Soils and Land Evaluation of the Lake Ngami Region in Northwestern Botswana

by

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INTRODUCTION

In April 1982 the soil surveyor began a 1 year posting to Maun, in Northwestern Botswana, to initiate the reconnaissance level soil mapping of the region under the FAO-UNDP project BOT/80/003 - Soil Mapping and Advisory Services. He formed part of a team working towards mapping the soils of the entire country at the scale of 1:250,000, and became a coopted member of the Regional Agricultural staff in Maun. His primary duties were to describe, classify and map the soils of the area, prepare short demonstration courses for resource officer trainees on the identification of important field characteristics of soils and their relevance to crop production, and to train counterpart staff in all aspects of field and office soil survey operations.

The lack of information concerning the soils of Botswana became especially apparent in the late 70's during the planning stage of the Arable Land Development Programme (ALDEP). Earlier soil survey reports have produced only generalized soils information. In Northwestern Botswana, some of the soils have been described by Siderius (1971) and Staring (1978), including land evaluation for defined land use activities. SWECO (1976), in a study of water development in the Okavango Delta, evaluated the potential (soil, water, availability and costs) of specific areas for irrigated agriculture. The Government of Botswana realized, however, that a systematic and comprehensive soils inventory and land evaluation were necessary for sound agricultural land planning and development.

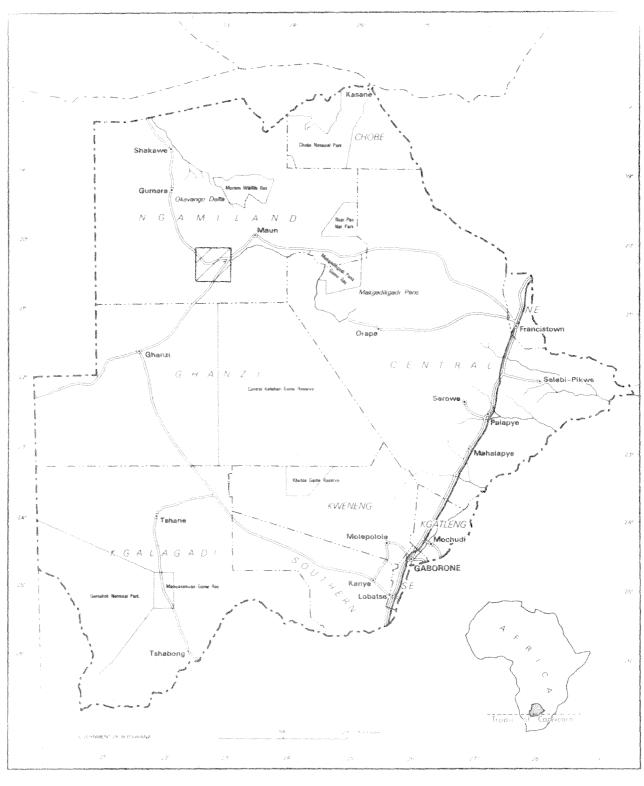
This report does by no means represent the work that is needed to complete the survey of Northwestern Botswana, but covers only a fraction of the area. It is a preliminary document, pending the completion of the project. It is hoped that the progress achieved by the survey team as a whole will greatly facilitate the acquisition and evaluation of soils data by the soil surveyors to come.

M. PAUL FAO SOIL SURVEYOR MAUN APRIL 1983

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LOCATION MAP





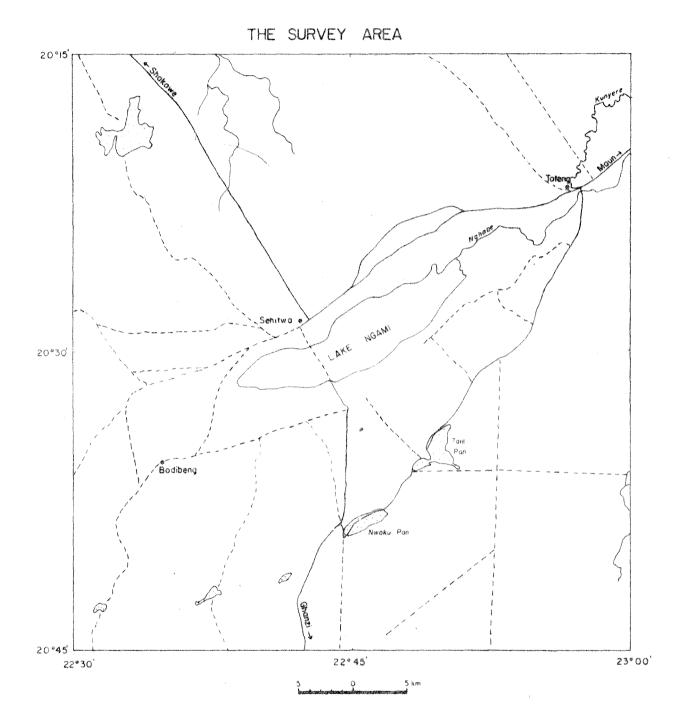
1. The Survey Area

1.1 Location and History

The survey area is located in Northwestern Botswana between 22°30' and 23°00' East and 20°15' and 20°45' South, and has an area of 286,000 ha. It belongs to the Northwest District (known as Ngamiland) with Maun being the district's largest village and administrative center. (See map of survey area on following page).

Toteng and Sehitwa are the two main villages within the survey area. Sehitwa, the larger of the two, is a distance of 100 km southwest of Maun. Numerous smaller villages are scattered throughout the area. Accessibility is good, as the area is traversed by the main road (dirt) from Maun northwards via Sehitwa to Gomare and Shakawe, and southwards via Toteng to Ghanzi. From Sehitwa there is a 30 km stretch of paved road north. Many other roads, tracks and cutlines crisscross the survey area facilitating relatively easy travel and orientation.

The salient physical feature of the survey area is the Lake Ngami Depression, situated at the southern end of the Okavango Delta. The catchment of the Delta is in the Angolan Highlands, and the water enters Botswana above Shakawe in the north via the Okavango River. The water then spills into an inland delta through channels, overflow plains and floodplains. Due to the low gradient and blockages of channels by aquatic weeds, 95% of the inflow is lost due to evapotranspiration from open water, bare soil, and aquatic plants (Staring, 1978). However, a portion of the outflow of the Delta has traditionally found its way into Lake Ngami. Historically, a very large and continuous body of water may have been formed by the Okavango - Ngami Depression (Grey and Cooke, 1977).



Aerial photographs do reveal older beach ridges which suggest that the area of the Lake Ngami Depression most recently flooded in only a fraction of what it once was, when the explorer David Livingstone referred to the Lake as "a magnificent sheet of water" (after Potten, 1975).

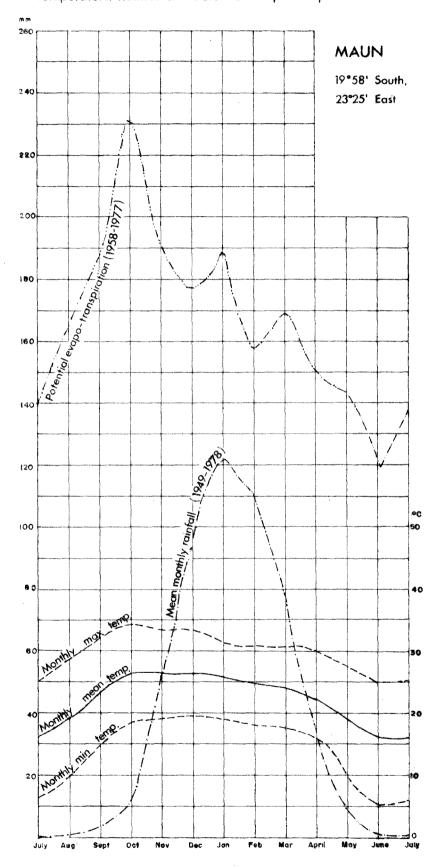
While numerous schemes have been prepared for the development of the Okavango - Ngami water system since Livingstone's visit to the lake area in 1849, only few have come to fruition. (Potten, 1975). The Delta area remains the subject of much interest, facing an influx of people and development projects all geared to taking advantage of the Delta's vast potential, and sure to bring change in the coming years.

1.2 Climate

The climate of the Sehitwa area is not markedly different from that of Maun, being characteristically hot and semi-arid. The summer day temperature may rise above 37°C with night temperatures seldom below 21°C. The winter is dry, with day temperatures rising above 21°C and night temperatures sometimes below 0°C, with the chance of frost occurring in low lying areas between June and August (Cole and Brown, 1976).

The average annual rainfall in Maun is 457 mm (Department of Meteorological Services). The monthly rainfall distribution is illustrated in fig. 1, and is highly variable from one year to the next. The rain occurs between October and April with up to 60% falling between January and March. The potential evapotranspiration is higher than rainfall throughout the year.

Temperature, Rainfall and Potential Evapotranspiration



Soil temperatures for the Maun area are shown in table 1. The general trends indicate the lowest temperature at any depth and time of day to be in July, increasing to the highest temperatures during the period from November to January. The soil temperature appears to increase with depth at 0800, but decreases with depth at 1400 and 2000 due to the incoming solar radiation and retention of heat at the surface. The soil temperature regime is 'hyperthermic; with the mean annual soil temperature being higher than 22°C and the difference between mean summer and winter soil temperature at 50cm depth being more than 5°C (USDA, 1975). The winds are predominantly easterly and northeasterly.

1.3 Geology and Geomorphology

The survey area is made up predominantly of deposits of the Kalahari Beds. Of Tertiary to Recent age, they include sands, calcretes, alluvial - fluvial and lacustrine (pans) deposits, usually covered with loose, undisturbed sand and characteristic longitudinal dunes (Geological Map, of Botswana, 1973).

Prominent relief occurs where resistant bedrock forms hills and undulating to rolling upland, such as the quartz and feldspar porphyries of the late Precambrian Kwebe formation comprising the Kwebe and Ngwanalekau hills southwest of Lake Ngami.

MEAN MONTHLY SOIL TEMPERATURES ** (MAUN) °C 1965 - 1980 TABLE 1

	mean monthly	29.6	28.5	28.2	792	23.2	19.9	19.4	21.6	25.2	28.7	29.8	29.4	
	120	29.5	28.2	27.7	26.9	25.2	21.8	20.8	21.7	24.3	27.4	28.7	28.8	25.9
	09	29.7	28.5	28.1	26.8	23.8	20.1	19.5	21.4	24.7	28.3	29.5	29.2	25.8
2000	30	30.7	29.5	29.1	27.4	24.0	20.4	19.7	22.1	26.1	29.8	30.5	30.6	26.6
	50	31.5	30.1	30.4	27.9	24.4	20.3	19,9	23.0	27.3	30.9	31.7	30.8	27.4
	0	30.6	29.4	29.7	27.5	23.9	20.2	20.7	23.7	28.4	31.5	33.3	31.2	27.5
	120	29.2	28.3	28.0	27.1	6.472	22.0	21.1	21.9	24.1	26.7	29.0	28.7	25.9
8	09	29.3	28.3	28.2	26.6	24.0	20.2	19.7	21.3	24.7	28.3	29.1	28.9	25.7
1400	30	29.5	28.3	28.0	26.2	23.2	19.2	19.0	21.3	25.2	28.8	29.3	29.3	25.6
	20	4	29.7	29.3	27.2	22.9	19.2	19.0	21.7	25.7	29.9	30.9	30.5	26.4
	0	34.6	32.9	32.5	30.6	26.1	22.3	22.7	25.9	30.9	34.6	36.0	34.1	30.3
	120	28.7	28.5	27.8	26.6	24.2	21.5	20.8	21.7	23.9	26.5	28.4	29.0	25.6
0800	09	28.7	28.2	28.0	26.2	23.1	20.5	19.6	21.7	24.7	27.7	28.6	28,	23.6 24.4 25.5 25.6
Õ	30	28.0	27.1	26.5	24.3	21.2	18,6	18.2	20.6	23.0	27.9	28.7	28.5	7.77
	20	27.3	26.2	25.8	23.5	19.7	17.6	17.4	19.8	23.7	27.4	27.7	26.5	23.6
	10	25.4	24.7	23.8	21.7	17.3	14.1	13.4	16.7	20.9	25.0	25.4	25.7	21.2
time	depth (cm)	January	February	March	April	May	June	July	August	September	October	November	December	mean annual

** measurements taken in loamy sand

*

source: Dept. of Meteorological Services

Minor relief occurs along old drainage courses where former streams have incised valleys into the bedrock, and where aeolian sands have been reworked by lacustrine and alluvial processes. The sandy beach ridges of Lake Ngami are an example of the aeolian sands reworked by lacustrine processes, while the densely dissected Thaoge overflow plain moving southwards towards the Lake Ngami Depression (northwest section of the survey area) illustrates the aeolian sands reworked by the action of the fluvial deposits.

The alluvial plain of Lake Ngami is a prominent physiographic feature of the survey area. Traditionally receiving fresh deposits from the inflow of the Kunyere and Nghabe rivers, it has in recent years been drying out due to the low floods descending from the Angolan highlands through the Okavango Delta. There is presently only very little surface water in the area, found at Toteng village.

Cyclical climatic changes have been cited as possible factors influencing the formation of the Okavango Delta. Garner (after Grey and Cooke, 1977) has suggested that a succession of drier and wetter climates will affect the flow volume of the channels, and thus the sediment load capacity, resulting in the Delta's complex and unstable drainage pattern.

Calcrete, believed to cement the Kalahari Beds at depth (Cole and Brown, 1976) is commonly found in pans, interdunal depressions and low lying areas at depth, but often at or near the surface due to evaporation from high groundwater levels (Staring, 1978).

1.4 Vegetation and Land Use

The vegetation found within the survey area is primarily savanna woodland. Acacia tree species are abundant with A. tortilis (setswana name - moshu), A. mellifera (mongana), A. erioloba (mogotlho), A. erubescens (moloto), and such Terminalia species as T. prunoides (motsiara), and T. sericea (mogonono) found on both the savanna and low savanna woodland areas.

Associated with the above species are shrub communities which include Dichrostachys cinerea (moselesele), Boscia foetida (mopipi), B. albitrunca (motopi), Grewia flava (moretlwa), G. bicolor (mogwana), Combretum apiculatum (mohudiri), and Zizyphus mucronata (mokgalo). Generally speaking, tall trees are found on the upper slopes and ridges, while low growing shrubs dominate on the lower slopes. Soil and microclimatological factors are most likely related to this variability, with certain species being better adapted to the deeper, better drained soils of the upper slopes, and others preferring the low lying areas where the colder air settles and drainage may be somewhat poorer.

The lowest lying basin of the Lake Ngami Depression is characterized (seasonally) by a dense cover of the weed Sesbania, with grasses such as Digitaria spp., Cynodon dactylon and Echinochloa also found on the floodplain and channels of the Lake. Eragrostis, Stipagrostis, and Aristida grass species are found on higher, sandy areas, with Setaria verticiliata and Acacia tortilis (shrub) found mainly on disturbed land (overgrazed). The midslope of the Depression (towards the high water line) is covered with C. dactylon and some scattered shrubs of Acacia spp. and Z. mucronata.

Other indicators are Cataphractes alexandrii shrubs for areas where there is calcrete development, and T. sericea and Croton gratissimus shrubs for areas with a deep sand cover. C. apiculatum is dominant on red sandy soils. (Cole and Leroux, 1978; Weare and Yalala, 1971). Cattle grazing is the dominant land use activity within the survey area. This has led to severe overgrazing and competition for the diminishing water supply. Arable farming, mainly sorghum and maize cultivation, is practised by some farmers at a subsistence level, but only on a very limited scale due to tribal preferences for cattle rearing.

At present, the water shortage is critical. With the low rainfall and the drying up of Lake Ngami, the existing boreholes are being heavily drawn from to meet the needs of the large numbers of cattle.

The Okavango Delta is being increasingly exploited by hunters and safari tour operators because of the beauty of the natural area and the abundant wildlife. Wildlife can still be found in the survey area, with numerous bird species gathering at Lake Ngami and small numbers of Kudu and other small antelope seen on the eastern and southern sides.

2. Methods of Investigation

2.1 Airphoto Interpretation and Fieldwork

The soil survey was carried out utilizing airphoto interpretation in conjunction with field observations. Both aerial photography and satellite imagery of the survey area were readily available.

Aerial photography: scale 1:70,000

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13 June 1975 series 151-BT 12 photo no. 067-074
14 June 1975 " 151-BT 13 " " 039-048
3 June 1978 " 1/78 C.K.1A " " 001-008
1 June 1978 " " 1 " 034-067
1 June 1978 " " 2 " " 023-033
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Satellite imagery: scale 1:250,000 26 November 1972 bands 4, 5, 7 scene ID: 10126-07580 - false colour composite, edge enhanced.

A preliminary interpretation of the airphotographs was carried out prior to commencing the fieldwork, the aim being to identify the main physiographic units (land forms) and the nature of the surficial deposits and to delineate the soil boundaries. Lacustrine, alluvial and aeolian deposits, were generally discernible on the photographs.

The ground survey was then carried out at a 'detailed' reconnaissance level, using a 4 x 4 vehicle to facilitate travel on difficult terrain. Photomaps at the scale of 1:50,000 were used for accurate orientation and site recording. The 'free survey' method was employed, with observations being sited in relation to landform. Field observation consisted mainly of augerings to a depth of 100-120 cm, or shallower if an inpenetrable layer was encountered. The soil characteristics recorded were in keeping with the standard FAO 'Guidelines for Soil Profile Descriptions' (FAO, 1977) including the use of the Munsell Soil Colour Chart.

With the information acquired from the photointerpretation and fieldwork, the initial list of soil units was constructed. Subsequent photointerpretation and field work allowed for the checking of soil boundaries, the redefinition of soil units, the delineation of additional units and associations of units, and the sampling of representative soils. The number of augerings was 132, with 13 pits being dug and 40 samples taken. The soil map was then produced using the cumulative field data and revised photointerpretation. The physiographic features and soil boundaries as seen on the aerial photographs were for the most part, distinguishable on the satellite image, thus facilitating the transfer of soil boundaries directly onto the image. The soil units of the survey area were correlated with those of the other team surveyors, and a comprehensive legend of the soils of Botswana was produced.

All field data from the survey area will be kept by the FAO Soil Surveyor at the Regional Agricultural office in Francistown.

2.2 Laboratory Analysis

All samples were sent for analysis to the FAO soil chemist at the Sebele Agricultural Research Station, near Gaborone. A standard series of determinations was carried out including:

- pH : H_2O and $CaCl_2$
- electrical conductivity
- available phosphorous (Bray and Kurtz method)
- organic carbon (Walkley and Black method)
- Cation exchange capacity
- exchangeable Cations (Ca, K, Mg, Na) exchanged by ammonium acetate
- particle size distribution (USDA system); sand fraction by sieving; clay and silt by hydrometer method.

3. Soils of the Survey Area

3.1 Soil Classification

The soil classification system employed for the soil survey of Botswana is the one set out by the Food and Agriculture Organization of the United Nations (FAO). Soil units are identified by the recognition of diagonostic horizons and properties, and are described in the legend to the Soil Map of the World (FAO-UNESCO, 1974). With respect to the survey area, only the mollic and ochric A, cambic and argillic B, and calcic C horizons are recognized as being diagnostic. The petrocalcic C, not usually recognized as diagnostic, was considered as such after communication with FAO owing to its significant occurrence in Botswana.

For the soils of the survey area, the following definitions have been drawn from the above mentioned legend. They are given here for the benefit of the reader who is familiar with soil classification terminology. Definitions of terms used are to be found in the FAO-UNESCO legend. A discussion of the occurrence and distribution of the soil units will follow in the section entitled 'Description of the Soil Units'.

Fluvisols (J)

Soils developed from recent alluvial deposits (fluviatile, marine, lacustrine, or colluvial), having no diagnostic horizons other than (unless buried by 50 cm or more new material) an ochric or an umbric A horizon, a histic H horizon, or a sulfuric horizon.

Eutric Fluvisols (Je)

Fluvisols having a base saturation on 50% or more at least between 20 and 50 cm from the surface but which are not calcareous at the same depth; lacking a sulfuric horizon and sulfidic material within 125 cm of the surface.

Regosols (R)

Soils from unconsolidated material, exclusive of recent alluvial deposits, having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon, lacking hydromorphic properties within 50 cm of the surface, lacking the characteristics which are diagnostic for Vertisols and Andosols, lacking high salinity; when coarse textured, lacking lamellae of clay accumulation, features of cambic or oxic B horizons or albic material which are characteristic of Arenosols.

Calcaric Regosols (Rc)

Regosols which are calcareous at least between 20 and 50 cm from the surface.

Arenosols (Q)

Note: The modified definition of Arenosols, and the inclusion of Arenosol units not found in the FAO-UNESCO legend comes as a result of personal communication between the project's soil corrolator and senior FAO Land Resource Officers, and is felt to better express the representative sandy soils found in Botswana.

Soils from coarse textured (loamy fine sand or coarser) unconsolidated material, and less than 35% of rock fragments

or other coarse fragments in all subhorizons to a depth of 100cm or to a lithic, petroferric, or petrocalcic contact, exclusive of recent alluvial deposits, consisting of albic material occurring over a depth of at least 50 cm from the surface or showing characteristics of argillic, cambic or oxic B horizons which, however, do not qualify as diagnostic horizons because of textural requirements; having no diagnostic horizons (unless buried by 50 cm or more new material) other than an ochric A horizon, an albic E, or a calcic or petrocalcic horizon; lacking hydromorphic properties within 50 cm of the surface; lacking high salinity.) (includes Eutric Arenosols - Qe).

Cambic Arenosol (Qc)

Arenosols showing colouring or alteration characteristics of a cambic B horizon immediately below the A horizon; lacking lamellae of clay accumulation; lacking ferralic properties.

Ferralic Arenosol (Qf)

Arenosols showing ferralic properties and evidence of alteration (B horizon characteristics); lacking lamellae of clay accumulation within 125 cm of the surface.

Calcaric Arenosol (Qc)

Other Arenosols showing soft powdery lime within 125 cm from the surface, or which are calcareous at least between 20 and 50 cm from the surface.

Calcic Arenosol (Qk)

Other Arenosols having a calcic horizon within 125 cm from the surface.

Petrocalcic Arenosol (Qp)

Other Arenosols having a petrocalcic horizon within 125 cm from the surface.

Luvic Arenosol (Ql)

Other Arenosols showing lamellae of clay accumulation.

Cambisol (B)

Soils having a cambic B horizon and (unless buried by 50cm or more new material) no diagnostic horizons other than an ochric or an umbric A horizon, a calcic or a gypsic horizon; the cambic B horizon may be lacking when an umbric A horizon is present which is thicker than 25 cm; lacking high salinity, lacking the characteristics diagnostic for Vertisols or Andosols; lacking an aridic moisture regime; lacking hydromorphic properties within 50cm of the surface.

Calcic Cambisol (Bk)

Cambisols having an ochric A horizon and showing one or more of the following: a calcic horizon, a gypsic horizon or concentration of soft powdery lime within 125 cm of the surface; calcareous at least between 20 and 50 cm from the surface; lacking hydromorphic properties within 100 cm of the surface, lacking permafrost within 200 cm of the surface.

3.2 Description of the Soil Units

For the soil map of the survey area, 7 parameters are used to describe the individual soils. These are: the parent material, depth, drainage, colour, texture, topography and calcium carbonate content. The limits of these parameters are as set out by FAO (FAO, 1977).

The soils are first grouped according to the parent material. Four main units have been distinguished in the survey area:

C unit - soils on highly calcareous material (calcrete)

L unit - soils on lacustrine deposits

A unit - soils on alluvial deposits (exclusive of lacustrine)

S unit - soils on coarse-grained sedimentary rocks (sandstones, aeolian sands, etc.)

The units will be discussed individually. The sequence of soils listed under each unit is indicative of a general increase in soil development. The symbols used are those of the general soil map legend of Botswana. Chemical properties are given here for the most commonly found soils. Descriptions of representative profiles can be found in Appendix 1.

C Unit - soils on highly calcareous material

The soils of the C unit are shallow, calcareous, and are found exclusively in areas surrounding pans.

1. Shallow, moderately well to well drained, very dark to dark greyish brown, loamy fine sand to fine sandy loam; flat to gently undulating; classification: Calcaric Regosol (Rc); SU: G2 partly petrocalcic.

L Unit - soils on lacustrine deposits

This unit encompasses the soils found on the alluvial plain of Lake Ngami, or the Lake Ngami Depression. They are generally fine textured (silt loams to silty clays) non-calcareous soils with a weak platy structure within angular and subangular peds. Towards the high water line these soils are underlain by fine sand to loamy fine sands. Both the platy structure and sharp textural difference seem due to sedimentation (Siderius, 1971).

Also observed are the sandy to loamy soils (calcareous, calcic) of the alluvial plain edge and the sandy clay loam to clay loam soils of smaller pans.

The following soil units have been distinguished:

- very deep, imperfectly drained, black to very dark greyish brown, silt loam to silty clay abruptly over dark brown to brown (fine) sand to loamy fine sand; flat to gently undulating; non-calcareous.
 - classification: Eutric Fluvisol (Je) soil unit (SU): L9; profile no. To 180
 - found in the lake bed of Lake Ngami towards the high water line. The variation within the unit includes the increasing proportion of the silty layer to the sandy layer as you move towards the deepest basin of the floodplain.
- very deep, poorly, drained, black to very dark grey, silt loam to silty clay; flat; non-calcareous. classification: Eutric Fluvisol (Je); SU: L9a; profile no. To183 found in the deepest basin of the lake hed

The soil reaction for units L9 and L9a are commonly strongly acid to slightly acid (to slightly alkaline for L9, with pH (CaCl₂) values of 2.88-7.65, with the topsoil being generally moderately acid to slightly alkaline (pH CaCl₂ 4.04-6.57). The organic carbon content of the topsoil is very high with values ranging from 2.25-4.64%, decreasing substantially to values of .01-.8% in the sandy subsoil of unit L9. The CEC of the topsoil is high (29.08-44.85 me per 100 g soil) decreasing to low in the subsoil of L9 (2.16-6.65 me). Base saturation is greater than 60%. Available phosphorous is very low to moderate with topsoil values of 2.5-26.6 ppm (subsoil 1.2-28.4 ppm). Exchangeable cations (Ca, Mg, K) are all high.

- 3. moderately deep, imperfectly drained, dark greyish brown sandy clay loam to clay loam; calcareous; calcic within 125cm. classification: Calcic Cambisol (Bk); SU: L14 found in pans.
- 4. deep, imperfectly drained, very dark grey to dark greyish brown clay over very fine sandy loam; flat; calcareous; calcic.

classification: Calcic Cambisol (Bk); SU: L20

A unit - soils on alluvial deposits (including colluvium)

This unit includes the soils formed on embankments, in river valleys, old stream beds and interdunal depressions.

- 1. very deep, imperfectly to poorly drained, brown to dark greyish brown, silt and silty clay; valley bottom; non-calcareous.

 classification: Eutric Fluvisol (Je); SU: A24

 -found in river valleys of Kunyere River near Toteng.
- 2. deep to very deep, moderately well to well drained, black to dark greyish brown loamy fine sand over silt loam to silty clay over loamy fine sand; flat; non-calcareous.

classification: Arenic Eutric Fluvisol (Jea); SU: A24a -colluvium, found at base of beach ridge on north side of Lake Ngami, transitional to (L)S unit. Also found in river valley of Nghabe River at Toteng (alluvium).

- 3. moderately deep, well drained, dark greyish brown to brown, fine sand to loamy fine sand over gravel; gently undulating; non-calcareous.
 - classification: Eutric Arenosol (Qe); SU: A22a -colluvium, found on embankment on south side of Lake Ngami.
- 4. deep to very deep, moderately well to well drained, dark greyish brown, fine sand to loamy fine sand; flat; non-calcareous.
 - classification: Eutric Arenosol (Qe); SU: A22 -found in old stream beds.
- 5. moderately to very deep, moderately well to well drained, dark greyish brown to yellowish brown, loamy (fine) sands; flat to gently undulating; calcareous. classification: Calcaric Arenosol (Qc); SU: A20 —found in old stream beds and interdunal depressions, often in association with Eutric Arenosols.
- 6. deep to very deep, imperfectly to moderately well drained, dark greyish brown to brown, sandy loam to sandy clay loam over loamy fine sand; flat to gently undulating; calcareous (calcic).
 - classification: Calcic Cambisol (Bk); SU: A4C ; profile no. To 176 —found in old stream beds, usually in association with Eutric and Calcaric Arenosols. The soil reaction for soil unit A4C is moderately acid in the topsoil (pH CaCl₂ 3.81-4.52) increasing to very strongly alkaline in the subsoil (pH CaCl₂ 7.92). The organic carbon content of the topsoil is high with 3.63%, but drops to 0.05% in the subsoil. The CEC is high in the topsoil at 36.24 me, decreasing to 2.82 me in the subsoil. Available phosphorous is moderate (6.2-22.3 ppm). The exchangeable cations (Ca, Mg, K) are generally very high in the topsoil, and low to moderate in the subsoil (except for the high calcium of the calcic horizon). The high topsoil values are suggestive of a recent alluvial deposit.

S Unit - soils on coarse-grained sedimentary rock (including sandstones, aeolian sands, etc.)

The soils of the S unit are by far the most predominant in the survey area, and in the district as a whole. They are, generally speaking, deep, fine, windblown Kalahari sands to loamy fine sands, and can either be calcareous, (if they have been subjected to high water table resulting in the accumulation of carbonates) non-calcareous, or recently deposited non-calcareous sands covering calcareous profiles. They show little evidence of structural development, and horizonation is only weakly evident. Staring (1978) has distinguished 3 non-calcareous and 5 calcareous Kalahari sands. Corrolation with Staring's series is generally good, differing mainly in the depth criteria of the carbonates, and in the distinction of a calcic and petrocalcic horizon.

These soils are generally of low inherent fertility. The soil reaction is moderately acid to very strongly alkaline (pH CaCl₂ 5.58-7.94). The organic carbon content is typically low with values of less than 0.4%. The CEC is low, with values generally less than 3 me, and the base saturation is over 80%. Available phosphorous is very low to low (2.4-11.8 ppm). Exchangeable cations (Ca, Mg, K) are generally low, except for high calcium values in calcaric soils, or soils with a calcic or petrocalcic horizon. Sandy soils of the A unit have comparable chemical properties.

- 1. shallow to moderately deep, well to somewhat excessively drained, dark yellowish brown to reddish brown, loamy fine sand; flat to gently undulating; non-calcareous. classification: Arenic Eutric Regosol (Rea); SU: S1b -upland soils.
- very deep, moderately well to well drained, dark greyish brown to dark brown, fine sand to loamy fine sand; flat; non-calcareous.
 classification: Eutric Arenosol (Qe); SU: S17 profile no. To 143 and To 175
 -includes soils of the Lake Ngami beach ridges.
- 3. deep to very deep, well to somewhat excessively drained, strong brown to yellowish red, fine sand; flat to gently undulating; non-calcareous.

 classification: Ferralic Arenosol (Qf); SU: S3; profile no. To 227—includes dunes.
- 4. deep to very deep, well drained, very dark grey to brown, fine sand to loamy find sand; flat; calcareous. classification: Calcaric Arenosol (Qc); SU: S15
 -found in sandy section of the (west) Lake Ngami Depression.
- 5. moderately to very deep, moderately well to well drained, dark greyish brown to brown, fine sand to loamy fine sand; flat; calcareous; calcic.

 classification: Calcic Arenosol (Qk); SU: S13; profile no. To 160 and To231

 -found primarily in lower lying areas in association with Eutric Arenosols.
- 6. moderately deep to deep, well drained, dark brown, loamy fine sand (non-calcareous) over very calcareous material; flat. classification: Petrocalcic Arenosol (Qp); SU: S13a -generally found around soils of the C unit.
- 7. very deep, well drained, dark greyish brown to dark brown; loamy fine sand; flat; non-calcareous.

classification: Luvic Arenosol (Q1); SU: S5b; profile no. To196—found near Toteng Village, in lower lying areas on approach to the Nghabe River floodplain.

3.3 Soil Mapping Units and the Soil Map

Because of the complexity of the landforms and the low level intensity of the survey, it was often not possible to separate out the individual soil units as described in the previous section. In such cases, the mapping unit will be made up of an 'association' of soil units, with the proportion of the individual soil units being shown on the map in parentheses. Where the mapping unit was considered homogeneous, the soil unit and mapping unit are identical.

In the case of the S unit, the letters 'K' and 'L' have been used as descriptors. When the soil unit has been derived from Kalahari (aeolian) sands, as opposed to having developed in situ from sedimentary rock (sandstone), the mapping unit is expressed as KS. When lacustrine deposits are found reworked by aeolian action, and the results of the deposition occur within the former lake environment (such as the Lake Ngami beach ridges) an 'L' is added and the mapping unit is expressed as LS (main unit sand).

The soil map itself has been produced at the scale of 1:250,000. This scale should facilitate the identification of the forms of development that are physically possible within a region of a given country (FAO, 1979). The level of detail within the survey area is sufficient to identify a number of factors which could limit potential development. This will be discussed in more detail in the section on 'land evaluation'. It must be realized, however, that the soil map presents only a general picture of the occurences and distribution of the soil units and does not give specific information about individual fields.

Table 2 lists the mapping units and associations, and the proportions in which they occur in the survey area.

TABLE 2

SOIL MAPPING UNITS

oping unit (soil unit)	classification	unit area (ha)	% of survey area
	D -	0.000	0.1
G2	Re	9,000	3.1
L9	Je	21,100	7.4
L9a	Je	6,500	2.3
L14	Bk	900	0.3
L20	Bk	7,500	2.6
A24	Je	1,000	0.3
A24a	Jea	3,200	1.1
A22a	Qe	3,100	1.1
A22	Qe	2,000	0.7
A20	Qc	8,200	2.9
A4C	Bk	7,100	2.5
S1b	Rea	24,800	8.7
KS17 (S17)	Qe	5,800	2.0
LS17 (S17)	Qe	17,700	6.2
KS3 (S3)	Qf	12,200	4.3
LS15 (S15)	Qc	18,200	6.4
KS13 (S13)	Qk	-09E0	****
KS13a (S13a)	Qp	19,200	6.7
KS5b (S5b)	Q1	600	0.2
associations:	√- ••••		
A22(50) + A20	(50)	32 , 500	11.4
A22(40) + A20	(30) + A40(30)	26,800	9.4
S1b(60) + C2(1	40)	7,200	2.5
KS17(60) + KS	513(40)	11,500	L+ • O
KS17(60) + S11	0(40)	7,600	2.7
KS17(60) + KS	3(40)	8,300	2.9
KS17(40) + KS	3(30) + A20(30)	21,300	7.4
LS17(50) + A22	2(50)	2,700	0.9
		286,000	100 %

^{*} proportions given in parentheses (%)

4. Land Evaluation

4.1 Land Suitability Classes and Land Qualities

The method of land evaluation that is used for Botswana is that developed by Venema and Rhebergen (1983), based on the FAO Framework for Land Evaluation (FAO, 1976).

Land evaluation is concerned with the assessment of land performance when used for specified purposes. For this report, the survey area will be evaluated for sorghum and maize production under dryland agriculture utilizing improved traditional management, as this is representative of the arable agriculture presently being practiced (or aspired to) in the district, and in many parts of the country. Dryland farming under rainfed conditions, utilizing improved traditional management implies a good knowledge of modern, non-mechanical farming practices. These may include timely (row) planting, improved seeds, crop rotation, weeding, modest fertilizer use, insecticides, the use of a planter or inter-row cultivator, contour plowing, and proper storage of the harvest.

In the system of land evaluation there are two orders, suitable (S) and non-suitable (N). Within order S, there are four classes:

S1- highly suitable

Land which is expected to be highly productive for the defined use. High returns amply justify required inputs. No significant limitations.

S2- moderately suitable

Land which is expected to be moderately productive for the defined use. Moderate returns justify required inputs. Limitations reduce crop yields by 10-25% and/or increase recurrent costs for production and conservation.

S3- marginally suitable

Land which is expected to have a low productivity for the defined use. Yield benefits are just high enough to justify required inputs. Limitations reduce yields by 25-50% and/or considerably increase costs for production and conservation.

Land which is expected to have a very low productivity for the defined use. It is doubtful whether yield benefits alone justify required inputs. Severe limitations reduce crop yields by more than 50% and/or substantially increase costs for production and conservation.

(Land classed S4 may still be cultivated for traditional farming where capital inputs are extremely low, and some produce can be obtained, or where severe limitations occur seasonally such as in years of poor or unreliable rainfall).

Within order N, there are two classes:

N1- currently unsuitable land.

Land with severe limitations which at present cannot be corrected economically.

N2- permanently unsuitable land.

Land Qualities- Twelve land qualities have been distinguished which could be considered as factors limiting maize or sorghum cultivation depending on the extent to which they are expressed in the soil (e.g. nutrient, moisture availability) or in the environment (e.g. climatic factors).

- a. accessibility
- c. correct temperature regime
- e. resistance to soil erosion
- f. absence of damaging floods
- g. adequacy of conditions for germination
- m. moisture availability
- n. nutrient availability
- o. oxygen availability
- p. absence of pests and diseases
- r. adequacy of foothold for roots
- t. absence of toxic substances
- w. workability

When any of the land qualities appear to limit cultivation it will be indicated by subclasses, with the corresponding lower case letter being placed after the suitablility class. This will be discussed in the section entitled 'Limits to Cultivation'.

4.2 Crop Requirements

To evaluate the land for its suitability for crop production, the crop requirements must be known. A partial list of requirements for maize and sorghum follows (after Venema and Rhebergen, 1983; Sims, 1981):

	maize	sorghum
mean temperature—OC optimum (range)	20–30 (18–35)	20-30 (18-35)
moisture (mm)	500-800	450-650
pH (H ₂ O) optimum(range)	5.5-7.5 (5.2-8.2)	5.5-7.0 (5.2-8.2)
drainage: optimum range	mod.well-well (imp-s.exc)	same
ponding tolerance	few hours	few days
nutrient status	moderately-high for good yields	moderate for good yields, but does reasonably well on poor soils.
Salinity: EC(mmhos)		
optimum (prohibitive)	0-2(10+)	0-4(18+)
CaCO3 %		
optimum (prohibitive)	0-15(50+)	0-25(80+)

4.3 Limitations to Cultivation

In the land evaluation system each land quality mentioned in section 4.1 has been rated, using numbers through 1-6, with 1 being the best, decreasing in suitability for all land use types. However, these ratings are not specific for sorghum and maize. Each land quality is then weighted according to the requirements for sorghum and maize grown under improved traditional dryland farming. To illustrate this, consider land quality 'o' - oxygen availability in the root zone, which is mainly a function of drainage. Five ratings have been established:

			Ponding Frequency during Growing Season					
rating		drainage class	every 1-2 yrs	every 3 mm 5 yrs	every 6-10 yrs			
1	3-6	moderate-somewhat excessively	none	none	1 day			
2	2-3	imperfect-moderate	none	1 day	1-7 days			
3	2	imperfect	1 day	1-7 days	7-30 days			
4	1	poor	1-7 days	7-30 days	30-60 days			
5	0	very poor	7-30 days	30-60 days	60 days			

For sorghum, which is more tolerant to ponding than maize, the characteristics of both ratings 1 and 2 would be highly suitable, with no significant limiting affect (suitability class S1). An imperfectly drained soil (rating 3) would then be moderately suitable (suitability class S2). For maize, the rating for land quality 'o' would correspond to the suitability class (rating 1 to suitability class 1) as it is more sensitive to ponding. For most land qualities, given the defined land use activity, the rating corresponds to the suitability class. The lowest suitability class among all of the land qualities will establish the final evaluation, with each soil mapping unit being considered individually. The land quality(ies) bringing it to that class will be expressed as subclasses.

To use the previous example, a poorly drained soil (rating 4) would have a suitability class S3 - marginally suitable. If this was the most severe limitation to sorghum production, the final evaluation would be S30. If other land qualities also merited suitability class S3, they would be expressed as additional subclasses, up to a maximum of three.

While it is not practical in this report to reproduce the complete land evaluation system, it is hoped that this introduction will serve to illustrate the workings of the system. The rating of each land quality is often dependent on a number of interrelating factors and while the criteria for each will be discussed here, the derivations and the practical limits of each rating will not. Where possible the suitability class for the defined land use activity (sorghum and maize under improved traditional agriculture) will be indicated in parentheses. Where the suitability class for maize differs from that of sorghum, it will be listed second (applies only to land quality 'o'). While the moisture and nutrient requirements also differ from sorghum to maize, these differences were not considered significant for the evaluation within the survey area.

a - accessibility

The following elements are of importance:

- access of the farmer and implements to the land: distance, quality of roads and possibilities for improvement.
- 2. distance and quality of roads between the farm and a suitable market for sale of produce.
- 3. distance and quality of roads between the farm and a source of supplies and services.

Four ratings have been established:

- 1. good access(S1)
- 2. somewhat limited access (S1)
- 3. limited access (S2)
- 4. poor access (S3)

For the survey area as a whole, access is considered as somewhat limited to good - suitability class S1.

c - correct temperature regime

The following factors are considered:

- -mean daily temperature
- -mean maximum and mean minimum temperature.
- -occurrence of frost in the growing season.
- -daylength.

Four ratings have been established:

- 1. correct temperature regime and daylength (S1)
- 2. low possibility of extreme temperatures resulting in crop failure or reduced yield. (S2)
- 3. high possibility (S3-4)
- 4. temperature or daylength not correct. (S4-N1)

 For the entire survey area, the temperature regime is
 considered as correct -suitability class S1.

e - resistance to soil erosion

Resistance to soil erosion by water and by wind are assessed separately—the lowest rating being the final one. Five ratings are distinguished. Erosion by water depends on many factors such as rainfall erosivity, soil erodibility, vegetative cover, slope, infiltration rate and conservation measures. The rating for erosion by water is determined taking the following factors into account:

soil characteristics-relates to the resistance of soil.

- -soil texture
- -soil structure
- -% organic matter

land characteristics-relates to quantity and velocity of runoff.

- -slope %
- -slope length
- -infiltration rate

climatic-mean annual rainfall, relates to rainfall erosivity

The rating for erosion by wind is dependent on climatic factors, (windspeed, rainfall in relation to evaporation), topographic factors, and soil erodibility (soil structure, consistence, texture).

f - absence of damaging floods.

This refers to the occurence of damaging floods during the growing season which may damage crops or infrastructure.

Five ratings have been established:

- 1. frequency of floods less than once in 10 years. (S1)
- 2. once every 5-10 years. (S2)
- 3. once every 3-4 years (S3)
- 4. once every 2 years. (S4)
- 5. every year. (N1)

g - adequacy of conditions for germination

The main soil characteristics which determine the conditions for germination in a moist soil are surface crusting, surface stones and gravel, and the structure and consistence of the topsoil. Three ratings have been established.

m - moisture availability

The rating for moisture availability takes into consideration the climate (rainfall, potential evapotranspiration), modified by topography (upslope or downslope), and the soil characteristics infiltration, permeability, and available water holding capacity (texture, depth, and stoniness). Six ratings have been established.

n - nutrient availability.

The nutrients considered for land quality 'n' are calcium, magnesium, potassium. Insufficient data are available to consider nitrogen, but organic carbon will be used as an indicator. Cation exchange capacity and pH are also taken into account. Four ratings are used.

o - oxygen availability in the root zone

Discussed in introductory paragraph to this section.

rating	1.	S1	S1
	2	S1	S2
	3	S2	S3
	4	S3-4	S4
	5	N1	N1

p - absence of pests and diseases

While difficult to quantify such a land quality due to the variability in type and intensity, four ratings are established.

- 1. potential damage by pests and diseases is limited and/or easy to control by individual farmers. (S1).
- 2. potential damage considerable: moderate input needed in the form of labour (weeding, bird deterence). (S2)
- 3. potential damage high: moderate input in the form of materials (fencing, insecticides) or very high labour input needed. (S3-4)
- 4. potential damage very high: very high input in the form of materials and/or paid labour needed. (N1).

For the entire survey area, the potential damage is considerable, mainly from birds and small animals - suitability class S2.

r - adequacy of foothold for roots.

Adequacy of foothold is a function of effective soil depth, i.e. the part of the soil in which root growth is possible. Five ratings have been established.

	effectiv depth (c	ive soil		
1.	100	(S1)		
2.	50-100	(S1)		
3.	25-50	(S2)		
4.	10-25	(S3)		
5.	10	(N2)		

t - absence of toxic substances.

Certain salts (chlorides, sulphates and carbonates causing salinity), sodium, and calcium carbonate can be considered toxic if they occur in high concentrations, and cause significant decreases in yield. In the land evaluation system, land quality 't' is rated separately for salinity, alkalinity, and calcium carbonate/gypsum. Five ratings have been established for each. Chemical data indicates that salinity

and alkalinity are at optimally low levels within the entire survey area-suitability class S1. Soils with a calcic horizon have been downgraded one class, while the petrocalcic horizon in not considered within the rooting zone.

w - workability

Workability, the ease with which a soil can be cultivated, is mainly a function of soil consistence, stoniness and rockiness. Four ratings have been established.

In the following section, each of the soil mapping units will be evaluated for the defined land use activity.

4.4 Evaluation of the Soil Mapping Units

In this section, each of the soil mapping units have been evaluated as to their suitability for the defined land use activity-sorghum and maize production under rainfed conditions utilizing improved traditional management. Soil mapping units with similar suitability classes and subclasses will be considered together, with a summary of all evaluations presented in tabular form (table 3). The final evaluation will be the one used on the land suitability map. Where two ratings are given, the first is for sorghum, and the second for maize. Where one rating is given it is the same for both crops.

C Unit - soils on highly calcareous material

C2 - currently unsuitable-class N1

Main limitations are very low moisture holding capacity due
to sandy texture and shallow depth, and very poor topsoil
workability due to surface or near surface stoniness.

L Unit - lacustrine soils

L9 and L20 - marginally suitable-class S3 mwg/S3 mow

The main limitations are poor moisture availability, poor oxygen availability and poor topsoil workability. Moisture availability is commonly low throughout the entire survey area because of the climatic zone in which it falls, where the potential evapotranspiration exceeds mean annual rainfall throughout the year. Workability is poor due to the hard to very hard topsoil consistence. These soils could be productive under non-traditional management.

L9a - currently unsuitable-class N1

The Lake Ngami basin is currently unsuitable because of the high frequency of ponding due to annual flooding (flooding 7 out of 10 years).

L14 - marginally suitable-class S3mfo/S3mfw

The main limitations to these pan soils are a low moisture availability due to texture and only moderate depth, and the potential for seasonal flooding.

A Unit Alluvial, colluvial soils

A24 - marginally suitable-class S3me/S3moe

Main limitations are low moisture availability, low oxygen availability and the potential of erosion by water.

A24a - marginally suitable-class S3mme

Main limitations are a low moisture availability, low
fertility, and the potential of erosion by water.

A22a - very marginally suitable-class S4m

Main limitation is very low moisture availability.

A22 - marginally suitable-class S3mne

Main limitations are a low moisture availability, low
fertility, and the potential of erosion by wind.

A20 - marginally suitable-class S3mne same limitations as A22.

A4C - moderately suitable-class S2mne/mno

Main limitations are a moderate moisture availability, moderate fertility, and the potential of erosion by both water and wind. These are the highest rated soils in the survey area.

<u>S Unit - soils on coarse grained sedimentary rock</u> (including aeplian sands)

S1b - very marginally suitable-class S4m

Main limitation is very low moisture availability.

KS17 - marginally suitable-class S3mne

Main limitations are a low moisture availability, low fertility, and the potential of erosion by wind. The following soil mapping units are given the same rating: LS17, KS3, LS15, KS13, KS5b

KS13a - very marginally suitable-S4m same limitations as S1b

associations

The suitability (sub)class for the individual soil units may be different, resulting in an association of suitability (sub)classes.

When the final evaluation of the association differs from that of the individual soil units, the suitability (sub)class of the dominant soil unit will be used on the map, followed by a number in parentheses which will refer the reader to table 3, where the associations are given in full. The proportions of the individual soil units and suitability (sub)classes within the associations are in parentheses immediately following their listing.

Table 3 Land Suitability - Evaluation of the Soil Mapping Units land qualities

uation maize	S3mow		S3mfw	S3mow	Symoe	Symne	Sylm	Symne	Symne	S2mno		S/m	Symne	Symne	S3mne	Symne	Symne	S.4m	S3mne
final evaluation sorghum	S3mwg	NI	S3mfo	S3mw	S3me	S3mne	S/tm	S3mne	S3mne	S2mne		S/m	S3mne	S3mne	Symne	S3mne	Symne	Stm	Symne
M	23-4	83-4	53	83	27	31	22	S	S	52	H	82	S	N T	S	SI	Ŋ	S	정
**	SI	SI	\$2	*	*	22	22	S1	S	SI	*	S	었	S	SI	S	\$2	SI	22
£-1	S.	S	SI	23	27	21	SI	덦	₩.	S	83	N N	81	SI	51	S	SI	턳	27
o lo	\$2	\$2	22	32	32	22	20	32	22	\$2	\$2	22	32	32	32	82	32	32	32
o r maize	83	Z	83	83	83	82	D	57	S	22	N N	S	S	Ŋ	21	SI	덦	S.	S
o sorgh.	\$2	NI	\$2	32	\$2	S.	Ŋ	Ŋ	S1	S	S1	21	Ŋ	S	SI	S	21	ry Ly	Ŋ
ч	\$2	32	*	*	*	53	83	23	33	\$2	*	83	83	83	23	83	83	83	83
ш	23	83	83	83	83	83	87	83	83	\$2	IN	34	S_{2}	83	53	83	83	78	83
50	83	83	32	\$2	SI	ts.	\$2	52	SI	\$2	22	Ŋ	SI	SI	S	S	SI	27	SI
4-1	rs Es	75	83	SI	ry T	S E	SI	S	SI	S1	ST	S1	N L	Ŋ	S	S.	S	21	S1
Φ 72	SI	ST	\$2	32	ა ლ	\$2	83	83	83	22	83	53	83	83	83	53	83	3	83
0	22	\$2	SI	\$2	83	83	32	S	51	22	S1	S1	Ŋ	Ŋ	S	S	Z.	S	EZ.
O	ES.	SI	S	SI	S	SZ	SI	덩	31	81	S	S	N	S	21	51	S1	SI	Ŋ
ಗ	IS.	S1	21	S	S	SI	27	d	51	S1	SI	SI	55	81	21	S	27	SI	S
soil mapping unit	Т9	L9a	1214	L20	A24	A24a	A22a	A22	A20	A4c	G2	S1b	KS17	KS17	KS3	LS15	KS13	KS13a	KS5b

 e_1 - erosion by water; e_2 - erosion by wind

* - data unavailable

** - evaluation for CaCo_3 only. Evaluation for salinity and alkalinity is S1.

association*	suitability (sub)class*	mapping symbol
A22(50) + A20(50)	S3mne(50) + S3mne(50)	Symne
A22(40) + A20(30) + A4c(30)	S3mne(40) + S3mne(30) + S2mno(30)	S3mne(1)
S1b(60) + C2(40)	S4m(60) + N1(40)	S/m (2)
KS17(60) + KS13(40)	S3mne(60) + S3mne(40)	S3mne
KS17(60) + S1b(40)	S3mne(60) + S4m(40)	S3mne (3)
KS17(60) + KS3(40)	S3mne(60) + S3mne(40)	Symne
KS17(40) + KS3(30) + A20(30)	S3mne(40) + S3mne(30) + S3mne(30)	S3mne
LS17(50) + A22(50)	S3mne(50) + S3mne(50)	S3mne

* proportions (%) given in parentheses

5 Conclusions and Recommendations

The land suitability map represents an evaluation of the soil mapping units found within the survey area for the defined land use activity. Like the soil map, it must be noted that the boundaries, while appearing to be sharp separations between mapping units, may represent transitional zones where the units merge into each other. Both maps are based on a limited number of observations, and the soil mapping units and land suitability classification may be amended with additional field and laboratory data. The table below illustrates the distribution of the suitability (sub) classes as shown on the land suitability map.

suitability	7
-------------	---

Down Oct District Long		
subclass	area (ha)	% of survey area
S2mne/S2mno	7,100	2.5
S3mw/mow	7,500	2.6
S3mwg/mow	21,100	7.4
S3mfo/mfw	900	0.3
S3me/S3moe	1,000	0.3 73.1
S3mne	144,200	50.4
S3mne(1)	26,800	9.4
S3mne(3)	7,600	2.7
S4m	47,000	16.5 7 19.0
S4m(2)	7,200	2.5
N1	15, 500 00.000.000.000.000.0000.0000.0000	5 a Li-
	286,000	100.0

There was no land in the survey area which was classed as highly suitable (S1) for the defined land use activity. A small proportion (2.5%) of the survey area was found to be moderately suitable (S2). This unit occurs in old stream beds and depressions in the northwest of the survey area (soil mapping unit A4c). While there are some limitations to cultivation in the form of moderate fertility, slight potential of erosion, and a fair topsoil workability, it is the most suitable land in the survey area. Even though these areas can be small and discontinuous, they should be considered for small scale cultivation as only moderate inputs are required to maintain productivity.

Land classified as marginally suitable (S3) occupies the greatest proportion of the survey area (73.1). The main limitations to cultivation are a low moisture availability, low fertility (mainly the sandy soils), the potential for erosion, and the low oxygen availability due to somewhat impeded drainage in lower lying areas, which may contribute to significant reductions in crop yields. The land classified as S3mow for maize, encompassing soil units L9 and L20, should be considered separately as they occur within the Lake Ngami depression. These areas outside the lowest basin, should be looked upon favourably due to their higher inherent fertility, and their close proximity to the water source of Lake Ngami which traditionally floods seven out of ten years. While only marginally suitable for dryland farming, they may be upgraded for irrigated agriculture. Potten (1975) speaks of proposals for irrigated agriculture on the Eastern part of the floor of Lake Ngami as early as 1926. Siderius (1971) has identified an area on the northern fringe of Lake Ngami as being recommended for irrigated farming. SWECO (1976), the Swedish consulting group, has identified 2 areas on the northern and northeastern fringe of the Lake Ngami floodplain as being moderately to marginally suitable for irrigated land use. While the tribal preference for cattle rearing in the area should not be overlooked, the development potential of the Lake Ngami depression should be looked at in more detail with the laying down of trials to assess productivity quantitatively.

Land classified as S4 and N1 is not recommended for the defined land use activity, as limitations in the form of very low moisture availability will severely hamper cultivation even though these areas may presently be cultivated on a subsistence level. Soil mapping unit L9a, in the Lake Ngami basin is classified N1 due to the occurence of flooding and hazard of ponding. However, the flooding is variable, and this area should be looked at on a seasonal basis to assess its suitability for cultivation. Upon recession of seasonal floods, areas may become more suitable for molapo cultivation.

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ANNEX 1

Soil Profile Descriptions

Laboratory Analyses

Profile No.	Soil classification	Mapping unit
To 180	Je	L9
To 183	Je	L9a
то 176	Qe	A4c
То 175	Qe	LS17
То 227	Qf	KS3
To 231	Qk	KS13
То 196	Ql.	KS5b

Laboratory Analyses

class./ mapping unit	Je/ L9	Je/ I.9a	Bk/A4	Qe/KS17	Qf/KS3	Qk/KS13	Q1/KS5b
BS%	71 65 100+	80 53 53	95 100+	833	72 70 67	\$ 5 5 5	872
ns Na	0.52	0.16 0.34 0.32 0.26	0.41	0.02	000	0.01	000
cations K N	2.91 0.06 0.26	7.20 1.06 0.68 2.54	6000	0.22	00.10	0000	000
exch.	4.04	64.4 64.4 64.4 64.4 64.4 64.4 64.4 64.4	5.70	00	0.97	2000	0.49
) Ca	13.03	23.03 13.89 8.23 10.45	14.31 0.58 6.69	1.56	2.57 1.96 1.84	7.72 15.96 19.49	2.20
CEC(meq/100g)	30.08 2.16 5.18	42.84 36.74 37.30 29.08	36.24 2.82 4.86	2.56	5.34 4.70 5.18	2.33 2.42 102 102	3.94
org.0%	2.76 0.01 0.03	33°.05°.47°.	3.63	0,15	2.00	0.39	0.442
P(ppm)	000 000 000	26.6 11.9 28.4 20.5	22.24	70.00	H & 7	0 4 0 0 0 W	000 000
EC(mmho)	0,110		0,263	1 1	1 1 1	000000000000000000000000000000000000000	1 1 1
cac12	4.56 4.79 7.25	4 23.09	7.92	6.37	6.05 5.46 4.47	7.62	5.77
H20 H	5.93 7.66 7.50	70.00 4.00 4.00 4.00 4.00 4.00 4.00 4.00	4.84 4.61 9.25	0 1. 9	6.54 6.41 5.24	8 8 8 . 46 . 65 . 65 . 65	6.53
depth(cm)	15-35 40-60 80-100	0-15 50-76 90-110 115-130	0-10	0-20	0-10 20-40 50-70	0-20 30-50 70-85	0-25 40-60 90-110
profile no.	To 180a b	To 183a b c	To 176a b	: To 143a	To 227a b	To 160a	To 196a b

^{* -} To 143 is outside the survey area. The soil is similar to To 175 (within the survey area). Both profile descriptions are given.

^{** -} To 160 is outside the survey area. The soil is similar to To 231 (within the survey area). Both profile descriptions are given.

SOIL PROFILE	E DESCRIPTION	SHEET SOI	L SURVEY		photo ser DTSWANA	_		The state of the s		
PROFILE NO		SHEET NO. 2022			REF. FN 900	AND A PARTY OF THE PARTY OF THE PARTY OF THE PARTY.	UNIT L			
-	and the control of th	Lake Ngami all	THE REAL PROPERTY OF THE PARTY		Carried State of the Control of the	and the same and t				
		AUTHOR Paul a				1000 0	-0118 11-611	VP CA CONTRACTOR CONTR		
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	FICATION (ST)				And the second s					
ELEVATION		SIOGRAPHIC POS	SITION	(flood)plain	ALL THE STATE OF T	terapolish <mark>Angulah sa duni 198</mark> 1 dalam sa Assistan magaman sa Assistan San Assistan sa Assistan San Assistan San			
TOPOGRAPH	Y flat			MICRO						
SLOPE			and the state of t	SURFAC	CE COND.		rindra visco como e provide de Pero I indicada de empresa por 1 indica da de esta como especia de la como espe			
LAND - USE /	VEGETATION	open shrub sa	vanna	animatus angga sa Alah Marin addan anasas at sa ga Al		mercuma direction folgonic Lan. Lancing processing the state of processing or Principles asserted		the many field the territorial and adults are an extended in photos and many and are account and account and a		
SPECIES	shrubs: Z. muc	ronata, A. tor	tilis, A	.leude	ritzii	arvonaniana de Professione en e	and a province of the contract	energian de Adria de Arresta de La composição de la composição de la composição de Adria de La composição de Adria de Composição de La Composi		
gra	sses: C.dactyl	.on	ar fan Johann yn y gag yn yr ei diweredd o eildiad ag y hagly y di'n ei en wered a'i	na una de plaç e paga e ^{la m} erca conside <mark>nte de capación e e e e e e de me</mark> ción	en video entremente a controver e Prifri d'Arton elle predigionne en la prifri de la primi de la primi de la p	inkrisminus kusus (1949–1946) ilikuli kuri dindensansi Lepundensansi	a sa manan nang gaga gag a an anan in anan-poping-agag-agag-an-an-ang ang ga gagag	, manutara ¹⁸ P - 18 P - 18 A (SA), CASA (SA) (SA) (P - 18 A (SA) (SA) (SA) (SA) (SA) (SA) (SA) (S		
PARENT MATERIAL lacustrine DRAINAGE imperfect.										
MOISTURE COND. dry SURFACE STONES _										
ROCK OUTCE	ROPS -		and the second s	SALINI	TY _					
E. SION /	DEPOSITION		managaran (1884) oo roo aa a	interestation and the second s			**************************************			
HUMAN INF	LUENCE		appropriate the second							
REMARKS	area heavily	grazed								
HORIZON DE	ESCRIPTION			Mark and separate (MARK AND TO MAKE AND		and which the second in the second				
hor. symbol	Ah	2Ah	3C1		302					
depth	0–10	10-35	35-70		70-110)+				
colour moist dry	10YR2.5/1 3.5/2	10YR2/1 3/2	10YR5,		2.5Y4/ 5/					
mottling	few, fine+med prominent, 7.5YR5.5/8	few coarse prominent 7.5YR5/8	few fir distir 7.5Y	ne nct R/8	few fir disting 7.5YR5	ie Ż				
texture	sandy loam	silty clay	loamy	·	sandy lo		**************************************			
s ture	weak, med subang block	weak, med subang block	structu massi		structure		o destror e emmano confin de Cili descri e con mança, que popular en mante en como con el como como como como como como como com	***************************************		
consistence	sl.hard	v.hard	soft	Andrew Western under Print Print State Communication und des Communication und des Communications under Communication under Co	sl•hard	-hard				
cutans		Market		THE NEW STATE AND THE MEMORY STATES AND THE STATES			r van erde vannige van gefrei in Nederlân in Sterverlage geeld villedin in Sterverlage			
cementation			-	THE STATE OF THE S		en transcriptor del la collègica de la collègi				
pores	common fine	common fine	common	fine	common f	ine				
rock fragm.	rossa	Name of the state	apasso.				der et a titologicale popular (d. d.) et e e e encene e escapa and el Millioth decreas			
mineral nod.	•				American interface in the contract of the cont		tit för filman som viller rindisk til till från en en sille för å för för			
carbonates	***************************************	general section of the section of th			Annual An					
biol. feat.	****		common b	orrowi	ng		the committees are project on a committee of the committe			
roots	common fine-med	common fine	few fir	ne	few fine-	-coarse				
boundary	grad smooth	abrupt smooth	wavy sr	Was familiarly & Turbon Mayor and Andreas (1978) of Antonio Provider	er u song menganja dar Nuri					
samples		a 15-35	b 40-60		c 80-100)				

photo series 1/78 C.K. no. 2-030

			Ţ	onoto	series 1/78 C.	.K. no. 2-03	₹0
SOIL PROFI	LE DESCRIPTION	SHEET SC		-	OTSWANA	FAO BOT/8	
PROFILE NO	O. To 183	SHEET NO. 2022	2D1	GRID	REF. FN817276	UNIT	
LOCATION	, COORDINATES	south side of	f Lake Ng	ami, a	at base of esc.	aroment (ac	ross Sehitue)
DATE 16/	12/82		ul and Ket			the same of the sa	cood Bellinway
SOIL CLASS	SIFICATION (FAC	O) Eutric Flu		Je		American Apparent a per Architectul de American de Control (Appl. et American) des comites communication (Appl	
SOIL CLASS	SIFICATION (ST)		omre minimo del midde di dino i monero mendido el del relicio como calendado o un				
ELEVATION	m. PH	SIOGRAPHIC PC	SITION	slight	convex slope		
TOPOGRAP	HY gently	undulating		MICRO			
SLOPE	1%			SURFA	CE COND.	 	
LAND - USE	/ VEGETATION	open savann	a woodlar	nd		о на семент на пород на рома (пос на сем ент на постава на	
SPECIES	A.tortilis, Z	.mucronata	And the second s			a marija (Marija) daga maga maga maga maga maga maga maga	
	dorminant gra	ss: setaria ve:	rticiliat	a	The second section of the second seco	dara rusus ka neessa puud oppi oo oo dara varda kaba saadan yo ga doda asaasiin ka k	
PARENT MA	TERIAL lacust:			DRAIN	NAGE poor		
MOISTURE C		ist at 90 cm		SURFA	CE STONES	d data ta distintante e sua como quanto proporto de como por es pero deporto por consecuencio de consecuencio Distributo	
ROCK OUTC				SALIN	ITY _		
ENSION /	DEPOSITION				nde Liste film of districted for his his option region hand and some some a high name grant and the district di		
HUMAN IN	FLUENCE			ran a marine a majoja nje dijeljenje deni in nevenovaja kaji deni dela			
REMARKS							
				removal firth all servers and resources		And Angeles (1974) describe Aller (1974) Angelogic Labrada manamananananan Labra (1974) republik persengan damanan	
HORIZON D	ESCRIPTION	and the second s	A CONTROL OF THE CONT	n edition in material segment and consider a various		nininana aman'ny avon'ny taona na ao	
hor. symbol	Ahl	Ah2	C1		02		
depth	0-15	15-90	90-11	5	115-130+		
colour moist dry	10YR2/1 3.5/2	10YR2.5/1 3/1	10YR3/2		10YR3.5/1		
mottling	few, fine prominent 7.5YR5/8	many coarse prominent 7.5YR5/7	90.03	n an Salatin Manadamin (Advine) fram, sur and an			
texture	humic silt loam	silty clay	silty cl	ay	silt		
s ture	weak, fine subang blocky	weak, med- coarse, subang blocky	structur	~			
consistence	soft	ext.hard	friable-	-firm	soft	٨	
cutans	Mark to	namet.		1			
cementation	******		**************************************		Albuqua		
pores	common,fine	common, fine	common, f	ine.	common, fine		
rock fragm.	The state of the s	-		interest of the control of the contr			
mineral nod.	ands.	Long.		And the second s			
carbonates					prime to		
oiol. feat.		America				enterententen persona del	
roots	common, fine	v.few, v.few					
boundary	wavy, smooth	gradual, smoo				process of the delegation of the substitution and substitution of the delegation of the delegation of the substitution of the	
samples	a 0-15	b 50-70	0.00.110	_			

photo series 1/78 C.K. no. 1A-001,002 SOIL SURVEY OF BOTSWANA FAO BOT/80/003 OIL PROFILE DESCRIPTION SHEET SHEET NO. 2022B3 'ROFILE NO. To 176 GRID REF. FN707495 UNIT A4c OCATION, COORDINATES 15.4 km from Sehitwa junction, on road to Tsau)ATE 14/12/82 **AUTHOR** Paul and Ketlogetswe SOIL CLASSIFICATION (FAO) Calcic Cambisol Bk SOIL CLASSIFICATION (ST) m. PHYSIOGRAPHIC POSITION ELEVATION slight convex slope **OPOGRAPHY** MICROTOP. gently undulating SLOPE 1% SURFACE COND. AND-USE / VEGETATION woodland savanna T.prunoides, D.cinerea, A.erubescens, A.mellifera PECIES ARENT MATERIAL DRAINAGE alluvium imperfect-moderate dry MOISTURE COND. SURFACE STONES **CK OUTCROPS** SALINITY EROSION / DEPOSITION HUMAN INFLUENCE **₹EMARKS** HORIZON DESCRIPTION nor. symbol Ah Bt Ck depth 0 - 2525-60 60-1:00+ colour moist 10YR2.5/1 10YR2.5/1 10YR4/3 4/1.5 4/1.5 dry 5.5/3 nottling exture sandy loamy sandy loam clay loam fine sand mod, fine-med v.weak, med subang blocky structureless structure ang blocky massive to crumb sl. hard consistence hard hard-v.hard soft cutans cementation pores common, fine common, fine v.few, fine rock fragm. mineral nod. carbonates 4 ++ in patches

common burrowing

biol. feat.

boundary

rare fine

rare fine

clear, smooth clear, smooth

roots

FAO BOT/80/003 SOIL SURVEY OF BOTSWANA SOIL PROFILE DESCRIPTION SHEET UNIT SHEET NO. 2023 A1 GRID REF. FN 289804 PROFILE NO. To 143 KS17 LOCATION, COORDINATES island across Moshu experimental station DATE **AUTHOR** 16/9/82 Paul and Ketlogetswe SOIL CLASSIFICATION (FAO) Eutric Arenosol Qe SOIL CLASSIFICATION (ST) m. PHYSIOGRAPHIC POSITION **ELEVATION** plain TOPOGRAPHY flat MICROTOP. 0-2% SURFACE COND. SLOPE LAND-USE / VEGETATION woodland savanna **SPECIES** A.erioloba, Grewia flava, G.bicolor, C.hereroensis PARENT MATERIAL DRAINAGE well-somewhat excessive aeolian MOISTURE COND. SURFACE STONES dry ROCK OUTCROPS SALINITY EROSION / DEPOSITION HUMAN INFLUENCE **REMARKS** HORIZON DESCRIPTION hor. symbol Ah C depth 0-30 30-120+ colour moist 10YR3/1.5 10YR4/2 dry mottling texture fine sand fine sand silocture structureless structureless consistence soft soft-sl.hard cutans cementation pores kommon fine common fine rock fragm. mineral nod. carbonates biol, feat. roots few fine few, v.fine boundary clear, smooth samples

				T		/ 10 0.	170 1100	TU COT	002	
SOIL PROFIL	E DESCRIPTION	SHEET SOI	L SURVEY	OF BO	OTSWANA	FAO	BOT/8	0/003		
PROFILE NO	. To 175	SHEET NO. 2022B	3	GRID I	REF. FN7144	,81	UNIT	LS17		
OCATION,	COORDINATES	Sehitwa-Tsau r	oad, 14.	1 km f	rom Sehitv	ra junct	ion			
And the second s		AUTHOR Paul		-				New Control of the Co	popularino de la	
SOIL CLASSI	FICATION (FAO) Eutric Aren	osol Qe		et geren et de la companyation d	historia e e e e e e e e e e e e e e e e e e e	***************************************	Miles in Commission State in Lance or agree and a paper or a paper or	New York And An International Conference on the	
30IL CLASS	IFICATION (ST)							NAMES OF THE PROPERTY OF THE P	CONTRACTOR MANAGEMENT AND	
ELEVATION	m. PHYS	SIOGRAPHIC POS	OITION p	lain			And the second s	NECESTRATES AND	and a succión y an oraquint y agrand a grand a	
OPOGRAPH	IY flat			MICRO	iTOP.				The second secon	
SLOPE	0-1%			SURFAC	CE COND.		Add the believe the second		unico de la superiorio con al associação de Mario Colo Mario Antique (Mario Antique Colo Antique	
.AND - USE /	VEGETATION	shrub savanna								
SPECIES	A.mellifera,	A.tortilis, G	rewia fl	ava						
PARENT MAT	TERIAL aeolia	n		DRAIN	AGE well					
MOISTURE CO	OND. moist a	t 40 cm		SURFACE STONES -						
R SK OUTCE	ROPS -			SALINI	TY			***************************************		
EROSION /	DEPOSITION		more residency of the proposition of the propositio	ONE AND THE RESIDENCE OF THE PARTY OF THE PA	**************************************	and a second			enferelesses communicative studies of 1985 was are welchalance or one made alleballistic (1980/1985).	
HUMAN INF						Oddo Americano de Perfuguero e de a specipa e del meso albido scomo				
REMARKS	not sampled,	but profile s	similar t	o To 1	43		encontrol to the control of the cont			
						The state of the s				
HORIZON DI	ESCRIPTION		-					****		
hor, symbol	Ah	C1	C2							
depth	0-30	30–50	50-11	0+						
colour moist dry	10YR2.5/2 4/2	10YR3/3 5/2	10YR2.	5/3 6/3						
mottling									Market and the state of the sta	
texture	loamy fine sand	loamy fine sand	loa fine sa						ну-транция и интерприциприций по том выполнений и из придост на выполнений и и и и и и и и и и и и и и и и и и	
structure	structureless			· · · · · · · · · · · · · · · · · · ·					The continues are considered as a particle of the desired or consequence of the clothes are a \$400 feet of \$100 feet of \$1	
	massive	massive	massive							
consistence	sl.hard	soft	soft							
cutans	_	·····				Approximately - the - dynamics				
cementation		antia di Carantia							один од видина принција (во од	
pores	few fine-med	few fine-med	few fin	e-med						
rock fragm.	and the second s		No.				And the property of the second		THE RESIDENCE OF THE PROPERTY	
mineral nod.			30004				VIII			
carbonates			W-194				MATERIA PAR, CARRA ART AND MEDICAL CARROLL IN SUPERIOR AS A COMPANY OF THE STATE OF		Art consistence and application of the second and application of t	
biol. feat.		- SALEY							Age (11-14-16-16-16-16-16-16-16-16-16-16-16-16-16-	
roots	few, fine-med	few fine	v.few,	fine				The state of the s		
boundary	gradual smoot	n gradual smoo	are the first of the second				**************************************			

photo 151 BT 12 - 071

OIL PROFILE DESCRIPTION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003												
ROFILE NO	· To 227	SHEET NO. 2022	2D2	GRID R	EF. FN 935109	UN	IIT KS3					
OCATION,	COORDINATES	cutline south	east of	Pelobo	thoko							
)ATE 23/2/	['] 83 .	AUTHOR Paul	and Ket	logets	we							
OIL CLASSI	FICATION (FAO) Ferralic Ar	enosol	Qf								
OIL CLASS	IFICATION (ST)											
LEVATION	m. PHYS	SIOGRAPHIC POS	I NOITI	olain	·							
OPOGRAPH	IY flat - gen	ntly undulating))	MICRO	TOP.			-				
SLOPE 0-	1%			SURFAC	E COND.							
AND - USE /	VEGETATION	shrub savanna		obilit de disconnecessor major (MANSAN) i Malifornicia spiso		terioria salarga 20 fornio agram a saganaga saganaga sagan sagan sagan sagan sagan sagan sagan sagan sagan sag						
PECIES	PECIES T.prunoides, A.erubescens, C.apiculatum, G.bicolor, D.cinerea											
PARENT MATERIAL aeolian DRAINAGE Well												
MOISTURE COND. dry SURFACE STONES -												
K OUTCE	ROPS -			SALINI	ſΥ ·			The state of the s				
EROSION /	DEPOSITION											
HUMAN INF	LUENCE											
REMARKS				annough page of the State of th		ik Provinski v sov ⁹⁹⁰ obrenik omanije prim regorinske v seleti i Provins		handa analah erifateka Al-manda analah eri analah erak eri analah eri analah eri analah eri analah eri analah e				
AMAZANIA SIRIKA MININA MANANA MAN				en morana mario escas (Million de Sallion de Agricos).								
HORIZON DE	SCRIPTION					ar direction and gift in the contract of the c		annekan siya kalanda kalan kunan sa kalankan kara kalan k				
nor. symbol	Ah1	Ah2	В									
depth	0-10	10-45	45-10	0+	бол такта на голија АР 1909 A Nobel Sidney Salves (мето помера у правода Ар Афай, набестваја по помера у поме							
colour moist dry	7.5YR3/4 4/4	7.5YR3/4 4/4	7.5YR4 5	/6 /6								
nottling												
exture					vander steren de sie ver der 1987 1987 1987 des des des services de perfect de 1998 (spekkensen bek							
	fine sand	fine sand	fine sa		ndern mit enterne und ⁽¹⁸⁸ 00000000000000000000000000000000000							
structure	weak, fine- med subang blocky	weak, med- coarse subang blocky	weak coarse subang									
consistence	soft-sl.hard	soft-sl.hard	soft-sl	.hard								
cutans	-	_	_									
cementation		AMERICA.				***						
pores	common find	common fine	common :	fine	PPATRONO E EL PETRO PETRO E ESPAPA DE LA CALLA DE TERRA EL CALLA DE TERRA EL CALLA DE LA C			Producerona, Pro-security and productive symptoms and considerate Market				
rock fragm.					in vid majaru saksa) hiin dibibih di oo kansa oo oo qaashac caan 1994 haddiis nd maraacaal							
- Open and a consequence of the					en de suma sus de la companya del la companya de la							
mineral nod.	,											
carbonates	, 17 man	•										
biol. feat.												
roots	common fine	common fine	few fir	ne				Processing and the first state of the state				
boundary	grad smooth	grad smooth				APPENDENCE OF THE SECRETARISM STATE OF THE SEC		neuropologica e de sel mentre de como de conseder non de consederación de la consederación de la consederación				
							1					

no photo

D-100-00-00-00-00-00-00-00-00-00-00-00-00					Actual commence of the Commenc		-				
SOIL PROFIL	E DESCRIPTION	SHEET SOI	L SURVE	OF BO	OTSWANA F	AO BOT/8	0/003				
PROFILE NO	. то 160	SHEET NO. 2023	B4	GRID F	REF. GN 973437	UNIT	KS 13				
LOCATION,	COORDINATES	1 km after Sa	medupe 1	bridge	on road to Mak	alamabedi					
DATE 17/	11/82	AUTHOR Paul	and Ket	tlogets	we						
SOIL CLASSI	FICATION (FAO) Calcic Ar	enosol	Qk			kalan geri disebendekan kalan semangganggeli disebendekan dan dan dan se	жини тигуру жүн түртөн коруу жана таруунун жүн байтай байдай байдай байдай.			
SOIL CLASS	IFICATION (ST)			Andrew on the property of the control of the contro			Company of the Control of the Contro				
ELEVATION	m. PHYS	SIOGRAPHIC POS	SITION	plain		од 19 19 (Бр. М.), от не у ро б обобите се се и пове се истова (Бр. М.) от	Andrew To Table 2 to The Control of Control				
TOPOGRAPH	Y flat			MICRO	TOP.	THE CONTRACTOR AND A CONTRACTOR OF THE CONTRACTO		The second secon			
SLOPE				SURFAC	CE COND.			- Managa-maga-maga-maga-maga-maga-maga-maga			
LAND - USE /	VEGETATION	shrub and tre	e savann	.a		the angle of the second		Market to Live To Control of Stranger Landback of the Control of Stranger Control			
SPECIES	T.prunoides	, A. mellifera	, A.tort	ilis, A	A.leuderitzii						
PARENT MATERIAL aeolian DRAINAGE well											
MOISTURE COND. dry SURFACE STONES -											
OCK OUTCROPS - SALINITY -											
EROSION / DEPOSITION											
HUMAN INF	LUENCE										
REMARKS											
HORIZON DI	ESCRIPTION										
hor. symbol	Ah1	Ah2	Ck1		Ck2						
depth	0-20	20-70	70-8	8	88-100+	The second secon		 Proportion of the property of the			
colour moist	10YR3.5/3	10YR3.5/3	10YR5	/3.5				And the second distribution of the second distri			
dry				anne de la Contraction de la C				en rango a, un ggalem com unicon mayongganga, ang hili dalam na piblicidalam n			
mottling		and the state of t									
texture											
	loamy sand	loamy sand	loamy s	sand	soft calcrete rock						
structure	v.weak	The second secon									
	subang blocky	structureless	structu	reless							
consistence		_			Mining						
cutans											
	No. of the control of				-terms						
cementation	- American	****		ant a supplication for the supplication of the	Arma.						
pores											
	few fine	v.few, fine	v.few,	v.fine							
rock fragm.			To provide the second s								
mineral nod.			-					Andres conductors construction in the Control of th			
THE PROPERTY OF THE PROPERTY O		volume.	_	-	wine						
carbonates	+	-11-	1-1				4				
biol. feat.	_										
roots	common fine, m	d few fine	rare fi	ne							
boundary						enamen sigh agreeping gas a properties held of the filter reasons are a seal of the held of the filter and the seal of the sea		THE PARTY OF THE P			
	clear smooth	clear smooth	clear s	mooth				Effects thanks and the state of			

SOIL PROFILE DESCRIPTION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003											
PROFILE NO	To 231	SHEET NO. 2022	D1 GRI	D REF. FN951171	UNIT KS 1	3					
LOCATION,	COORDINATES	campsite at 1	Matamanyane			nanonany ngo 46/110 6-00 mili nanonaharanny no pula 200 (10/20/4/4/4/20/00/11/4					
DATE 24/2	2/83	AUTHOR Pau	L and Ketlog	etswe							
SOIL CLASSI	FICATION (FAO)) Calcic Areno	osol Qk								
SOIL CLASSI	FICATION (ST)					Angles a manggat the Principle of the column annuage angus angular (NA COM LANCE WAS ANGUS					
ELEVATION	m. PHYS	SIOGRAPHIC POS	ITION pl	ain							
TOPOGRAPH	Y flat		MIC	ROTOP.		na segunya ya ya hasin saka saka segun segunya na ya ya ya ya ya kata kata kata kata kat					
SLOPE	na magayayayayayayi di waxaa waxaa ahaa ahaa ahaa ahaa ahaa ah			FACE COND.		та компеции учин 17 м 17 м на также учини учини учини учини и при при при при при при при при при					
LAND - USE /	VEGETATION	woodland sa				nt kalangan juga 1974 97 milan maga ing panga kalangan kalangan Ambanga an di Salandi <mark>kalangan</mark>					
SPECIES	T.prunoides,	A.erubescens, (a.bicolor, D	.cinerea		maringko kansul ^{an, pangga} dan dan dalah sakuran sumanyang pagga pangka Makarinan angka banangga pa					
DADENIT MATERIAL 1. DRAINIAGE											
PARENT MATERIAL aeolian DRAINAGE Well											
MOISTURE COND. dry SURFACE STONES _											
COCK OUTCE	orașe, care o su grand projecti de câmbilită pe a dimensiona a nome par aprovenția grand distribută din la bistă din America desgran a napr		SAL	INITY –		and the second s					
EROSION /						whiteconscious and the control for the control management against the first the control of the desirable to					
HUMAN INF											
REMARKS	not sampled,	but profile si	milar to To	1.60		na mananany iyo hii hii dhii mindaga arana mayya ay ay yayay ay ay ay ay ahaan ah dhiidh dhii					
						nnya katu ningapan Madillan kita A mada aktoo minga nguyay ya waadi dah aktoo katu da sakan sakan sakan sakan					
HORIZON DE	ESCRIPTION		and the second of the second o								
hor. symbol	Ah1	Ah2	Bt1	Bt2	Ck						
depth	0-10	10-45	45-70	70-120	120+						
colour moist dry	10YR3/2 4.5/3	10YR3/3 4•5/3	10YR4.5/3 6/3	10YR4.5/3 6/3							
mottling			donas								
texture					soft						
	loamy sand	loamy sand	sandy loam	sandy loam	calcrete rock						
Siructure	mod, med subang blocky	weak,fine-med subang blocky	,		Ŋ						
consistence	soft-sl.hard	soft-sl.hard	soft.sl.har	d soft-sl.hard		The control of the co					
cutans				· ·							
cementation											
pores	common	common	common	common							
gerignesse van sekken in verken biologisch kontroller van de gegeneraal van de 1997 van de 199	fine, med	fine, med	fine, med	fine, med							
rock fragm.	manar .		enew.			Spiral distribution control of					
mineral nod.	man financia and a company of the financia and a company of the co		MANIEL A BOR SERVICE AND AND STATE OF AN ARCHITECTURE AND								
carbonates											
biol. feat.			THE STATE OF THE S	++							
roots	common fine a	nd w fine	this and this was a way of the defendence and the world was a supply of the second party of the second second	8 0:							
boundary		TO A T TTIE	few fine	few fine							
Journal y	grad smooth	grad smooth	grad smooth	clear smooth							

				pho	oto series	1/78	C.K. no. 1.	A-007	
SOIL PROFIL	E DESCRIPTION	SHEET SO	IL SURVE	Y OF BO	OTSWANA	FAC	BOT/80/	′ 003	
PROFILE NO	. To 196	SHEET NO. 202	2B4	GRID F	REF. GN 4830)55	UNIT KS	55b	
LOCATION,	COORDINATES	2.1 km from	Toteng b	ridge o	n Toteng M	laun Ro	ad	er dage gazar agaza yang generala sa sajaya bangga bermanang a kayayay sa milin ana bermana sa sa ka	
DATE 2/2/	['] 83	AUTHOR Paul	and Ket	logetsw	.6			### 16 mil 18 mil 19 mil 18 mi	
SOIL CLASSI	FICATION (FAO) Luvic Arenc	sol Q1	one frequencia a como de se de s		the character of the ch		dikki dama sapapanga sakila manumun oran junga pendinan menengkan pangapan menenaman menenggan pangab	
SOIL CLASS	IFICATION (ST)			agency person and a segment of the second and the second and second and second and second and second and second	ar the lacer-commons, you'd individual an accompany of the William distributions as successive in the research	erakonomien filologia erako filologia erako filologia erako filologia erako filologia erako filologia erako fi			
					plain				
TOPOGRAPHY flat-gently undulating				MICROTOP.					
SLOPE 1%					SURFACE COND.				
The second of the second	/ VEGETATION						egendas hat di 1800 di		
SPECIES	And the state of t	, T.sericea, C	•apicula	itum, B.	.albitrunc	3			
DADERT MAR	and the second s	gitaria spp.	addit distributes in statement (014 6 himship and day on a Maritte distribute	DDAIN	ACE ::	oldele gelekteren Militalija kilation menoven halikaranden sens			
PARENT MATERIAL aeolian					DRAINAGE Well				
MOISTURE COND. dry					SURFACE STONES - SALINITY -				
	DEPOSITION		A CT - A	JOHLIM		ngan agagaga printi natari namagagaga na irawana a		na Marijankon mangapung a Aran Marijang na pangan habi dankan makan manjari Karansa dankan kaban kaban kaban k Marijankon mangapung a Aran Marijang na pangan na pangan kaban kaban kaban kaban kaban kaban kaban kaban kaban	
HUMAN INF			a german mananang anjungah kan maranananan sa ininih katabana			na antara de la composição de la composi	antakan seritari da akai tahun dalam da arah 1800 mentendah ang ang mendah dan sama sakara	gyph Park Holma Janus congress Printed de Holma consensation in the Farest and consensation in the major may expense	
REMARKS	Sign Tark E . To Topy the		Million contraction from Million September 2 and 10		The same of the sa		majoris a gallitici timo con con con con que ma Pallico de Silvano con casa per de escribiro de constancion de	and the second control of the second control	
A TOWN R T T TO THE TOWN OF THE PROPERTY OF TH			y any retronoment ny kaomininy ny ny faritr'i Architecture a Mary ang any ary 1974 di Architecture.					мун того на между у суство того то менера мун бай в начасно не менера буб в начасно не мун в в в в начина в на	
HORIZON DI	ESCRIPTION	had, sidah sujuka sarra n dan interpopunya serindakan paggapi m enterbapa kecanga serinda selakan selaka	iggy milleuten alst namag virmentillet sienstaas (1964) van neme	KARA ARAN PERENGANINAN YANG BERMINININ MARINI	ericol/deliverice or autoparticity direct chairm autopies representation representation con	in delanting year of the time of the second property of the delay decay.	у надовальня без перешення проведення против в захований в того от у в терена		
hor. symbol	Ah	BI	B2t						
depth	0-27	27-70	70–120+						
colour moist	10YR3/2	10YR3/3	10YR5/3				oomaayoyi Moore Balkaguun olay yeen shirinda aayay barahan ahaabaa isaabaa oo		
dry									
mottling	******								
texture	loamy	loamy	loamy fine sand				de delimentario (1889) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (1884) (18		
	fine sand	fine sand			and the providing agent region as a CMA refer refer to the change of the control of the first research or so car				
Siructure	weak, med subang blocky	v.weak-weak med-coarse subangblocky	weak-mod med-coarse subang blocky		and the security of the second		- The second		
consistence	soft-sl.hard	sl.hard	sl.hard			g-Paradiculos de la companya de la c			
cutans		AND THE RESIDENCE OF THE PARTY	thin, patchy				navata shinii maanaa ka k		
cementation				ald a dalar a confidencia demonstrap, casa y el libro com un copazione d un confidencia			Market in payable in Color of the Color of t		
pores							от с наставляний при		
1 /	common fine	common fine	common	fine					
rock fragm.		and the same of th				And a second sec		**COMPANY COMPANY	
mineral nod.	The state of the s	THE SECOND SECON		:					
carbonates				****	The state of the s		oraciones de Antonios (merenantes de Antonios serandos, se de armente plane)		
biol. feat.									
roots	few fine, v.fi	ne same	same	2			and the second	CONTRACTOR OF THE PARTY OF THE	
boundary	grad smooth	grad smooth							
samples	- 0 0r.	1 10 10			independential per entre production de la company de la company de company de la compa	or the construction of the Section Construction of the Constructio			