widespread degeneration of the soil, erosion by wind and water and the formation and drifting of sand-dunes, especially within a radius of many miles around the stronger water points, it is of great importance that research into these problems be intensified both with the object of checking the widespread deterioration and of building up the productivity of the land to the optimum extent.

Foremost in these investigations should be integrated land use surveys of critical areas, preferably on the scale of 1:50,000 or larger, carried out by competent staff under experienced supervision. Furthermore, an agricultural census of selected areas, based on air photographs and relative ground surveys, would give results of immediate value.

On the basis of these surveys it should be possible first to appraise the land capabilities of an area scheduled for development, to determine the crops it should produce and the stock it should carry, and then to determine what water points are necessary to bring this development into effect, and finally, but most importantly, to arrange on the basis of such study the necessary, and acceptable, controls of woodland, cultivation, grazing and watering so as to ensure that the long-term productivity of the land be maintained at the highest level.

See Recommendation 3

#### 4. Social Studies

There are large areas of the arid zone in the Sudan where present methods of land use cannot long be continued. Over-stocking and over-grazing, particularly round the main water points, owing to the very widespread increase in the numbers of people and cattle living there, are leading to degradation and impoverishment of the vegetation which results, in its turn, in wind or water erosion of the soils, the net result being that the water resources available are much less fully used.

The technical methods necessary for ensuring the more rational and economic development of these regions are frequently known: rotation of pasture land, limitation of size of herds and so on, but serious problems arise at the psychological level, when it comes to applying them, since they often run counter to local traditions. The alteration of current practices and the introduction of new ones inevitably cause social and psychological repercussions which need studying in detail.

Very thorough psychological studies will therefore have to be carried out as a preliminary to the development of these regions. These must include a basic survey of local farming and grazing methods designed to discover their efficiency, and practical surveys to determine the best method for enabling the local people to adopt the necessary technical changes.

Research on these subjects is already being carried out at the Universities it should be possible to extend it.

See Recommendation 4

#### 5. Demonstration plots and areas

In many respects the most difficult aspect of preventing the degeneration of land by misuse, or of reclaiming land already despoiled and eroded, is to develop an awareness of these problems amongst the rural people and to persuade them to adopt preventive or remedial measures of the kind now well understood by the technical and administrative authorities concerned. It is however usually accepted that the best way of convincing the people of the value of the new measures to be introduced is to demonstrate them on suitable plots in areas in which the old and the proposed new ways are brought into sharp contrast; this can be done, and is in fact being done in some

notable instances, in such matters as over-stocking, rotation of grazing, rotation of crops, soil erosion, fire control, wind-breaks, etc. Furthermore, mobile exhibitions demonstrating similar features by means of films, photographs, diagrams and models also give encouraging results.

See Recommendation 5

#### SPECIAL PROBLEMS IN THE VARIOUS DISCIPLINES

##### 6. Hydrology

There is in the Sudan a great lack of hydrological data required for purposes of agriculture, irrigation, construction of dams and hafirs, etc., and this lack is a great handicap to systematic development. The information required includes normal meteorological data such as total rainfall, intensity of rainfall, temperature, etc., as well as radiation, run-off, infiltration, streamflow, and evapotranspiration and evaporation rates, and the collection of this data requires a greatly increased number of rain-gauge stations, stream gauge stations, evaporimeters, etc., and the use wherever possible of automatic recorders. Furthermore, since the establishment of an adequate net of such stations would take many years, it would be advisable in the first place to take observations in limited areas regarded as representative of larger regions in such matters as rainfall variations, run-off, evaporation, etc., and these areas, comprising small to medium catchment basins in many cases, could be selected according to such factors as the nature of the rocks, topography, soils, vegetation, etc.

See Recommendation 6

##### 7. Hydrogeology

During the past few years a number of important reports by international experts have been prepared on the hydrogeology of the Sudan, and the conclusions reached in these reports have much in common with those given in the following paragraphs, but in view of their importance and the fact that in many cases the recommendations made have still to be implemented it seems desirable to repeat them here.

###### (a) Quantitative aspects of ground water.

It is often important to know not only that ground-water exists in an area or in a given aquifer, but also how much, and where water occurs in a bore-hole it is necessary to know what, on a long-term basis, is the safe yield in gallons per hour or per day. Similarly, it is necessary to know what is the rate of infiltration and of recharge of aquifers in particular cases. Information of this nature can normally be obtained from pumping tests and from observations on water levels in bore-holes, and on stream flow, etc.

(b) Recharge areas.

Certain deltas, alluvial fans formed where mountain streams debouch on to plains, parts of stream courses and aggraded valleys, form natural ground-water recharge areas of considerable importance, and they should be carefully examined for ground-water supplies by geological, geophysical and drilling methods.

(c) Supervision of drilling operations.

For reasons of staff and organization it is still difficult in many cases to achieve the desired close co-operation of geological and engineering advice in water-boring operations, as well as the necessary geological and engineering supervision of these operations at sufficiently frequent intervals. Such co-operation and supervision are essential for economical and efficient drilling, and it is hoped that the proposed direction of operations at the provincial level will help to achieve these aims.

(d) Control of water points.

Although the Land Use and Rural Water Development Department is now providing new bore-hole and other water points at the rate of about 50 a year, the demand still remains at a high level. In general, before such water points are constructed it is important to employ to the maximum extent the procedure of the Provincial Land Use Boards, whereby the land concerned is carefully appraised as to suitability for development and arrangements are made for the control of the water, grazing, etc., for unless these precautions are strictly observed the provision of the new water points may prove definitely harmful to development rather than beneficial.

(e) Bore hole records

For reasons of permanence and ready accessibility it is important that the former practice of publishing details of bore-holes, in respect to locality, depth, yield, standing water level, formations, penetrates, etc., be resumed.

(f) Hydrogeological mapping

It is of great importance to many users that available hydrogeological and hydrological data be suitably recorded on maps at the earliest possible date.

See Recommendation 7

## 8. Soils

a) As mentioned earlier in another connection, it is of vital importance to draw up a chart of the soils of the arid region of the Sudan, even if only on a scale of 1:500,000. For certain sectors (northern and central Kordofan, El Fasher, Kutum, Mellit and Malha areas, valleys along the northern edge of the hills in Darfur, inland valleys and principal Khors of the Red Sea coastal region) a pedological map should also be made, on a scale of 1:50,000 for instance; plus a map showing the utilization of this land. By using the photointerpretation method, it should be possible to make these maps quickly. The work should be done in collaboration with the appropriate government department.

b) It is especially important that certain types of soil in this region should be studied with particular care, namely brown and black vertisol soils, soils on basalt in Darfur, fossil soils in the centre of Kordofan. Except in the last case, where the type and relative age of the soils will have to be established, research will concentrate mainly on their physical properties and water profile. The aim should be to work out farming techniques which allow the root systems of the crops to penetrate deeper in order that the cultivation of the crops may be extended over wider areas.

c) Research on wind erosion should be both theoretical - especially on the clayey Kassala plains or on certain plains of compact soils in north-central Kordofan - and practical, bearing for instance on the application of familiar principles to specific places in the vicinity of Port Sudan, Mellit, Kutum or Kheiran.

See recommendations 2, 8, 9, 10

## 9. Vegetation

a) In collaboration with the Government and University Departments, a general survey of types of vegetation must be made, and a chart prepared. A detailed map of species of vegetation should be made for certain sectors specified above (8.a)

b) Since vegetation is a natural element in a state of rapid evolution, it is essential to determine the rules governing its evolution in relation to farming methods, grazing and fire. In grazing areas, special attention should be paid to maintaining a balance between annual and perennial Graminaceae.

c) Very thorough physiological studies will have to be made on the water supply of plants and the drought resistance of certain species, such as the plants of the Gizu, Acacias, etc. In addition, biochemical research will have to be done on the nutritive value to cattle of the main fodder plants which can be grown in drought conditions, and on the medicinal qualities of various plants growing naturally in these areas.

d) On the strength of the above research it may be decided to select certain useful plants of the Sudan for further development, or to introduce new species into the area.

See Recommendations 2, 11, 12

#### 10. Fauna

a) Surveys of the fauna will need to be pursued, in collaboration with the Department of Zoology at the University. It will be interesting to note how the fauna changes with changes in the main farming methods, grazing practices, etc.

b) It will be essential to make physiological and ecological studies on the drought resistance of certain wild species, such as guinea-fowl and gazelles; and on certain domestic animals such as the ovines and bovines traditionally bred in the country. It will also be useful to make a survey of the feeding of domestic animals in connection with the practice of moving herds.

See Recommendations 12, 13

#### 11. Agronomic Studies

A great deal of work on this subject has been done by the various departments of the Sudanese Government, each operating in its own special field. It would be extremely useful if a long-term integrated survey could be made of the agriculture-forest-pasture balance, especially in semi-arid regions (evolution of the vegetation, soils and crop-yield). Certain crops (e.g. date-palms, fruit-trees, cotton) could be further developed.

See Recommendations Nos. 3, 11, 15

#### 12. Social anthropology studies

The importance of these studies has already been stressed (c.f. No. 4) not merely in a general sense but also in connection with specific subjects, such as the repercussions of the partial sedentarization of nomadic tribes; the changing of the traditional migration routes and system for the moving of flocks; the limitation of certain types of crops and herds in specific zones; and the changing of agricultural and grazing practices (checking fires, forbidding grazing in certain areas, etc.).

It may be possible to facilitate the application of some of these measures by an appropriate price and marketing policy. All general surveys of the development of the arid zone in the Sudan should include research on these subjects.

See Recommendations 4, 15

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13. Experts and bodies to be responsible for carrying out research on the arid zone.

It should be possible for the study of the general and special problems outlined above to be carried out by the following experts and organizations:

a) Expert of Unesco Technical Assistance Service (1961-1962)

The expert on the budget of the Unesco Technical Assistance for 1961-1962 should be either a soil physicist or a plant ecologist, and his mission should be to investigate some particular aspect of the soil-water-vegetation relations as exemplified in one of the main ecological environments of the arid zone in the Sudan.

Either a soil physicist or a plant ecologist will be selected to do this work, according to the candidates available.

Arrangements have been made for the expert to be given considerable assistance either by the Department of Animal Resources and, as regards laboratory work, by the University (Faculty of Agronomy or Faculty of Sciences); and also, for field work, by the Department of Land Use and Rural Water Development.

b) University

Many University departments are very much interested in the problems of research on the arid zone of the Sudan and have already embarked on this research. Several of these departments (geology, botany, zoology, anthropology) have already set up an "Arid Zone Study Group", whose programme of basic research should be able to be carried out with the help of subventions from foreign bodies.

This group is prepared to co-operate with any other organization interested in solving the problems of the arid zone.

It could extend the scope of its work and do more detailed research if provided with the necessary resources (transport and field equipment in particular).

c) Government Departments

Research, usually applied research, carried out in very many cases in conjunction with the University, is already being done by various of the Government Departments, including in particular the Departments of Animal Production, Land Use, Agronomic Research, Geology and so on. It is essential that this research should be continued, and any new organization undertaking surveys designed to promote the utilization of the arid land in the Sudan should contribute towards expanding the work already being done.

There should be the closest possible collaboration between United Nations experts, University and Government research workers and any new organization entering the field.

d) Research Fellowships.

Research work could be developed if fellowships could be made available immediately to scientists willing to undertake certain of these surveys, relating to anthropology, sociology, pedology, plant ecology and so on.

e) Social study of the Messereiya Tribe

In Kordofan the Messereiya, a nomad tribe living in the area in the vicinity of the railway could, probably be settled west of the Nuba mountains. In order to do this a full survey would have to be made of the "reception milieu" followed up subsequently by an "integrated survey".

It would be useful if a detailed investigation could be made now of the social habits and customs of this tribe; this work could be carried out by the Department of Anthropology of the University if it were provided with the resources necessary.

This detailed survey could be made prior to the establishment of the Arid Zone Research Institute in the Sudan, a description of which is given below.

f) Arid Zone Research Institute in the Sudan

On the strength of our discussions with the various people we met, and of the observations we were able to make in the course of our trips round the Sudan, we consider that it is necessary to establish a Sudanese Arid Zone Research Institute. It should be set up jointly by the Sudanese Government and the United Nations Specialized Agencies.

The aim of the Institute would be to conduct research with a view to fuller development of the arid zone and, in particular, to solve the problems outlined in the foregoing pages, which would involve both applied and fundamental research. It should be supported not only by FAO and Unesco, but also to a certain extent by other organizations such as, for instance, WMO.

The Institute should work in full co-operation with the University and the appropriate Government Departments (Land Use, Animal Production, Geology, Meteorology, etc.)

As it developed the Institute would enrol the research fellowship-holders mentioned above (13-d), and would be responsible for completing the research begun by the University on the settlement of the Messereiya tribe (13-e). The expert whose services are to be provided for 1961 (13-

(13-a) might constitute the nucleus of this Institute. In any case the Institute would begin work on a very small scale, with full-time research workers in five subjects: hydrology, soil science, botany, zoology and humanistic sciences. Each of these sections would consist, initially, of one United Nations expert and two young Sudanese research workers allocated as local counterparts.

The Institute would not need to set up new laboratories immediately, since the University could supply laboratory facilities for two or three research workers per section.

A more detailed scheme for the project is appended.

See Recommendations 8, 16, 17, 18

#### RECOMMENDATIONS

1. The training of technical officers in all scientific branches of the service should be speeded up to the maximum extent so that the recommendations of expert missions can be more readily put into effect and the time of scientific officers more usefully employed. This will require a long-term policy of increased scientific instruction in later school years and of increased provisions for technical schools. Increased provision is urgently necessary also for scientists at graduate and research levels. Special instruction in arid zone problems should be given at a suitable centre, as within the Agricultural Institute.
2. Basic research in respect of geomorphology, soils, vegetation, hydrology, climate, microclimate, land use, etc., should be greatly extended, and the coverage of 1:100,000 or, if possible 1:50,000 maps and of air-photo mosaics should be increased for this purpose. Basic information already gained, as in the case of geological and hydrogeological maps and reports, should be issued for general use as early as possible, and integrated surveys in respect of geomorphology, soils, vegetation, land use, etc. carried out in areas considered for development.
3. Research into the closely associated problems of over-stocking, over-cultivation, grass fires, wind breaks, wind and water erosion, and the provision and proper use of water supplies should be intensified; moreover, land use and social surveys of selected areas should be undertaken by competent staff, both to determine the land capabilities and to develop a land use policy, whereby proper joint control of vegetation, grazing, stock, cultivation and water the disastrous deterioration of land in many areas may be checked and the productivity of the land built up.

4. Greatly extended study of the modes of life and the mental attitudes of the people is required to bring them to a better sense of land use, and to persuade them of the desirability of the necessary controls in stock numbers, grazing, cultivation and water use, so that their land may be maintained in production.
5. In order to convince the rural population of the evils of over-stocking, over-grazing, soil erosion, etc., and of the economic advantages of proper land use, demonstration plots and areas and mobile exhibitions should be employed to the maximum extent.
6. For purposes of agriculture, irrigation, hafir construction, ground-water recharge, etc., it is important to speed up the collection of hydrological data, particularly as regards rainfall, stream-flow, run-off, infiltration and evaporation, and it is desirable also to make detailed hydrological surveys of small areas, such as stream catchments, which can be regarded as representative of larger regions of similar geology, topography, vegetation, etc.
7. With the object of increasing the efficiency of the investigation and development of ground waters, due attention should be given to such questions as the quantitative aspects of ground-water, re-charge areas, co-operation between and supervision by geologists and engineers in drilling operations, control of water points, bore-hole records, and hydrogeological mapping, as enumerated under Conclusions 7, Hydrogeology. .
8. The expert for whom UNTAA provision has been made in 1960-61 should be a plant ecologist or soil physicist, and he should study arid zone problems in his field in the Sudan .
9. With a view to extending certain crops (cotton plants, for instance), eventually, into the more arid zones, specialists should study the effects of agricultural methods on the evolution of the water-profile of certain soils (Vertisols in particular), the extent of penetration of crop root-systems, and the water supply of these crops.
10. Thorough studies of wind erosion should be made first of all on the large clayey plains (influence of wind erosion on the texture and surface structure, the organic matter content and the water profile of the soil).
11. With a view to laying sound foundations for a rational combination of agriculture, forest and pasture land, long-term detailed surveys should be made of the evolution of the soils in relation to farming, forestry and grazing methods (including a special study of the effects of various types of bush fires), especially in the north-central region of Kordofan.
12. Plant and animal physiological studies should be made of the drought-resistance of the following:

- a) plants such as those in the Gizu, and certain types of Acacia;
- b) wild animals such as guinea fowl and gazelle;
- c) domestic animals: Sudanese species of ovines and bovines.

13. Studies of fauna should be continued, accompanied by research on the evolution of fauna in relation to changing farming and grazing methods.

14. The possibility of extending the cultivation of certain crops mentioned earlier (Conclusion 11) might be considered.

15. It is, we consider, highly desirable that social studies of the people of the arid zone should be extended, especially in the economic field, in order firstly to foresee what social and economic repercussions the technical changes considered necessary in the farming, grazing and forestry methods of the various tribes may produce; and secondly, in order to decide whether a special price and marketing policy will make it possible to introduce in practice such changes as are considered desirable.

## A P P E N D I X

### PROPOSALS FOR AN ARID ZONE RESEARCH INSTITUTE IN THE SUDAN

#### NOTE:

It is for consideration whether such an Institute could preferably be supported on a somewhat larger scale jointly by Unesco and FAO, the one being concerned more with basic research and the other with applied research.

#### 1. The Institute

- (a) The objective of the Institute would be to conduct and encourage basic and applied arid zone research with a view to the solution of urgent national problems as already described.
- (b) The Institute should be financially and administratively independent and subject only to the direction of its Advisory Council.
- (c) The work of the Institute should be complementary to that of Government and University Departments and international bodies engaged on arid zone research, and the Institute should work in close consultation and co-operation with these organizations. It is noted that the University has been actively considering

the formation of a University Arid Zone Research Unit, and it is cordially hoped to secure the full co-operation of the University in the Institute now proposed.

- (d) The Institute should be maintained at a sufficiently high level to attract foreign scientists of comparable interests to visit it for purposes of research.
- (e) The Institute should assist in the carrying out of basic surveys and in the organization of integrated surveys in the various sciences as required.
- (f) The headquarters of the Institute should be situated at Khartoum, but at an early convenient stage field stations should be established to study regional problems and to conduct experimental plots and pilot schemes. For example, such stations could be set up in the first instance as follows:
  - (i) At El Obeid, to study the inter-relations of soil, vegetation and water.
  - (ii) At Port Sudan for hydrological and hydrogeological studies in the semi-desert area.
  - (iii) At Kassala for photo-ecological studies comparable with those carried out at El Obeid, but related specially to clay plains subjected to soil erosion.
- (g) The work and success of the Institute will be judged by the number and standard of the papers published by its staff, and accordingly adequate provision should be made for the publication of its research.
- (h) The Institute should be prepared to give limited post-graduate instruction in subjects related to its work, and could assist in the organization of training courses that would advance its objects. It could also advise on mass education aimed at extending knowledge of proper land use.

## 2. The Advisory Council

This should be a body closely comparable, or identical, with the Sudanese Co-operating Committee in the Major Project on Scientific Research in the Arid Lands, with adequate representation of the Government, University and other bodies engaged in arid zone research. This Council would assist the Director in the formulation and co-ordination of policy and of programmes of scientific investigation.

To facilitate contacts and consultation with the Director the Council could appoint a small Technical Committee composed of a group of scientists, say four to six, closely connected with the work of the Institute, and drawn from the University and from the Government Departments most concerned.

### 3. The Divisions of the Institute

The Divisions that appear to merit earliest attention are the following:-

- (a) Social science
- (b) Soil science
- (c) Botany
- (d) Zoology
- (e) Hydrology

In view of the considerable programme of basic and applied work in hydrogeology at present in hand by ICA, the Geological Survey and the L.U. and R.W.D. Department, the inclusion of this branch of hydrology could be deferred to a later stage.

Geomorphological studies are in hand by the University, and will be included in the proposed Seven-Year Land Use Survey of L.U. and R.W.D. Other Divisions or subjects may need consideration later, such as human physiology.

### 4. Staff

The Director must be a scientist and administrator of international repute, and should have a rank and status not less than that of a university professor or comparable head of department. He should preferably be specially experienced in soil science or biological science, or possibly social science.

As Assistant Director of proved scientific standing would also be required.

The Heads of Divisions should also be well-established scientists in their own fields, and should have a status comparable with that of professors. In some cases it may be necessary to appoint scientists of somewhat less experience for limited periods.

To each Head there should be appointed if possible one or two counterpart members of proved research ability.

Fellowships should be awarded to candidates of the requisite high standard for study at foreign universities, two Fellowships to each Division. Research posts may be established to enable scientists of adequate research experience to study arid zone problems at the University.

Adequate secretarial, clerical and technical staffs should be available to facilitate the work of the scientists and to assist them in their duties.

It is hoped that Government Departments engaged in or interested in Arid Zone Research would be prepared to second carefully-selected competent staff at the various levels considered to take part in the work of the Institute.

5. Co-operation with the University

The University Departments have shown much interest in arid zone problems, and are in fact considering the establishment of a University Arid Zone Unit. Where members of the University staff are prepared to give their time and experience to problems of special interest to the Institute, it is proposed that the Institute should assist them as far as possible in such matters as technical assistants, transport, equipment, etc.

6. Office and Laboratory Accommodation

A first essential would be a suitable office for the Director and his administrative staff. This building, like others of the Institute, should be such as to uphold the prestige of the Institute and to inspire confidence in its work from the beginning.

It has been suggested that in the first instance the University might provide laboratory accommodation for the scientific staff of the Institute. If this were possible it would save great initial expenditure and enable the scientists to settle down to their work without delay. Additional special equipment as required and subordinate staff could be provided by the Institute. Provisional budgeting for Institute Laboratories could be made in the first instance with a view to construction when the Institute is well established in its work.

7. The Library of the Institute could gradually be built up, possibly with assistance from Unesco and from foreign universities and scientific institutions; in the meantime the University and Departmental libraries would perhaps be available for consultation.

8. Field Equipment

The fruitfulness of the Institute's activities will be essentially dependent upon the adequacy and reliability of its motor transport, and too much stress cannot be laid upon this point. Each Senior Officer should have one 2½ ton pick-up and one land rover, and relative camp equipment and field staff.

It is also highly desirable that helicopter or other air-transport be made available in special cases.

It is equally important that for co-operating and visiting scientists there should be available adequate additional transport and equipment; where such scientists are prepared to devote their time, knowledge and experience to approved Institute studies the Institute should be in a position to offer them these field facilities, subject to the approval of the Director.

9. Financial provisions

If the above suggestions are approved in principle the necessary financial provision for capital and recurrent expenditure can be worked out on a five (or seven) year basis; in the detailed working out of these estimates on the basis of local costs, the assistance of the Government and the University would be appreciated.

When an estimate of the total cost has been arrived at the question of the source or sources of the funds required can be considered by the competent authorities.

10. Priorities

- (a) Appoint - Director and staff  
Heads of Divisions or appropriate scientists  
Clerical and technical staffs  
Counterpart staff  
Candidates for fellowships.
- (b) Order field equipment.
- (c) Build headquarters office for Director and staff.  
(a), (b) and (c) for action concurrently.
- (d) Set up regional stations.
- (e) Design complete new headquarters, including laboratories, as and when required.