A PRELIMINARY SURVEY OF THE NATURAL ENVIRONMENT AND THE AGRICULTURAL RESOURCES OF OKAVANGOLAND

PROFILES (16)

undertaken for the

DEPARTMENT OF BANTU ADMINISTRATION AND DEVELOPMENT
PRETORIA
Republic of South Africa

JUNE, 1967

A.O.C. Technical Services (Pty) Ltd.,
P. O. Box 39265,
BRAMLEY. Tvl.

TS/1/67

A PRELIMINARY SURVEY OF THE NATURAL ENVIRONMENT AND THE AGRICULTURAL RESOURCES OF OKAVANGOLAND

undertaken for the

DEPARTMENT OF BANTU ADMINISTRATION AND DEVELOPMENT
PRETORIA
Republic of South Africa

JUNE, 1967

A.O.C. Technical Services (Pty) Ltd.,
P. O. Box 39265,
BRAMLEY. Tvl.

TS/1/67

TABLE OF CONTENTS

INTRODUCTION

During mid to late 1966 a soil survey was undertaken in Okavangoland; the study comprised a reconnaissance investigation of about 1,000 sq. miles in the environs of the Okavango River in the Caprivi strip and the adjacent terrain, followed by a flying reconnaissance of about 13,000 sq. miles covering the greater part of Ovamboland. In this latter study the riparian land, through its total length in South West Africa, received special attention. The inland plateau, where communications are particularly poor, was investigated by means of traverses along all motorable access; through subsequent photo interpretation, the field observations were extrapolated to produce a natural resources map showing physiographic regions defined in terms of the main soil and vegetation associations. Development aspects and land use potential are emphasized in the presentation of these data at 1/250,000 scale. The results of the more detailed reconnaissance of the riparian land are presented on aerial mosiacs at 1/75,000 scale. On these photo-maps the nature and capability of the soils, with particular reference to irrigation are shown in greater detail. Mosaics compiled from 1/75,000 photography were used as base maps for all phases of the soil survey.

The investigation was directed primarily at an assessment of the irrigation potential of riparian land located on the terraces which flank the Okavango River. However, during the course of the field work the survey party collected much useful information which had a much wider application to land use in general than the specific requirements of the irrigation study. In this report these data have been reworked and extended into a form which will serve as a useful base for regional planning and organisation of additional or supplementary investigations.

ENVIRONMENT

Geomorphology and Drainage

There are two outstanding physiographic regions; the vast inland Sand Plateau and the terrace system of the Okavango River, the largest perennial river in South West Africa. The riverine landform comprises a floodplain, which shows strong evidence of a braided river system, and the gently sloping alluvial terrace which occupies a prominent landscape contiguous to the floodplain at a mean elevation of about 20 ft. above the river. The Sand Plateau is a monotonous plain of Recent aeolian sand with a relief varying from flat to gently undulating in regions of seif dune formations. Parallel systems of seif dune and intervening Omarambas, the current drainage courses, are a prominent feature in the south central parts of Okavangoland.

The Omuramba Omataka is the largest tributary of the Okavango River in the area covered by this survey. Minor alluvial terraces are present though in general this seasonal water course, in common with all other tributaries, is incised with steep banks and narrow V-shaped valleys. The dissection by the tributaries has not produced any appreciable bevelling or general lowering of the Sand Plateau.

Settlement and Land use

Agricultural production by the indigenous Bantu is essentially at the subsistence level, practised almost exclusively along the Okavango Terrace and the valley sides of the major tributaries. Arable cropping, in which millet is the most important crop, is supplemented by stock farming with cattle and goats. Pilot irrigation schemes have recently been established as q means of introducing an intensification of land use through irrigation with the ultimate objective of expanding and stabilising food production. Water points and fencing have also been provided on a limited scale to extend the grazing of cattle into the Sand Plateau behind the settlements on the River Terrace.

Pit sawing of Pterocarpus angolensis is a small local industry which supplies a modest volume of sawn timber.

The Bushmen inhabit the Sand Plateau where they are employed as casual labour for the construction and maintenance of roads and firebreaks.

Fire control, recognised as a pre-requisite for effective pasture and forestry management is enforced in Ovamboland; the control measures which appear to be well respected by the entire population are of particular interest.

Vegetation

The vegetation can be broadly classified into four main associations :-

1) The Terminalia sericea-Burkea africana Woodland Savanna of the deep aeolian sands.

2) The Acacia girafae - other species Bush Savanna.

3) The open Grassland of the Omurambas.

4) The Acacia girafae-Combretum imberbe Tree Savanna of the Okavango River Terrace.

The Terminalia sericea-Burkea africana Woodland Savanna is associated with Guibourtica coleosperma, Baikaea plurijuga and Ricinodendron rautanenii, with a sparse grass cover of dominantly fibrous Aristida spp. On the margins of this vegetation type, within the Termitaria zone, Acacia giraffae and Combretum spp. occur. These species are normally indicative of more favourable soil conditions.

The Acacia giraffae Bush Savanna normally occurs on the Brown Aeolian Sands. The bush is of medium density but sufficient to effectively suppress grass growth. Medium sized A. giraffae may occur either singly or in small communities together with Combretum spps.

The vegetation of the Omurambas is essentially an open grassland which forms a variation to the general Woodland Savanna of the Inland Plateau. The more favourable soils are indicated by scattered wellgrown A. giraffae within a dense grass cover characterised by Schmidtia bulbosa. The areas of Grey Sands, usually on to calcrete at shallow depths, carry a tall sour grass cover of mainly Loudetia superba.

The Acacia giraffae-Combretum Tree Savanna of the cultivated River Terrace comprises a selection of scattered, very well-grown individual trees. Sclerocarya (marula), Boscia albitrunca, Albizia spp., Lonchocarpus spp., Ficus spp are also common constituents.

Pterocarpus angolensis, occurring on the deep aeolian sands, was the only commercial timber tree encountered. Distribution is ubiquitous but specimens of commercial size and reasonable frequency were only seen in the western part of Okavangoland. Many of these specimens have suffered fire damage. The only other species that may have possible economic value is Ricinodendron rautanenii. The oil obtained from the nuts has been favourably reported upon as a quick drying oil for use in paint manufacture. Exploitation would require that the Bushman, who now gather the nuts for food, be prevailed upon to collect for sale and to purchase food with the proceeds.

Climate

The climate may be classified as seim-arid and sub-tropical with a mean annual precipitation of from 525 to 575 mm. The period of effective rainfall is very short, from December through to March, when 80% of the average precipitation can be expected. Summers are hot and somewhat dry with temperatures of 34°C and higher in October and November, the hottest months of the year, prior to the onset of the rainy season. The winters are mild, July being the coolest month with a mean daily minimum of 6.2°C. The diurnal range varies between 20°C in mid-winter to about 13°C in mid-summer. The temperature data given in Table 1 have been recorded at Ondangua and, although outside the survey area, may be considered as being representative of Okavangoland. Other relevant climatic data are given in Table 1.

TABLE 1 : CLIMATIC DATA : S.W.A. WEATHER STATIONS

1200/866	Ondangua	Lat. 17°56'S	- Long. 15°59'E	Altitude 1095m
1160/814	Andara	Lat. 18°04'S	- Long. 21°28'E	Altitude 1100m
1206/187	Kuring Kuru	Lat. 17°37'S	- Long. 18°37'E	Altitude 1110m
1208/475	Runtu	Lat. 17°55'S	- Long. 19°46'E	Altitude 1311m

AIR TEMPERATURES °C : ONDANGUA

Month	Mean Max.	Daily Min.	Mean Highest Monthly Max.	$\frac{Max + Min}{2}$	Monthly means No. of days with Temp. below 0 °C
January	32.4	10.2	36.4	25.5	0.0
February	31.2	18.8	34.8	25.0	0.0
March	30.7	18.4	33.4	24.6	0.0
April	31.0	16.7	33.3	24.1	0.0
May	29.1	13.0	31.9	20.3	0.0
June	26.3	7.2	29.3	16.7	0.1
July	26.5	6.2	28.9	16.4	0.3
August	29.4	8.3	32.7	18.8	0.1
September	32.9	12.8	35.9	22.9	0.0
October	34.4	16.3	37.3	25.3	0.0
November	33.3	18.0	38.0	25.7	0.0
December	32.0	18.7	35.6	25.3	0.0
Year	30.8	14.5	-	22.5	0.5
Period in Years	7	7	7	7	7

RAINFALL NORMALS mm

	ONDANGUA	ANDARA	KURING KURU
January	110	137	110
February	123	130	115
March	93	94	97
April	36	28	34
May	3	5	4
June	0	0	0
July	0	0	0
August	0	0	0
September	2	1	1
October	13	17	18
November	46	52	57
December	91	108	94
Year	517	572	530
Period in Years	44	30	30

FROST INCIDENCE

	ONDANGUA	RUNTU
Average : First Date	1/7	23/6
Average : Last Date	9/7	6/7
Number of Years of Data	15	12
Number of Years in which frost occurred	7	5

Except for the rainfall which is marginal for crop production, the climatic environment can be considered as suitable for a wide range of tropical and sub-tropical crops. The cool season, May to September, is particularly suited to the more sensitive range of crops, vegetables for instance, which are somewhat intolerant of the exacting summer conditions. Irrigation development, involving supplementary irrigation during the summer and total irrigation during the cool season, can thus be highly recommended in Okavangoland, and a great volume of gross production per unit area should be feasible. Limitations of soil will be discussed later.

THE SOILS OF OKAVANGOLAND
THEIR CLASSIFICATION, UTILISATION AND POTENTIAL PRODUCTIVITY

With respect to their occurrence, land use (both current and potential) and parent materials, the soils can be conveniently grouped according to five distinct landforms. These are :-

a) the Floodplain;
b) the 24 ft. terrace commonly referred to as the River Terrace;
c) the aeolian Sand Plateau;
d) the Omurambas;
e) the Pan-veld of the south-western region.

The pertinent details of the soils are also summarised in Table 2.

THE FLOODPLAIN

This landform is typical of an aggrading river system characterised by dissected micro-relief produced by a braided stream system. The abundance of cut-off meanders and relic water courses and levees indicate the historical seasonal flood cycle. The component soils are not cultivated, either because of the inherent low fertility (type D), a high water table (type F) or inundation by flood water. There is however, a useful potential for dry season grazing. The following are the common soil types :-

Type D : Grey Sands (Profile No. 21, page 1)

The Grey Sands within this landform are generally limited to the levee and its immediate surroundings; they do sometimes occur further from the river - as in the vicinity of Masivi - in which case a water table is present at about 3 ft. These sands are very loose and generally contain less than 4% clay. They support only a sparse grass vegetation. The inhabitants build their kraals on these sands but never cultivate them.

The vast expanse of type D occurs on the Inland Plateau, whereas the Grey Sands on the Floodplain are not true examples of the type since they often have water tables, overly lime and are alluvial in origins. Their general potential and morphological properties being somewhat similar, no differentiation has been made on the map.

Of the soils within the survey area these have the lowest potential.

Type F : Black Sandy Loams of Omurambas and Floodplain
(Auger boring No. 30, page 11)

These soils are slightly lower lying than type D; they are normally subject to flooding or to waterlogging during the rainy season. In some places, such as in the wide swamp at the Botswana border, the soil underlying the permanent water falls within the definition of this soil type.

In the mapping unit there normally occurs a complex of soils comprising types F and D. This complexity of pattern is due to the discontinuity of the black sandy loam to silty clay over a deposit of sand. The heavy material varies in depth, often disappearing in places.

The inhabitants do not utilize this soil except as grazing - it supports a grass and reed vegetation.

At Shamvura the F.C.U. Jute scheme was established on this soil. Here the overlying materials were found to be heavier and more impermeable than normal and the underlying (and surrounding) sandy materials to be coarser than normal. A permanent water table is present at 3 ft.

These soils cannot be recommended for irrigation but they could be used for certain specialised crops such as rice or jute. More detailed soil surveys of the complex pattern would be essential to establish final capability. The feasibility of flood control works is unknown at this writing but would appear to be formidable.

THE 20 FT. TERRACE

The boundary between the Floodplain and this physiographic unit is quite distinct, though the outer margin does tend to vagueness in places where it is defined by only a gradual rise in elevation.

This landform is quite flat to even and gently sloping except for minor drainage lines and anthills. Topographically speaking it is ideally suited to irrigation. It is within this region that the major part of present agriculture is practised.

Parent materials encountered within this area are generally fairly uniform, fine sandy loams to sandy clay loams overlying the basement of Tertiary limestone. It is postulated that these deposits are Pleistocene fluviatile terrace materials. Since the river has flowed largely through sands of aeolian provenance, little sorting of materials has taken place except the concentration of a little clay relative to total sand content. Local mixing of the terrace material with aeolian sand undoubtedly occurred as manifested by the tendency of the materials to become sandier from the inner to the outer edge of the landform. The following are the important soils :-

Type B2 : Red Sands - Riparian phase (Profile No. 2, page 11)

These Red Sands occur along the outer edge of the 20 ft. terrace where the parent materials are sandiest; they normally occupy a narrow strip in the zone transitional between the Terrace plain and the Aeolian Sand Plateau. The slope here averages about 5% - steeper than on the actual terrace itself.

These soils are cultivated by the inhabitants in areas where there is an insufficiency of the better class soils. Productivity under dryland cropping is limited due to a low inherent fertility but with additions of nutrients good yields are feasible.

With a silt plus clay content of between 7% and 9%, these sands can be compared with those of the Vaalhartz irrigation scheme, where experience has demonstrated that similar red sands have a high potential under irrigation. This scheme has also shown that conventional flood irrigation is somewhat hazardous due to the rapid internal drainage which leads to the build-up of a water table. In view of the situation of these soils (along the Okavango) on the outer edge of the heavier Terrace soils it is our considered opinion that only sprinkler irrigation should be attempted on Type B2. Water holding and cation exchange capacities are somewhat low, and frequent water and fertilizer applications will be necessary. With judicious management, the irrigation development of these soils is a feasible proposition; they remain marginal, however, due to the limitation of internal drainage.

Type E2 : Brown to Yellowish Brown Sands - Riparian phase

These normally occupy a position similar to B2 - the Red Sand with 7-9% clay plus silt - which is transitional between the 20 ft. Terrace and the dune country.

Sands with 7 - 9% silt plus clay, with hues 7.5YR or yellower and increasing chromas were mapped as E2, i.e. all those sands which were brown in the upper horizons and yellowish brown in the lower and which had an average silt plus clay content of 7-9% in the upper 36 ins.

In the absence of better soils these sands are cultivated. They are comparable to the Red Sands (B2) with respect to dryland cropping. Their use under irrigation is limited to sprinkler systems due to their excessively rapid permeability.

Low water holding and cation exchange capacities will necessitate frequent fertilizer and water applications.

Type A1 : Red Loamy Sands of the Terrace - Deep Phase
(Profile No. 101, page IV)

These red loamy sands normally occur in complex association with Type C1, between B2 and the heavier terrace soils. In the mapping of this soil, two phases have been recognised; the deep phase (A1) and the shallow phase (As), in which the gravel and/or calcrete layer is found at less than 30 inches below surface. The latter is more fully described in a later section. Slope averages about 3%.

The soils included in this unit generally have a gradual increase in silt plus clay content from about 7-9% in the surface horizon to about 15% at 36 inches. Occasional soils with a marked increase in clay content to about 20% at depth have been included in this unit. The main diagnostic characteristic distinguishing A1 from A2, which is somewhat similar, is that A1 has less than 15% clay in the upper sub-surface horizons while A2 has 15% and more.

These soils are invariably cultivated by the inhabitants. With adequate fertilizer treatment and correct management techniques, the potential of these soils is high. For the same reasons as outlined under Type B2, sprinkler systems are to be preferred on this soil.

Type As : Red Loamy Sands of the Terrace - Shallow phase
(Profile No. 27, page V)

More than one soil has been included in this unit for sake of convenience since they are closely related and their potentials are similar. Typically the soils encountered here have a loamy fine sand surface horizon with a sandy clay loam subsoil overlying a variety of C materials: terrace gravels, laterite and/or limestone within 30 ins. of the soil surface. None of these materials are really limiting to water penetration. With excessive irrigation, however, temporary perched water tables could build up. This fact, together with the shallow effective rooting depth places the soil in the marginal capability class for irrigation. Under sprinkler irrigation their potential is comparable with Type A1.

These soils are not very extensive; they normally occur in complexes either with one of the heavier red soils (A1 or A2) or with rock outcrops. Generally they were found under cultivation at the present time; their productivity is relatively high for dryland cropping.

Type A2 : Red Sandy Loams of the Terrace (Profile No. 3, page VI)

These red sandy loam soils are nowhere very extensive. They normally occur in association with the Grey Brown sandy loams (Type C).

The surface horizon is generally a fine sandy loam with clay increasing with depth to a sandy clay loam within 36 inches. Generally these soils overly terrace gravels and often occur in a complex with the shallow As.

This soil type, which is invariably cultivated by the inhabitants, is a very good irrigable soil; indeed, the best encountered within the survey area. These soils will require fairly heavy fertilisation for realisation of their optimum potential. Due to their good physical characteristics their potential is very high. Within the controls of the rainfall the dryland cropping potential is also high.

Type C1 : Grey Brown Sands to Loamy Sands (Profile No. 17, page VII)

These soils are fairly extensive on the 20 ft. Terrace, especially west of Shamvura, where they supersede Type C in dominance within this landform. They occur either alone on flat terrain or in complex association with A1 in micro-undulating terrain of low relief. They occupy the position either closest to the inner edge of the plain or between the Red soils (B2 and B1) and Type Cs. Average slope is 1-2%.

Included in this unit are all grey brown soils with a sandy surface horizon, with a gradual increase in clay content to about 15% at 30 inches. Differentiation between type C and these soils is made on the basis of surface texture. Type C has 15% clay or more in the surface horizon normally increasing with depth (though not necessarily) while C1 must have less than 15% in the surface.

These soils are all under cultivation on the Terrace. There do occur areas of C1 away from the Terrace in depressed sites in the Aeolian Sand Plateau, as well as the Omurambas, which are not cultivated.

The site, topography, physical and chemical characteristics of these soils make them well suited to irrigation and dryland cropping. A limiting factor is the permeability which does tend to be somewhat excessive so that sprinkler irrigation is recommended in preference to conventional surface flooding. The narrowness of the area and proximity to the natural drainage line of the river would circumvent all but the most serious over irrigation. A shallow phase (C1s) has been recognised when soil depth to underlying calcrete is less than 30 inches.

<u>Type C : Dark Grey Brown Sandy Loams - Deep Phase</u>
<u>(Profile No. 16, page VIII)</u>

These soils are extensive on the 20 ft. Terrace between Bogani Pont and Shamvura. East of Bogani the terrace has been invaded by sand or is very limited; west of Shamvura C1 dominates the landscape. Type C invariably occurs along the inner edge of the terrace - closest to the river. It is normally associated with Cs especially at the inner margin where the terrace material has been removed to some extent, exposing the basement limestone in places. It may occasionally be found in association with Type A2.

Included in this unit are all brown to dark grey brown soils with 15-35% clay in which the surface horizon has about 15% or more clay and in which the depth to underlying limestone is 36 inches or more. The soil generally is dark grey brown with a sandy loam (15-20% clay) surface horizon with a gradual increase in clay content with depth to about 20%. Lime in the form of powdery accumulations overlying nodules and limestone occur at about 60 inches. Although the associated termite mounds are saline the soil itself is not; it is neutral becoming slightly alkaline in the lower horizons.

About all of Type C encountered is at present under cultivation. This soil has no apparent limitations to either dryland cropping or irrigation; it has a high potential. Inherent fertility is expected to be fairly high - higher than the red soils, although physical characteristics are not as favourable as Type A2. The proximity of Type C to the river simplifies drainage control provided the high lying land is not over-irrigated. Either sprinkler or flood irrigation can be practised.

When levelling the land of termite mounds, due cognizance must be taken of their high sodium content; indiscriminate spreading of the material is inadvisable. Deeper soil layers appear to be saline and any rise in water table resulting from over-irrigation will most certainly bring about salinisation of surface layers.

Type Cs : Dark Grey Brown Sandy Loams - Shallow phase
(Profile No. 23, page IX)

Nowhere extensive, these soils generally occur at the inner edge of the 20 ft. Terrace where it has been bevelled by erosion. Together with this phase in the mapping unit Cs we have mapped all of the grey soils with more than 10% clay overlying calcrete or rock at less than 36 inches. Outcrops of rock where the limestone has been exposed also occur in this unit. Except for the patches of non-arable land and the steep areas bordering on the river plain, most of the shallow soils on calcrete have been cultivated.

The shallow effective rooting depth and slight impedance of the calcrete to water penetration are limitations to irrigation use; sprinkler irrigation systems would be preferred should the soil be extensively irrigated.

The Vungu Vungu irrigation scheme is located partly on this soil, and by using short beds, flood irrigation has proved successful without the apparent build-up of a water table. Here the problem with flood irrigation appears to be rather that of excessive drainage than of water table. The area is adjacent to the river and sub-surface drainage is not impeded.

Type A : Red Sandy Clay Loams to Clays

Only one significant area of this soil was encountered; at Mamano near Andara, occupying a flat slightly depressed site. This was a red sandy clay soil, strongly saline, moderately alkaline and moderately to slowly permeable.

The few areas which were mapped as Type A had more than 35% clay in the lower horizons (below 15 inches) and more than 20% clay in the surface horizon.

These soils are cultivated by the inhabitants although at Mamano it would not appear to be a favoured soil since cultivation is only patchy.

Before Type A could be extensively irrigated it would have to be drained and leached of excess salts. The slow permeability would present some difficulties as would the high sodium content; chemical amendments may be necessary. In view of these limitations, the soil is marginal for irrigation use.

Type H : Black Clays and the Fine Textured Soils of Minor Drainage Lines (Profiles Nos. 12 & 28, pages X & XI)

Only one area of the true black clay type was encountered: on the Botswana border in a depressed site on the left bank of the river. (Auger Site 12).

Also mapped as H are those soils of minor drainage lines on the 20 ft. Terrace which clearly increase in clay content from sandy loam in the surface to clay in the sub-surface (Profile No. 28). In both cases the clay is non-saline to slightly saline, neutral to slightly alkaline and slowly permeable; other more saline forms are likely; but were not encountered.

Generally, the solonetzic soil - the type of the minor drainage lines - is not cultivated and cannot be recommended for irrigation due to both the salinity hazard and the impeded sub-surface drainage.

The black clay, sensu stricto, although poorly drained and slowly permeable, could be used with specialised management techniques.

THE AEOLIAN SAND PLATEAU

The riverine margin of this landform is generally marked by a distinct rise in elevation, forming a minor scarp, as at Runtu for instance. It is presumed that a high level river terrace or erosion surface everywhere underlies the aeolian sand, though only rarely at the edges, as at T.P. No. 18, was the terrace material actually encountered under the sand mantle. It is postulated that the sandy loam material at depth in Type A1 as well as the heavier material in the Omurambas may be related to this terrace deposit - a postulation borne out by the uniformity in texture of the deeper materials in Type G and by the occurrence of outcrops of the basement limestone in the Omurambas.

The soils of this landform are sandy, but for a few low lying areas; the generalised catena being Type B1 on higher lying steeper sloping sites, E on middle medium sloping sites, D on flat sites and G in slightly depressed sites (excluding the Omurambas).

It is seldom that any of these soils are cultivated by the inhabitants.

Type B1 : Red Sands - Plateau phase (Profile No. 18, page XII)

Generally, these Red Sands were found on the margin of the Aeolian Sand Plateau, adjacent to the riverine plain. They were also found on the steeper sloping older dunes further inland. Average slope is about 5%.

These soils generally have about 4% silt plus clay in the surface horizons increasing with depth to about 7% at 36 inches, giving an average for the upper 36 inches of less than 5% (whereas the average for B2 the Riparian phase of the Red Sand, is greater than 5%). Some members, e.g. Profile 18, have a very low clay content (approx. 3%).

Soils with such low clay percentages cannot normally be recommended for irrigation even though the sand content is largely of the fine sand fraction. The reasons for this lie in their excessively rapid permeability, inherent low water holding capacity and low cation exchange capacity. Sprinkler irrigation is essential, frequent water and fertilizer applications are necessary; moreover, in areas with such a high evapo-transpiration rate only crops with extensive root systems can obtain sufficient water to supply their needs from a soil of great depth but low available moisture capacity. For similar limitations the dryland cropping potential is also low.

The Red Sand as a type, incorporating the Riparian phase (B2) and the Plateau phase (B1), is a marginal soil due to its low clay content and poor moisture retention properties. The crop potential of these sands under irrigation is directly related to the percentage clay; the productivity, mutatis mutandis, decreasing proportionately with decreasing colloid content, till a point is reached where production is uneconomic and the sand then cannot be recommended for irrigation development. The precise point of changeover or economic break-even is not accurately known and can only be determined by experimentation and field testing in the local environment, both natural and sociological.

By both laboratory and field test, we have attempted to differentiate between the very low and, say, moderate percentage clay classes because of the obvious land use significance. We feel we have been partially successful though only detailed soil survey can solve this problem with any degree of certainty. There is an apparent indication - though not proven to our complete satisfaction - that in the upper 36 inches the Riparian phase has 7-9% silt plus clay and the Plateau phase has about 4-5% silt plus clay. The Riparian phase is of course also more conveniently located in relation to the water supply, a factor which enhances its potential.

Thus, for the time being, pending more detailed soil survey and possible agronomic research, the Riparian phase has been assessed as marginal irrigable land, whereas the Plateau phase is not recommended, though approximately 800,000 hectares of plateau phase (both Red B1 and the Brown E1) are not entirely devoid of at least some potential which could be profitably exploited at some future date. About half of this area is located on the plateau adjacent to the riverine terrace.

Type E1 : Brown to Yellowish Brown Sands - Plateau phase
(Profile No. 219, page XIII)

These Brown Sands generally occupy slightly flatter or lower lying positions than B1. Average slope is about 2-3%.

Mapped as Type E1 are all sands which are brown to strong brown or yellow brown in colour. Generally, the surface is a dark brown with chromas gradually increasing with depth to above 4 (10YR 5/6 5/8 yellowish brown or 7.5YR 5/6 5/8 strong brown). The clay content is low, apparently in the order of 3% in the top 36 inches. Brown sands with higher clay appeared to be limited and ubiquitous.

As with Type B1 these soils have a marginal arable development potential.

Type D : Grey Sands (Auger boring No. 44, page XIV)

These loose Grey Sands occupy a flat more-or-less featureless plain, typically with an average slope of 0-1%. They average less than 1-2% clay in the top 36 inches.

At no time were these soils found to be cultivated nor could they be recommended for arable use; they have lower water holding and cation exchange capacities than either E1 or B1 the Brown and Red Sands.

Type G : Solonetz soils (Profile No. 10, page XV)

These sandy solonetzic soils occupy flat somewhat depressed areas with little or no slope.

Typically, a grey loose sand abruptly overlies an olive grey sandy loam at about 48 inches. This sandy loam is extremely hard when dry and has a weak very coarse prismatic structure with a moderate to slow permeability.

Never was this soil found under cultivation and neither can it be recommended for cultivation. Although the solonetzic B is at present not impermeable, it will become so with time under the influence of irrigation. This type of soil should not be irrigated.

THE OMURAMBAS

The Omurambas which are low lying areas within the Aeolian Sand Plateau, serve as discontinuous drainage lines in the poorly dissected plateau landscape. The soils in the Omurambas are generally finer in texture than the surrounding soils and in some places they have quite a high potential. Similar soils are also found on the River Terrace; indeed, in those Omurambas which were investigated the sequence of soils is almost identical. For instance, starting at the river in Omuramba Mahango, Type F is found in the lower part, whereafter C and Cs may be encountered with rare patches of A1. Further up the Omuramba C1 and C2 are found. This analogous soil sequence does tend to substantiate the existence of the terrace materials and limestone basement below the Aeolian Plain.

By comparison with the Terrace, the pattern of distribution is complex on a micro-scale due to the narrow cross-section of the Omurambas. Detailed soil survey would be required to establish the distribution of the soils, and thereby, the overall potential of Omurambas. The land use potential of individual soils are similar to that of their counterparts occurring on the Terrace.

Field reconnaissance suggested that the suitable soils are scattered and discontinuous; the general irrigation potential of Omurambas thus being of not much significance. Engineering problems of water supply may be formidable, except in isolated cases, such as the very long Omurambas where further detailed study may be justified.

THE PAN-VELD OF THE SOUTH WEST

This area is quite flat, marked by numbers of blow holes and pans now serving as waterholes for game. There appears to be a marked change in particle size distribution which suggests that these sands represent the residue after deflation and local resorting by wind.

Type K : Reddish Brown Pan-veld Sands (Auger boring No. 49, page XVI)

These sand have not been differentiated; all coarser sands with less than 7% clay have been mapped as K, though generally they were found to have about 4% clay. No areas of K are cultivated as there is no settlement in this landform. The extremely rapid permeability of these sands and their low water holding and cation exchange capacities are serious limitations and they are not recommended for arable development.

TABLE 2 : CLASSIFICATION AND GENERAL CHARACTERISTICS OF THE SOILS OF OKAVANGOLAND

Map Symbol	SOIL TYPE	GENERAL CHARACTERISTICS	POTENTIAL FOR IRRIGATED CROPS	POTENTIAL FOR DRYLAND CROPS
A	Red sandy clay loams to clays	Heavy red soils overlying lime. Very minor occurrence. Somewhat impeded internal drainage. Slightly to moderately saline.	LOW salinity hazard	LOW salinity hazard
	Red loamy sands of the Terrace	Red loamy sands with 10-15% silt plus clay in the surface horizons. Somewhat excessive internal drainage. Moderate water holding capacity. Non-saline. Limited extent only.		
A1	Deep phase		HIGH highly recommended under sprinkler irrigation.	MODERATE
As	Shallow phase	Gravels and/or limestone occur at less than 30 inches below surface. Mapped in complexes only.	MODERATE limitations of shallow soil and low total available moisture capacity; recommended under sprinkler irrigation only.	MODERATE
A2	Red sandy loams of the Terrace	Red sandy loams with 15-20% clay in the surface horizons; at depth the clay sometimes increases to 20-35%. Excellent irrigation soils. Good internal drainage and high water holding capacity. Limited extent only.	HIGH conventional flood irrigation feasible but highly recommended under sprinkler irrigation.	HIGH

TABLE 2 : (contd.)

Map Symbol	SOIL TYPE	GENERAL CHARACTERISTICS	POTENTIAL FOR IRRIGATED CROPS	POTENTIAL FOR DRYLAND CROPS
	Red Sands	Red aeolian sands - 5YR and redder throughout. Slightly loose and less than 10% silt plus clay in the upper 36 inches. Excessive internal drainage. Low water holding capacity.		
B1	Plateau phase	Red sands with less than 7% silt plus clay in the upper 36 inches, commonly 4%. Occurs extensively on the Inland Sand Plateau.	LOW somewhat excessive internal drainage and low water holding capacity. Can be recommended under sprinkler irrigation.	LOW low inherent fertility; somewhat droughty.
B2	Riparian phase	Red sands commonly with 7-10% silt plus clay in the upper 36 inches. These sands have been separated from B1 due to physiographic position, topography and slightly higher clay content.	MODERATE somewhat excessive internal drainage and low water holding capacity. Can be recommended only under sprinkler irrigation.	LOW more desirable than type B1 but still low inherent fertility and somewhat droughty.
	Dark grey brown sandy loams	Brown to dark grey brown sandy loams with no clay increase or with a gradual clay increase with depth. May have 15-35% clay. Overlies lime in nodular or massive (calcrete) forms at depth. Good internal drainage and good water holding properties. Non-saline.		
C	Deep phase		HIGH conventional flood irrigation feasible but sprinkler irrigation recommended.	HIGH reasonable inherent fertility
Cs	Shallow phase	Less than 30 inches soil depth to calcrete on rock	MODERATE limitation of shallow soil depth and recommended under sprinkler irrigation only.	MODERATE

TABLE 2 : (contd.)

Map Symbol	SOIL TYPE	GENERAL CHARACTERISTICS	POTENTIAL FOR IRRIGATED CROPS	POTENTIAL FOR DRYLAND CROPS
	Grey brown sands to loamy sands	Grey brown sands to loamy sands with a gradual to clear increase in clay content to 10-15% clay at 36 inches. Included in this unit are those soils with less than 15% clay in the upper horizons increasing with depth to 20%. Overlies lime at depth. Good internal drainage and low to moderate water holding capacity.		
Cl	Deep phase		MODERATE soil moisture properties less than optimal and recommended under sprinkler irrigation only.	MODERATE
Cls	Shallow phase	Less than 30 inches soil depth to calcrete on rock.	LOW limitations are shallow and variable soil depth.	LOW
D	Grey Sands	Loose grey to grey brown sands with less than 7% silt plus clay within the upper 36 inches, commonly less than 4% clay. Excessive internal drainage and very low water holding capacity. Occurs very extensively on the Inland Sand Plateau. Also included in this mapping unit are those loose grey sands of the river levees and Floodplain.	NIL exceptionally unfavourable soil moisture properties and very low inherent fertility.	NIL droughty and very infertile

TABLE 2 : (contd.)

Map Symbol	SOIL TYPE	GENERAL CHARACTERISTICS	POTENTIAL FOR IRRIGATED CROPS	POTENTIAL FOR DAYLAND CROPS
	Brown to yellowish brown sands	Brown sands which become yellowish brown with depth. Slightly loose and less than 10% clay. Excessive internal drainage and low water holding capacity.		
E1	Plateau phase	Brown to yellowish brown sands with less than 7% silt plus clay (commonly <4%). Occurs extensively on the Inland Sand Plateau.	LOW unfavourable soil moisture properties and somewhat excessive internal drainage	NIL droughty and very low inherent fertility
E2	Riparian phase	Brown to yellowish brown sands with 7-9% silt plus clay in the upper 36 inches. These sands have been separated from E1 due to physiographic position, topography and slightly higher clay content.	LOW less than optimal moisture properties and somewhat excessive internal drainage. Recommended under sprinkler irrigation only.	LOW somewhat droughty soil and low inherent fertility.
F	Black sandy loams of Omurambas and the Floodplain	Black sandy loam to sandy clay loam (commonly 6 - 12 ins. thick) abruptly overlying bleached coarse sands at between 6" and 36". Rapidly permeable but poor internal drainage; seasonally flooded. Due to a high silt content the upper material may be very slowly permeable at some sites.	LOW limitations of flooding and seasonal water table; special hydrophytic crops only.	NIL special hydrophytic crops only on selected sites.

TABLE 2 : (contd.)

Map Symbol	SOIL TYPE	GENERAL CHARACTERISTICS	POTENTIAL FOR IRRIGATED CROPS	POTENTIAL DRYLAND CROPS
G	Solonetz soils	Grey loose sands abruptly overlying a grey brown loamy fine sand to fine sandy loam at about 36 inches. This heaveier material becomes extremely hard when dry. Saline/sodic in the heavier material. Drainage impeded at about 36 inches.	NIL impeded internal drainage at abrupt transition will promote waterlogging and salinisation	LOW low fertility of sandy surface soil.
H	Black clays and fine textured soils of minor drainage lines.	Black clay soils overlying lime. Of very minor occurrence. Slowly permeable. Very firm consistence. Poor surface drainage.	LOW drainage hazard.	LOW poor drainage.
K	Reddish brown pan-veld sands	Brown to red brown aeolian sands with significantly higher coarse sand fractions. Less than 7% clay, commonly about 4%. Excessive internal drainage. Very low water holding capacity.	NIL very poor soil moisture properties and excessive internal drainage.	LOW somewhat droughty and low inherent fertility.

PHYSIOGRAPHIC REGIONS AND ASSOCIATED SOILS AND VEGETATION

In this chapter a brief outline of the classification and the general characteristics of the various physiographic regions and their components will be given; the relevant cartographic data are presented on a map at a scale of 1/250,000.

THE OKAVANGO RIVER TERRACE

The limits of the Terrace and the extent of the land considered suitable for intensive development are shown on the 1/250,000 map. The favourable geographical location of the Terrace in relation to the Okavango - a permanent source of water for domestic, stock and irrigation use - and the occurrence of favourable soils and terrain constitute an environment of outstanding potential for intensive agricultural development based on irrigation. Provided reasonable standards of irrigation management are maintained, no problem of drainage or salinisation are likely to develop. The distribution of the soils is shown in some detail on the 1/75,000 mosaics. Land use potential can be interpreted through the legend and the discussion on soils in the text and Table 2.

THE INLAND SAND PLATEAU

There is evidence to suggest that the Plateau is an erosion surface over which aeolian sands have been deposited. Seif dune formations are a striking feature of an otherwise monotonous sand plain; and of particular interest, is the system of parallel dunes and Omurambas. Variations in the depth and uniformity of the sand mantle were observed, probably due to some reworking by wind in very recent times.

These topographic features are normally correlated with soil differences, but in view of the uniformity of parent materials from which all the soils have been derived, variations in the basic soil characteristics are small. The sandy soils are uniformly low in clay content. Maximum soil differences occur in the Omurambas and their margins where the influence of the underlying terrace material is most pronounced.

Within the Inland Sand Plateau there are two physiographic units, the Seif Dune Formations and the Featureless Plains.

Seif Dune Formations

The seif dune formations have been differentiated on the form and degree of development of the dunes. Four types were recognised :

Map Unit 31: This unit consists of uneven dunes developed along the margin of the Okavango Terrace and the sides of the major tributaries. Omurambas are absent. Observations indicate the accumulation of deep sand deposits. Within this mapping unit - shown by the map symbol B1-E1 - areas of more level, even sloping Red and Brown Sands occur. Selected areas would be capable of exploitation through tranditional agricultural methods and it may be possible through research to extend irrigation onto portions of these soils. For the balance of Map Unit 31, the only utilisation could be low quality grazing for stock.

The remaining three types consist of variations of the Parallel Systems of Seif Dunes and Omurambas:

Map Unit 32 : System faintly discernible
Map Unit 33 : System clearly discernible
Map Unit 34 : Prominent dunes

Map Unit 32 : Here the parallel system of seif dunes and Omurambas is barely discernible. The Omurambas are few and normally poorly developed. The area consists predominantly of Grey Sands supporting Woodland Savanna suited only to extensive grazing.

Map Unit 33 : The system is clearly discernible but the dunes are normally small and discontinuous. The soils of the dune areas are Grey Sands with small sections of Brown Sands confined to the actual crests of the larger dunes. The majority of the Omurambas are well developed with a significant proportion of favourable soils. The latter soils would allow dryland arable production and settlement, the balance of the dune areas providing low quality grazing.

Map Unit 34 : The dunes are large and prominent; the crests of the dunes consisting of Red and Brown Sands. The tree canopy is usually open and these soils support a dense growth of fine stemmed Aristida grasses. The foot slopes and the flat margins of the dunes consist of loose Grey Sands. This margin is characteristic of all the parallel dune formations and is recognised both by the soils and the very open low Burkea africana – Terminalia sericea tree communities. Here the grass cover is very sparse, mainly Loudetia superba and fibrous Aristida spp. In this mapping unit the Omurambas are well developed with a significant proportion of favourable soils except in the southern section, where, although the Omurambas are wide there appears to be a secondary infilling of loose sand supporting short Terminalia-Bauhinia scrub which lowers the agricultural potential. The more favourable soils of the Omurambas would support dryland arable production and the balance of the Omurambas together with the Red and Brown sands of the dunes could provide medium quality grazing. The best prospects of settlement, based on dryland arable production supplemented by livestock production, would be found within this unit.

Flat Featureless Plains

Map Unit 41: This unit comprises large, incipient, poorly defined Omurambas within the extensive featureless Grey Sand areas. The drainage pattern is very diffuse. The Omurambas consist mainly of Grey Sands with areas of skeletal soils onto calcrete carrying a very sparse grass cover. Large termitaria mounds are prominent. Areas of more favourable soils are extremely limited and will support only localised settlement. The unit as a whole could be utilised only for very extensive livestock production.

Map Unit 42: This is the most extensive soil and vegetation type encountered. It consists of a uniform featureless terrain of Grey Sands with no Omurambas. The variations are the very occasional small depressions and isolated low mounds of Red and Brown Sands. The typical Woodland Savanna is characterised by the scattered well grown Guibourtica coleosperma. No potential exists for dryland arable production; the only feasible utilisation being very extensive stock production.

Map Unit 43: The characteristics and potential of this mapping unit are very similar to the previous unit. There is a very diffuse pattern of extensive, very flat, slight elevations carrying open Woodland Savanna and depressed areas carrying Scrub Savanna, presumed to be Terminalia sericea with Loudetia superba. No overall drainage pattern can be identified but very occasional incipient Omurambas occur, similar in character to those in Map Unit 41 (Grsy Sands and skeletal soils onto calcrete).

Map Unit 44: A faint hummocky relief is apparent. The soils are Brown Sands with Grey Sands occupying the depressed areas. Within this mapping unit isolated rises carrying well grown stands of Acacia giraffae and Combretum spps. occur. Omurambas are absent and no defined drainage pattern is evident. Certain of the isolated rises carrying well grown A. giraffae could provide sites for dryland arable production, but in general, and similar to the previous mapping units, the possibilities of permanent arable production are extremely limited. The only land use potential is very extensive livestock production.

Map Unit 45: This unit consists of a very flat plain supporting Bush Savanna and wide poorly defined Omurambas with numerous large deep waterholes. Extensive areas of Red and Brown Sands are encountered within the general Grey Sand areas. The soils vary slightly from the previous units in that the coarse sand fraction is higher. The deep waterholes and higher coarse sand fraction indicate the action of recent deflation and resorting by wind. The areas of Red and Brown Sands support Acacia – other species bush and scrub whilst the Grey Sands carry Terminalia–Burkea bush. Extensive areas of Grey Sands occur in the Omurambas with minor areas of more favourable soils. These latter areas would permit dryland arable production which might be extended onto portions of the Red Sands. Veld management would present particular problems in the control of scrub communities which have seriously suppressed the grass cover. In these communities, browse provides a valuable source of fodder, but any further increase in the density of bush will seriously reduce the carrying capacity.

OMURAMBAS

The Omurambas, although they now form the drainage depressions, have been formed by wind action and more recently by the removal of the sand mantle so that the underlying calcrete is now exposed or is encountered at relatively shallow depths. Various types of Omurambas have been recognised.

Well Developed Omurambas with significant areas of potential arable soils.

These are the most important of the Omurambas as they would allow dryland arable production and thus form the nucleus for settlement and the wider utilisation of the Inland Sand Plateau. The margins of the omurambas are outlined by a sloping section of hummocky, Brown Sands with termitaria mounds and well grown A. giraffae and Combretum spps. The centres are wide and level except for the water-holes which provide secondary relief. The more favourable soils, mainly Grey Brown Sands to Loamy Sands (Type C), are indicated by scattered well grown A. giraffae and a dense grass cover characterised by Schmidtia bulbosa, often with vigorous A. giraffae scrub regeneration. Associated with these better soils are the Grey Sands, normally onto calcrete at shallow depths, carrying a tall mixed sour grass cover, mainly Loudetia superba and fibrous Aristida spp. The waterholes consist of Black Clays with calcrete often outcropping along the margins.

Poorly Developed Omurambas

These Omurambas do not show the pronounced form or step down from the sides into the centre of the depression as so the previous ones. They are generally wide and very flat with little variation in height from the surrounding Grey Sand areas. The soils are predominantly Grey Sands with a sour grass cover. Included within this category are those Omurambas found in the southern portion of the prominent dune formations, Map Unit 34, containing extensive deposits of loose Red and Brown Sands.

Raised Omurambas

These are extensions of the well developed Omurambas which narrow down; the Brown Sand margins close to form this particular raised feature. They normally carry well grown A. giraffae.

Valley Cultivation

This is confined to the steeply sloping Brown and Red Sands of the valley sides of the major tributaries.

Terrace Cultivation

Isolated small pockets of Terrace soils are encountered along certain of the major tributaries. In general, all the tributaries are sharply incised and only minor sections of river terrace are found.

OVERALL ASSESSMENT OF THE AGRICULTURAL POTENTIAL

Okavangoland consists of two major agricultural regions: the River Terrace, suited to intensive agricultural development based on irrigation, and the Inland Sand Plateau, suited only to a very low intensity of land use. Development within the Inland Sand Plateau would comprise on the one hand: settlement centred on those omurambas with significant proportions of favourable soils supporting limited arable farming supplemented by livestock production, and on the other hand: very extensive livestock production for the remainder of the region where arable soils are rare or insignificant in area.

Intensive Agricultural Development - Irrigation

The Reconnaissance Soil Survey has demonstrated the outstanding irrigation potential of the River Terrace. Some 3,350 hectares can be recommended for immediate development, whereas another 34,970 hectares fall within the marginal class. The latter constitutes a class of land which has definite irrigation potential, though certain limitations exist which will need particular management techniques to accomplish the best possible economic exploitation in the long term. Distribution of water is facilitated by the even terrain and the favourable proximity and elevation of potential irrigable land in relation to the river. This potential should be developed as rapidly as possible within the limits of available capital, management skills and market outlets.

To achieve these objectives, a comprehensive Regional Plan, integrating the utilisation of the Terrace and adjoining Sand Plateau would be required to provide a blue print and priority sequences for co-ordinated development. Detailed soil, vegetation and topographic data regarding the people, their agriculture and land tenure, would be required. The physical data must be combined with engineering and economic studies to test feasibility. The very high inherent agricultural potential of this region warrants detailed planning. The possibilities of extending irrigation onto the plateau phases of the Red and Brown Sands will depend on research. Extensive areas of these soils adjoin the Okavango Terrace within reasonable command of the water supply. The other major occurrences of potential irrigable soils are the Red Sands of the major dunes (Map Symbol 34) and those within Map Unit 45. However, the fact that these latter soils are located some 45 to 65 miles from the Okavango River may constitute a prohibitive limitation.

Potential irrigable soils also occur within the well developed omurambas. In toto, the areas of the latter are considerable but the wide distribution and the distance of these soils from the water supply could inhibit their development. The scattered distribution and insignificant area of terrace soils along the major tributaries exclude them from serious consideration.

Expansion of Settlement based on Dryland Arable Production

Present settlement is confined to the margins of the Okavango River and along its tributaries where permanent water is available for both domestic and stock use. The cultivation of dryland millet (Pennisetum typhoides) provides the bulk of the staple food supplies. This arable production is supported by stock - cattle and goats - which utilise the grazing from fallow lands, crop residues and the adjoining sand country. Provided limitations of permanent water supplies are overcome then this pattern of settlement could be extended along the Well Developed Omurambas where significant proportions of favourable soils occur. The arable land in the omurambas would form the nucleus of arable farming and settlement, the balance of the omurambas and adjoining sand country being utilised for grazing. The most favourable sites are located in Map Unit 34, where the Red and Brown Sands of the prominent dunes provide the best grazing conditions for the supporting stock, followed in order of potential by Map Unit 33 and then, to a lesser extent, by Map Units 32 and 45.

The feasibility of establishing settlement within these areas is substantiated by the growth of settlement away from the Okavango River Terrace up the valleys of the major tributaries - shown on the map by the symbol VC - and settlements in the vicinity of the Dossa Pan where borehole supplies supplement existing water holes.

Expansion of Stock Farming - Very Extensive Production

Stock farming can be considered as either supplementary to arable production, as mentioned in the previous paragraphs, or entirely as ranching in areas where no alternative forms of agricultural development are feasible, namely: the extensive areas of Grey Sands - Map Units 41, 42, 43, 44 and portions of 45 and 32.

The utilisation of the Grey Sand areas will present particular problems. Careful management will be required to prevent veld deterioration. Capital expenditure for water points and fencing, essential to sound veld management, will be heavy relative to the low output that can be expected by virtue of the very low carrying capacities.

The determination of both the carrying capacity of the various vegetation types and the management systems required to maintain or improve the carrying capacity is pertinent. Our assessment of grazing potential is based on observations of the density and species composition of the grass cover and expressed as "carrying capacity" - the only practical measure of the productivity of natural veld. Our conclusions must be considered as tentative as they are not supported by detailed study.

Well Developed Omurambas with significant proportion of favourable soils	1 Livestock equivalent per 4 hectares
Poorly Developed and Poorly Defined Omurambas; predominantly Grey Sands	1 Livestock equivalent per 8 to 16 hectares
Red and Brown Sands with open tree canopy	1 Livestock equivalent per 8 hectares
Grey Sands	1 Livestock equivalent per 16 hectares

To maintain and improve the carrying capacity, clearly defined veld management practises will have to be implemented. These practises should be guided by the general principles of veld management applicable to bushveld conditions where bush encroachment constitutes a permanent threat to the effective use of the land for grazing. Some of the important criteria are : periodic full growing season rest from time to time to build up root reserves and allow re-seeding, followed by burning to even up and maintain the density of the grass cover in relation to the trees and bush. In general, a light stocking rate is advocated to promote accumulation of litter and an effective burn. A late burn, following a full season's rest would be required at least once in four years.

Fire, under these extensive systems of land use is the only effective means of modifying and improving the habitat and the only economic means of containing bush encroachment. It was observed that extensive damage had been done to all vegetation communities, even in areas of mature woodland characterised by very large Guibourtica coleosperma. It was concluded that the fire damage to the mature trees could only have occurred after several seasons of complete protection as the grass cover in these communities is very sparse.

The need for the introduction of recognised systems of veld management has been stressed. Veld management should be implemented as and when new areas are opened for stock by the provision of water supplies. Without control, a pattern of continuous selective grazing will develop around each water point. Initially, these new areas will support a relatively high stocking rate but after 4 - 5 years, the carrying capacities can be expected to decrease rapidly, a direct result of the deterioration in the vigour of the grass cover. The weakening of the grass communities will lead to aggressive bush encroachment which will be difficult, if not impossible, to control in the absence of a vigorous grass cover. Fencing and correctly sited water points must be provided before veld management can be applied. The only other alternative is through the periodic suspension of water supplies on a rotational basis as a means of discouraging overgrazing.

The assessment of the grazing potential of the various vegetation communities of the Inland Sand Plateau will require well planned field studies to derive simple criteria for grazing valuation. In view of the vast areas involved, rapid reconnaissance methods must be evolved. The only practical means is through establishing soil/vegetation correlations.

It can be expected that production and responses to management practises will be closely linked with the clay plus silt content of the various sands. It will be necessary to establish threshold values where satisfactory responses can be expected. It appears that in parts of the Grey Sand areas these responses may be so low that their economic exploitation by stock may not be feasible. In general, the gradation in clay plus silt is from the Red Sands, through the Brown Sands to the Grey Sands where the combined percentage may drop to below 2%.

According to observations, three general grass associations were recognised; the most favourable grass cover occurring in areas of Red Sands. Within Map Unit 34, a vigorous dense stand of fine stemmed Aristida spp. has developed within open areas on the prominent Red Sand dunes. On similar soils on the dune slopes, bordering the Okavango River on the eastern bank near the Botswana border, dense tall stands of Dactylitineum spp. were seen in areas where fire had severely damaged open Acacia giraffae woodland. On the Red and Brown Sand associations, a mixed grassland with various Aristida, Digitaria and other species, as well as regular communities of Schmidtia bulbosa were observed. On the Grey Sands similar species composition and forms were noted but the tall fibrous Aristida spp. are more prominent and the grass cover sparser. On the road to the Dossa Pan, striking variations in vegetation form were observed on the Grey Sands. These changes were attributed to fire effects. Within the Burkea africana community, various Eragrostis, Aristida, Digitaria spps. and scattered Loudetia spp. were present. Total production appeared to be low though the grasses had been readily grazed by stock. Immediately adjacent was open grassland with nearly pure stands of Loudetia superba and scrub Terminalia sericea. Stock had regularly passed through this community but had not grazed it at all. Through the elimination of the tree canopy, a low carrying capacity had been reduced to zero. Very extensive areas of short scrub occur within Map Units 43, 44 and 45. The Terminalia/Bauhinia scrub of the Grey Sands gives way to Acacia giraffae other species on the Brown Sands.

These cursory recordings indicate different responses to fire by the various vegetation communities on the different soils. On the Red Sands, the removal of the trees can lead to an increase in carrying capacity whilst on the Grey Sands the opposite may result. These casual observations stress the need for a functional vegetation classification. Assessment of the reaction of the various vegetation communities to specific management practises, particularly fire, and the determination of the successional stages that will provide the highest sustained production are ecologically important.

The successful exploitation of the Inland Sand Plateau will depend upon detailed ecological studies. Problems of veld management that can be expected have been stressed. Production is limited by the low inherent fertility of the soils; management is complicated by the natural tendency of the vegetation, under these climatic and soil conditions, to change rapidly towards bush and tree communities. However, this area falls within a favourable rainfall zone for stock farming and an assured annual production can be obtained from the natural vegetation.

Forestry : alternative forms of Land Use

Within the Inland Sand Plateau, dryland arable production supplemented by stock, as well as extensive ranching have been proposed. In the latter case, attention has been directed at the problems of managing the natural vegetation to ensure stable production and the possible limitations imposed on economic development through the low unit production.

Forestry, through the exploitation of the naturally occurring timber trees, would appear to provide the only other or supplementary form of commercial land use. The low eratic rainfall precludes the establishment of plantations of exotic timbers. Pterocarpus angolensis is the only recognised timber tree of commercial size occurring in Okavangoland. Ricinodendron rautanenii may offer limited possibilities for exploitation; both for nuts and for the timber, which has been reported to be a suitable filler for plywood and a substitute for balsa. Baikaiea plurijuga, Terminalia sericea and Burkea africana - normally medium to small trees - are, with treatment suitable only for fencing poles. Guibourtica coleosperma, the largest tree, has a short multi-stemmed trunk of little or no commercial value. The most important forestry management practice would be fire control, though there is a clash between the management needs of rancing and forestry. With respect to veld management, periodic late hot burns are required, say in October/November, when the most damage can be inflicted on scrub and tree growth, the aim being the control of bush encroachment. Pterocarpus angolensis and Ricinodendron rautenenii are two fire resistant species and experience may show that they would be able to tolerate such a controlled fire policy, particularly since grazing would limit the excessive build up of litter. Severe fire damage was observed in all vegetation types but it was concluded that this was the result of accidental late hot fires following a prolonged period of complete protection and the accumulation of an abnormally large bulk of litter. Such severe fires can have disastrous consequences, both for vegetation and game. To overcome this fire hazard, regular early burning - that is, patch burning - as early in the season as possible, has been found successful in open savanna woodland in other parts of central Africa. There it was found impossible to render fire protection completely effective and early burning did not seriously damage tree growth.

The role of a forestry industry in the overall land use plan for the region is debatable. We consider that rancing should be given preference in the allocation of the use of land, especially in areas where stock can supplement arable production. In the event of a clash between forestry and grazing, we recommend land management to enhance the grazing potential at the expense of forestry. For the remainder of the area where general potential is low there is a choice between extensive stock production and forestry or forestry management pro tem until the land can be brought into a higher form of use. In relation to fire control this dual system would imply fire protection and occasional late hot burns in ranching areas and early burning in the remaining of "forestry" areas. It is appreciated that fire control and land use policy in relation to the competing needs of agriculture, grazing, forestry, game and the Bushmen in the Inland Sand Plateau is a complex problem. Forestry's role would include not only the commercial exploitation of timber but of equal, or greater importance, also the protection and management of those areas where the natural productive potential is so low that development will be delayed or precluded for economic reasons. Fire, in this open woodland savanna is an ever present hazard, but by its judicious application it can be a very important and effective tool with which to modify and improve the habitat.

MAP SYMBOL : D — GREY SANDS — TEST PIT No. 21

Site: On river levee; 75 yards from Okavango River

Parent Material: Alluvium/aeolian sand on Tertiary limestone

Sample No.	Horizon	Depth (in.)	Description
F174	A1	0 - 14	(10YR 3/2) very dark greyish brown; fine sand; apedal; soft consistence; very rapid permeability; gradual transition
F175	AC	14-34	(10YR 4/2) dark greyish brown; fine sand; apedal; soft to loose consistence; very rapid permeability; gradual transition
F176	C1	34-64	(10YR 5/3) brown; fine sand; apedal; loose consistence; very rapid permeability; abrupt transition
F177	C2ca	64-70	(10YR 7/3) very pale brown; loamy fine sand; apedal; slightly hard consistence; very rapid permeability; rare soft $CaCO_3$ accumulations

ANALYTICAL DATA

Sample No.	F174	F175	F176	F177
Depth in.	0-14	14-34	34-64	64-70
Horizon	A1	AC	C1	C2ca
Particle size distribution (%)				
c. sand	3.1	4.0	3.1	3.7
m. sand	27.4	31.4	21.8	23.8
f. sand	63.8	59.6	69.8	60.4
silt	2.8	1.5	2.2	2.5
clay	2.4	2.5	3.3	9.6
pH.H_2O	7.4	7.7	7.7	8.0
Ohms R 60°F	2000	2200	2250	2700

MAP SYMBOL : F

BLACK SANDY LOAMS OF OMURAMBAS AND FLOODPLAIN

AUGER SITE No. 30

Site: On bank of Okavango River at F.C.U. Jute scheme

Parent Material: Alluvium

Sample No.	Horizon	Depth (in.)	Description
T179	A1	0 - 6	(10YR 2/1) black; silty clay; apedal; hard consistence; few worm casts; slow permeability; gradual transition
	AC	6-12	(10YR 2/1) black; clay; apedal; hard consistence; slow permeability; gradual transition
T180	C1g	12-24	(10YR 3/1) very dark grey; clay; weak coarse blocky structure; firm consistence; weak slickensides; slow permeability; gradual transition
	C2g	24-30	(N4/0) dark grey; clay; apedal; plastic consistency; abundant distinct fine (5YR 4/6) yellowish red mottles; very slow permeability; abrupt transition
	W.T.(C3)	30 +	Sand and free water

ANALYTICAL DATA

Sample No.	T179	T180
Depth in.	0-12	12-24
Horizon	A1	C1g
Particle size distribution (%)		
c. sand	0.1	2.3
m. sand	2.5	1.5
f. sand	14.0	8.7
silt	28.9	17.0
clay	54.6	69.9
Net extractable cations (me/100 gm.)		
Na	0.30	0.30
K	0.20	0.40
Ca	10.10	11.10
Mg	8.85	18.75
S. value	19.45	30.55
T. value/C.E.C.	23.45	29.65
C.E.C. clay	43	42
pH.H_2O	5.2	6.3
Ohms R 60°F	1000	285

MAP SYMBOL : B2 — RED SANDS — TEST PIT No. 2

Site: On 60 ft. terrace; 1 - 2% slope

Parent Material: Aeolian sand on terrace material

Sample No.	Horizon	Depth (in.)	Description
F91	A1	0-11	(5YR 3/4) dark reddish brown; sand; apedal; soft consistence; very rapid permeability; rare distinct brown inclusions; gradual transition.
F92	B21	11-30	(5YR 5/6) yellowish red; sand; apedal; soft consistence; very rapid permeability; rare distinct brown inclusions; gradual transition
F94	B22	30-48	(2.5YR 5/6) red to (5YR 5/6) yellowish red; sand; apedal; soft consistence; rapid permeability; rare distinct brown inclusions; rare sub-angular fine quartz gravel; gradual transition
F95	B23+C	48-72	(5YR 5/6) yellowish red; sand; apedal; friable consistence; rare distinct brown inclusions; rare sub-angular fine quartz gravel. Included in this horizon is a lens, of small sub-angular quartz stones and laterite fragments, in which stratification is evident. This lens dips from 56 inches to 72 inches

ANALYTICAL DATA

Sample No.	F91	F92	F94	F95
Depth in.	0-11	11-30	30-48	48-72
Horizon	A1	B21	B22	B23/C
Particle size distribution (%)				
c. sand	6.1	5.4	7.3	7,1
m. sand	46.6	39.8	43.9	39.6
f. sand	40.4	47.0	40.7	43.6
silt	2.6	3.0	2.7	2.0
clay	4.2	5.7	6.3	7.6

MAP SYMBOL : A1 RED LOAMY SANDS OF THE TERRACE - DEEP PHASE TEST PIT No. 101

Site: On 20 ft. terrace; old land

Parent Material: Aeolian sand on terrace material

Sample No.	Horizon	Depth (in.)	Description
T22	A1	0-12	(5YR 4/6) yellowish red; sand; apedal; soft consistence; frequent fine grit; rapid permeability; gradual transition
T23	B21	12-32	(5YR 4/8) yellowish red; loamy sand; apedal; soft consistence; frequent yellow inclusions; frequent fine grit; rapid permeability; gradual transition
T24	B22	32-44	(5YR 4.5/8) yellowish red; loamy sand; apedal; soft consistence; frequent fine grit; few small sub-angular stones; rapid permeability; abrupt wavy transition
	C	44-60+	Slightly loose mass of rounded and sub-angular stones and Fe/Mn concretions in a yellowish red sandy loam matrix

ANALYTICAL DATA

Sample No.	T22	T23	T24
Depth in.	0-12	12-32	32-44
Horizon	A1	B21	B22
Particle size distribution (%)			
c. sand	10.5	13.0	11.7
m. sand	37.0	30.1	37.3
f. sand	44.1	33.9	36.6
silt	2.6	2.9	2.9
clay	6.5	11.0	11.9
Net extractable cations (me/100 gm.)			
Na	0.10	0.15	0.10
K	0.20	0.45	0.10
Ca	0.65	1.70	1.45
Mg	0.30	0.65	0.70
S. value	1.25	2.95	2.35
T. value/C.E.C.	0.70	3.75	1.85
C.E.C. clay	11	34	16
pH.H_2O	5.5	6.1	5.2
Ohms R 60°F	9200	3500	4700

MAP SYMBOL : As — RED LOAMY SANDS OF THE TERRACE - SHALLOW PHASE — TEST PIT No. 27

Site: On 15 ft. terrace; 100 yards from river; 1% slope

Parent Material: Terrace material

Sample No.	Horizon	Depth (in.)	Description
F13	Ap	0- 6	(5YR 3/2) dark reddish brown; fine sandy loam; apedal; hard consistence; rapid permeability; clear transition
F14	B2	6-18	(5YR 3/3) dark reddish brown; fine sandy loam; weak blocky structure; hard consistence; moderate permeability; abrupt transition
	C	18 +	Semi-continuous $CaCO_3$ in a dark reddish brown sandy clay loam matrix

ANALYTICAL DATA

Sample No.	F13	F14
Depth in.	0-6	6-18
Horizon	Ap	B2
Particle size distribution (%)		
c. sand	3.3	5.0
m. sand	24.9	27.5
f. sand	54.2	46.2
silt	6.8	6.1
clay	11.9	15.8
texture	SaLM	SaLm
Net extractable cations (me/100 gm.)		
Na	0.10	0.05
K	0.10	0.10
Ca	4.90	
Mg	6.80	
S. value	11.90	
T. value/C.E.C.	12.30	11.90
C.E.C. clay	103	75
$pH.H_2O$	7.1	7.3
Ohms R 60°F	1000	950

MAP SYMBOL : A2 RED SANDY LOAMS OF THE TERRACE TEST PIT No. 3

Site: On 20 ft. terrace; 2% slope

Parent Material: Aeolian sand on terrace material

Sample No.	Horizon	Depth (in.)	Description
F87	A1	0-14	(7.5YR 4/4) brown to dark brown; loamy fine sand; apedal; slightly hard; rapid permeability; gradual transition
F88	B21	14-27	(5YR 4/8) yellowish red; sandy loam; apedal; firm consistence; rare faint brown inclusions; rapid permeability; rare termite channels; gradual transition
F89	B22	27-49	(5YR 4/6) yellowish red; fine sandy loam to sandy clay loam; apedal; friable consistence; frequent distinct brown inclusions - old termite channels; rapid permeability; gradual transition
F90	B23	49-63	(5YR 4/6) yellowish red; sandy loam; apedal; friable consistence; rapid permeability; abrupt wavy transition
	C	63-83	Slightly loose mass of laterite fragments and small sub-angular quartz stones, with thin $CaCO_3$ encrustations, in a yellowish brown sandy loam matrix

ANALYTICAL DATA

Sample No.	F87	F88	F89	F90
Depth in.	0-14	14-27	27-49	49-63
Horizon	A1	B21	B22	B23
Particle size distribution (%)				
c. sand	7.4	7.7	7.3	7.2
m. sand	35.9	38.3	32.6	31.9
f. sand	45.0	32.0	37.7	37.9
silt	3.4	4.3	3.4	5.2
clay	9.9	17.5	19.0	18.8
Net extractable cations (me/100 gm.)				
Na	0.05	0.10	0.10	0.10
K	0.15	0.20	0.15	0.20
Ca	1.20	1.30	1.45	2.00
Mg	0.10	1.20	0.45	0.70
S. value	1.50	2.80	2.15	3.00
T. value/C.E.C.	2.25	6.95	5.65	2.90
C.E.C. clay	23	40	30	15
pH.H_2O	5.2	5.0	4.8	5.1
Ohms R 60°F	>10,000	4000	6100	5750

MAP SYMBOL : C1 GREY BROWN SANDS TO LOAMY SANDS TEST PIT No. 17

Site: On 15 ft. terrace; 3% slope

Parent Material: Old alluvium on basement Tertiary limestone

Sample No.	Horizon	Depth (in.)	Description
F147	Ap	0- 8	(10YR 3/1.5) very dark greyish brown; loamy fine sand; apedal; soft consistence; very rapid permeability; gradual transition
F148	B21	8-20	(10YR 4/1.5) dark greyish brown; loamy fine sand; apedal; soft consistence; very rapid permeability; gradual transition
F149	B22	20-31	(10YR 4/2) dark greyish brown; loamy fine sand; apedal; soft consistence; rare fine soft $CaCO_3$ accumulations; rapid permeability; gradual transition
F150	B3	31-40	(10YR 4/2) dark greyish brown; fine sandy loam; apedal; soft to slightly hard consistence; rare small $CaCO_3$ concretions; rapid permeability; clear transition
	Cca	40-52+	(10YR 5/3) brown; gravelly fine sandy loam; apedal; soft consistence; abundant $CaCO_3$ concretions forming in the lower part, a semi-continuous vesicular limepan

ANALYTICAL DATA

Sample No.	F147	F148	F149	F150
Depth in.	0-8	8-20	20-31	31-60
Horizon	Ap	B21	B22	B3
Particle size distribution (%)				
c. sand	4.9	3.5	5.5	4.7
m. sand	31.2	32.5	29.5	27.3
f. sand	52.7	52.0	53.9	51.0
silt	1.9	2.5	2.5	4.7
clay	8.8	9.2	8.8	12.2
Net extractable cations (me/100 gm.)				
Na	0.10	0.10	0.15	0.15
K	0.10	0.10	0.10	0.10
Ca	5.30	(		)
Mg	0.20	(	not determined	)
S. value	5.70	(		)
T. value/C.E.C.	4.60	5.05	7.70	4.30
C.E.C. clay	52	55	87	35
pH. H_2O	7.5	7.8	7.6	7.7
Ohms R 60°F	2000	2250	2100	2500

MAP SYMBOL : C — DARK GREY BROWN SANDY LOAMS – DEEP PHASE — TEST PIT No. 16

Site: On 15 ft. terrace; 4% slope; numerous large anthills

Parent Material: Old alluvium on basement Tertiary limestone

Sample No.	Horizon	Depth (in.)	Description
F143	A1	0- 8	(10YR 3/2) very dark grey brown; fine sandy loam; apedal to weak very coarse blocky structure; hard consistence; rapid permeability; gradual transition.
	B21	8-16	(10YR 3/2) very dark grey brown; fine sandy loam; apedal to weak blocky structure; slightly hard consistence; rare soft white $CaCO_3$ accumulations; rapid to moderate permeability; gradual transition
F144	B22ca	16-38	(10YR 3/2) very dark grey brown; sandy clay loam; apedal to weak blocky structure; soft to slightly hard consistence; frequent fine $CaCO_3$ concretions and fine mycelia; moderate permeability; gradual transition
F145	B3ca	38-54	(10YR 4/3) dark grey brown; sandy clay loam; apedal to weak blocky structure; hard consistence; rare $CaCO_3$ concretions; frequent mycelia; moderate permeability; gradual transition
F146	C	54-78	(10YR 6/3) pale brown; gravelly sandy clay loam; apedal; soft to slightly hard consistence; abundant small $CaCO_3$ concretions; moderate to rapid permeability

ANALYTICAL DATA

Sample No.	F143	F144	F145	F146
Depth in.	0-16	16-38	38-54	57-78
Horizon	AB	B21	B3ca	C
Particle size distribution (%)				
c. sand	9.0	8.0	6.3	5.5
m. sand	24.7	23.4	20.8	18.0
f. sand	44.6	45.5	37.5	34.7
silt	6.4	7.0	11.3	10.8
clay	16.6	17.4	22.7	29.9
Net extractable cations (me/100 gm.)				
Na	0.20	0.20	0.20	0.20
K	0.30	0.20	0.25	0.25
Ca	(			)
Mg	(	not determined		)
S. value	(			)
T. value/C.E.C.	6.90	6.35	5.80	5.70
C.E.C. clay	42	37	26	19
$pH.H_2O$	7.9	7.7	7.6	7.7
Ohms R 60°F	1400	1420	1500	1550

MAP SYMBOL : Cs   DARK GREY BROWN SANDY LOAMS - SHALLOW PHASE   TEST PIT No. 23

Site: Dissected 15 ft. terrace; lower slope; 4% slope

Parent Material: Old alluvium overlying basement Tertiary limestone

Sample No.	Horizon	Depth (in.)	Description
F182	Ap	0- 8	(10YR 3/2) very dark greyish brown; fine sandy loam; apedal to weak blocky structure; slightly hard consistence; rapid permeability; gradual transition
F183	B21	8-24	(10YR 3/2) very dark greyish brown; sandy clay loam; weak fine blocky structure; slightly hard consistence; rare fine mycelia; rapid to moderate permeability; gradual transition
F184	B22ca	24-36	(10YR 4/2) dark greyish brown; sandy clay loam; weak fine blocky; slightly hard consistence; frequent soft and hard $CaCO_3$ nodules; rapid to moderate permeability; gradual to clear transition
	Cca	36 +	Semi-continuous $CaCO_3$ nodules in a grey brown sandy clay loam matrix

ANALYTICAL DATA

Sample No.	F182	F183	F184
Depth in.	0-8	8-24	24-36
Horizon	Ap	B21	B22ca
Particle size distribution (%)			
c. sand	2.0	1.9	1.9
m. sand	13.1	11.4	9.2
f. sand	60.7	57.3	53.8
silt	7.3	9.3	10.8
clay	17.0	20.9	25.5
Net extractable cations (me/100 gm.)			
Na	0.05	0.15	0.05
K	0.15	0.10	0.10
Ca	2.25	(	)
Mg	9.40	(not determined	)
S. value	11.80	(	)
T. value/C.E.C.	13.15	11.00	6.75
C.E.C. clay	77	53	26
pH.H_2O	7.7	7.6	7.5
Ohms R 60°F	1850	1600	1500

MAP SYMBOL : H | BLACK CLAYS | AUGER SITE No. 12

Site: Slightly depressed area on 20 ft. terrace in S.W.A. - B.P. border trace.

Parent Material: Alluvium

Sample No.	Horizon	Depth (in.)	Description
F162	A1	0- 6	(10YR 4/1) dark grey; sandy clay loam; weak coarse blocky structure; hard consistence; weak self-mulching properties; abundant surface cracks; weak crusting; slow permeability; gradual transition
F163	C1	6-12	(10YR 4/1) dark grey; clay; weak coarse blocky structure; extremely hard consistence; rare fine $CaCO_3$ concretions; slow permeability
F164	C2	12-24	(10YR 4/1) dark grey; sandy clay loam; moderate coarse blocky structure; very firm consistence; weak slickensides; frequent fine $CaCO_3$ concretions; slow permeability

ANALYTICAL DATA

Sample No.	F162	F164
Depth in.	0-6	12-24
Horizon	A1	C2
Particle size distribution (%)		
c. sand	3.4	5.6
m. sand	26.8	26.4
f. sand	26.8	26.2
silt	12.5	8.2
clay	31.8	34.6
Net extractable cations (me/100 gm.)		
Na	0.10	0.85
K	0.65	0.25
Ca	14.00	24.70
Mg	10.90	3.35
S. value	25.65	29.15
T. value/C.E.C.	26.35	25.50
C.E.C. clay	83	74
pH.H_2O	7.1	7.1
Ohms R 60°F	465	400

MAP SYMBOL : H | FINE TEXTURED SOILS OF MINOR DRAINAGE LINES | TEST PIT No. 28

Site: Dissected 15 ft. terrace; in drainage line; 1% slope

Parent Material: Alluvium

Sample No.	Horizon	Depth (in.)	Description
F15	A1	0- 8	(10YR 3/1) very dark grey; loam with stratified lenses of brown fine sand and an overburden of pale brown sand; apedal; slightly hard consistence; moderate permeability; abrupt transition
F16	A1b	8-20	(10YR 2/1) black; loam; weak coarse blocky structure; slightly firm to firm consistence; slow permeability; gradual transition
F17	C1	20-30	(10YR 3/1) very dark grey; sandy clay loam; weak to moderate coarse blocky structure; slightly firm consistence; rare weakly formed slickensides; slow permeability; gradual transition
F18	C2	30-40	(10YR 3/1) very dark grey; sandy clay loam; weak coarse blocky structure; firm consistence; rare soft $CaCO_3$ accumulations; slow permeability

ANALYTICAL DATA

Sample No.	F15	F16	F17	F18
Depth in.	0-8	8-20	20-30	30-40
Horizon	A1	A1b	C1	C2
Particle size distribution (%)				
c. sand	4.0	5.0	4.8	5.4
m. sand	17.0	19.4	16.0	18.4
f. sand	38.6	38.6	35.6	33.2
silt	24.2	21.4	12.2	13.0
clay	16.6	16.2	31.6	31.1
Net extractable cations (me/100 gm.)				
Na	0.10	0.10	0.05	0.05
K	0.65	0.35	0.25	0.25
Ca	23.00	24.00	22.40	19.90
Mg	0.60	1.60	2.40	5.40
S. value	24.35	26.05	25.10	25.60
T. value/C.E.C.	26.45	26.95	22.60	19.90
C.E.C. clay	159	166	72	64
pH.H_2O	7.0	7.2	7.1	7.5
Ohms R 60°F	400	410	475	460

MAP SYMBOL : B1 RED SANDS - PLATEAU PHASE TEST PIT No. 18

Site: On 60 ft. terrace covered by seif dune; 3% slope

Parent Material: Aeolian sand

Sample No.	Horizon	Depth (in.)	Description
F153	A11	0-12	(5YR 4/3) reddish brown; sand; apedal; soft consistence; very rapid permeability; gradual transition
F154	A12	12-30	(5YR 4/4) reddish brown; sand; apedal; soft consistence; very rapid permeability; gradual transition
F155	B21	30-78	(5YR 5/8) yellowish red; loamy sand; apedal; soft consistence; very rapid permeability; clear transition
	C	78 +	Laterite boulders, terrace gravels and artifacts in a yellowish red loamy fine sand matrix

ANALYTICAL DATA

Sample No.	F153	F154	F155
Depth in.	0-12	12-30	20-78
Horizon	A11	A12	B2
Particle size distribution (%)			
c. sand	2.0	2.1	1.6
m. sand	45.7	43.2	39.7
f. sand	48.1	51.7	53.3
silt	1.0	1.7	1.7
clay	2.7	3.0	3.1

MAP SYMBOL : E1 BROWN TO YELLOWISH BROWN SANDS - PLATEAU PHASE TEST PIT No. 219

Site: Flat aeolian plain

Parent Material: Aeolian sand

Sample No.	Horizon	Depth (in.)	Description
T110	A1	0-12	(10YR 5/2) grey brown; sand; apedal; loose consistence; very rapid permeability; gradual transition
T111	B21	12-30	(10YR 6/4) light yellowish brown; sand; apedal; loose consistence; very rapid permeability; gradual transition
T112	B22	30-60	(10YR 7/6) yellow; sand; apedal; loose consistence; very rapid permeability

ANALYTICAL DATA

Sample No.	T110	T111	T112
Depth in.	0-12	12-30	30-60
Horizon	A1	B21	B22
Particle size distribution (%)			
c. sand	2.3	2.3	2.1
m. sand	54.6	50.9	46.1
f. sand	40.6	44.6	48.9
silt	1.2	0.9	0.3
clay	2.1	1.8	2.3
Net extractable cations (me/100 gm.)			
Na	0.10	0.10	0.10
K	0.05	0.00	0.00
Ca	0.75	0.35	0.35
Mg	0.00	1.15	0.05
S. value	0.90	0.60	0.50
T. value/C.E.C.	0.65	0.40	0.50
C.E.C. clay	33	22	22
pH.H_2O	6.0	6.3	6.1
Ohms R 60°F	10,000	>10,000	>10,000

MAP SYMBOL : D | GREY AEOLIAN SANDS | AUGER BORING No. 44

Site: On flat featureless plain; 16 miles south of Gaudam

Parent Material: Aeolian sand

Sample No.	Horizon	Depth (in.)	Description
T154	A1	0-10	(10YR 4/1) dark grey; sand; apedal; loose consistence; very rapid permeability; gradual transition
T163	C	10-48	(10YR 5/2) greyish brown; sand; apedal; loose consistence; very rapid permeability

ANALYTICAL DATA

Sample No.	T154	T163
Depth in.	0-10	10-48
Horizon	A1	C
Particle size distribution (%)		
c. sand	2.7	3.7
m. sand	51.0	42.5
f. sand	43.0	52.1
silt	1.7	1.4
clay	2.2	0.5

MAP SYMBOL : G | SOLONETZ SOILS | TEST PIT No. 10

Site: Flat aeolian sand plain; diffuse surface drainage

Parent Material: Aeolian sand overlying terrace material

Sample No.	Horizon	Depth (in.)	Description
F125	A1	0- 8	(10YR 3/1) very dark grey; sand; apedal; soft consistence; very rapid permeability; gradual to clear transition
F126	A2	8-28	(10YR 6/2) light brownish grey; sand; apedal; soft consistence; rare fine strong brown mottles; very rapid permeability; abrupt transition
F127	B21	28-40	(2.5Y 5/2) grey brown; sand to loamy fine sand; weak very coarse prismatic structure; firm (moist) to extremely hard (dry) consistence; sand coatings on prism surfaces; rare fine black Fe concretions; rare faint fine strong brown mottles; moderate permeability; gradual transition
F128	B22	40-58	(2.5Y 6/2) light brownish grey; loamy fine sand; weak very coarse prismatic breaking to weak very coarse blocky structure; slightly firm (moist) to extremely hard (dry) consistence; rare faint fine strong brown mottles; moderate permeability; gradual transition
F129	B3	58-70	(2.5Y 6/2) light brownish grey; sandy loam; apedal; friable to slightly firm; few faint fine strong brown mottles; rare soft $CaCO_3$ concretions; moderate permeability; clear transition
F130	Cca	70 +	(2.5Y 7/2) light grey; sandy loam; apedal; soft consistence; abundant $CaCO_3$ concretions; rapid permeability

ANALYTICAL DATA

Sample No.	F125	F126	F127	F128	F129	F130
Depth in.	0-8	8-28	28-40	40-58	58-70	70-100
Horizon	A1	A2	B21	B22	B3	Cca
Particle size distribution (%)						
c. sand	4.9	6.4	6.1	6.5	5.8	5.4
m. sand	61.1	58.8	54.3	48.6	45.6	41.0
f. sand	30.3	32.0	30.1	28.3	29.4	33.8
silt	2.8	1.3	2.9	2.2	3.2	6.3
clay	2.2	1.6	6.8	13.6	15.3	12.9
Net extractable cations (me/100 gm.)						
Na	0.05	0.05	0.15	0.10	0.20	0.15
K	0.05	0.00	0.35	0.25	0.25	0.10
Ca	0.85	0.60	3.60	3.75	(	)
Mg	1.10	0.20	1.30	6.60	(not determined	
S. value	2.00	0.85	5.40	10.70	(	)
T. value/C.E.C.	0.80	2.00	5.10	10.10	3.60	6.60
C.E.C. clay	36	125	75	74	24	51
pH.H_2O	7.0	7.8	6.1	5.9	7.0	7.6
Ohms R 60°F	6250	6000	2750	1600	850	1500

MAP SYMBOL : K REDDISH BROWN PAN-VELD SANDS AUGER SITE No. 49

Site: Flat plain; near edge of aeolian sand - peneplain contact; in vicinity of blow holes which have become waterholes.

Parent Material: Re-sorted aeolian sand

Sample No.	Horizon	Depth (in.)	Description
T184	A1	0-15	(7.5YR 4/4) brown to dark brown; sand; apedal; loose consistence; very rapid permeability; gradual transition
T185	B2	15-48	(5YR 4.5/6) yellowish red; sand; apedal; loose consistence; very rapid permeability

ANALYTICAL DATA

Sample No.	T184	T185
Depth in.	0-15	15-48
Horizon	A1	B2
Particle size distribution (%)		
c. sand	15.4	16.3
m. sand	35.6	31.2
f. sand	40.4	47.5
silt	4.0	2.6
clay	3.8	4.3
Net extractable cations (me/100 gm.)		
Na	0.20	0.30
K	0.05	0.05
Ca	0.25	0.05
Mg	0.75	0.20
S. value	1.25	0.60
T. value/C.E.C.	0.85	2.30
C.E.C. clay	22	53
pH.H_2O	5.1	4.3
Ohms R 60°F	410	575