

Soil Mapping and Advisory Services

Botswana

SOILS AND LAND SUITABILITY OF THE MOTLOUTSE AREA  
BETWEEN MMADINARE AND BOBONONG



FOOD & AGRICULTURE  
ORGANIZATION OF THE  
UNITED NATIONS



UNITED NATIONS  
DEVELOPMENT  
PROGRAMME



REPUBLIC OF  
BOTSWANA

AG: BOT/85/011  
FIELD DOCUMENT 6

Soil Mapping and Advisory Services  
Botswana

SOILS AND LAND SUITABILITY OF THE MOTLOUTSE AREA  
BETWEEN MMADINARE AND BOBONONG

by

P.V. DE WIT

and

A. CAVALIERE-PARZANEZE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS  
UNITED NATIONS DEVELOPMENT PROGRAMME  
GOVERNMENT OF BOTSWANA

Gaborone, 1990

The conclusions given in this report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of this project.

The definitions employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Food and Agricultural Organization of the United Nations concerning the legal or constitutional status of any country, territory or sea area or concerning the delimitation of frontiers.

De Wit, P.V. , Cavaliere-Parzaneze, A., 1990. Soils and land suitability of the Motloutse area between Mmadinare and Bobonong. FAO/UNDP/Government of Botswana. Soil Mapping and Advisory Services Project AG: BOT/85/011, Field Document 6 . 104 pp, 2 maps

## Table of contents

1. THE SURVEY AREA .....	1
1.1 Location and infrastructure .....	1
1.2 Climate .....	3
1.2.1 Rainfall and potential evapotranspiration .....	3
1.2.2 Temperature .....	5
1.2.3 Other climatic parameters .....	5
1.2.4 Soil climate .....	7
1.3 Geology .....	8
1.4 Hydrology .....	8
1.5 Geomorphology .....	9
1.6 Natural vegetation .....	10
1.7 Agricultural land use .....	11
2. SOILS .....	13
2.1 Introduction .....	13
2.2 Soil classification .....	14
2.3 Legend construction .....	14
2.4 Main units .....	14
2.5 Soil units .....	15
2.5.1 General .....	15
2.5.2. Soils on alluvial deposits .....	16
2.5.3 Soils on basic igneous and metamorphic rocks .....	21
2.5.4 Soils on highly calcareous materials .....	23
2.5.5 Soils on acid and intermediate igneous and .....	24
metamorphic rocks	
2.5.6 Soils on coarse grained sedimentary rocks .....	26
2.6 General soil distribution .....	28
3. LAND EVALUATION .....	33
3.1 Rainfed agriculture .....	33
3.1.1 Methodology .....	33
3.1.2 Results .....	35
3.1.3 Conclusions .....	38
3.2 Irrigation .....	39
3.2.1 Methodology .....	39
3.2.1.1 General .....	39
3.2.1.2 Land utilization types .....	40
3.2.1.3 Selection of land characteristics .....	41
3.2.1.4 Rating of land characteristics .....	42
3.2.1.5 Identification of land units .....	50
3.2.1.6 Matching land use requirements with .....	50
land units	
3.2.2 Results .....	53
3.2.3 Conclusions .....	56

## REFERENCES

## APPENDICES

1. Representative soil profiles and analytical data
2. Abbreviations used

### List of Figures

1. Location of the survey area in Botswana .....1
2. The survey area .....2
3. Agro climatic zones of Botswana .....6
4. Soil cross section of alluvial deposits at Mmadinare .....29
5. Soil cross section of alluvial deposits at Selebi-Phikwe ...29
6. Soil cross section of alluvial deposits at Tobane .....30
7. Soil cross section of alluvial deposits at Bobonong .....30
8. Structure of moisture limited yield model .....34
9. Probability of achieving "good" and "acceptable" yields ....37

### List of Tables

1. Average monthly rainfall data for selected rainfall .....3  
stations
2. Length of the growing period and its occurrence .....4
3. Onset month of the growing period .....4
4. Summary of climatic data for Francistown .....7
5. Number of farm holders by production mix in the Bobonong ..12  
region
6. Planted area for different crops in the Bobonong region ....12
7. Average yield per ha harvested in the Bobonong region .....12
8. Characteristics of land units .....35
9. Maximum moisture limited yields for optimal planting .....36  
decade
10. Relationship between limitation levels and numeral .....42  
ratings
11. Temperature requirements of the considered crops .....43
12. Ratings of land characteristics for the considered land ....48  
use types
13. Salinity tolerance, alkalinity tolerance and minimum .....49  
optimal rooting depth of the considered crops
14. Assessment of temperature for maize for different .....53  
planting months
15. Optimal planting times and corresponding temperature .....54  
indices for the considered crops
16. Calculated land indices for different crops, land units ....55  
and irrigation systems

## Abstract

This report describes the results of a soil survey carried out between 1985 and 1988 in the area between Selebi-Phikwe and Bobonong along the Motloutse river.

The objective of the semi-detailed soil inventory and land evaluation was to improve the planning base for agricultural and rural development. The exercise is related to the need to diversify the economic activities in the area, as the copper-nickel mine is expected to have a limited remaining life.

In a first chapter the environment of the survey area is discussed. The climate can be described as semi-arid with low and erratic rainfall concentrated in the summer. Considering the calculated length of the growing period, rainfed agriculture is very marginal in the area, even for drought resistant crops such as sorghum.

Three major geological formations can be recognized : the Basement Complex with granitic gneisses on the gently undulating to undulating plains in the west, the Karoo-Supergroup with basalts and sandstones in the eastern part characterizing undulating plateaux, and flatter alluvium along the Motloutse.

The main agricultural production mix is the combined cattle/crop/small stock farm with sorghum as the main crop, mixed with beans and pulses and some other crops. Average yields are very low.

In chapter two the soils of the survey area are discussed. They were mapped at the scale of 1/50 000, and classified following the FAO/UNESCO classification of 1974 with amendments made by the Soil Mapping and Advisory Services Project. Emphasis was put on the soils developed on alluvial deposits near the Motloutse, which were expected to have a higher agricultural potential than the upland soils.

On the alluvial deposits sandy soils are common on the levees; terraces show finer textured soils like luvic Xerosols with a clay increase in depth. The soils in the backswamps have a clayey texture and are poorly drained.

The uplands near Selebi-Phikwe are characterized by shallow sandy soils with often a gravel layer in the subsoil. The soils on the undulating dissected plateaux near Bobonong are also shallow but finer textured. They are associated with sandy soils developed on sandstone.

Chapter three deals with the land evaluation exercise for rainfed and irrigated agriculture.

For rainfed cropping a methodology based on modelling the soil water balance over a number of years for mapped units under sorghum was used. The model generates moisture limited yields which are compared both between years and between sites. It provides a quantitative comparison of yields that can be expected at different levels of probability.

It could be concluded that although moisture limited yields in Selebi-Phikwe are expected to be slightly higher than in Bobonong, they are very marginal in general. Hence rainfed agriculture is not recommended in the study area.

Two irrigation systems, namely sprinkler and centre pivot irrigation, were tested for some 25 different crops ranging from vegetables such as cabbage and lettuce to grain crops like maize including also the cash crop cotton.

Relevant land characteristics were selected, rated and matched with the land

use requirements of the considered land use types.

The outcome of the exercise is a crop, land and land use specific quantitative land index. By comparing the obtained land indices sound decisions on crop choice, planting time, choice of irrigation system and production potential were taken.

It could be concluded that for maximum crop production centre pivot systems must be recommended on the sandier soils (arenic luvisc Xerosols) which are predominant in the area. A major limitation for this type of irrigation is the heterogeneity of the lands.

Finer textured luvisc Xerosols are the only soils that can be rationally irrigated under sprinkler irrigation.

Most of the proposed crops are not or only slightly limited by temperature at one or another time of the year. Thus crop rotation is flexible, growing vegetables during winter and grain crops during summer. It is very unlikely that cotton, wheat and especially potatoes are high yielding at any time of the year.

# 1. THE SURVEY AREA

## 1.1 Location and Infrastructure

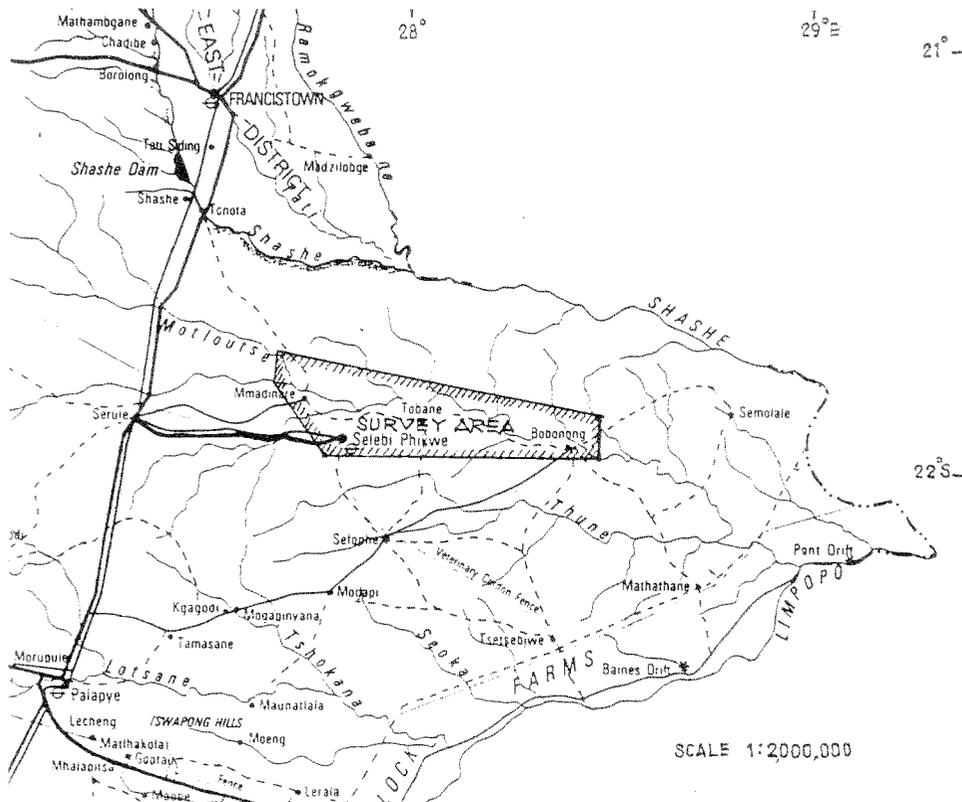
The survey area is located in the eastern part of Botswana along the Motloutse river from Mmadinare in the west to Bobonong in the south, roughly between latitudes  $21^{\circ}50'$  and  $22^{\circ}$  and longitudes  $27^{\circ}45'$  and  $28^{\circ}20'$  (see fig. 1 and 2). The main centre of population is the mining town of Selebi-Phikwe, which has about 30 000 inhabitants. Other major centres are Bobonong, Mmadinare and Tobane.

A 60km tarmac road links Selebi-Phikwe with the main north-south highway at Serule. This road provides easy access to most of the major population centres in eastern Botswana. A railway line from Selebi-Phikwe to Serule joins the main railway line from Harare to the Republic of South Africa.

Within the basin tarred roads connect Selebi-Phikwe with Bobonong and Mmadinare. Reliable unsurfaced roads provide access to other large settlements. There are no bridges across the Motloutse resulting in problems during the rainy season.

Water supply for industrial, domestic and agricultural use is a major factor for future development and expansion. Selebi-Phikwe is connected with the Shashe dam by an 80 km long pipeline. Water supplies for Bobonong and Mmadinare are coming from wells in the sandy river bed of the Motloutse. Other villages obtain their water from boreholes.

Fig.1 Location in Botswana



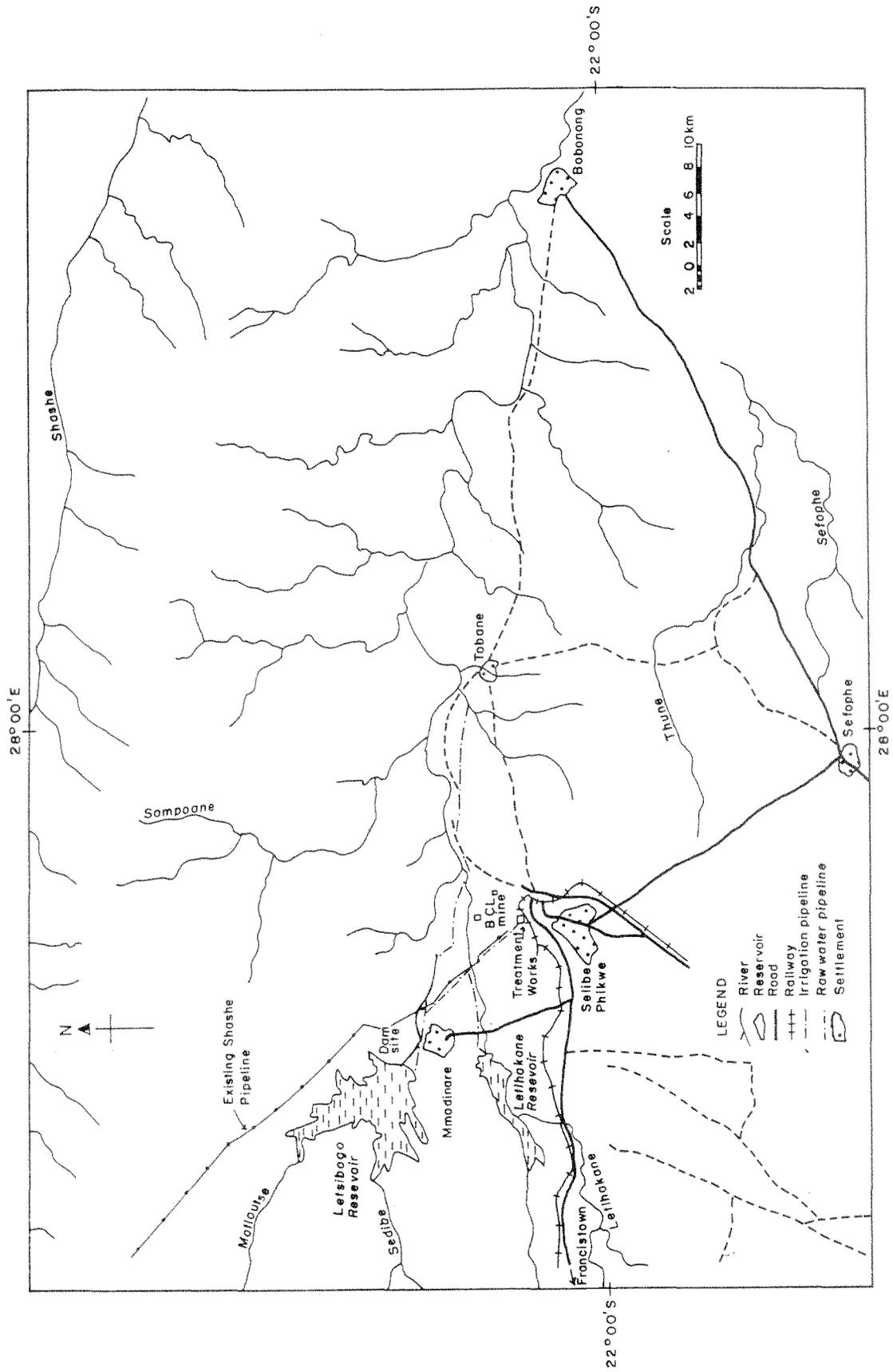


Fig. 2: The survey area (adapted from Mac Donald, 1990)

## 1.2 Climate

Although several rainfall stations with relative long term data are located near to the survey area, only two stations are situated in the area itself, namely Bobonong (20 years of observations) and Selebi-Phikwe (16 years of observation). Not one synoptic station, where other climatic parameters are measured, is within the study area; Francistown is the nearest synoptic station. In order to obtain synoptic data relevant for the area, triangular interpolations can be made between the closest representative stations.

### 1.2.1 Rainfall and Potential Evapotranspiration.

Table 1 gives average monthly rainfall data for the stations in the area and adjacent to the area. They are compared with the rainfall data of the more humid area's of Mahalapye and Francistown. With the exception of Selebi-Phikwe the mean total annual rainfall ranges from 316 mm in Mogapi to 359 mm in Bobonong. Selebi-Phikwe shows a considerable increase to 418 mm. Compared with Francistown and Mahalapye it can be concluded that the study area is much drier, with the exception of Selebi-Phikwe that forms a transition between the dry eastern part and the more humid western part of the country.

Thus Bobonong can be considered as a typical station for the eastern study area and Selebi-Phikwe for the western study area.

On a year to year basis, rainfall ranges from 155 mm to 794 mm in Selebi-Phikwe, which is comparable to the annual variation in Bobonong (144 mm to 786 mm).

The distribution of the rainfall throughout the year shows also similarities and is as follows : 55% - 57% falls in summer, 19% - 20% in autumn, 26% - 27% in spring and about nothing during the winter months. Hence 90% of the rain is concentrated between October and March.

Table 1 Average monthly rainfall data for selected rainfall stations

Station	J	F	M	A	M	J	J	A	S	O	N	D	annual
Beitbridge	73	58	31	27	9	3	1	2	13	26	50	58	351
Bobonong	69	75	36	31	4	1	0	0	5	28	52	58	359
Baines Drift	72	63	40	21	4	3	0	3	9	24	50	58	347
Mogapi	68	79	21	19	2	2	0	0	4	20	42	59	316
Sefhophe	77	64	26	30	8	4	0	0	5	31	59	49	353
Selebi Phikwe	100	54	50	23	4	0	2	1	15	29	63	77	418
Tsetsebye	70	55	28	22	8	3	0	1	9	22	47	54	319
Francistown	100	83	59	25	6	3	0	1	6	27	60	90	460
Mahalapye	88	83	68	26	9	3	2	2	8	31	68	79	467

For agricultural purposes mean data are not very useful and an analysis on a year to year basis has to be made, paying particular attention to the variability in the length of the growing season and the onset dates.

FAO (1978) estimates that, as a rule, the rainy season and the growing period starts when rainfall (P) exceeds half the potential evapotranspiration (ETP). A humid period occurs when P exceeds full ETP, while the rainy season ends when P falls again below half ETP. Taking into account a maximum of 100 mm stored soil moisture, the growing period ends when the soil is completely dry. The length of this growing period is an important parameter in the evaluation of the climate for rainfed agriculture. For sorghum a growing period of around 80 days is required to have a good potential yield. A length of growing period between 60 and 80 days will give a marginal yield, while less than 60 days of growing period will indicate an unsuitable rainfall pattern for sorghum production.

A second parameter that directly influences the on-farm planning of agricultural operations is the reliability of the onset date of the growing period, as this factor will determine the practical feasibility of rainfed farming. Above mentioned parameters were analyzed on a decade basis for different climatic stations in and around the survey area. The results are presented in tables 2 and 3 and are referring to the longest growing period for each year. In view of the short observation periods (less than 25 years) they should be taken with some care.

**Table 2** Length of the growing period and its occurrence (in % of years)

Station	length of the growing period (days)			
	<40	40-60	61-80	81-100
Bobonong	75	20	5	-
Baines Drift	75	25	-	-
Mogapi	69	19	12	-
Sefhophe	70	18	12	-
Selebi Phikwe	56	25	13	6
Tsetsebye	76	24	-	-

**Table 3** Onset month of the growing period (in number of events)

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Bobonong	-	1	2	5	8	2	1
Baines Drift	1	2	8	7	5	3	2
Mogapi	-	1	3	5	5	-	1
Sefhophe	-	3	2	6	3	1	1
Selebi Phikwe	-	1	3	8	1	1	1
Tsetsebye	-	4	6	9	1	3	2

The results can be summarized as follows :

- Very severe moisture stress occurs when the growing period is less than 60 days. This occurs in 95% of the years in Bobonong and in 81% of the years in Selebi-Phikwe. No or very marginal yields can be expected.
- Severe moisture stress occurs when the length of the growing period is between 61 - 80 days. This occurs in 5% of the years in Bobonong and in 13% of the years in Selebi-Phikwe. Marginal yields should be expected.
- Slight to no moisture stress is expected when the length of the growing period is between 81 - 100 days. In the study area this occurs only 6 seasons out of 100 around Selebi-Phikwe, and never in Bobonong.
- The onset month of the growing period is generally in January to February in Bobonong and December to January in Selebi-Phikwe. Late planting especially in Bobonong implies low temperatures at the end of the growing season (May) and thus yield reduction.

The general conclusion is that rainfed agriculture in the survey area is very marginal. Chances for obtaining "some" yield are higher in the western part around Selebi-Phikwe than near Bobonong.

The above analysis was confirmed by a more general study on the agroclimate of Botswana (Dambe, 1987) presented in fig 3.

The eastern part of the area falls within zone 4B3, with an average length of season of 41 to 60 days including 11 to 20 dry days.

The western part characterized by zone 3B4 is slightly better with a season length of 61 to 80 days and 11 to 20 dry days.

### 1.2.2 Temperature

Temperature and other climatic parameters except rainfall are derived from the nearest synoptic station of Francistown (table 4).

The mean maximum temperature ranges from a low in June (23.0°C) to a high in October (31.0°C). The mean minimum temperature ranges from 4.8°C in July to 19.0°C in January. The extreme minimum temperature ever recorded was -5.0°C.

Around 30 ground frost days are occurring during an average year, mostly in June and July; 8 air frost days can be measured. Thus care should be taken for the growth of frost sensitive crops during the winter.

This temperature regime is suitable for a wide range of crops, including winter and summer cereals but excluding equatorial crops such as coffee, cocoa and tea.

### 1.2.3 Other climatic parameters

The relative humidity of the air is moderate during the nights and mornings but low during day time. The highest humidity occurs during the rainy season from December to March (56% - 62%). The lowest values occur at the end of the dry period in August and September (39% - 43%).

# REPUBLIC OF BOTSWANA

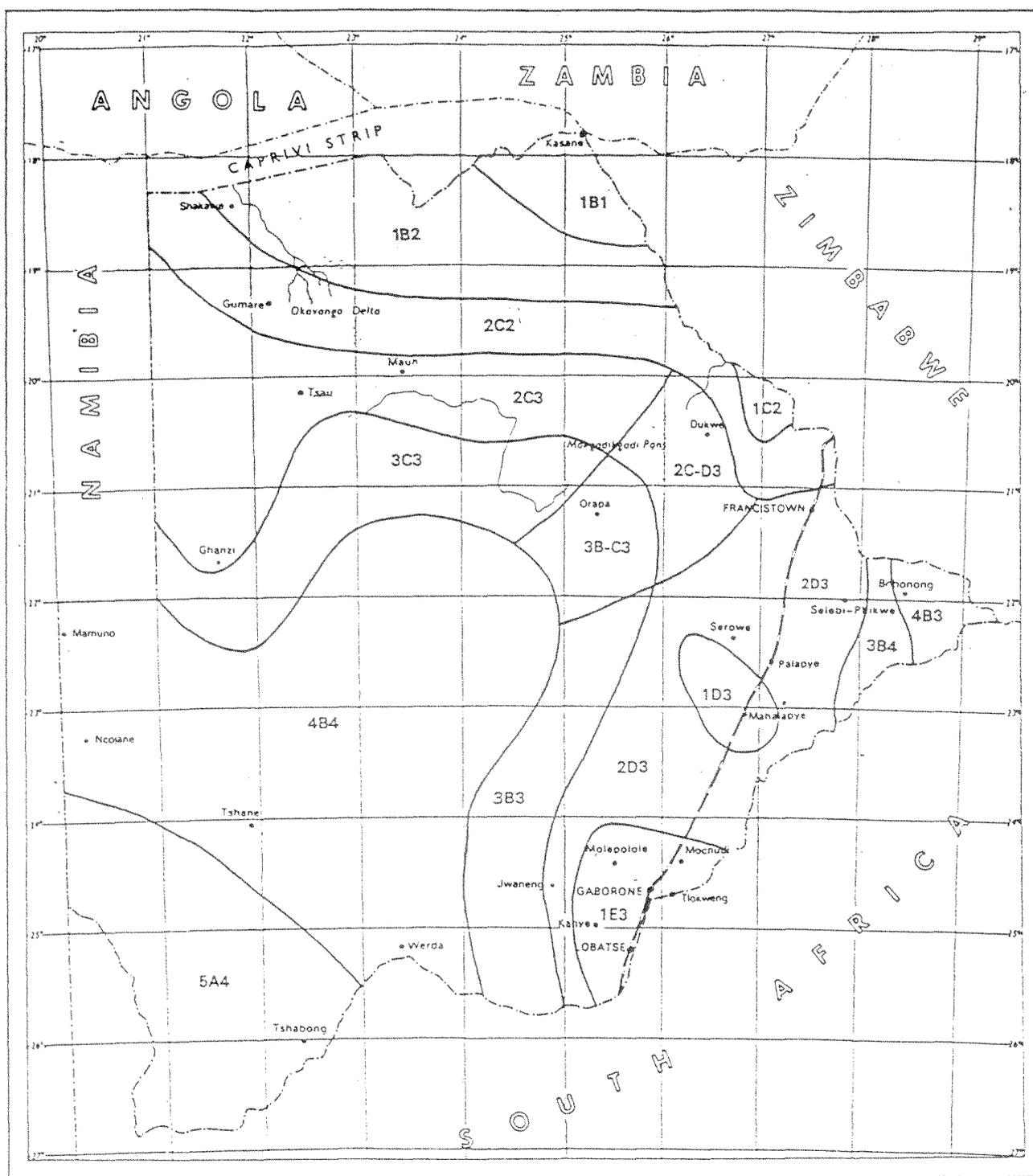


Fig. 3: AGRO-CLIMATIC ZONES OF BOTSWANA (Dambe, 1987)

Length of Season

Number of Dry Days  
within the Season

Length of Humid Period

Duration (days)	Frequency (%)
1. 101-120	75-100
2. 81-100	75-100
3. 61-80	75-100
4. 41-60	75-100
5. 41-60	50-74

A	0-10
B	11-20
C	21-30
D	31-40

Duration (days)	Frequency (%)
1 41-60	75-100
2 20-40	50-74
3 20-40	25-49
4 20-40	25

Sunshine hours are high to very high, being lowest during the period from November to March (7.4h/day - 8.2h/day) coinciding with the rainy season, and highest in winter reaching 9.9 h/day in August.

Windspeeds are generally moderate to low with a highest value of 9.2 km/h during October.

Table 4

Summary of climatic data for Francistown

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	Extr. max.	40.6	38.4	38.8	35.6	34.0	31.1	30.6	35.5	37.0	40.2	41.1	39.5
	Mean max.	30.7	29.5	29.3	27.7	25.6	23.0	23.1	25.1	29.8	31.5	31.0	30.3
	Mean min.	19.0	18.2	16.9	13.7	8.5	5.3	4.8	7.7	12.3	16.2	16.9	18.5
	Extr. min.	10.6	10.5	4.0	4.0	-1.0	-4.5	-5.0	-4.2	1.5	4.0	4.1	8.8
Relative Humidity (%)	08.00 hrs	69	74	72	74	62	67	70	60	51	56	59	68
	14.00 hrs	48	50	46	41	32	34	29	26	27	32	41	44
Sunshine (hours/day)		8.0	8.2	8.2	8.5	9.4	8.9	9.6	9.9	9.6	9.0	8.1	7.4
PET (mm)		180	161	155	128	107	89	98	127	162	188	182	181
Frost days	air	0	0	0	0	0	4	3	1	0	0	0	0
	ground	0	0	0	0	3	12	12	4	1	0	0	0

#### 1.2.4 Soil climate

Climatic parameters are considered in soil classification, particularly in the Soil Taxonomy (Soil Survey Staff, 1975 and 1987).

Considering the existing climatic data, the soils of the study area are mainly characterized by an aridic soil moisture regime.

In an aridic soil moisture regime the moisture control section is in most years dry in all parts more than half the time (cumulative) that the soil temperature at 50 cm depth is above 5°C. Additionally the control section is never moist in some or all parts for as long as 90 consecutive days when the soil temperature at 50 cm depth exceeds 8°C.

An aridic moisture regime is normally occurring in arid climates but also under semi-arid conditions depending on soil properties such as the presence of surface crusts and soil shallowness.

In the western part of the survey area the aridic moisture regime is transitional to ustic.

The mean annual soil temperature at 50 cm depth is 25.5°C; the difference between mean summer and winter soil temperature is more than 5.0°C.

This implies a hyperthermic soil temperature regime.

### 1.3 Geology

Three major geological formations can be recognized in the area : the Pre-Cambrian Basement complex in the west, the Karoo-Supergroup in the east and alluvial deposits along the Motloutse river.

Most of the Basement complex consists of migmatitic and granitoid gneisses and high-grade metamorphic tectonites of Precambrian age, associated with the Limpopo belt. Several phases of metamorphism and folding have produced the general WSW-ENE trend.

The Precambrian rocks have been divided into two structurally conformable formations termed the Banded Gneiss Formation and the Granitic Gneiss Formation respectively.

The Banded Gneiss Formation consists of variable granitized quartzofeldspathic gneisses and interbanded amphibolites. The varied lithology is responsible for a characteristic banded appearance on the aerial photographs and photogeological structural trendlines are often well developed.

The Granite Gneiss Formation is composed predominantly of migmatitic, porphyroblastic and granitoid gneisses and is more homogeneous than the terrain underlain by rocks of the Banded Gneiss Formation. Within the Granite Gneiss Formation several subordinate rock types of the Banded Gneiss Formation are present.

The amphibolites and ultramafic intrusive rocks are the host rocks to copper-nickel mineralizations. A major one is explored at Selebi-Phikwe mine.

The Karoo-Supergroup formation in the eastern part of the area consists mainly of Stormberg basalts underlain by Karoo sediments.

The basalt mass, much transected by dykes and small faults, has the overall structure of a syncline. They show a dark grey-brown regolith with several erosion remnants on the surface.

The Karoo sediments consist of mainly sandstone, probably Cave Sandstone, with occasionally siltstone outcrops. In some places these sediments are moderately well exposed and for the most part dip north because the northern side of the basin is fault controlled.

Older alluvial terraces are occurring around Tobane and Bobonong. More recent alluvial deposits are found along the Motloutse river.

### 1.4 Hydrology

Most of eastern Botswana drains into the Limpopo, but neither this river nor any of its tributaries has a perennial flow.

Although it carries large quantities of water during the rainy season, it frequently ceases to flow during the dry season. The rivers which flow into the Limpopo carry large quantities of water for periods of only a few days in a year.

The Motloutse river is one of the largest tributaries of the Limpopo catchment. It is a sand river characterized by a mobile, wide and shallow bed with a continuous cover of sand of variable depth. This sand cover is valuable in many areas as a perennial water reservoir. It was observed in some parts, some distance upstream from the confluence with the Tume river, that water appeared

to drain out of the sand during the dry season. In other areas however the water level is maintained in the sand throughout the winter. Presently some small scale irrigation farmers are pumping water from the sand river bed.

In order to meet increasing water demand, a proposal for the construction of a dam has been carried out. According to MacDonald (1990) the proposed Letsibogo dam is located 3 km upstream of Mmadinare village. They identified an optimum storage of  $125 \text{ m}^3 \cdot 10^6$ , with a yield of  $30.8 \text{ m}^3 \cdot 10^6$  a year.

### 1.5 Geomorphology

The geomorphology of the Hardveld is directly related to the underlying rocks. The landscape developed on the granitic gneisses of the Basement complex is gently undulating to undulating. According to De Wit and Bekker (1990) it corresponds with land system Hg1 of the Hardveld. It is part of the Quaternary erosion surface described by Bawden and Stobbs (1963). Major river courses such as the Motloutse incised the Tertiary surface and gave rise to an incised zone parallel to these rivers.

More to the east towards Bobonong, where the basalt outcrops occur, the major rivers incised the Tertiary erosion surface more profoundly. This process formed a dissected undulating plain (land system Hb1) with smaller areas of flatter ground around the Motloutse. This land system is topographically the lowest of all land systems in Botswana, varying from 590 masl in the east to 790 masl in the west.

Adjacent to this land system on basalt, dissected undulating plateaus on sedimentary rocks can be recognized. Due to subsequent river erosion, a dissected, rugged country with successive parallel ridges and scarps are formed. It corresponds with land system Hs1.

Alluvium is found in a narrow strip along the Motloutse river, the Letlhakane river and downstream of the Sedibe river. On both sides of the river natural levees and backswamps occur. In places along the Motloutse river terraces are found.

The natural levees are wedge-shaped ridges of sediment bordering stream channels. The levees gently slope from the river bank into backswamps away from the channels.

Natural levees are formed by deposition of sediment when flood waters of a stream overflow the banks. The stream velocity is reduced, causing deposition of the suspended sediment. The coarser sediments are deposited near the channel and grain size decreases away from the channel. The maximum height of natural levees indicates the water level reached during the highest floods.

The backswamps are the lowest-lying parts of a river flood plain. They are poorly drained areas with little or no relief. Backswamps are flat and form basins, in which the suspended fine-grained sediments settles out from over-bank flows, after the coarser sediments have been deposited on the levees.

The terraces are situated between two levees. They are flat, moderately well drained and consist of medium textured sediments.

## 1.6 Natural vegetation

The vegetation types of Botswana are described by Field (1978) and Timberlake (1980).

In this relatively densely populated area not many undisturbed areas can be found. *Acacia tortilis* is found encroaching in many vegetation types, which can be seen as a sign of disturbance.

The vegetation types often grade into one another. Within an area of anyone type small areas of other types may be found.

The major vegetation types which are recognized are:

### 1. Tree and shrub savanna on Hardveld (Basement complex).

Dominant species:

*Colophospermum mopane*  
*Acacia spp.*  
*Combretum spp.*  
*Commiphora spp.*  
*Sclerocarya caffra*  
*Boscia albitrunca*  
*Kirkia acuminata*  
*Grewia spp.*

### 2. Shrub savanna on Hardveld (Basalt).

Dominant species:

*Colophospermum mopane*  
*Kirkia acuminata*  
*Grewia spp.*  
*Acacia spp.*

### 3. Shrub savanna on clay-rich alluvial soils.

- On calcrete or calcium carbonate rich shallow soils:

The *Acacia mellifera* shrub savanna.

Dominant species:

*Acacia mellifera*  
*Grewia flava*  
*Acacia nebrownii* on calcrete ridges.

- On the clay-rich alluvial soils along smaller water courses and rivers and in depressions.

Dominant species:

*Acacia mellifera*  
*Acacia tortilis*  
*Combretum imberbe*  
*Ziziphus mucronata*

#### 4. Riverine woodland. (*Acacia tortilis* fringing woodland.)

Woodland of larger trees fringing the banks of the larger seasonal watercourses.

Dominant species:

*Acacia tortilis*  
*Combretum imberbe*  
*Acacia karroo*  
*Ziziphus mucronata*

#### 1.7. Agricultural land use

The major part of the area is used for traditional grazing by cattle and goats. Heavy pressure on the range around boreholes has led to the deterioration in productivity of grazing. The Range Ecology Section of the Ministry of Agriculture (1989) gives carrying capacities of 27-34 ha/LSU for the area of Selebi-Phikwe and of 35-46 ha/LSU for Bobonong.

The total area that is cultivated is relatively small at around 30 000 ha (MacDonald, 1988), and is generally concentrated around the major villages of Mmadinare, Tobane and Bobonong.

According to MacDonald (1990) four types of farming systems can be distinguished.

- Large livestock farms which mainly concentrate on cattle production, and are rarely involved in arable cropping.
- Smaller livestock owners which manage their animals from cattle posts. They become rarely involved in arable farming.
- Small mixed farms which combine livestock with arable farming. The cultivated land area generally varies between 2-5 ha per farm.
- Arable smallholdings without livestock, mostly operated by the poorer sections of the community.

Table 5 gives the distribution of farm holders by production mix. It can be concluded that the most common production mix is arable agriculture combined with cattle and smallstock.

For the small mixed farms and the arable smallholdings, sorghum is the main crop (see table 6). It is the staple food of the local people and the main source of local beer. Sorghum is usually interplanted with a mixture of cow-pea, pulses, pumpkin, squash and melon.

The enormous fluctuations in the areas planted over the different years should be noted.

**Table 5** Number of farm holders by production mix in the Bobonong region  
(Botswana Agricultural Statistics)

	1983	1985	1986	1988
cattle	1000	50	250	200
cattle+smallstock	2100	300	500	750
cattle+crops	200	400	100	250
cattle+crops+smallstock	1200	3050	2650	2900
crops	100	800	500	800
crops+smallstock	200	750	950	1250
smallstock	700	150	400	500
others	300	-	150	150

**Table 6** Planted area for different crops in the Bobonong region  
(in 000 ha's) (Botswana Agricultural Statistics)

	1983	1985	1986	1988
sorghum (pure stand)	0.5	1.8	3.3	5.9
sorghum (mixed stand)	3.2	10.5	6.8	14.3
maize	1.7	6.5	3.2	3.6
millet	0.1	0.6	0.8	1.0
beans/pulses	1.0	1.7	1.6	1.0

Usually farmers use traditional farming practices. According to the 1988 Agricultural Statistics, only 24% of the farmholders plough before the month of December. The main draft power used is donkeys and mules (59.6%); tractors are used by only 15.4% of the farmers.

Around 92% of the seed is broadcasted; row planting is an uncommon practice. Weeding control constitutes one of the major problems in traditional agriculture in Botswana; 87% of the farmers in the Bobonong region are weeding only once and 7% is never weeding.

Yields under traditional farming practices are very low. Table 7 depicts yield data for the major crops.

**Table 7** Average yield per ha harvested in the Bobonong region (kg/ha)  
(Botswana Agricultural Statistics)

	1983	1985	1986	1988
sorghum	225	292	118	247
maize	50	76	50	119
millet	-	207	200	225
beans/pulses	100	150	100	50

The land area occupied by irrigated agriculture along the Motloutse is insignificant. A few farmers are practicing small-scale irrigation, cultivating especially vegetable crops.

## 2. SOILS

### 2.1 Introduction

A reconnaissance soil survey at the scale of 1/250 000 was carried out by Venema in 1983 (Venema, 1983 ; Radcliffe, Venema and De Wit, 1990). Although this soil map gives a general idea on the occurring soil types and their spatial distribution, it is too general for locating potential irrigable lands. The current semi-detailed survey at the scale of 1/50 000 was prepared by Parzaneze in 1986 (report not published), and was later slightly modified by Marcus and Sinnige. At the same time MacDonald (1990) studied the area specifically for irrigation purposes.

For the current study a free survey method was used, based on the identification of physiographic patterns.

The maps are constructed by a combination of interpretation of aerial photographs and satellite imagery with field checks (ground truth). The photos used were runs 25 and 26 of the 1981 Motloutse Block survey.

The majority of the observations were augerings and have the purpose of verifying soil boundaries as interpreted from the photographs. The following features were described at each site : physiography, vegetation, drainage, soil moisture, presence of surface stones/rocks, erosion, and for each horizon the colour, texture, depth and presence of gravel and calcium carbonate.

More detailed observations were made from pits representative of soil units. The soil horizons of these profiles were studied in more detail and sampled. Also described were: mottling, structure, consistence, cutans, cementation, pores, roots, biological features and the nature of the boundaries between horizons. Samples were taken from every horizon where possible.

Soils were described using the "Guidelines for Soil Profile Description" ( FAO 1977) and "Botswana Soil Database: Guidelines for Soil Profile Description" (Rommelzwaal and Van Waveren, 1988). All observation points were registered on the 1:50,000 topographical maps (sheets 2123D3, 2127D4, 2128C3, 2128C4).

Soil analysis was done at the Agricultural Research Station at Sebele and included particle size distribution, exchangeable cations, cation exchange capacity, organic carbon, available phosphorus and electric conductivity. The laboratory methods used are given in the laboratory procedures manual (Breitbart, 1988).

## 2.2 Soil classification

The soils are classified following the FAO-UNESCO (1974) system with amendments made by the Soil Mapping Project, as described in the General Soil Legend of Botswana (Rommelzwaal 1988). Also the classification according to Soil Taxonomy (USDA, 1975, 1987) is given. Both systems have in common the principle of diagnostic horizons. The definitions of diagnostic horizons and properties can be found in Soil Taxonomy and in the Legend of the Soil Map of the World (FAO 1974).

Soils are also correlated with the Revised Legend of the Soil Map of the World (FAO/UNESCO/ISRIC, 1988).

## 2.3 Legend construction

The mapping symbol consists of a maximum of three elements. At the first level a distinction is made in main units according to the parent material; the second level consists of a subdivision into soil units. The third level makes a distinction between specific soil characteristics where necessary. Additionally soil phases are indicated.

## 2.4 Main units

The first level distinction is based on parent material and rock. In the mapping symbol it is presented as a capital letter. The definitions of the units distinguished in the Motloutse area read as follows :

- C : Soils which are highly calcareous, having a calcium carbonate content of 40% or more equivalent, within a depth of 50cm from the surface. This unit includes soils on shallow calcrete, nodular calcareous materials as well as limestone.
- A : Soils developed in alluvial deposits or alluvial reworked materials. The unit also includes soils formed in colluvium of mixed origin, provided that the substratum clearly consists of colluvially reworked material and is distinguishable from in situ weathered parent rock.
- G : Soils on acid and intermediate igneous and metamorphic rocks. This unit consists mainly of soils formed on granites, gneisses, diorites and quartzites of the Basement Complex.
- B : Soils on basic igneous and metamorphic rocks. This unit comprises soils developed on Karoo basalts, various dolerite/diabase intrusions and ultrabasic rocks.
- S : Soils developed in unconsolidated sand deposits or coarse grained sedimentary rocks. The texture of the soils is loamy fine sand or coarser to a depth of at least 50cm from the surface and not finer than fine sandy loam at a depth of 100cm.

## 2.5 Soil units

### 2.5.1 General

The soil units are defined according to a standard format. In the mapping symbol they are presented by a number, following the main unit capital letter. The main diagnostic criterion is the classification according to the FAO/UNESCO Legend of the Soil Map of the World (FAO 1974) with authorised changes to fit Botswana conditions. Further subdivision of the soil units is made by adding a suffix to the number, to separate similar soils on their different characteristics. It is unavoidable that soils mapped in a certain area differ slightly from the soil unit descriptions.

The soil unit description consists of elements related to:

- soil characteristics: colour, depth, texture;
- site characteristics: topography, drainage;
- phases: e.g. lithic, petric, saline, sodic, petrocalcic etc.;
- soil moisture regime: e.g. Luvisols versus Xerosols.

- **Soil depth.** The range is indicated using soil depth classes; the lower limit in the unit description indicates the depth to which roots of grasses and crops can penetrate. The soil depth is limited by the occurrence of hard rock or cemented layers.

0-25cm	very shallow
25-50cm	shallow
50-100cm	moderately deep
100-150cm	deep
>150cm	very deep

- **Drainage.** The classes are defined according to the FAO guidelines for soil profile description and the Soil Survey Manual (1951). The range given in the soil unit definition varies between two or three classes:

- **Colour.** The colours are described according to the Munsell Soil Color charts (Munsell, 1975). The colours refer to the B horizon or the C horizon, (if no B is present) in moist state. The indicated range lies within a square formed by the diagonal between the two value/chroma units either across one hue sheet or crossing several pages, comprising all colours in between:

- **Texture.** Textural classes are described following the revised subdivision by Remmelzwaal and Van Waveren (1988). The texture generally refers to the maximum expression of the B horizon within the profile, or to the texture at a depth of 100cm or immediately above a lithic/paralithic contact or a cemented horizon. If diagnostic for the soil classification the texture may refer to a depth of 125-150cm. Normally the texture range covers two to three classes.

- **Phases.** Phases are derived from the Legend of the Soil Map of the World (FAO/UNESCO, 1974) with amendments to fit Botswana conditions. The indication "partly" stands for the occurrence of the phase in 30-70% of the soil unit. Sometimes two phases were included in the soil unit description.

- **Topography.** The topography classes are described by Remmelzwaal and Van Waveren (1988). A general indication of the topography is given, often extending over a larger area (e.g. the landform) than covered by the individual soil unit. Where relevant the description of the physiography was added.

- **Site characteristics.** A general description of the hydrological conditions of the site was added to the unit description after the development of the "Land evaluation system for arable farming in Botswana" (Rhebergen 1988). The following classes are distinguished: receiving, slightly receiving, normal to (slightly) receiving, normal, normal to (slightly) shedding, slightly shedding, shedding.

The soil units recognized in the survey area and represented on the map are listed below. Details are given on occurrence, soil characteristics and vegetation.

Selected profiles with analytical data are given in Appendix 1. Other profiles are available from the Botswana Soil Database.

#### 2.5.2 Soils on alluvial deposits

A1                      FAO(1974): Pellic Vertisol, partly sodic phase  
                          FAO(1988): Pelli-eutric Vertisol, partly sodic phase  
                          ST: Typic Pellustert

Deep to very deep, poorly to imperfectly drained, very dark gray to dark grayish brown clay.

Flat to almost flat, normal to water receiving.

Characteristics: Structure is weak to moderate coarse to very coarse prismatic breaking into moderate medium to coarse angular blocky. Consistence when dry is hard to very hard in the topsoil increasing to extremely hard in the subsoil. Texture is uniformly clay. Slickensides may occur even in the topsoil and increase in the subsoil, where they are also intersecting, with the formation of wedge shaped aggregates. Surface mulches and gilgai are not well developed. A regular pattern of wide (up to 5 cm at the surface) and deep cracks is common. A concentration of sodium can be present in the subsoil.

Occurrence: Limited to interterrace depressions at Mmadinare and to very narrow backswamps near Bobonong.

Representative profile: SP16

Vegetation: open shrub savanna

A2                      FAO(1974): Chromic Vertisol  
                          FAO(1988): Eutric Vertisol  
                          ST: Mollic Torrert



Representative profile: SP115

Vegetation: Open tree savanna

A22a  
FAO(1974): Cambic Arenosol  
FAO(1988): Ferralic/Cambic Arenosol  
ST: Typic Torripsamment

Deep to very deep, well to somewhat excessively drained, dark brown to yellowish red sands to loamy sands.  
Flat to gently undulating, normal

Characteristics: Structureless to very weak medium to coarse subangular blocky.

Occurrence: Natural levees at Tobane and Bobonong.

Representative profile: SP41

Vegetation: Riverine woodland

A33a  
FAO(1974): Eutric Cambisol, salic phase  
FAO(1988): Eutric Cambisol, salic phase  
ST: Aridic Ustochrept

Deep to very deep, imperfectly drained dark grayish brown, clay loam to clay  
Flat, normal.

Characteristics: The structure is very weak to moderate coarse prismatic breaking to very weak to moderate medium to coarse subangular blocky. The consistence is hard to very hard. Slickensides are moderately developed even in the topsoil but not enough to form wedge-shaped aggregates. Moderate levels of salt accumulation occur in the subsoil in Selebi-Phikwe.

Transitions occur to calcic Cambisols with calcareous nodules in the subsoil

Occurrence: Limited areas in valley bottoms at Selebi-Phikwe and Tobane.

Representative profile: SP54

Vegetation: savanna

A34.1  
FAO(1974): Eutric Regosol, petric phase  
FAO(1988): Eutric Regosol, petric phase  
ST: Typic/Ustic Torriorthent

Moderately deep to deep, well to somewhat excessively drained, dark brown to

reddish brown sand to loamy sand.  
Flat to gently undulating, normal.

Characteristics: Weakly developed sandy soils with a gravel layer in the sub soil

Occurrence: on natural levees in Selebi-Phikwe and lower terraces in Mmadinare.

Representative profile: SP116

Vegetation: Tree savanna

A36  
FAO(1974): Luvic Xerosol  
FAO(1988): Haplic/Chromic Luvisol  
ST: Ustollic/Ustalfic/Typic Haplargid

Deep to very deep, moderately well to well drained, dark yellowish brown to dark reddish brown sandy loam to sandy clay loam.  
Flat to undulating, normal.

Characteristics: The structure is very weak to weak medium to very coarse sub-angular blocky. The consistence is in general very hard when dry and very firm when moist. Clay illuviation in the subsoil.

Occurrence: On broad complex terraces along the Motloutse river at Selebi-Phikwe and Bobonong where it forms the transition between levees and inter terrace depressions.

On terraces of major secondary streams at Selebi-Phikwe and Tobane.

Along secondary tributaries in Selebi-Phikwe and Bobonong where the parent material is gneiss or sandstone.

Narrow terraces along Motloutse river in the whole area.

Representative profile: SP111

Vegetation: Riverine woodland and shrub savanna

A36.1  
FAO(1974): Arenic luvic Xerosol  
FAO(1988): Arenic haplic/chromic Luvisol  
ST: Arenic Ustalfic Haplargid

Deep to very deep, moderately well to well drained, dark brown to reddish brown loamy sand to sandy clay loam.  
Gently undulating, normal.

Characteristics: The structure of the sandy topsoil is very weak medium to coarse subangular blocky or structureless, the subsoil has a very weak very

coarse subangular blocky structure. Clay illuviation in the subsoil.

Occurrence: Natural levees in Selebi-Phikwe and Mmadinare.  
From Tobane to Bobonong in broad terraces where it is the transition from the more sandy levee to the finer swale or from the lower slope to the terraces.

Representative profile: SP2026

Vegetation: Savanna, tree savanna and shrub savanna

A36.2                      FAO(1974): Luvic Xerosol, petric phase  
                            FAO(1988): Haplic Luvisol, petric phase  
                            ST: Ustalfic/Typic Haplargid

Deep, well drained, dark brown sandy loams to sandy clay.  
Gently undulating to almost flat, normal

Characteristics: The structure is massive to weak medium to coarse subangular blocky both in the topsoil and in the subsoil. Clay illuviation in the subsoil; a gravel layer is occurring.

Occurrence: On the interterrace depressions of the broad terraces along the Motloutse river at Selebi-Phikwe and Tobane.  
Along the major secondary streams at Selebi-Phikwe.  
In complex with A22a, A36, A36.1

Representative profile: SP23

Vegetation: Riverine woodland and open tree savanna

A37                         FAO(1974): Calcic luvic Xerosol  
                            FAO(1988): Calcic Luvisol/ Luvic Calcisol  
                            ST: Typic/Ustalfic Haplargid

Deep to very deep, imperfectly to moderately well drained, dark brown to strong brown sandy clay loam to clay.  
Flat to gently undulating, normal

Characteristics: The structure is very weak to weak medium to very coarse subangular blocky. Calcium carbonate concentration the matrix of the sub-soil, together with abundant lime nodules, cemented in places. Clay illuviation can be observed.

Occurrence: Along major tributaries at Selebi-Phikwe.  
Mainly along minor tributaries at Bobonong and Mmadinare.  
Along Motloutse river.  
Minor areas at Mmadinare.

Representative profile: SP118

Vegetation: Riverine woodland and shrubland

A37a                                      FAO(1974): Calcic luvic Xerosol  
  FAO(1988): Calcic Luvisol/ Luvic Calcisol  
  ST: Typic/Ustalfic Haplargid

Deep to very deep, moderately well to well drained, yellowish brown to yellowish red sandy loams to sandy clay loam.  
Gently undulating, normal.

Characteristics: Dark reddish brown to reddish brown sandy loam to sandy clay. The structure of the topsoil is very weak to weak medium to very coarse subangular blocky and in the subsoil massive to weak coarse to very coarse subangular blocky. A calcic horizon and clay illuviation is present within 125 cm.

Occurrence: In deep uniform terraces along the Motloutse river at Bobonong. At deep secondary tributaries where the parent material is basalt.

Representative profiles: SP2031, BE247

Vegetation: Shrub savanna

A39                                        FAO(1974): Haplic Xerosol  
  FAO(1988): Haplic Cambisol  
  ST: Ustollic Camborthid

Deep, imperfectly to well drained, brown to reddish yellow sandy loam to sandy clay.  
Flat to undulating, normal.

Characteristics: Very weakly structured topsoil, structureless subsoil. Weakly developed profile with a cambic-B horizon.

Occurrence: In a very limited area at Selebi-Phikwe along the Lethlakane river near the confluence with the Motloutse river. Along tributaries in Tobane.

Representative profile: SP38

Vegetation: Riverine woodland

### 2.5.3      Soils on basic igneous and metamorphic rocks

B1                                        FAO(1974): Eutric Regosol, lithic phase  
  FAO(1988): Eutric Regosol, lithic phase/Eutric Lep-  
  tosol  
  ST: Lithic Torriorthent

Very shallow to shallow, well to somewhat excessively drained, reddish brown to dark brown sandy loams to clay loam.

Undulating to hilly, water shedding.

Characteristics: Shallow soils with massive to very weak structure. A lithic contact occurs within 50 cm. Lime often occurs as soft coatings on the weathered basalt.

Occurrence: Bobonong upland on basalts. In complex with B1b and B6c.

B1b  
FAO(1974): Calcaric Regosol, lithic/shallow petric phase  
FAO(1988): Calcaric Regosol, lithic/shallow petric phase/Calcaric Leptosol  
ST: Lithic Torriorthent

Very shallow to shallow, well to somewhat excessively drained, reddish brown to dark brown sandy loams to clay loam.

Undulating to hilly, water shedding.

Characteristics: As B1, but with calcareous soft segregations

Occurrence: Bobonong upland on basalts. In complex with B1 and B6c.

Representative profile: BE261

B6c  
FAO(1974): Calcic luvisol Xerosol, partly petric phase  
FAO(1988): Calcic Luvisol/Luvisol Calcisol  
partly petric phase  
ST: Typic Haplargid

Shallow to moderately deep, well drained dark brown to reddish brown, clay loam to clay.

Undulating to rolling, water shedding.

Characteristics: Shallow soils with very weak to weak, medium to coarse subangular blocky structure. Concentrations of soft powdery lime in the upper zone of the weathered basalt.

Occurrence: Bobonong upland on basalt, in complex with B1 and B1b.

Representative profile: BE274



### 2.5.5 Soils on acid and intermediate igneous and metamorphic rocks

G1c                                      FAO(1974): Eutric Regosol, shallow petric phase  
  FAO(1988): Eutric Regosol, shallow petric phase  
  ST: Lithic/Typic Torriorthent

Moderately deep, moderately well to well drained, dark grayish brown to reddish brown sands to loamy sands.  
Almost flat to rolling, water shedding.

Characteristics: Shallow soils with massive to very weak subangular blocky structure. A gravel layer occurs within 50 cm, often within 25 cm of the surface

Occurrence: Upland on acid igneous and metamorphic rocks. In complex with G1e, G2e and G8a.

Representative profile: SP3

Vegetation: Open tree and open shrub savanna

G1e                                      FAO(1974): Lithosol  
  FAO(1988): Lithic/Eutric Leptosol  
  ST: Lithic Torriorthent

Very shallow, well to somewhat excessively drained, grayish brown to brown coarse sand to loamy coarse sand.  
Undulating, water shedding.

Characteristics: These very shallow soils are structureless to very weak subangular blocky.

Occurrence: Upland on igneous and metamorphic rocks. In complex with G1c, G2e and G8a.

Vegetation: Open savanna and shrub savanna

G2e                                      FAO(1974): Luvic Xerosol, shallow petric/petric phase  
  FAO(1988): Haplic/Chromic Luvisol, Haplic Lixisol,  
  shallow petric/petric phase  
  ST: Typic/Ustalfic Haplargid

Moderately deep, moderately well to well drained, grayish brown to red coarse sandy loam to sandy clay loam.  
Almost flat to undulating, water shedding to normal.

Characteristics: The structure is in general very weak medium to coarse subangular blocky massive in places. A gravelly layer occurs within 75 cm.

Occurrence: On the uplands in complex with G1c, G1e.

Representative profile: SP43, BE901

Vegetation: Shrub savanna and savanna

G6b  
FAO(1974): Luvic Xerosol, partly petric/petroferric phase  
FAO(1988): Haplic/Chromic/Ferric Luvisol, Haplic Lixisol partly petric/petroferric phase  
ST: Typic/Ustalfic Haplargid

Moderately deep to deep, moderately well to well drained, reddish yellow to red loamy coarse sand to clay. No petric or petroferric horizon within 75 cm. Almost flat to undulating, normal to slightly water shedding.

Characteristics: The structure is very weak to weak fine to coarse subangular blocky and may become massive. Clay illuviation in the subsoil, and a gravelly layer may occur between 75-125 cm.

Occurrence: On uplands north of Tobane and near Selebi-Phikwe.

Representative profile: SP2001, BE902

Vegetation: Savanna, tree savanna and shrubland

G14a  
FAO(1974): Arenic luvic Xerosol  
FAO(1988): Arenic chromic/haplic Luvisol  
ST: Arenic Ustalfic/Typic Haplargid

Very deep, well to moderately well drained, yellowish red to dark red sandy clay loam to sandy clay. Almost flat to undulating, normal.

Characteristics: Topsoil is loamy sand. The structure is massive to weak coarse subangular blocky. Deeper in the profile clay illuviation can be observed.

Occurrence: On pediments from acid igneous and metamorphic rocks at Selebi-Phikwe and Tobane.

Representative profile: SP2004

Vegetation: Shrub savanna and savanna



S11a                                   FAO(1974): Arenic luvic Xerosol  
                                      FAO(1988): Arenic haplic Luvisol  
                                      ST: Typic/Arenic Haplargid

Very deep, well to somewhat excessively drained, red to brown fine and fine-medium sandy loams.

Flat to undulating, normal

Characteristics: Weakly structured soils with a clay illuviation in depth.

Occurrence: Only one area west of Bobonong, north of the Motloutse river

S12a                                   FAO(1974): Arenic calcic luvic Xerosol  
                                      FAO(1988): Arenic luvic Calcisol  
                                      ST: Arenic Haplargid

Deep to very deep, well to somewhat excessively drained, brown to yellowish red sandy loams

Flat to undulating, normal

Characteristics: The structure is massive to very weak subangular blocky. A petrocalcic horizon may occur below 1.25 m.

Occurrence: North and west of Bobonong on fine sandstones, mainly in the area south of the Motloutse river.

S13a                                   FAO(1974): Petrocalcic Arenosol  
                                      FAO(1988): Arenic petric Calcisol  
                                      ST: Arenic Paleorthid

Moderately deep to deep, well to somewhat excessively drained, grayish brown to yellowish red sands and loamy sands.

Flat to undulating, normal.

Characteristics: The structure is massive to very weak subangular blocky. A petrocalcic horizon occurs within 1 meter depth.

Occurrence: West and North of Bobonong on fine sandstones, south of the Motloutse river.

Representative profile: SP145

## 2.6 General soil distribution

### Recent alluvial soils (main unit A)

The distribution of recent alluvial soils is shown in fig 4-7.

(a) The alluvium of the Motloutse upstream of Mmadinare is typified by the sequence riverbed - lower terrace - levee - backswamp.

The lower terraces show arenic eutric Regosols (A34.1) which are weakly structured. On the levees arenic luvisc Xerosols (A36.1) are encountered. In the backswamps deep, poorly drained, heavy clay soils with vertic properties occur (soil unit A1). More towards Mmadinare a more loamy luvisc Xerosol (A36) which is deep and moderately well to well drained can be found on the terraces and the levee and backswamp soils are not present.

(b) Close to Selebi-Phikwe a similar sequence of riverbed - levee - transitional terrace - backswamp can be recognized. The levees are sandier, with brownish eutric Arenosols (A22) in association with arenic eutric Regosols (A34.1). The transitional zone towards the backswamps is characterized by luvisc Xerosols (A36). The backswamps are less clayey than near Mmadinare, showing luvisc Xerosols (A36) with a sandy clay loam texture and a gravel layer within 100 cm of the surface.

(c) More eastwards towards Tobane larger and higher levees can be expected with cambic Arenosols (A22a). The sandier levees can be explained by the influx of sandy sediments derived from the Karoo sandstones.

The depressions between two levees are typical for this area. They show deep to very deep, medium textured luvisc Xerosols (A36) with sometimes a gravel layer within 100 cm of the surface (A36.2). The transitional lands between the levees and the terraces/depressions show arenic luvisc Xerosols (A36.1).

(d) Further eastwards to Bobonong the same sequence occurs. The interlevee depression soils are more extensive here.

It should be mentioned that the four sequences discussed above have a width of maximum 500 m, and that consequently great textural, morphological and chemical variations occur over very short distances.

### Older alluvial soils (main unit A)

The older alluvial soils are primarily found on terraces, especially near Tobane and Bobonong. West of Tobane terraces with deep to very deep, moderately well to well drained, sandy loams to sandy clay loams occur (A36). Sometimes the top soil is sandier (A36.1).

Minor terraces are characterized by soils with an accumulation of calcium carbonates at depth (calcic luvisc Xerosols A37a). These calcium rich soils can also be found on the major terraces around Bobonong.

The old alluvial soils are more homogeneous than the recent alluvial soils; much broader and uniform areas were mapped.

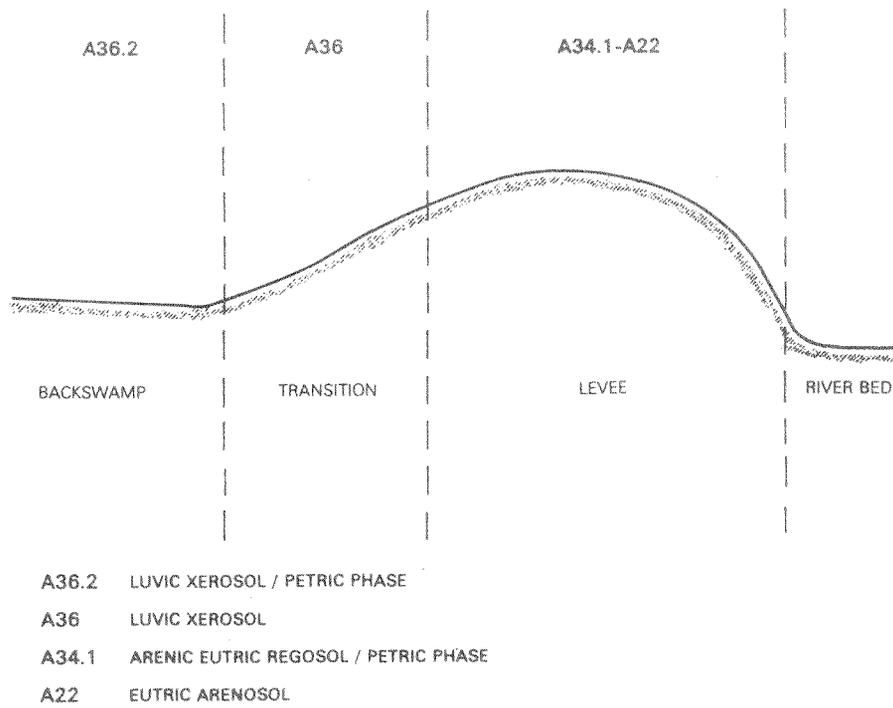


Fig. 5: Soil cross section of alluvial deposits at Selebi - Phikwe

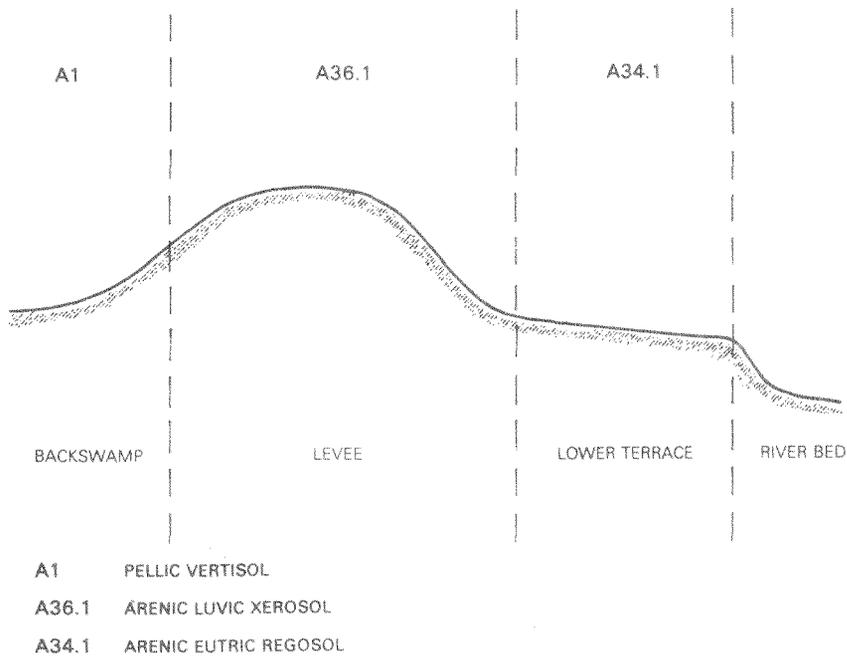
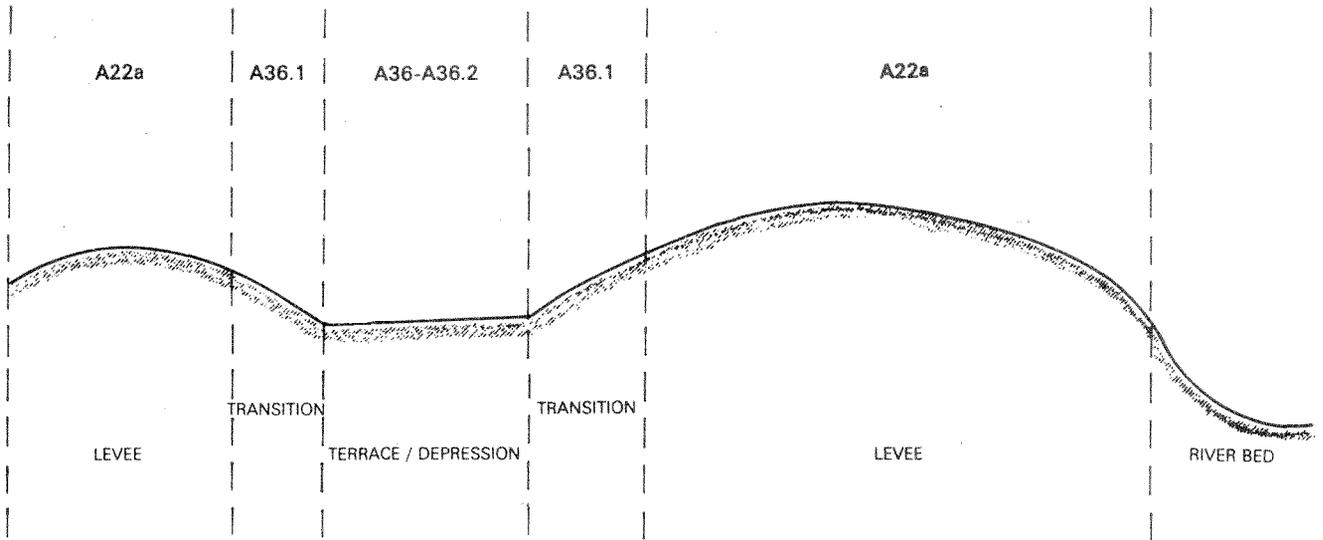
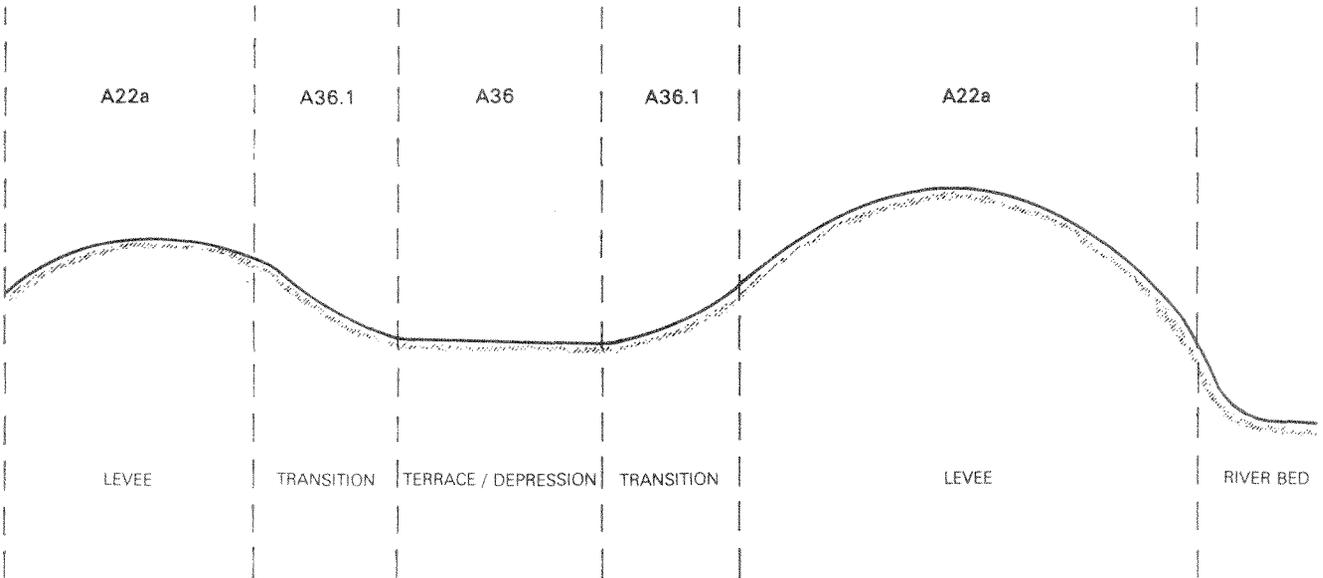


Fig. 4: Soil cross section of alluvial deposits at Mmadinare



- A22a CAMBIC ARENOSOL
- A36.1 ARENIC LUVIC XEROSOL
- A36 LUVIC XEROSOL
- A36.2 LUVIC XEROSOL / PARTLY PETRIC

Fig. 6: Soil cross section of alluvial deposit at Tobane



- A22a CAMBIC ARENOSOL
- A36.1 ARENIC LUVIC XEROSOL
- A36 LUVIC XEROSOL

Fig. 7: Soil cross section of alluvial deposit at Bobonong

#### **Soils on basalt (main unit B)**

Soils derived from basalt are exclusively found in the eastern part of the survey area near Bobonong. The upper and middle slopes of the dissected landscape are characterized by very shallow to shallow eutric Regosols (B1) which sometimes can be calcareous (B1b). For the lower parts, shallow to moderately deep, fine textured calcic luvisc Xerosols (B6c) with a gravel layer within 100cm of the surface are characteristic. Most of these soils are very eroded.

#### **Soils on acid igneous and metamorphic rocks (main unit G)**

These soils mostly developed in situ from siliceous gneisses, sometimes colluvial of origin, occur in the western part of the study area. The gently undulating to undulating uplands are characterized by very shallow (less than 10 cm), sandy, almost structureless lithosols (G1e), associated with moderately deep, sandy eutric Regosols (G1c) with a gravel layer within 50 cm of the surface. Sometimes clay illuviation can be observed in depth, resulting in a heavier texture, from sandy loam to sandy clay loam (G2e). On the lower slopes the soils are often moderately deep to deep sandy clay loams with a gravel layer that can occur deeper than 75 cm (G6b). Some very deep colluvial soils, sandy clay loam in depth but with a coarse sandy topsoil, can also be recognized (G14a).

#### **Soils on sedimentary rocks (main unit S)**

Soils derived from coarse grained Karoo - sedimentary rocks are found adjacent to B-soils in the eastern part of the area. The soils on the ridges and scarps are very shallow (S1) to moderately deep (S1a) ferralic Arenosols. A finer type of sedimentary rock gives deeper sandy loam soils exhibiting a calcium carbonate accumulation in depth (S12a). A moderately deep to deep Arenosol, showing an indurated calcic layer at depth (S13a) occurs in association with soils derived from highly calcareous materials.

#### **Soil on highly calcareous materials (main unit C)**

These soils derived from calcareous materials occur on patches of Karoo deposits, often remnants within the gneisses, especially near Tobane. The soils are generally very shallow (C1), rarely moderately deep (C5a) with an accumulation of calcium carbonates in the profile; sometimes an indurated calcrete layer can be observed.

### 3. LAND EVALUATION

#### 3.1 Rainfed agriculture

##### 3.1.1 Methodology

In semi-arid environments like this of the study area, the assessment of land suitability for rainfed cropping depends on understanding the soil water balance throughout the growing season, the interannual variation in soil moisture balance, and the impact of periods of moisture stress on crop yields. Ratings based on average conditions have very limited value under this climate as they fail to indicate the risks associated with growing a particular crop on a particular area of land.

A methodology based on modelling the soil water balance over a number of years for defined land units under a particular crop, and of predicting the impact of moisture stress on crop yield has been developed (Nachtergaele and De Wit, 1989; Radcliffe, De Wit and Schalk, 1990). The main elements of this soil moisture balance /crop yield model are illustrated in fig 8.

The underlying principle is that the impact of moisture stress on crop yield can be expressed by the use of "yield response factors" which are specific to individual crops and crop stages within the growth cycle of these crops.

This relationship is expressed in the following equation (Doorenbos and Kassam, 1979).

$$1 - (Y_a/Y_m) = k_y(1 - [E_{Ta}/E_{Tm}])$$

where:

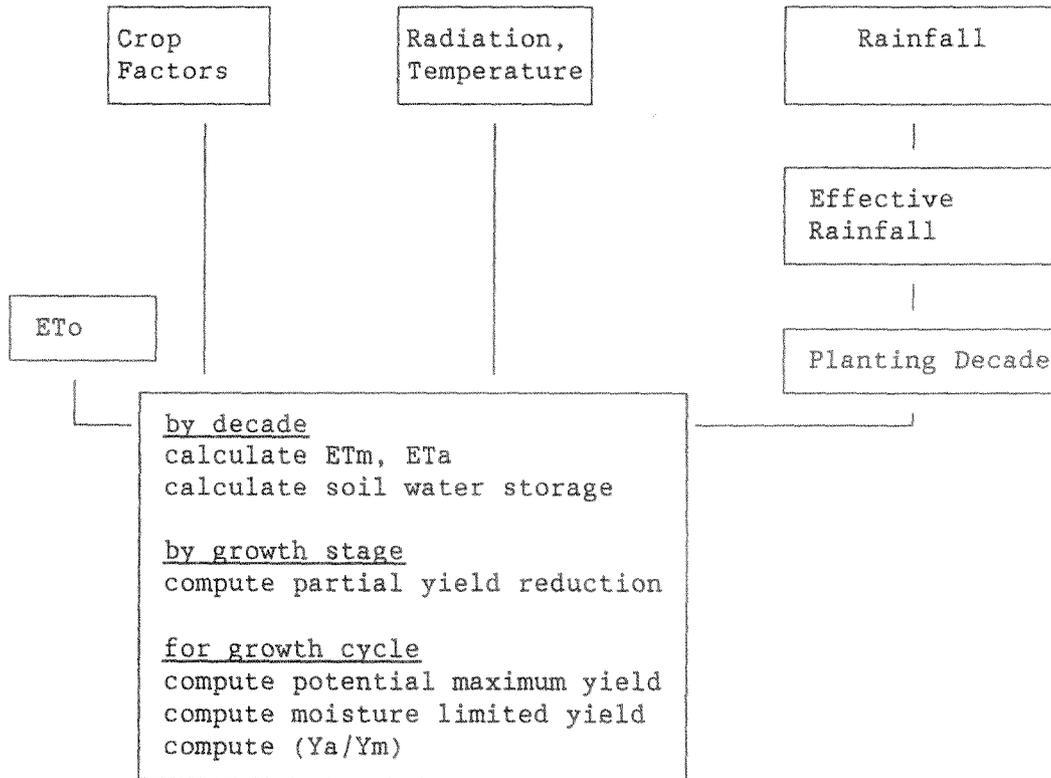
- Y<sub>a</sub> = moisture limited crop yield
- Y<sub>m</sub> = potential maximum yield (based on radiation, temperature conditions)
- k<sub>y</sub> = yield response factor
- E<sub>Ta</sub> = actual evapotranspiration (based on available water)
- E<sub>Tm</sub> = potential maximum crop evapotranspiration.

Thus k<sub>y</sub> relates the relative yield decrease (1-[Y<sub>a</sub>/Y<sub>m</sub>]) to the relative evapotranspiration deficit (1-[E<sub>Ta</sub>/E<sub>Tm</sub>]). The magnitude of k<sub>y</sub> is normally greatest in the flowering and yield formation periods, indicating a greater sensitivity to moisture stress at these times. Through combining estimates of the relative yield decrease through the growth stages of the crop, an estimate of the relative yield decrease and of the moisture limited yield (Y<sub>a</sub>/Y<sub>m</sub>) over the entire crop growth cycle is derived. Moisture limited yields generated by the model can then be compared both between years and between sites to provide a quantitative comparison of yields that can be expected at a stated level of probability on any defined land unit for which a suitable run of rainfall data is available.

Calculation of the soil moisture balance and of moisture limited yields was computerised by De Baveye (1986) and the resulting CYPAC programme is currently under further development by the Soil Mapping and Advisory Services Project. The model presently runs for individual hydrological years (September - August) using ten day (decadal) rainfall data and accesses crop and climatic data directly from data files (Schalk, 1990). Potential planting dates are recognised when rainfall in the preceding decade exceeds 15 mm and soil mois-

Figure 8

Structure of Moisture Limited Yield Model



ture balance and crop evapotranspiration are calculated by decade up to the end of the crop growth cycle.

Essential inputs to the model are:

- i) actual rainfall data for the reference climatic station (by decade)
- ii) average decadal PET data for the reference station, calculated according to SMEC (1987). As the coefficient of variation of total annual PET is less than 5% (Bhalotra, 1987), the use of long term mean PET as opposed to values for individual years is unlikely to substantially affect the results of this analysis.
- iii) soil available water holding capacity (averaged over the maximum rooting depth).
- iv) crop characteristics, such as effective rooting depth, the crop coefficient (kc), which determines the rate of evapotranspiration relative to PET and the yield response factor (ky) which the impact of moisture stress on eventual yield. These characteristics are required for the entire crop growth cycle and, in some cases, for individual growth stages.

### 3.1.2 Results

The model was run for the most promising and relevant land units listed in table 8.

It should be noted that rainfall data for Bobonong and Selebi-Phikwe covered 19 and 15 years respectively.

**table 8** Characteristics of land units

soil unit	soil classification	soil profile number	rainfall station	soil depth	soil AWC*
B6c	LVk**	BE 274	Bobonong	0.60	59
A37a	LVk	BE 247	Bobonong	1.25	122
G2e	LVx***	BE 901	Selebi-Phikwe	0.60	60
G6b	LVx	BE 902	Selebi-Phikwe	1.00	50
G14a	LVx	SP 2004	Selebi-Phikwe	2.35	92
A36	LVx	SP 2026	Selebi-Phikwe	1.70	67
A37	LVk	SP 2031	Selebi-Phikwe	1.95	146

\* corrected for gravel content if applicable

\*\* calcic Luvisol

\*\*\* chromic Luvisol

The results are presented in terms of moisture limited yield (Ya/Ym) likely to be exceeded in i) 50% of years (the 'median yield') and ii) 75% of years (the 'dependable yield') on the each of the land units in Table 9. Two scenarios are presented: the first in which it is assumed any planting decade in the period September - February can be utilized, and second which assumes that that only decades in the period 1st December - 31st January can be effectively utilized for planting by farmers. The second scenario is more realistic in most of Botswana where farmers rarely plant before November. Moreover for crops planted from February onwards, cool temperatures are likely to adversely affect crop production.

**Table 9** maximum moisture limited yields for optimal planting decade

	all planting decades		plantings decades in December and January	
	Median	Dependable	Median	Dependable
<b>Bobonong</b>				
B6c	20	17	18	15
A37a	27	21	22	18
<b>Selebi-Phikwe</b>				
G2e	24	20	21	17
G6b	28	24	25	19
G14a	31	25	27	18
A36	30	26	27	18
A37	33	26	28	18

These results give a quantitative comparison of the impact of moisture availability on potential yield and hence on land suitability between the land units considered. Assuming the farmer selects the potentially best yielding decade in the normal planting period of begin December to end January, he may expect a median yield of maximum 22% of the potential maximum on the best soil in Bobonong(A37a), and only 18% of the potential maximum yield in 3 out of 4 years.

Yields in Selebi-Phikwe increase to 28% on the best soil (A37) for the 50% probability limit, but decreases to 18% for the 75% probability limit.

It can be concluded that although moisture limited yields in Selebi-Phikwe are expected to be slightly higher than in Bobonong, they are very marginal in general.

Fig. 9 Probability of achieving "good" and "acceptable" yields

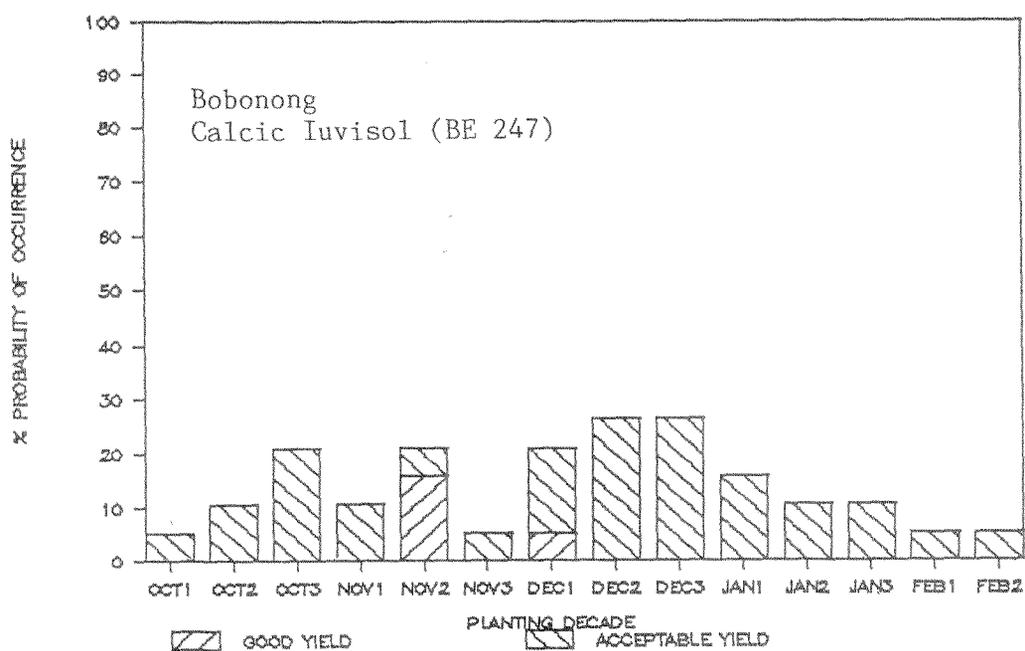
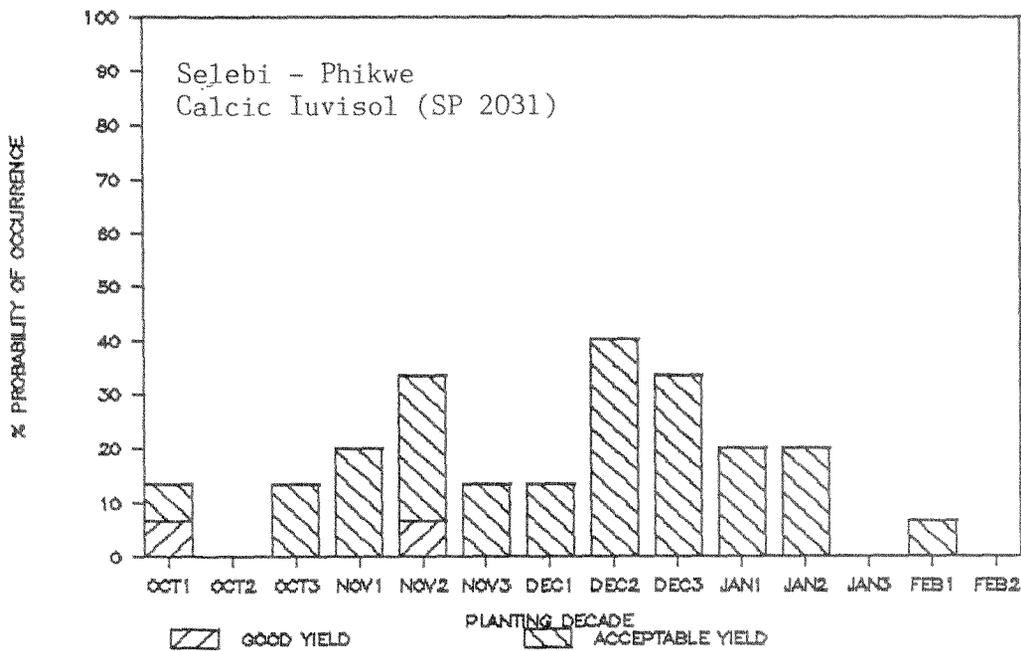


Figure 9 gives more detail on the probability of achieving threshold moisture limited yields in particular planting decades. It compares the probability of achieving a 'good' yield (defined as >50% of the potential maximum) and an 'acceptable' yield (defined as >25% of the potential maximum) over the potential cropping season for the best soil in Selebi-Phikwe and Bobonong.

The probability for obtaining a 'good' yield is very low. In Bobonong it peaks at the second decade of November (15% probability); in Selebi-Phikwe the first decade of October and the second of November show probabilities of 7% only. Thus early plantings in November are likely to yield higher than late plantings.

The probabilities for obtaining an acceptable yield are highest for both areas with planting dates in December. For Selebi-Phikwe four out of ten years will give an acceptable yield if farmers plant in the second decade of December. Probabilities for obtaining the same yield in Bobonong are much lower, with 25% in the second and third decade of December.

### 3.1.3 Conclusions

It can be concluded that due to low and erratic rainfall, rainfed sorghum production in the survey area is very marginal.

Around Selebi-Phikwe the chances for obtaining 'some' yield are higher than in Bobonong. Higher yields can be expected if planting occurs early in the season in November, but the risk of crop failure is also higher.

The lowest risks of crop failure are associated with plantings in December.

## 3.2 Irrigation

### 3.2.1 Methodology

#### 3.2.1.1 General

The following steps are to be considered for the exercise:

- definition of the land use types
- identification of the land use requirements
- identification of the land units
- evaluation and rating of the individual land characteristics
- evaluation of the overall land suitability

Two land use types are retained, namely portable/semi portable sprinkler irrigation and centre pivot irrigation.

Land use requirements are defined in terms of relevant land characteristics. These are measurable properties of the physical environment related to the productivity of land. They are described and measured during soil surveys, and can be used directly for the land evaluation exercise.

The identification of the land units of the Motloutse area is based on the semi-detailed soil survey. Only relevant and most promising land units, downstream of the projected Letsibogo dam to Tobane are considered.

By matching the land use requirements with the land units, the individual land characteristics are rated numerally on a normal scale from 0 to 100. Combining the different land characteristics, three indices can be calculated. The temperature index reflects the adaptability of a specific crop to the temperature regime of the area. The soil site index gives an appreciation of the land characteristics which do not influence crop production through the rooting system of the crop. The layered soil index regroups land characteristics which influence crop growth and yield through the root system of the crop; their importance decreases with depth. By combining these three indices in a multiplicative function, an overall land index is obtained; this index is crop, land and land use system specific.

### 3.2.1.2. Land Utilization Types

The land evaluation exercise that is worked out here is aimed to evaluate land for currently used irrigation systems in Botswana.

Two types of irrigation are widespread; (a) the portable/semi portable sprinkler irrigation and (b) the centre pivot irrigation.

#### Portable and semi portable sprinkler system

Portable and semi portable sprinkler systems are mostly related to small scale irrigation, with irrigation units of maximum a few hectares.

An important factor which restrains the exploitation of bigger sized fields is the technical and managerial expertise of the small farmer, and the capital availability. Considering capital availability, many farmers are limited by the number of sprinklers and respective pipe installation.

Currently the irrigation frequency under this land use system is low and it must be assumed that at least a 7 day period between 2 irrigation applications is a normal practice ( independent of the soil type ). This implies that the soil water storage is very important.

Management practices comprise mainly high fertilizer use, weeding, crop protection. No additional organic matter is used; liming is not a common practice.

The selection of crops is based on several factors, like : technical know-how of the farmer, suitability of climatological conditions ( especially temperature and frost sensitiveness ), current crop pattern, labour requirements, yield potential and marketing possibilities. The crops considered for the land evaluation exercise are given in table 11 (page 46).

#### Central pivot system

The central pivot system in Botswana is especially used for medium and large scale irrigation schemes. The system is designed to irrigate circles of a large radius, with low manual labour intensity. The radius varies from 300 m to 500 m, which corresponds respectively with irrigated surfaces of 28 ha and 79 ha. Technical knowledge is high.

The water application rate depends on the radius of the pivot, and is determined by the most distant point. For a 300 m pivot an average application rate of 10mm/15 min (or 40mm/h) is used. For a 500m pivot, it becomes 10mm/8 min (or 75mm/h). Thus in order to avoid erosion, a high soil infiltration rate is necessary. Under current irrigation schemes, the irrigation frequency is high; 1 application every 24 hours.

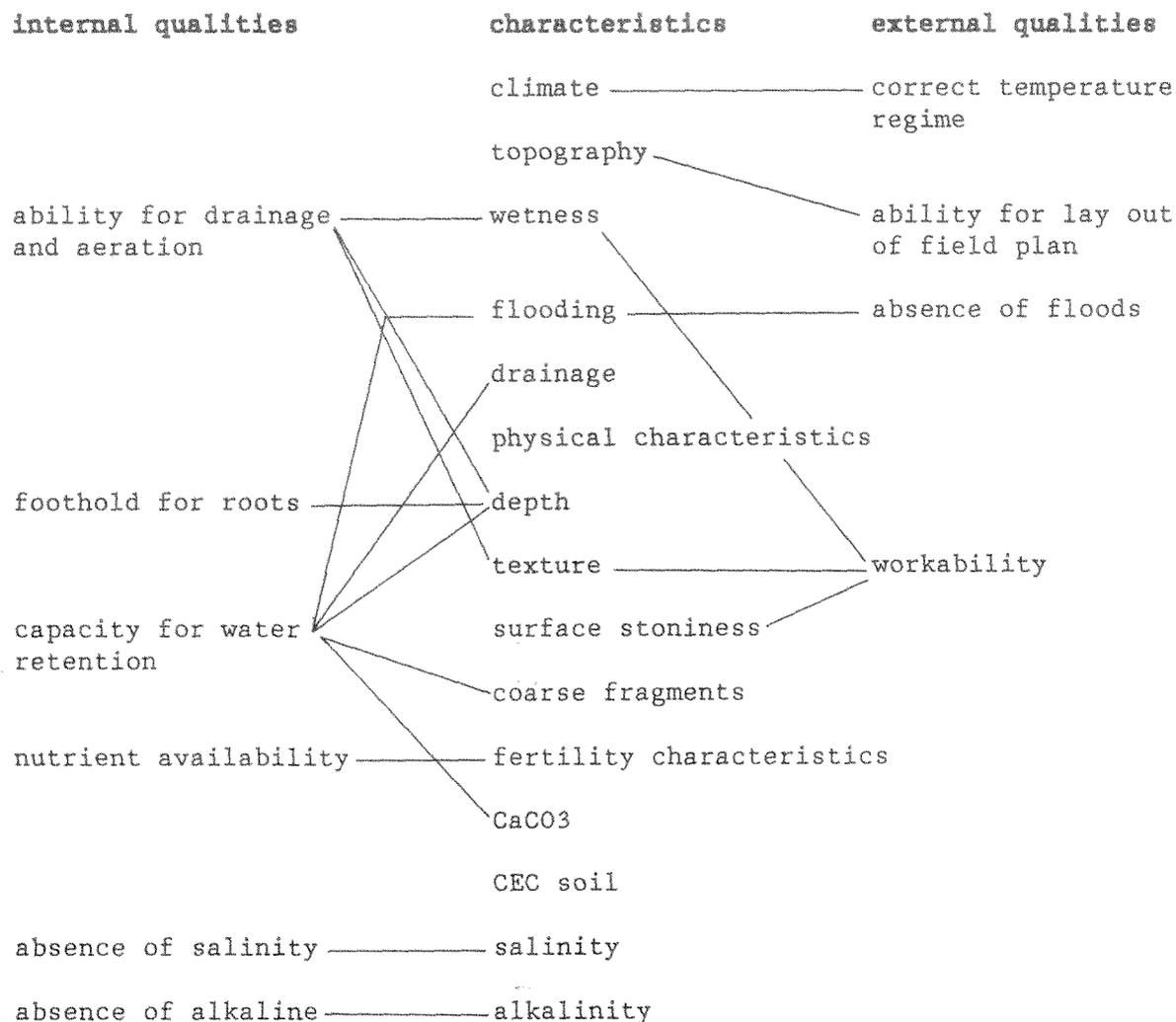
The management practices are almost the same as for small scale irrigation. Additionally small bunds crossed by ditches oriented at right angles are constructed to prevent run-off.

### 3.2.1.3 Selection of Land Characteristics

The selection of relevant land characteristics depends on the land qualities which are related to crop production and management. The land qualities to be considered for the proposed land use types are :

- correct temperature regime
- ability for drainage and aeration
- capacity for water retention
- foothold for roots
- absence of floods
- nutrient availability
- absence of salinity and alkalinity
- ability for lay-out of field plan
- workability of the land

The relation between these land qualities and the corresponding land characteristics is listed below:



#### 3.2.1.4 Rating of Land Characteristics

For each land characteristic, critical values in terms of limitation levels are determined for optimal, marginal and unsuitable conditions for the crop performance. If a land characteristic is optimal for plant growth, it has no limitation; on the other hand when the same characteristic is unfavourable for plant growth, it has a severe limitation.

Five degrees of limitations can be retained.

- 0 : no limitation - The characteristic is optimal for the proposed land utilization type.
- 1 : slight limitation - The characteristic is nearly optimal for the proposed land utilization type and affects productivity for not more than 20% with regard to the optimal benefit.
- 2 : moderate limitation - The characteristic has moderate influence on productivity; however benefit can still be made and the use of the land remains profitable.
- 3 : severe limitation - The characteristic has such an influence on the productivity of the land that use becomes marginal for the considered land utilization type.
- 4 : very severe limitation - Such limitations will not only decrease the productivity below profitable level, but may even totally inhibit the use of the land.

These limitation levels can be rated numeral on a normal scale. The relationship between limitation levels and numeral ratings is given in Table 10

Table 10

#### Relationship between limitation levels and numeral ratings

Limitation level	Rating
0	100-98
1	98-85
2	85-60
3	60-45
4	<45

## Temperature regime

There are three main effects of temperature upon plant growth:

- plant growth ceases below a critical temperature
- the growth rate varies with temperature
- very high or very low temperatures have adverse effects and may kill plants

Appropriate land characteristics for assessing temperature regime depend on the crop. Some crops, like potatoes, require a very strict temperature regime. Other crops, like some vegetables as radish and eggplant, have a much wider temperature range for optimal production.

Table 11 gives the critical temperature values for the proposed crops under irrigation in Botswana. It must be emphasized that different temperature characteristics (in kind and number) are used for the assessment. This is not a restriction because only the lowest rating is retained for the calculation of the overall suitability.

Table 11

### Temperature requirements of the considered crops

degree of limitation	0	1	2	3	4
carrot					
-----					
mean temp.	16-21	12-16	8-12	4-8	<4
growing period		21-25	25-29	29-35	>35
cabbage					
-----					
mean temp.	16-21	12-16	8-12	4-8	<4
growing period		21-25	25-29	29-35	>35
lettuce					
-----					
mean temp.	15-20	12-15	8-12	4-8	<4
growing period		20-22	22-24	24-27	>27
pea					
----					
mean temp.	15-20	12-15	8-12	4-8	<4
growing period		20-22	22-24	24-27	>27

degree of limitation	0	1	2	3	4
onion					
-----					
mean temp.	16-21	15-16	14-15	12-14	<12
growing period		21-25	25-29	29-35	>35
radish					
-----					
mean temp.	15-18	12-15	10-12	7-10	<7
growing period		18-20	20-22	22-24	>24
spinach					
-----					
mean temp.	15-18	12-15	10-12	7-10	<7
growing period		18-20	20-22	22-24	>24
phaseolus					
-----					
mean temp.	20-24	17-20	14-17	10-14	<10
growing period		24-26	26-29	29-33	>33
eggplant					
-----					
mean temp.	22-25	19-22	17-19	15-17	<15
growing period		25-28	28-32	32-35	>35
pumpkin					
-----					
mean temp.	22-25	19-22	17-19	15-17	<15
growing period		25-28	28-32	32-35	>35
sweet melon					
-----					
mean temp.	22-25	19-22	17-19	15-17	<15
growing period		25-28	28-32	32-35	>35
watermelon					
-----					
mean temp.	22-25	19-22	17-19	15-17	<15
growing period		25-28	28-32	32-35	>35

Degree of Limitation	0	1	2	3	4
groundnut					
-----					
mean min temp	18-20	18-16	16-14	14-12	<12
growing season		20-28	28-30	>30	
mean temp	22-26	22-20	20-18	18-16	<16
growing season		26-28	28-30	30-32	>32
mean max temp	34-36	36-38	38-40	40-42	>42
growing season		34-15		<15	
maize					
-----					
mean temp	22-25	22-18	18-16	16-14	<14
growing season		25-30	30-35	35-40	>40
mean min temp	16-18	16-12	12-9	9-7	<7
growing season		18-24	24-28	28-30	>30
safflower					
-----					
mean temp	15-20	15-13	13-10	10-5	<5
month 1		20-22	22-24	24-26	>26
mean temp	22-28	28-30	30-32	32-34	>34
month 2 to 4		22-20	20-17	17-12	<12
sesame					
-----					
mean min temp	18-20	18-16	16-14	14-12	<12
growing season		20-28	28-30	>30	
mean temp	24-27	27-28	28-30	30-38	>38
growing season		24-20	20-18	18-16	<16
mean max temp	34-36	36-38	38-40	40-42	>42
growing season		34-25	25-15		<15
soya					
-----					
mean temp	22-25	22-18	18-16	16-14	<14
growing season		25-30	30-35	35-40	>40
mean min temp	16-18	16-12	12-9	9-7	<7
growing season		18-24	24-28	28-30	>30

degree of limitation	0	1	2	3	4
cotton					
-----					
mean day temp vegetative stage	>30	30-25	25-20	<20	
mean temp day flowering stage	20-30	30-35	35-40	>40	
mean temp night flowering stage	12-18	18-22	22-27	>27	
mean temp ripening stage	27-32	32-38 <27	>38		
mean temp growing season	>26	26-24	24-22	22-20	>20
cowpea					
-----					
mean temp growing season	22-26	22-20	20-18	18-16	<16
mean temp month 1	>18	18-17	17-16	16-15	<15
mean minimum temp coldest month	>18	18-16	16-13	13-7	<7
sorghum					
-----					
mean temp growing season	22-26	22-20	20-18	18-16	<16
mean max. growing season	<36	36-38	38-40	40-42	>42
mean min. growing season	>18	18-16	16-14	14-12	<12

### Soil physical and chemical characteristics.

The rating of soil physical and chemical characteristics is discussed in depth in field document 20 (De Wit and Moganane, 1990).

An overview of the ratings for the different land utilization types is given in table 12.

Table 13 depicts the sensitiveness to salinity and alkalinity of the considered crops, as well as their minimum optimal rooting depth.

Some clarifying remarks should be made :

- Texture is evaluated with regard to water holding capacity and infiltration rate. For sprinkler irrigation, an irrigation frequency of 7 days is considered with a peak application intensity of 10 mm/h. Under the centre pivot

management system irrigation is applied every day, and peak application intensities of 40-80 mm/h, dependant on the radius of the system, are considered.

- Soil depth is indirectly evaluated as a function of the minimum optimal rooting depth of the specified crop (see section 3.2.1.6). The minimum optimal rooting depth is defined as the minimum soil depth necessary to show no limitation for crop production.

- As high fertilizer inputs are considered under the proposed management systems, the quantity of nutrients present in the soil is less important. Soil fertility is determined by the capacity to retain added nutrients in the topsoil.

**Table 12** Ratings of land characteristics for the considered land use types

land characteristics	land use type	0	1	2	3	4
topography (%)	sprinkler	<2	<4	<8	<16	>16
	centre piv.	<1	<2	<4	<8	>8
flooding (class)	all	F0			F1	F2
drainage (class)	all	well	mod. well	imperf.	poor	very poor
texture (class)	sprinkler	SC, SC1	L, SiL, fSL, SL	SiCl, CL, cSL, LfS, LS	C-60, SiC, LcS, fS	other
	centre piv.	coarser than cSL	fSL, SL	SCL	SC	other
subsurface stoniness(%) gravel, cobbles stones	all	<5	<10	<25	<50	>50
		0	<0.1	<0.5	<5.0	>5.0
CEC soil (meq/100g)	all	>6	>4	<4		
CaCO3 (class)	all	moder.	no, slight	strongly	extrem.	
salinity (mmho/cm)	sensitive	<2	<4	<8	<12	>12
	medium tol.	<4	<8	<12	<16	>16
	tolerant	<8	<12	<16	<30	>30
sodicity (ESP)	sensitive	<6	<12	<18	<24	>24
	medium tol.	<10	<18	<30	<50	>50
	tolerant	<18	<30	<50	>50	

Table 13

Salinity tolerance, alkalinity tolerance and minimum optimal rooting depth  
of the considered crops

crops	salinity	alkalinity	minimum optimal rooting depth
cotton	3	3	100 cm
cowpea	2	1	100 cm
eggplant			100 cm
groundnut	2	1	75 cm
maize	2	1	100 cm
phaseolus	1	1	75 cm
pumpkin	2		100 cm
sesame	2	2	100 cm
sorghum	2	2	100 cm
soya	2	1	100 cm
sunflower	2	1	100 cm
sweet melon	2	1	100 cm
water melon	2	2	100 cm
chickpea	2	1	100 cm
potato	2	1	50 cm
safflower	2	2	100 cm
tomato	2	2	100 cm
cabbage	2	1	50 cm
carrot	2	2	100 cm
lettuce	2	2	50 cm
onion	2	2	50 cm
pea	2	1	100 cm
radish	1	1	50 cm
spinach	3	2	50 cm
wheat	2	3	100 cm

1 : sensitive  
2 : medium tolerant  
3 : tolerant

### **3.2.1.5 Identification of land units**

The water resource constraint is the major component for selecting relevant potential irrigable lands.

Bearing in mind the location of the Letsibogo dam (see map 2) distances, from the reservoir to irrigable lands range between 10 and 70 km.

According to MacDonald (1990) the main criterion in selecting the most suitable areas for preliminary designs is the distance from the dam. Only large and homogeneous blocks of irrigable land up to Tobane should be put forward. This implies that the most promising lands up to Tobane should be retained as potential irrigable lands in terms of water availability.

According to the soil map six mapped soil units must be evaluated, namely G2e, G6b, G14a, A36, A36.1 and A37a. A profile description with analytical data of these soil units is given in appendix 1.

With regard to temperature, data from the nearest synoptic station Francistown are retained (see table 4, page 12).

### **3.2.1.6 Matching land use requirements with land units**

The land characteristics can be divided into three major groups: temperature characteristics, general soil site characteristics and layered soil characteristics.

Comparing land use requirements with land units, a rating can be attributed to each land characteristic.

Combining these individual ratings, three indices are obtained, namely a temperature index, a soil site index and a layered soil index.

The calculation of the three indices is as follows:

#### **Temperature index**

The temperature index for a specific crop under irrigation is based on the temperature regime.

A set of temperature characteristics reflects the adaptability of a crop to the temperature regime of a specific land unit. The ratings for each characteristic are calculated by linear interpolation comparing Table 11 with Table 4.

The most severe rating is considered as the temperature index.

#### **Soil site index**

Some land characteristics like topography, flooding, drainage, surface stoniness and cation exchange capacity (CEC) can be obtained directly by matching the land use requirements with the land units, thus by comparing Table 12 with the soil profile data.

Ratings for topography, CEC, and surface stoniness are calculated by linear interpolation. For flooding and drainage, which are indicated as classes and

not as numeral values, the mean value of the corresponding numeral rating is taken.

The combination of the ratings of each soil site characteristic gives the soil site index (equation 1).

$$I_{\text{site}} = \frac{Y1 \times Y2 \times Y3 \times Y4 \times Y5}{10^8} \quad (\text{equation 1})$$

where

- Y1 = rating for topography
- Y2 = rating for flooding
- Y3 = rating for drainage
- Y4 = rating for surface stoniness
- Y5 = rating for CEC

### Layered soil index

Some land characteristics like texture, % coarse fragments,  $\text{CaCO}_3$  - status, salinity and alkalinity, influence crop growth and yield through the root system of the crop, and their importance decreases with depth. To take this into account, and also to reflect the presence of an impermeable or inert layer within the rooting depth, these factors are rated as a function of the depth at which they occur.

In practice, the soil profile is divided into 25cm thick layers and the weighted average of these factors is multiplied with a specific weight factor for each layer up to the minimum optimal rooting depth of the crop.

The layered soil index is obtained following the equation:

$$I_{\text{layered}} = \frac{\sum_{i=1}^n Li \cdot WF \cdot TH}{RD \cdot 10^{n-2}} \quad (\text{equation 2})$$

- Li: ratings of the layered soil characteristics : texture, coarse fragments,  $\text{CaCO}_3$  status, salinity, alkalinity
- WF: weight factor
- TH: thickness of the layer
- RD: specific rooting depth of the crop

In equation (2), the thickness factor 'TH' is equal to 25cm or the depth from the upper limit of the layer to the upper limit of a root restricting layer, whichever is smaller.

Thus the depth to a root restricting layer is rated indirectly through a reduction of the thickness of the bottom layer and a rating of '0' for all layers below the upper limit of a root restricting layer, compared against the specific rooting depth.

### Land index

By combining the temperature index, the soil site index and the layered soil index, an overall index, or land index is obtained, following the equation:

$$I_{\text{land}} = \frac{I_{\text{temperature}} \times I_{\text{site}} \times I_{\text{layered}}}{10^4} \quad (\text{equation 3})$$

The land index reflects the suitability of a specific land unit for a specific land use type in physical terms, on a scale from 0 to 100 without estimates of costs and returns of the land use type.

Table 15

Optimal planting times and corresponding temperature indices for the considered crops

crop	planting month	duration growing period (days)	degree of limitation	temperature index
<b>summer crops</b>				
cotton	october	180	2	80
cowpea	december	120-140	0	100
eggplant	summer	70-120 (a)	0	100
groundnut	november	90-120 (b)	1	95
maize	summer	120-130	0	100
phaseolus	summer	60-90 (c)	0	100
pumpkin	summer	100-120	0	100
sesame	november	100-140	1	93
sorghum	summer	90-120	0	100
soya	october	100-130	0	100
sunflower	december	130-150	1	95
sweet melon	summer	50-90	0	100
water melon	summer	75-110	0	100
<b>spring crops</b>				
chickpea	march, july	120-140	0	100
potato	august	90-120 (d)	3	45
safflower	august	120-180	0	100
tomato	september	90-130	1	91
<b>winter crops</b>				
cabbage	winter	90-150	0	100
carrot	winter	60-85	0	100
lettuce	winter	40-85	0	100
onion	winter	100-140	0	100
pea	winter	65-100	0	100
radish	winter	22-40	0	100
spinach	winter	40-50	0	100
wheat	june	120	2	79

(a) short variety eggplant

(b) sequential branched groundnut

(c) green phaseolus

(d) early potatoes

## Land index

Table 16 gives the overall land suitability indices for the different land units and land utilization types. The following conclusions can be drawn.

**table 16** calculated land indices for different crops, land units and irrigation systems

	G2a		A36.1		G6b		A37a		G14a		A36	
	S <sup>a</sup>	P <sup>b</sup>	S	P	S	P	S	P	S	P	S	P
<b>summer crops</b>												
cotton	48	38	42	72	50	61	58	65	53	67	71	63
cowpea	60	48	52	90	63	76	73	81	66	84	89	70
eggplant	60	48	52	90	63	76	73	81	66	84	89	70
groundnut	68	55	43	87	60	76	70	77	63	80	84	70
maize	60	48	52	90	63	76	73	81	66	84	89	70
phaseolus	72	58	45	92	63	80	74	81	66	84	88	74
pumpkin	60	48	52	90	63	76	73	81	66	84	89	70
sesame	56	45	48	84	59	71	68	75	61	78	83	65
sorghum	60	48	52	90	63	76	73	81	66	84	89	70
soya	60	48	52	90	63	76	73	81	66	84	89	70
sunflower	57	46	49	86	60	72	69	77	63	80	85	67
sweet melon	60	48	52	90	63	76	73	81	66	84	89	70
water melon	60	48	52	90	63	76	73	81	66	84	89	70
<b>spring crops</b>												
chickpea	60	48	52	90	63	76	73	81	66	84	89	70
potato	35	29	17	41	29	36	35	36	30	38	39	35
safflower	60	48	52	90	63	76	73	81	66	84	89	70
tomato	55	44	47	82	57	69	66	74	60	76	81	64
wheat	47	38	41	71	50	60	58	64	52	66	70	55
<b>winter crops</b>												
cabbage	78	65	37	92	64	81	78	79	66	84	86	78
carrot	60	48	52	90	63	76	73	81	66	84	89	70
lettuce	78	65	37	92	64	81	78	79	66	84	86	78
onion	78	65	37	92	64	81	78	79	66	84	86	78
pea	60	48	52	90	63	76	73	81	66	84	89	70
radish	78	65	37	92	64	81	78	79	66	84	86	78
spinach	78	65	37	92	64	81	78	79	66	84	86	78

a sprinkler irrigation

b centre pivot irrigation

### 3.2.3 Conclusions

#### a/ choice of irrigation system

It is clear that for all soils, except G2e and A36, the land indices for the centre pivot system are higher than for the sprinkler system. This can easily be explained by the sandy texture of these soils. The arenic luvisol Xerosols (A36.1 and G14a) give the highest values. They are characterized by respectively a sandy and loamy sandy topsoil with a high infiltration rate. The topsoil of the calcic luvisol Xerosol (A37a) is sandy loam and thus less permeable. The luvisol Xerosol (G6b) has a high infiltration rate but water retention is lower due to a higher gravel content.

The luvisol Xerosol with a petric phase (G2e) shows the lowest land indices for both irrigation systems. The effective soil depth (70 cm) is a major constraint for deep rooting crops. Although its sandy clay loam texture in depth is advantageous for water retention, infiltration rates are not high enough for centre pivot irrigation. The deep luvisol Xerosol (A36) shows higher land indices for sprinkler irrigation than for centre pivot irrigation.

It can be concluded that for maximum production, centre pivot systems must be recommended. A major limitation for this type of irrigation is the heterogeneity of the lands. Homogeneous plots of at least 25 ha should be retained. For sprinkler irrigation only land unit A36 can be retained.

#### b/ choice of most suitable soils

Only the luvisol Xerosol with a petric phase (G2e) has a limitation for effective rooting depth if deep rooting and moderately deep rooting crops are considered. For shallow rooting crops this depth limitation disappears and the land indices for these crops will increase.

The higher land indices for shallow rooting crops may give a somewhat optimistic view of the land suitability. In order to maximize revenues, an occupation of the land during most part of the year is necessary, and thus crop rotation is likely. Most vegetables can be cultivated in winter time, but high temperatures limit their yield in the summer. During the hottest months emphasis should be put on grain crops, which are all deep rooting.

The overall appreciation of the land suitability index should thus be based more on grain crops than on vegetables.

To compare the different soils, the land indices of e.g. maize can be compared. The arenic luvisol Xerosol (A36.1) gives the highest value (90) under centre pivot irrigation, followed by soil units G14a (land index 84) and A37a (land index 81). This ranking can be indicative for the development of irrigation schemes.

The luvisol Xerosol with a petric phase (G2e) should be excluded for irrigation.

For sprinkler irrigation soil unit A36 can give very high yields, and probably is the only soil that can be irrigated rationally under this system.

For soil unit A37a, yields will be lower but still acceptable under this management system.

## REFERENCES

- Bawden, M. G., and Stobbs, A.R., 1963. The Land Resources of eastern Bechuanaland. Forestry and Land Use Section, Directorate of Overseas Surveys, Tolworth, U.K.
- Bhalotra, Y.P.R., 1987. Climate of Botswana. Part II, Elements of climate. Department of Meteorological Services, Gaborone.
- Breitbart, R., 1988. Soil testing procedures for soil survey. 3 vols. FAO/ UNDP/ Government of Botswana Project BOT/85/011. Field Document No. 3, Gaborone.
- Cavaliere-Parzaneze, A., 1986. The soils of the Motloutse area FAO/ UNDP/ Government Botswana Project BOT/85/011 (not published)
- Dambe, D., 1987. Agro Climatic Zones in Botswana. Department of Meteorological Services, Botswana. Draft.
- De Baveye, J., 1986. CYPAC; A Climatic Yield Potential Prediction Model for Annual Crops. RUG, Ghent, Belgium.
- De Wit, P.V., Moganane, B.G., 1990. Land Evaluation for irrigation - a case study: the Maunatlala area. FAO/ UNDP/ Government of Botswana. Project BOT/85/011. Field Document No. 20, Gaborone.
- De Wit, P.V., Bekker, R.P., 1990. Land Systems Map of Botswana. Legend. FAO/ UNDP/ Government of Botswana. Project BOT/85/011. Field Document No. 31, Gaborone.
- Doorenbos, J., Kassam, A.H., 1979. Yield response to water. FAO Irrigation and Drainage Paper No. 33, FAO, Rome.
- FAO, 1977. Guidelines for Soil Profile Description. Land and Water Development Division, FAO, Rome.
- FAO, 1978. Report on the Agro-Ecological Zones Project. Volume 1. Methodology and Results for Africa. World Soil Resources Report No. 48, FAO, Rome.
- FAO/ UNESCO, 1974. Soil Map of the World 1:5 000 000. Volume 1: Legend. United Nations Educational, Scientific and Cultural Organisation, Paris.
- FAO/ UNESCO/ ISRIC, 1988. FAO - UNESCO Soil Map of the World. Revised legend. World Soil Resources Report No. 60. FAO, Rome.
- Field, D.I., 1978. A handbook of basic Ecology for range management in Botswana. Ministry of Agriculture, Republic of Botswana.
- Mac Donald and Partners, 1988. Motloutse dam Feasibility/ Preliminary design study. Scheme identification Report. Department of Water Affairs. Republic of Botswana.

- Mac Donald and Partners, 1990. Motloutse Dam. Feasibility/ Preliminary Design Study. Volume 5. Department of Water Affairs, Republic of Botswana.
- MOA/ MFDP, 1983-. Botswana Agricultural Statistics. 4 Volumes.
- MOA, 1989. Potential carrying capacity map of Botswana. Range ecology section, Ministry of Agriculture, Gaborone.
- Nachtergaele, F.O.F., De Wit, P.V., 1989. A methodology to calculate anticipated rainfed crop yields. FAO/UNDP/Government of Botswana. Project BOT/85/011. Technical Paper 13, Gaborone.
- Radcliffe, D.J., De Wit, P.V. and Schalk, B., 1991. Moisture availability: The key to land resource assessment in the semi arid zone. Proceedings 1st Scientific Conference, SADCC Land and Water Management Research Programme, Gaborone. (in press).
- Radcliffe, D.J., Venema, J., De Wit P.V., 1990. Soils and Land Suitability for north eastern Botswana. FAO/ UNDP/ Government Project BOT/85/011 Field Document No. 17.
- Rommelzwaal, A., 1988. General Soil Legend of Botswana. FAO/UNDP/Government of Botswana Project BOT/85/011. Field Document No. 11, Gaborone.
- Rommelzwaal, A., Van Waveren, E.J., 1988; Botswana Soil Database. Guidelines for Soil Profile Description. FAO/UNDP/Government of Botswana Project BOT/85/011. Field Document No. 9, Gaborone.
- Schalk, B., 1990. A methodological data base system for agricultural use. User Manual. FAO/UNDP/Government of Botswana Project BOT/85/011. Field Document No. 22, Gaborone.
- Soil Survey Staff, 1975; Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. United States Department of Agriculture. Washington DC.
- Soil Survey Staff, 1987; Keys to Soil Taxonomy (third printing). SMSS technical monograph No. 6. Ithaca, New York.
- Timberlake, J., 1980. Vegetation map of South East Botswana. Ministry of Agriculture, Gaborone.
- USDA, 1951; Soil Survey Manual. United States Department of Agriculture, Washington DC.
- Venema, J.H., 1983 Soils of North East Botswana, FAO BOT/85/011. Field Document (not published).

## APPENDIX 1

### Representative profiles and analytical data

Soil unit	Classification (FAO 1974)	Profile No.
A1	Pellic Vertisol	SP16
A2	Chromic Vertisol	SP94
A22	Eutric Arenosol	SP115
A22a	Cambic Arenosol	SP41
A33a	Eutric Cambisol, sodic phase	SP54
A34	Eutric Regosol, petric phase	SP116
A36	Luvic Xerosol	SP111
A36.1	Arenic luvic Xerosol	SP2026
A36.2	Luvic Xerosol, petric phase	SP23
A37a	Calcic luvic Xerosol	SP2031
A37a	Calcic luvic Xerosol	BE247
A39	Haplic Xerosol, petric phase	SP38
B1b	Calcaric Regosol, shallow petric phase	BE261
B6c	Calcic luvic Xerosol, shallow petric phase	BE274
C5a	Calcic luvic Xerosol	SP2020
G1c	Eutric Regosol, shallow petric phase	SP3
G2e	Luvic Xerosol, petric phase	BE901
G2e	Luvic Xerosol, petric phase	SP43
G6b	Luvic Xerosol	SP2001
G6b	Luvic Xerosol, petric phase	BE902
G14	Arenic luvic Xerosol	SP2004
G13a	Petrocalcic Arenosol	SP145

SOIL PROFILE DESCRIPTION

SHEET : 2127D3  
 LOCATION : 3.25km NW Mmadinare.  
 AUTHOR(S) : A.Cavaliere-Parzaneze C.I.Ketlogetswe  
 CLASSIFICATION FAO: Pellic Vertisol(1988) Pellic Vertisol (1974) sodic phase  
 ST : Typic Pellustert  
 LANDFORM : alluvial plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: cracks 3 cm wide, slight evidence of salt,  
 LAND USE: grazing  
 SPECIES : Trees -  
 : Shrubs - Colophospermum mopane (dom.)  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: dry 0 - 60 , slightly moist 60 - 90 cm  
 SURF. STONES: none  
 EROSION : nil

REMARKS:

SAMPLES: A: 0 - 20 B: 30 - 50 C: 60 - 80

A 0 - 25 cm Very dark gray (10YR 3/1) (moist) and dark gray (10YR 4/1) (dry), clay, moderate very coarse prismatic and moderate medium to coarse subangular blocky structure, extremely hard, broken slickensides, common fine pores, non calcareous, common fine to medium roots, abrupt wavy boundary.  
 Bw 25 - 55 cm Very dark gray (10YR 3/1) (moist) and very dark gray (10YR 3.5/1) (dry), clay, moderate medium to coarse subangular blocky structure, extremely hard, continuous slickensides, few fine pores, non calcareous, common fine to medium roots, clear wavy boundary.  
 Bn 55 - 90 cm Black (10YR 2-/1) (moist), clay, moderate medium to coarse angular blocky structure, very firm, continuous intersecting slickensides, few fine and few very fine pores, non calcareous, few fine roots.

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 17/12/90

print date: 21/01/91

## STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0016

SAMPLE DEPTH	pH	EC m	CaCl2	ms/cm	ppm	EC m	P m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR			
																		weight %	<-----	meq/100gr soil	%	%	vcS				cs	ms	fs
A	0	20	7.4	6.9	0.4	B	13	1.0	0.00	26.5	16.2	8.7	1.2	0.4	0.0	100			2	5	5	8	8	8	14	52	44	H	0
B	30	50	7.4	7.1	0.9	B	13	0.7	0.00	29.4	17.8	9.2	0.9	1.6	0.0	100			4	7	6	8	6	5	13	51	52	H	0
C	60	80	6.9	6.3	2.6	B	7	0.7	0.00	31.6	18.5	9.7	0.9	3.4	0.0	100	0.0		5	8	6	7	6	6	11	52	55	H	0

Soil Survey of Botswana FAO/BGT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART. SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128C4  
 LOCATION : 2km N. Bobonong N. of Motloutse river.  
 AUTHOR(S): A.Remmelzwaal A.Cavaliere-Parzaneze C.I.Ketllogetswe  
 CLASSIFICATION FAO: Eutric Vertisol(1988) Chromic Vertisol (1974)

GRID : PZ-472-721  
 COORD: 21-57-10-S 28-25-33-E  
 DATE : 13/07/86

AGRO CLIM.ZONE: 4B3  
 ELEVATION : 688 m  
 SMR: aridic

LANDFORM : pediment  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: no sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional dryland farming, crops: sorghum, peas  
 SPECIES : Trees  
 : Shrubs  
 : Grasses/forbs

LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY:  
 VEGETATION:

POSITION: lower part  
 SLOPE : 0 - 1 %

GRASSCOVER:

PARENT MATERIAL: alluvium  
 MOIST. COND: slightly moist 0 - 10 , moist 10 - 100 cm  
 SURE-STONES: none  
 EROSION : nil

ROCK TYPE:  
 ROCK OUTCROP: none

GEOLOG. UNIT: Basement complex  
 DRAINAGE : imperfectly drained  
 HUMAN INF: ploughing

REMARKS:

SAMPLES: A: 0 - 10 B: 10 - 20 C: 30 - 50 D: 65 - 80

- Ap 0 - 10 cm Very dark grayish brown (10YR 3/1.5) (moist) and dark grayish brown (10YR 4/1.5) (dry), clay, strong medium to coarse granular structure, hard, few very fine pores, very few rounded rock fragments, very few fine hard white calcareous nodules, strongly calcareous, common very fine to fine roots, abrupt wavy boundary.
- Bw1 10 - 20 cm Very dark grayish brown (10YR 3/1.5) (moist), clay, moderate very coarse subangular blocky structure, firm to very firm, patchy slickensides, common very fine pores, no rock fragments, very few fine hard white calcareous nodules, moderately calcareous, common very fine to fine roots, gradual wavy boundary.
- Bw1 20 - 60 cm Very dark grayish brown (10YR 3/1.5) (moist), clay, strong coarse to very coarse subangular blocky structure, firm to very firm, continuous intersecting slickensides, common very fine pores, very few fine hard white calcareous nodules, moderately calcareous, common very fine to fine roots, gradual wavy boundary.
- Bw3 60 - 100 cm Very dark gray (10YR 3/1) (moist), clay, strong coarse to very coarse angular blocky structure, very firm, continuous intersecting slickensides, few very fine pores, few fine hard white calcareous nodules, strongly calcareous, very few very fine roots.

## STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0094

SAMPLE DEPTH	pH	EC m	P ppm	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CECclay	METH	PRETR								
														H2O CaCl2	ms/cm	ppm	weight %	<-----				meq/100gr soil	----->	%	%	vcS	cS	mS	fS
A	0	10	7.7	7.2	0.0	B	3	0.4	0.00	55.4	81.3	9.5	1.3	0.2	0.0	100			1	2	2	8	41	7	13	57	94	H	0
B	10	20	7.7	7.2	0.0	B	2	0.7	0.00	55.2	81.7	10.0	1.1	0.2	0.0	100			1	1	1	6	10	10	13	57	92	H	0
C	30	50	7.6	7.2	0.0	B	1	0.7	0.00	56.4	81.2	14.7	0.7	0.5	0.0	100			1	1	1	7	11	11	12	56	95	H	0
D	65	80	7.7	7.2	0.0	B	1	0.7	0.00	56.2	79.0	18.0	0.7	0.9	0.0	100			1	1	1	5	9	8	13	62	86	H	0

Soil Survey of Botswana FAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
 LOCATION : 2.4km NE Motloutse-Letlhakane confl. N. McLo. R..  
 AUTHOR(S): K.Verbeek A.Cavaliere-Parzanze A.Remmelzwaal R.Kelebehang  
 CLASSIFICATION FAO: Luvisc Arenosol(1988) Eutric Arenosol (1974)

GRID : PF-548-798  
 COORD: 21-53-09-S 27-54-31-E  
 DATE : 08/05/86

AGRO CLIM.ZONE: 2D3  
 ELEVATION : 806 m  
 SMR: aridic to ustic

ST : Typic Torripsamment  
 LANDFORM : alluvial plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: no cracks,  
 LAND USE: traditional grazing  
 SPECIES : Trees - Acacia karroo (dom.) Acacia laederitzii var.laederitzii Acacia tortilis subs. heteroantha Acacia mellifera

LAND ELEMENT : levee  
 MICRO TOPOGRAPHY: uneven  
 VEGETATION: open tree savanna

POSITION: higher part  
 SLOPE : 3 - 4 %  
 GRASSCOVER:

: Shrubs -  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: dry 0 - 10 , slightly moist 10 - 110 cm  
 SURF.STONES: none  
 EROSION : nil

ROCK TYPE:  
 ROCK OUTCROP: none

GEOLOG. UNIT: Basement complex  
 DRAINAGE : somewhat excessively drained  
 HUMAN INF: nil

REMARKS: Acacia mellifera also added.

SAMPLES: A: 0 - 15 B: 30 - 50 C: 80 - 100

- A 0 - 15 cm Dark yellowish brown (10YR 4/4) (moist) and pale brown (10YR 6/3) (dry), sand, weak medium to coarse subangular blocky structure, slightly hard, few very fine pores, very few rounded rock fragments, non calcareous, few very fine to fine roots, gradual smooth boundary.
- C 15 - 110 cm Dark yellowish brown (10YR 4/4) (moist) and pale brown (10YR 6/3) (dry), sand, single grain structure, loose, few very fine pores, very few flat rock fragments, non calcareous, few very fine to fine roots.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 18/12/90

print date: 21/01/91

## STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0115

SAMPLE DEPTH	pH	H2O	CaCL2	mS/cm	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)										CECclay	METH	PRETR
																			weight %	<-----	meq/100gr soil	meq/100gr	%	%	vcS	cS	mS	fS			
A	0	15	5.5	4.3	0.0	B	27	0.4	0.00	2.8	1.1	0.5	0.4	0.0	0.0	71	0.0	0.0	6	22	34	20	7	4	3	5	22	H	N		
B	30	50	5.4	4.6	0.0	B	6	0.3	0.00	4.3	1.3	0.9	0.3	0.1	0.1	60	0.0	0.0	5	20	31	21	9	5	2	8	38	H	N		
C	80	100	5.6	4.8	0.0	B	6	0.1	0.00	3.6	1.2	0.6	0.3	0.1	0.1	61	0.0	0.0	5	21	34	19	7	2	1	12	27	H	N		

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART. SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128C3  
 LOCATION : 2.5km NW Tloane S. of Morloutse river.  
 AUTHOR(S): A.Cavaliere-Parzaneze C.I.Ketlogetswe  
 CLASSIFICATION FAO: Ferralic Arenosol(1988) Cambic Arenosol (1974)  
 ST : Typic Torripsamment

LANDFORM : alluvial plain  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: no sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional grazing  
 SPECIES : Trees - Acacia tortilis subs. heterocantha (dom.) Acacia erioloba Acacia mellifera Acacia erubescens  
 : Shrubs - Grewia bicolor (dom.)  
 : Grasses/forbs-

PARENT MATERIAL: alluvium  
 MOIST. COND: moist 0 - 45 , dry 45 - 120 cm  
 SURF.STONES: none  
 EROSION : nil

REMARKS:

SAMPLES: A: 0 - 20 B: 60 - 80

C1 0 - 90 cm Dark brown (7.5YR 3/3) (moist) and dark brown (7.5YR 4/4) (dry), coarse sand, single grain structure, loose, few fine pores, non calcareous, common fine to medium roots, gradual smooth boundary.

C2 90 - 120 cm Dark brown (7.5YR 3/4) (moist) and dark brown (7.5YR 4/4) (dry), coarse sand, single grain structure, loose, few fine pores, non calcareous, few fine roots.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0041

SAMPLE DEPTH	pH	H2O	CaCl2	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CECclay	METH	PRETR				
																		vcS	cS	mS	fS	vfS				cSi	fSi	Clay	meq/100gr
A	0	20	6.3	5.7	0.2	B	39	0.5	0.00	4.6	3.4	0.3	0.3	0.0					13	29	27	16	4	2	2	7	36	H	N
B	60	80	6.9	6.1	0.0	B	8	0.1	0.00	3.2	1.5	0.2	0.2	0.0					17	38	24	12	3	1	1	5	57	H	N

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
 LOCATION : 1.75km NNW Motloutse-Lerlhakane confluence.  
 AUTHOR(S):  
 CLASSIFICATION FAO: Sodi-Eutric Cambisol(1988) Eutric Cambisol (1974) saline and sodic phase  
 ST : Aridic Ustochrept  
 LANDFORM : plain  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: slight sealing, no cracks,  
 LAND USE: traditional grazing  
 SPECIES : Trees -  
           : Shrubs - *Acacia tortilis* subs. *heterocantha* (dom.) *Acacia mellifera*  
           : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOLST. COND: dry 0 - 3 , slightly moist 3 - 50 , moist 50 - 50 cm  
 SURF. STONES: none  
 EROSION : nil  
 REMARKS: Old field.

GRID : PF-901-792  
 COORD: 21-53-29-S 27-52-21-E  
 DATE : 04/12/85

AGRO CLIM.ZONE: 2D3  
 ELEVATION : 805 m  
 SMR: aridic to ustic

POSITION: intermediate part  
 SLOPE : 0 - 0.5% straight

GRASSCOVER:

LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: even  
 VEGETATION: shrub savanna

GEOL.UNIT: Basement complex  
 DRAINAGE : imperfectly drained  
 HUMAN INF: nil

ROCK TYPE:  
 ROCK OUTCROP: none

SAMPLES: A: 0 - 3 B: 5 - 20 C: 30 - 50 D: 80 - 100 E: 130 - 150

- A 0 - 3 cm Dark reddish brown (6YR 3/4) (moist) and brown (7.5YR 5/4) (dry), clay loam, massive and very weak fine to medium subangular blocky structure, hard, few fine pores, non calcareous, many very fine roots, clear smooth boundary.
- 2A 3 - 20 cm Dark brown (10YR 3/2.5) (moist) and dark grayish brown (10YR 4/2) (dry), clay, weak coarse to very coarse prismatic falling apart into weak medium to coarse subangular blocky structure, firm, many very fine and common fine pores, non calcareous, many very fine roots, clear wavy boundary.
- 2Bw 20 - 60 cm Very dark grayish brown (10YR 3/2) (moist), clay, weak coarse to very coarse prismatic falling apart into moderate coarse subangular and angular blocky structure, firm, continuous moderately thick slickensides, few fine pores, non calcareous, common very fine roots, diffuse boundary.
- 2Bwz1 60 - 115 cm Very dark grayish brown (10YR 3/2) (moist), clay, weak coarse to very coarse prismatic falling apart into moderate coarse subangular blocky structure, firm, continuous moderately thick slickensides, few fine pores, non calcareous, common very fine roots, gradual boundary.
- 2Bwz2 115 - 150 cm Dark brown (7.5YR 3/2) (moist), common medium distinct clear reddish mottles, clay, no cutans, no pores, slightly calcareous, no roots.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0054

SAMPLE DEPTH	pH	H2O CaCl2	EC	m P	m C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	MEIH	PRETR				
															weight %	<--	meq/100gr soil	%	vcS	cS				mS	fS	vFS	csi
A	0	3	6.2	5.6	0.2	B	22	1.0	0.00	16.1	8.0	4.0	1.5	0.1	84	0.0	1	2	2	6	16	23	18	34	36	H	0
B	5	20	6.5	5.6	0.1	B	4	0.7	0.00	22.7	11.7	5.4	1.9	0.3	85	0.0	1	2	2	6	12	13	17	46	43	H	0
C	30	50	6.4	6.1	1.0	B	2	0.5	0.00	27.5	19.3	8.2	0.8	1.0	100	0.0	2	4	3	6	8	9	15	54	47	H	0
D	80	100	6.8	6.7	4.1	B	4	0.4	0.00	28.2	23.4	12.1	0.8	2.8	100	0.0	3	6	5	8	8	12	10	50	53	H	0
E	130	150	7.6	7.4	13.7	A	6	0.2	0.00	23.9	38.2	10.4	0.8	3.1	100	0.0	3	5	6	10	9	10	9	48	48	H	0

Soil Survey of Botswana FAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water  
 P : Available Phosphorus determination m : method ... O = Olsen B = Bray  
 C : Organic Carbon determination Walkley-Black method  
 N : Total Nitrogen determination Kjeldahl method  
 CEC and bases : Ammonium acetate method  
 EXAC : Exchangeable acidity extracted with KCl  
 CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

Profile: SP 0116 Unit: A 34 Status: 2

SHEET : 2127D4  
 LOCATION : SP. 2.5km NE Motloutse-Letlhakane confl. N. Mot. R.  
 AUTHOR(S): A.Cavaliere-Parzaneze A.Remmalzwaal K.Verbeek  
 CLASSIFICATION FAO: Eutric Regosol(1988) Eutric Regosol (1974) petric phase  
 ST : Ustic Torriorthent  
 LANDFORM : alluvial plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: no cracks,  
 LAND USE:  
 SPECIES : Trees - Combretum imberbe (dom.) Combretum hereroense Acacia tortillis subs. heterocantha Acacia erubescens  
 : Shrubs -  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: moist 0 - 115 cm  
 SURF. STONES:  
 EROSION :

GRID : PF-549-797  
 COORD: 21-53-14-S 27-54-36-E  
 DATE : 08/05/86

AGRO CLIM.ZONE: 2D3  
 ELEVATION : 808 m  
 SMR: aridic to ustic  
 POSITION: intermediate part  
 SLOPE : 1 - 2 %

LAND ELEMENT : levee  
 MICRO TOPOGRAPHY: uneven

VEGETATION: savanna

GRASSCOVER:

GEOLOGICAL UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF:

ROCK TYPE:  
 ROCK OUTCROP: rocky

REMARKS: Acacia karroo also added. Analyses indicates too high clay % - A horizon.

SAMPLES: A: 0 - 20 B: 30 - 50 C: 60 - 80 D: 90 - 110

- A 0 - 25 cm Dark brown (10YR 3/2.5) (moist), coarse sand to loamy sand, very weak medium to coarse subangular blocky structure, very friable, few very fine and common very fine pores, very few fine rounded rock fragments, non calcareous, common fine to medium roots, gradual smooth boundary.
- Bw1 25 - 55 cm Very dark brown (10YR 2.5/2) (moist), coarse sand to loamy sand, weak fine to coarse subangular blocky structure, very friable, few very fine and common very fine pores, few fine rounded rock fragments, non calcareous, common fine to medium roots, clear wavy boundary.
- Bw2 55 - 85 cm Dark brown (9YR 3/3) (moist), coarse sand to loamy sand, very weak medium to coarse subangular blocky structure, friable, few very fine and common very fine pores, frequent fine rounded rock fragments, non calcareous, common fine to medium roots, clear wavy boundary.
- 1 85 - 115 cm Dark brown (9YR 3/3) (moist), fine sand, single grain structure, loose, few very fine and common very fine rounded rock and dominant coarse rounded rock fragments, non calcareous, few fine to medium roots.

Soil Survey of Botswana FAO/BOI/85/011

last changed : 03/12/90

print date: 21/01/91

## STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0116

SAMPLE DEPTH	pH	H2O CaCl2	mS/cm	EC m	P ppm	m C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)				CECclay	METH	PRETR					
																weight %	<----->	meq/100gr soil	%				voS	cS	mS	fS	vfS
A	0	20	7.3	6.6	0.2	B	2	0.5	0.00	9.9	8.7	0.5	1.2	0.0	0.0	100	2	15	17	19	9	6	1	32	25	H	N
B	30	50	7.9	7.1	0.2	B	1	0.1	0.00	7.5	8.0	0.4	0.7	0.0	0.0	100	27	24	16	14	6	2	0	11	67	H	N
C	60	80	8.2	7.5	0.3	B	2	0.1	0.00	6.6	27.8	0.3	0.6	0.0	0.0	100	29	20	13	12	7	2	6	11	58	H	N
D	90	110	8.5	7.5	0.1	B	1	0.1	0.00	4.1	10.9	0.2	0.4	0.1	0.0	100	28	24	17	14	6	4	2	7	55	H	N

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
LOCATION : 3.5km NNW SP mine.  
AUTHOR(S): K.Verbeek A.Cavaliere-Parzaneze A.Rommelzwaal  
CLASSIFICATION FAO: Chromic Luvisol(1988) Luvisol Xerosol (1974)  
ST : Ustalfic Haplargid

GRID : PF-868-765  
COORD: 21-54-57-S 27-50-28-E  
DATE : 07/05/86

AGRO CLIM.ZONE: 2D3  
ELEVATION : 823 m  
SMR: aridic to ustic

LANDFORM : valley  
TOPOGRAPHY: almost flat  
SURF. CHAR: no cracks,  
LAND USE:  
POSITION: intermediate part  
SLOPE : 0 - 1 %

LAND ELEMENT : valley floor  
MICRO TOPOGRAPHY: uneven

VEGETATION:

WOODLAND : Acacia tortilis subs. heterocantha (dom.) Acacia erioloba Combretum heteroense Combretum imberbe

EROSION :  
Grasses/forbs-

PARENT MATERIAL: alluvium  
MOIST. COND: moist 0 - 55 , dry 55 - 150 cm

ROCK TYPE:  
ROCK OUTCROP: rocky

GEOL.UNIT: Basement complex  
DRAINAGE : well drained  
HUMAN INF:

REMARKS: C is a complex of stratified layers mainly coarse sand and loamy sand, 2Bt2 is weakly stratified in places.

SAMPLES: A: 0 - 15 B: 40 - 60 C: 120 - 150

C 0 - 15 cm Reddish brown (5YR 4/4) (moist) and reddish brown (5YR 5/4) (dry), non calcareous, common fine to medium roots, clear wavy boundary.

2Bt1 15 - 80 cm Dark reddish brown (5YR 3/2.5) (moist) and dark reddish brown (5YR 3.5/3) (dry), weak medium to coarse subangular blocky structure, hard, friable, broken moderately thick cutans, common fine and many fine pores, non calcareous, termite/ant activity, common fine to medium roots, diffuse smooth boundary.

2Bt2 80 - 150 cm Dark reddish brown (5YR 3/3) (moist) and dark reddish brown (5YR 3.5/4) (dry), weak medium to coarse subangular blocky structure, very hard, no cutans, no pores, non calcareous, no biological features, no roots.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0111

SAMPLE DEPTH	pH	H2O CaCl2	EC mS/cm	P ppm	m C	N weight %	CEC	Ca	Mg	K	Na	EXAC	PBS		CARBO	Particle size (weight %)					CECclay	METH	PRETR			
													%	%		vcS	cS	mS	fS	vfS				cSi	fSi	Clay
0	15	7.0 - 6.2	0.0 B	13	0.2	0.00	7.4	4.4	0.6	0.9	0.0		80			15	29	25	11	4	2	4	11	63	H	N
40	60	6.4 5.7	0.0 B	4	0.2	0.00	11.6	7.6	0.6	2.0	0.0		88	0.0		4	14	19	20	9	5	2	28	39	H	N
120	150	7.1 6.3	0.0 B	5	0.2	0.00	13.9	9.2	0.8	2.0	0.1		87			1	14	15	22	0	5	4	40	33	H	N

Soil Survey of Botswana FAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
 LOCATION : IR4 Corner of Field 13km NE of Selebi Phikwe.  
 AUTHOR(S) : M.A.Hopkins  
 CLASSIFICATION FAO: Areni-Chromic Luvisol(1988) Arenic Luvisol Xerosol (1974)  
 ST : Arenic ustalfic Haplargid  
 LANDFORM : pediment  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: disturbed vegetation  
 SPECIES : Trees - Colophospermum mopane (dom.) Boscia albitrunca  
 : Shrubs - Acacia tortillis subs. heterocantha (dom.)  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: slightly moist 0 - 15 , dry 15 - 170 cm  
 SURF.STONES:  
 EROSION : nil

GRID : NF-960-797  
 COORD: 21-53-10-S 27-55-35-E  
 DATE : 26/10/88  
 LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: low hummocks  
 VEGETATION: dense shrub savanna  
 ROCK TYPE:  
 ROCK OUTCROP: none  
 SMR: aridic to ustic  
 POSITION: higher part  
 SLOPE : 0.5 - 1.0% straight  
 GRASSCOVER: 10 - 30 %  
 GEOL.UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF: clearing

REMARKS: Clay percentage of analyses are low.

SAMPLES: A: 0 - 20 B: 50 - 65 C: 90 - 105 D: 130 - 145

- A 0 - 28 cm Dark brown (7.5YR 3/2) (moist), sandy clay loam, weak structure, soft, friable, common fine to medium pores, non calcareous, common fine and common medium to coarse roots, gradual smooth boundary.
- Bt1 28 - 110 cm Dark reddish brown (5YR 3/4) (moist), sandy clay loam, weak structure, slightly hard, friable, slightly sticky, common fine to medium and few fine to medium pores, non calcareous, common medium roots, gradual smooth boundary.
- Bt2 110 - 170 cm Yellowish red (5YR 4/7) (moist), sandy clay loam, massive structure, slightly hard, friable, common medium to coarse pores, very few fine angular slightly weathered quartz fragments, non calcareous, common medium roots.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 2026

SAMPLE DEPTH	pH	H2O	CaCl2	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)	CECclay	METH	PRETR		
		ms/cm	ppm	weight %	<-----	meq/100gr soil	----->	%	%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr					
A	0	20	7.7	0.0	0.0	0.00	15.2	13.8	8.6	0.8	0.1	30.0	100	0	0	90	0	0	0	0	3	7	
B	50	65	7.8	0.0	0.0	0.00	16.5	10.8	17.6	0.6	0.1	25.0	100	0	0	87	0	0	0	0	3	11	
C	90	105	7.8	0.1	B	23	0.0	0.00	28.2	9.0	2.0	0.5	0.2	18.5	41	0	0	83	0	0	0	3	13
D	130	145	7.7	0.1	B	24	0.0	0.00	22.6	8.8	10.5	0.5	0.1	18.1	88	0	0	87	0	0	0	7	7

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 14/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

AGRO CLIM.ZONE: 2D3  
 ELEVATION : 835 m  
 SMR: aridic to ustic  
 POSITION: higher part  
 SLOPE : 0 - 1 %  
 GRASSCOVER:  
 GEOL.UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF: nil

GRID : NF-776-766  
 COORD: 21-54-55-S 27-45-04-E  
 DATE : 14/10/85

LAND ELEMENT : flood plain  
 MICRO TOPOGRAPHY: uneven  
 VEGETATION: open tree savanna  
 Acacia tortilis subs. heteroacantha

ROCK TYPE:  
 ROCK OUTCROP: none

SHEET : 2127D4  
 LOCATION : Mmadinare 4.5km S. Mmadinare S. Letlhakane river.  
 AUTHOR(S): A.Cavaliere-Parzaneze C.I.Ketlogetswe  
 CLASSIFICATION FAO: Haplic Luvisol(1988) Luvisol Xerosol (1974) petric phase  
 ST : Ustalfic Haplargid  
 LANDFORM : alluvial plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt, bleached sand on surface  
 LAND USE: no apparent management system  
 SPECIES : Trees - Acacia mellifera (dom.) Acacia luederitzii var.luederitzii  
 : Shrubs -  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: dry 0 - 20 , slightly moist 20 - 95 cm  
 SURF.STONES: none  
 EROSION : nil

REMARKS:

SAMPLES: A: 0 - 10 B: 30 - 50 C: 70 - 90

- A 0 - 10 cm Dark brown (10YR 3.5/2.5) (moist) and dark yellowish brown (10YR 4/3.5) (dry), sandy loam to sandy clay loam, massive and very weak medium to coarse subangular blocky structure, slightly hard, broken moderately thick cutans, common fine and few medium pores, non calcareous, few fine to medium roots, abrupt smooth boundary.
- Bt 10 - 55 cm Dark brown (7.5YR 3/2) (moist) and dark brown (7.5YR 3/3) (dry), sandy clay loam, weak medium to coarse subangular blocky structure, hard, broken moderately thick cutans, common fine and few medium pores, non calcareous, few fine to medium roots, abrupt smooth boundary.
- C 55 - 95 cm Very dark grayish brown (10YR 3/2) (moist) and dark brown (10YR 3.5/3) (dry), sandy clay loam to sandy clay, massive structure, hard, broken moderately thick cutans, common fine and few medium pores, frequent quartz fragments, non calcareous, no roots.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0023

SAMPLE DEPTH	pH	EC	mS/cm	EC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CEC	METH	PRETR								
				weight %	meq/100gr soil	%	%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr											
A	0	10	7.7	6.8	0.3	B	23	0.4	0.00	9.0	6.1	2.3	0.7	0.1	0.0	100	4	12	15	20	12	10	8	19	38	H	0
B	30	50	7.4	7.3	3.6	B	10	0.4	0.00	17.8	15.4	4.9	0.8	0.7	0.0	100	6	11	11	15	9	9	8	32	51	H	0
C	70	90	7.9	7.7	2.0	B	7	0.2	0.00	18.0	27.7	5.4	0.7	0.6	0.0	100	7	12	10	12	8	8	9	35	49	H	0

Soil Survey of Botswana FAO/BOF/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART. SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128C3  
 LOCATION : IR5 400m West of Tobane River.  
 AUTHOR(S) : M.A.Hopkins  
 CLASSIFICATION EAO: Calcic Luvic Xerosol (1988)  
 ST : Ustalfic Haplargid  
 CLASSIFICATION EAO: Calcic Luvic Xerosol (1974)

LANDFORM : pediment  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: no sealing, no cracks,  
 LAND USE: no apparent management system  
 SPECIES : Trees - Acacia mellifera (dom.)  
 : Shrubs -  
 : Grasses/forbs-

PARENT MATERIAL: alluvium  
 MOIST. COND:  
 SURF. STONES: none  
 EROSION : nil

REMARKS: No cutans observed.No CaCO3 in D sample.

SAMPLES: A: 0 - 20 B: 50 - 65 C: 100 - 115 D: 145 - 160

- A1 0 - 20 cm Dark brown (7.5YR 4/2) (moist), sand, weak structure, soft, very friable, non sticky, non plastic, few medium to coarse pores, non calcareous, few fine to medium roots, clear wavy boundary.
- B1 20 - 73 cm Dark brown (7.5YR 4/4) (moist) and dark brown (7.5YR 4/2) (dry), sandy loam, massive structure, friable to firm, sticky, plastic, common fine pores, non calcareous, burrows, few medium to coarse roots, gradual smooth boundary.
- Btk2 73 - 127 cm Reddish brown (5YR 4/4) (moist), sandy clay loam, massive structure, friable to firm, sticky, plastic, common coarse pores, slightly calcareous, few medium to coarse roots, gradual smooth boundary.
- Ck1 127 - 195 cm Dark reddish gray (5YR 4/2) (moist), sandy clay loam to clay loam, massive structure, friable, sticky, plastic, common medium to coarse pores, few fine angular hard and soft white calcareous nodules, moderately calcareous, few, few fine roots.
- Ck2 195 cm + dominant medium spherical hard and soft white calcareous nodules.

GRID : - -  
 COORD: 21-53-48-S 28-01-26-E  
 DATE : 29/10/88  
 LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: medium hummocks  
 VEGETATION: dense savanna  
 GRASSCOVER: 30 - 70 %  
 AGRO CLIM.ZONE: 2D3  
 ELEVATION :  
 SMR: aridic to ustic  
 POSITION: higher part  
 SLOPE : 0.5 - 3.0% straight  
 GEOL.UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF: nil  
 ROCK TYPE:  
 ROCK OUTCROP: none

## STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 2031

SAMPLE DEPTH	pH	EC mS/cm	EC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CEC/Clay	MEIH PRETR				
											weight %	<--- meq/100gr soil	%	vcS	cS			mS	fS	vfS	cSi
A 0 20	6.1	0.0 B 13	0.0	0.00	31.3	9.2	9.9	0.5	0.3	18.5	63	0	0	75	0	0	0	8	17		
B 50 65	6.3	0.1 B 23	0.0	0.00	56.5	7.3	10.7	0.7	0.2	28.0	33	0	0	80	0	0	0	15	5		
C 100 115	7.1	0.2 B 22	0.0	0.00	40.4	14.8	6.1	1.0	0.3	40.0		0	0	82	0	0	0	7	12		
D 145 160	7.8	0.7 B 23	0.0	0.00	83.5	16.0	11.8	0.5	1.7	18.1	35	0	0	77	0	0	0	9	14		

Soil Survey of Botswana EAO/BOT/85/011

last changed : 14/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known

PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

Profile: BE 0247 Unit: A 37a Status: 2

SHEET : 2228B1  
 LOCATION : 7.5KM SW of Molalatau.  
 AUTHOR(S) : T.D.Mafoko P.De Wit J.Maemboelwa  
 CLASSIFICATION FAO: Calcic Luvisol(1988) Calcic Luvisol Xerosol (1974)  
 ST : Typic Haplargid

GRID : PF-627-512  
 COORD: 22-08-26-S 28-35-00-E  
 DATE : 18/02/89  
 LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: even  
 VEGETATION:

AGRO CLIM.ZONE: 4B3  
 ELEVATION :  
 SMR: aridic  
 POSITION: intermediate part  
 SLOPE : 2 - 3 % straight  
 GRASSCOVER: 10 - 30 %

LANDFORM : plain  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional dryland farming, crops: sorghum  
 SPECIES : Trees -  
 : Shrubs - Colophospermum mopane (dom.)  
 : Grasses/forbs-

PARENT MATERIAL: alluvium  
 MOIST. COND: slightly moist 0 - 25 , dry 25 - 125 cm  
 SURF. STONES: none  
 EROSION : nil

ROCK TYPE:  
 ROCK OUTCROP: none

GEOLOG. UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF: nil

REMARKS:

SAMPLES: A: 0 - 20 B: 30 - 50 C: 60 - 80 D: 100 - 120

A 0 - 25 cm Dark brown (7.5YR 3/2) (moist) and dark brown (7.5YR 3/3) (dry), loamy sand, very weak subangular blocky structure, slightly hard to hard, common very fine to fine pores, few fine rock fragments, non calcareous, common fine roots, clear smooth boundary.

Bt1 25 - 57 cm Dark reddish brown (5YR 3/2.5) (moist) and dark brown (8YR 3/3.5) (dry), sandy clay loam, very weak medium to coarse subangular blocky structure, soft, patchy thin clay cutans on pedfaces, common fine to medium pores, frequent fine quartz fragments, non calcareous, few fine to medium roots, clear smooth boundary.

Btk2 57 - 87 cm Dark reddish brown (5YR 3/4) (moist) and yellowish red (5YR 4/5) (dry), sandy clay loam, very weak coarse subangular blocky structure, hard, patchy thin clay cutans on pedfaces, common fine to medium pores, frequent fine quartz fragments, moderately calcareous, few fine to medium roots, clear broken boundary.

Btk3 87 - 125 cm Dark reddish brown (5YR 3/4) (moist) and yellowish red (5YR 4/5) (dry), sandy clay loam, very weak coarse subangular blocky structure, hard to very hard, patchy thin clay cutans on pedfaces, common fine to medium pores, frequent fine quartz fragments, dominant fine spherical soft white calcareous soft segregations, strongly calcareous, few fine to medium roots.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: BE 0247

SAMPLE DEPTH	pH	H2O CaCl2	EC mS/cm	P ppm	M ppm	C ppm	N weight %	CEC <	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR			
																vcS	cS	mS	fS	vs	cs				fsi	Clay	meq/100gr
A	0	20	6.5	5.7	0.0	5 B	0.4	0.00	4.9	3.0	1.1	0.5	0.1	0.0	96	.	10	14	16	27	9	7	4	12	28	H	N
B	30	50	7.2	6.3	0.0	1 B	0.4	0.00	7.7	5.4	1.9	0.8	0.3	0.0	>100	.	5	15	19	20	16	3	4	17	35	H	N
C	60	80	8.1	7.3	0.1	4 B	0.3	0.00	6.1	5.9	1.2	0.7	0.3	0.0	>100	.	10	20	17	19	9	3	5	17	29	H	N
D	100	120	8.6	7.8	0.1	1 B	0.2	0.00	5.8	32.7	1.4	0.8	0.4	0.0	>100	.	11	20	18	17	6	3	4	21	23	H	N

Soil Survey of Botswana EAO/BOT/85/011

Last changed: 13/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART. SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128C3  
 LOCATION : 2km NW of Tobane S. Motloutse river.  
 AUTHOR(S) : A.Cavaliere-Parzaneze C.I.Ketlogetsewe  
 CLASSIFICATION FAO: Petri-Chromic Cambisol(1988) Haplic Xerosol (1974) petric phase  
 ST : Ustollic Camborthid  
 LANDFORM : alluvial plain  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: no sealing, no cracks, nil evidence of salt,  
 LAND USE: no apparent management system  
 SPECIES : Trees - Acacia tortilis subs, heterocantha (dom.) Acacia erioloba Terminalia sericea Acacia luaderitzii var.luaderitzii  
 : Shrubs -  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium  
 MOIST. COND: moist 0 - 20 , dry 20 - 85 cm  
 SURF. STONES: none  
 EROSION : nil

GRID : PP-061-781  
 COORD: 21-54-02-S 28-01-39-E  
 DATE : 17/10/85  
 LAND ELEMENT : Flood plain  
 MICRO TOPOGRAPHY: uneven  
 VEGETATION: woodland  
 AGRO CLIM.ZONE: 2D3  
 ELEVATION : 775 m  
 SMR: aridic to ustic  
 POSITION: lower part  
 SLOPE : 0 - 0.5% straight  
 GRASSCOVER:  
 GEOL.UNIT: Basement complex  
 DRAINAGE : somewhat excessively drained  
 HUMAN INF: nil

REMARKS:

SAMPLES: A: 0 - 20 B: 25 - 40

- A 0 - 25 cm Dark brown (7.5YR 3/2) (moist), loamy sand to sandy loam, very weak medium to coarse subangular blocky structure, loose, many fine and common medium pores, non calcareous, few fine to medium roots, gradual smooth boundary.
- Bw 25 - 40 cm Dark reddish brown (5YR 3/2.5) (moist) and dark brown (7.5YR 3.5/4) (dry), loamy sand to sandy loam, very weak coarse subangular blocky structure, slightly hard, many fine and few medium pores, non calcareous, few fine to medium roots, clear smooth boundary.
- C1 40 - 55 cm Dark brown (7.5YR 3/2) (moist) and dark brown (7.5YR 3/2) (dry), clay to loamy sand, single grain structure, loose, very frequent fine rounded quartzite fragments, non calcareous, few fine to medium roots, clear smooth boundary.
- C2 55 - 85 cm Dark brown (7.5YR 3/4) (moist) and dark brown (7.5YR 3.5/4) (dry), clay to loamy sand, single grain structure, loose, very frequent fine rounded quartzite fragments, non calcareous, few fine to medium roots.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0038

SAMPLE DEPTH	pH	H2O CaCL2	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CECclay	METH	PRETR				
		ms/cm	ppm	weight %	<	meq/100gr soil	vcS	cS	mS	fS	vfS	cSl	fSl	Clay	meq/100gr													
A	0	20	7.4	6.8	0.7	B	1	0.7	0.00	10.2	8.1	2.3	0.6	0.0	0.0	100		8	17	25	21	8	4	4	13	57	H	0
B	25	40	8.6	7.2	0.6	B	5	0.2	0.00	6.4	9.2	2.7	0.6	0.5	0.0	100		11	18	23	19	9	5	3	14	41	H	0

Soil Survey of Botswana HAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known

PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128D4

LOCATION : 4.2km S of Semolale.

AUTHOR(S) : T.D.Mafoko P.De Wit J.Maembolwa

CLASSIFICATION FAO: Calcaric Regosol(1988)

ST : Typic Torriorthent

LANDFORM : plain

TOPOGRAPHY: almost flat

SURF. CHAR: slight sealing, no cracks, nil evidence of salt,

LAND USE: traditional grazing

SPECIES : Trees - Colophospermum mopane (dom.) Terminalia prunioides Acacia nigrescens

: Shrubs - Colophospermum mopane (dom.) Terminalia prunioides Grewia bicolor Acacia nigrescens

: Grasses/forbs-

PARENT MATERIAL: in situ weathered

MOIST. COND: slightly moist 0 - 35 cm

SURF. STONES: few gravel

EROSION : slight sheet erosion

REMARKS: Bib, but the topography is almost flat.

SAMPLES: A: 0 - 20 B: 20 - 35

GRID : PF-884-754

COORD: 21-55-04-S 28-49-00-E

DATE : 26/04/89

shallow petric (skeletal) phase

LAND ELEMENT : not applicable

MICRO TOPOGRAPHY: even

VEGETATION: savanna

ROCK TYPE: basalt

ROCK OUTCROP: none

AGRO CLIM.ZONE: 4B3

ELEVATION : 710 m

SMR: aridic

POSITION: intermediate part

SLOPE : 0.5 - 1 % straight

GRASSCOVER:

GEOL.UNIT: Karoo supergroup

DRAINAGE : well drained

HUMAN INF: nil

A 0 - 20 cm Very dark grayish brown (10YR 3/2) (moist) and dark brown (10YR 4/3) (dry), sandy clay loam, moderate fine to medium subangular blocky structure, slightly hard, friable, common very fine to fine pores, few fine angular slightly weathered basalt fragments, non calcareous, many fine roots, clear wavy boundary.

Ck 20 - 35 cm Very dark grayish brown (10YR 3/2) (moist) and dark yellowish brown (10YR 4/4) (dry), sandy clay loam, weak fine to medium subangular blocky structure, hard, friable, common fine to medium pores, frequent fine angular slightly weathered basalt fragments, very frequent fine spherical soft white calcareous soft segregations, strongly calcareous, many fine roots.

C 35 cm + dominant coarse angular basalt fragments.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: BE 0261

SAMPLE DEPTH	pH	EC m	P m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR								
H2O	CaCL2	ms/cm	ppm	weight %	<-----	meq/100gr soil	----->						%	vcS	cS	mS	fS	vfS	cSl	fSl	Clay	meq/100gr								
A	0	20	7.5	7.1	0.1	0.1	6 B	0.2	0.00	23.6	31.6	3.4	0.5	0.9	0.0	0.0	>100	0.0	0.0	7	6	6	14	13	14	12	28	81	H	O
B	20	35	8.0	7.6	0.3	1 B	0.4	0.00	26.8	68.5	4.2	0.2	1.8	0.0	0.0	>100	1.7	0.0	8	6	6	10	9	12	13	36	70	H	O	

Soil Survey of Botswana FAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2228B1  
 LOCATION : 6.1km NW of Molalatau.  
 AUTHOR(S): T.D.Mafoko P.De Wit J.Maambolwa  
 CLASSIFICATION FAO: Calcic Luvisol(1988) Calcic Luvisol (1974) shallow petric (skeletal) phase  
 ST : Typic Haplargid  
 LANDFORM : plain  
 TOPOGRAPHY: undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional grazing  
 SPECIES : Trees - Colophospermum mopane (dom.) Combretum apiculatum Combretum hereroense  
           : Shrubs - Colophospermum mopane (dom.) Combretum apiculatum Combretum hereroense  
           : Grasses/forbs-  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: slightly moist 0 - 10 , dry 10 - 60 cm  
 SURF.STONES: common gravel  
 EROSION : moderate sheet erosion

REMARKS: Very marginal Bt horizon according to analyses, but clear cutans on pedfaces

SAMPLES: A: 0 - 15 B: 20 - 40 C: 43 - 60

- A 0 - 15 cm Dark reddish brown (5YR 3/2) (moist), sandy clay loam, weak fine to medium subangular blocky structure, friable, common fine to medium pores, frequent fine to medium angular slightly weathered basalt and weathered rock fragments, non calcareous, common very fine to fine roots, clear wavy boundary.
- Bt1 15 - 43 cm Dark reddish brown (5YR 2.5/2) (moist) and dark reddish brown (5YR 3/2) (dry), clay loam, weak fine to medium subangular blocky structure, very hard, broken thick clay cutans on pedfaces, common fine to medium pores, very frequent fine to medium angular slightly weathered basalt and weathered rock fragments, non calcareous, common fine to medium roots, clear wavy boundary.
- Bt2 43 - 60 cm Dark reddish brown (5YR 2.5/2) (moist) and dark reddish brown (5YR 3/2) (dry), clay loam, very weak fine to medium subangular blocky structure, very hard, no cutans, few very fine to fine pores, dominant fine to medium angular slightly weathered basalt and rounded weathered basalt fragments, strongly calcareous, few fine to medium roots, clear wavy boundary.

C 60 cm +

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: BE 0274

SAMPLE DEPTH	pH	H2O	CaCl2	mS/cm	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR			
																			weight %	<	meq/100gr soil	meq/100gr soil	vcS	cs				ms	fs	vfs
A	0	15	6.7	5.8	0.0	10	B	0.3	0.00	19.3	16.9	4.9	0.7	0.4	0.0	0.0	>100	0.0	0.0	5	6	8	15	11	11	20	25	73	H	0
B	20	40	7.3	6.6	0.1	3	B	0.3	0.00	30.0	20.3	4.3	0.2	0.9	0.0	0.0	86	6.4	6.4	6	9	7	12	10	10	18	27	105	H	0
C	43	60	8.0	7.4	0.3	3	B	0.2	0.00	29.3	36.0	4.1	0.1	2.0	0.0	0.0	>100	1.4	1.4	12	8	8	6	16	11	15	25	114	H	0

Soil Survey of Botswana HAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2128C3  
 LOCATION : IR9 18.5km East of Tobane.  
 AUTHOR(S) : M.A.Hopkins  
 CLASSIFICATION FAO: Hypercalci-Luvis Calcisol(1988) Calcic Luvis Xerosol (1974)  
 ST : Ustalfic Haplargid  
 LANDFORM : pediment  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional grazing  
 SPECIES : Trees - Colophospermum mopane (dom.) *Boscia albitrunca*  
 : Shrubs - *Acacia tortilis* subs. *heterocantha* (dom.) *Dichrostachys cinerea*  
 : Grasses/forbs-  
 PARENT MATERIAL: alluvium over calcrete  
 MOIST. COND: moist 0 - 15 , dry 15 - 120 cm  
 SURF.STONES: none stones  
 EROSION : slight sheet erosion

REMARKS:

SAMPLES: A: 0 - 16 cm B: 10 - 33 C: 50 - 65 D: 95 - 110

- A 0 - 16 cm Dark brown (7.5YR 3/2) (moist), sandy clay loam, weak medium to coarse platy falling apart into massive fine to medium subangular blocky structure, soft to slightly hard, very friable, sticky, plastic, few pores, non calcareous, common fine roots, clear wavy boundary.
- Bt1 16 - 33 cm Dark brown (7.5YR 3/2) (moist), sandy clay loam, massive fine to medium subangular blocky structure, soft to slightly hard, friable, sticky, plastic, common medium pores, non calcareous, common medium and very few medium roots, gradual smooth boundary.
- Btk2 33 - 66 cm Dark yellowish brown (10YR 4/4) (moist), sandy clay loam, massive fine angular blocky structure, slightly hard, friable, sticky, plastic, common medium pores, very few fine irregular hard and soft white calcareous nodules, strongly calcareous, few fine roots, gradual wavy boundary.
- Btk3 66 - 120 cm Dark yellowish brown (10YR 4/4) (moist), sandy clay loam, massive medium angular blocky structure, slightly hard to hard, firm, sticky, plastic, common medium pores, few fine irregular hard and soft white calcareous nodules, strongly calcareous, abundant open burrows, few medium roots, clear wavy boundary.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 2020

SAMPLE DEPTH	pH	EC m	P ppm	M ppm	C ppm	N weight %	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)									
															vcS	cs	ms	fs	vfS	cSi	fSi	Clay	meq/100gr	
A	0	10	8.0	0.1	B	11	0.0	0.00	15.0	13.1	18.3	0.6	0.2	24.0	100	0	0	88	0	0	0	0	5	7
B	10	33	7.8	0.1	B	23	7	0.0	52.2	18.5	25.0	0.8	0.1	31.0	85	0	0	80	0	0	0	0	7	13
C	50	65	7.8	0.2	B	24	0.0	0.00	20.4	26.4	0.2	0.8	0.1	32.0	100	0	0	75	0	0	0	0	3	22
D	95	110	7.8	0.2	B	23	0.0	0.00	15.2	19.5	32.7	0.8	0.1	32.0	100	0	0	75	0	0	0	0	3	22

Soil Survey of Botswana FAO/BOT/85/011

last changed : 13/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

SHEET : 2127D3  
 LOCATION : 4.5km W of Mmadinare.  
 AUTHOR(S): A.Cavaliere-Parzaneze C.I.Ketlogetswe  
 CLASSIFICATION FAO: Eutric Regosol(1988) Eutric Regosol (1974) shallow petric (skeletal) phase  
 ST : Lithic Torriorthent  
 LANDFORM : plain  
 TOPOGRAPHY: undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional grazing  
 SPECIES : Trees - Colophospermum mopane (dom.) Boscia albitrunca Acacia alba  
 : Shrubs - Combretum apiculatum (dom.) Commiphora pyracanthoides subsp. glandulosa  
 : Grasses/forbs-  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: dry 0 - 15 cm  
 SURF. STONES: none  
 EROSION : strong sheet erosion

REMARKS: Upper 10cm of C horizon predominantly gravels.

SAMPLES: A: 0 - 15

A 0 - 15 cm Dark brown (7.5YR 3/4) (moist) and brown (7.5YR 4.5/4) (dry), loamy sand, massive structure, slightly hard, broken thin clay cutans, common fine pores, few fine to medium rock fragments, non calcareous, few fine roots, clear smooth boundary.

C 15 cm + dominant medium to coarse rock fragments.

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0003

SAMPLE DEPTH	pH	EC m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CECclay	METH	PRETR			
	H2O	CaCL2	ms/cm	ppm	weight %	<-	meq/100gr soil	vcS	cS	mS	fS	vfS	cSl	fSl	Clay	meq/100gr									
0 15	6.2	5.7	0.0	B	8	0.2	0.00	5.7	2.7	0.8	0.4	0.1	70	0.0	6	11	17	25	16	9	5	11	46	H	0

Soil Survey of Botswana FAO/BOI/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

## SOIL PROFILE DESCRIPTION

Profile: BE 0901 Unit: G 02e Status: 1

SHEET : 2228B3  
 LOCATION : 5.8km South East of Tuli Backline.  
 AUTHOR(S) : T.D.Mafoko J.Maemboiwa  
 CLASSIFICATION FAO: Haplic Lixisol(1988) Luvisc Xerosol (1974) petric phase  
 ST : Typic Haplargid

LANDFORM : plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: commercial grazing  
 SPECIES : Trees - Colophospermum mopane (dom.) Combretum apiculatum Sclerocarya caifra  
 : Shrubs -

: Grasses/forbs-  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: dry 0 - 70 cm  
 SURF. STONES: very few stones  
 EROSION : nil

REMARKS: Profile is identical to BE0203.

SAMPLES: A: 0 - 20 B: 30 - 50

GRID : PF-740-249  
 COORD: 22-22-32-S 28-41-14-E  
 DATE : 17/02/89

LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: even  
 VEGETATION: dense tree savanna

ROCK TYPE: granite  
 ROCK OUTCROP: none

AGRO CLIM.ZONE: 4B3  
 ELEVATION : 752 m  
 SMR: aridic

POSITION: intermediate part  
 SLOPE : 0.5 - 1 %  
 GRASSCOVER: 30 - 70 %

GEOLOG. UNIT: Basement complex  
 DRAINAGE : moderately well drained  
 HUMAN INF: nil

A 0 - 20 cm Dark reddish brown (2.5YR 2.5/4) (moist) and dark reddish brown (2.5YR 3/4) (dry), sandy loam, weak fine to medium subangular blocky structure, slightly hard, few fine rounded slightly weathered quartz fragments, non calcareous, common fine to medium roots, clear smooth boundary.

Bt 20 - 60 cm Dark reddish brown (2.5YR 3/4) (moist) and reddish brown (2.5YR 4/4) (dry), sandy clay loam, moderate coarse to very coarse subangular blocky structure, hard, patchy thin clay curans on pedfaces, frequent fine rounded slightly weathered quartz fragments, non calcareous, common termite/ant activity, few medium to coarse roots, clear smooth boundary.

Cc 60 - 70 cm dominant fine to medium rounded slightly weathered quartz fragments, frequent fine irregular hard bluish-black iron-manganese concretions and medium irregular hard bluish-black iron-manganese nodules, non calcareous.

Soil Survey of Botswana FAO/BOI/85/011

last changed : 18/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: BE 0901

SAMPLE	DEPTH	pH	H2O	CaCl2	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)					CECclay	METH	PRETR			
			ppm	meq/100gr soil	<----->	meq/100gr soil											%	%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	6.5	5.6	0.0	B	5	B	0.5	0.00	4.3	2.4	1.2	0.7	0.1	0.0	100	0.0	9	17	18	19	12	7	2	17	14	H	N
B	30	50	5.4	4.7	0.0	B	1	B	0.2	0.00	5.0	1.8	1.6	0.3	0.2	78	0.0	8	14	17	16	11	4	2	28	15	H	N	

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

S O I L P H Y S I C A L P R O P E R T I E S

PROFILE: BE 0901

UNIT: G 02e

Location : 5.8km South East of Tuli Backline  
 Drainage : moderately well  
 Parent material : in situ weathered  
 Classification : Luvic Xerosol Luvic Xerosol phase

Horizons : A ( 0 - 20 cm): SL Bt ( 20 - 60 cm): SCL Co ( 60 - 70 cm):

INFILTRATION

No.	Basic (cm/hr)	a	n
1	23.8	0.80	0.87
2	21.4	0.50	0.93
3	19.3	0.82	0.84
4			
5			

METHODS: Infiltration:

double ring infiltrometer for cumulative time of 4 hrs. "a" and "n" are constants in equation  $F = at^n$ , where F = cumulative infiltration (cm) and t = elapsed time (min).  
 Bulk Density: oven dry, mean value of 5 measurements. (cl) = estimated on clods; (co) = estimated on core samples.  
 Moisture Retention: 1 bar tension and below: on core samples or clods (see bulk density); more than 1 bar tension: on crushed samples from fine earth fraction (< 2mm).  
 Structure Stability Index: relative collapse of larger pores (in the 1-2 mm fraction of surface soil) on slow and fast wetting. Values range from 0.00 (completely unstable) to 1.00 (completely stable) for well structured soils (no single grains).

SURFACE STRUCTURE STABILITY INDEX: 0.56  
 PERCENTAGE SINGLE GRAINS (1-2 mm): 44%

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %)
A 0 - 20	1.63 (co)	14.91 12.16 10.32 8.11 7.0 5.7 5.4 5.2
B 20 - 60	1.53 (co)	16.43 14.21 11.09 9.09 7.5 7.2 6.8 6.4

REMARKS:

Soil Survey of Botswana FAO/BOT/85/011

last changed: 21/12/89

Print date: 21/01/91

SOIL PROFILE DESCRIPTION Profile: SP 0043 Unit: G 02e Status: 2

SHEET : 2127D4  
 LOCATION : 2.5km NW Selebi-Phikwe mine.  
 AUTHOR(S) : A.Cavaliere-Paraneze C.I.Ketlogetse  
 CLASSIFICATION IAO: Chromic Luvisol(1988) Luvic Xerosol (1974) petric phase  
 ST : Ustalfic Haplargid

LANDFORM : plain  
 TOPOGRAPHY: gently undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE:

SPECIES : Trees -  
 : Shrubs - Colophospermum mopane (dom.) Acacia erubescens Acacia tortilis subs. heterocantha Grewia bicolor  
 : Grasses/forbs-

PARENT MATERIAL: colluvium  
 MOIST. COND: dry 0 - 10 , moist 10 - 70 cm  
 SURF. STONES: very few  
 EROSION : moderate sheet erosion

## REMARKS:

SAMPLES: A: 0 - 10 B: 15 - 30 C: 50 - 70

- A 0 - 10 cm Dark brown (7.5YR 3/4) (moist) and strong brown (7.5YR 4.5/6) (dry), loamy sand, very weak coarse subangular blocky structure, soft, many very fine and few fine pores, non calcareous, few very fine roots, clear smooth boundary.
- Bt1 10 - 30 cm Dark reddish brown (5YR 3/4) (moist), sandy loam to sandy clay loam, very weak medium to coarse subangular blocky structure, friable, patchy thin clay cutans, common very fine to fine pores, few fine rounded rock fragments, non calcareous, few fine to medium roots, gradual smooth boundary.
- Bt2 30 - 70 cm Dark reddish brown (2.5YR 3/4) (moist), sandy clay loam, weak medium to coarse subangular blocky structure, friable, patchy thin clay cutans and moderately thick cutans, common very fine to fine pores, frequent fine rounded rock fragments, non calcareous, few fine roots, clear wavy boundary.
- C 70 cm + very frequent fine rounded rock fragments, non calcareous.

Soil Survey of Botswana IAO/BOT/85/011

last changed : 28/09/89

print date: 21/01/91

GRID : PF-866-746  
 COORD : 21-56-00-S 27-50-22-E  
 DATE : 02/12/85

LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: even

VEGETATION: shrub savanna

AGRO CLIM.ZONE: 2D3  
 ELEVATION : 832 m

SMR: aridic to ustic

POSITION: middle slope  
 SLOPE : 1 - 2 % straight

GRASSCOVER:

GEOLOG.UNIT: Basement complex  
 DRAINAGE : well drained

HUMAN INF: nil

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0043

SAMPLE DEPTH	pH	H2O	CaCl2	EC	m	P	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR			
																		weight %	<	meq/100gr soil	meq/100gr soil	%	%				vcS	cS	mS
A	0	10	5.0	4.4	0.0	B	9	0.1	0.00	5.7	1.4	0.8	0.3	0.1		46	0.0	0.0	4	16	23	24	11	7	2	13	41	H	O
B	15	30	5.3	5.0	0.0	B	2	0.1	0.00	7.5	3.5	1.8	0.6	0.0		79	0.0	0.0	9	17	19	19	8	5	3	21	33	H	O
C	50	70	5.5	5.2	0.0	B	1	0.1	0.00	11.1	6.0	2.9	0.6	0.1		86	0.0	0.0	5	11	15	16	9	6	4	34	32	H	O

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

Profile: SP 2001 Unit: G 06b Status: 2

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
 LOCATION : IRI 100m upslope of SP2000 0.5km from confluence.  
 AUTHOR(S) : M.A.Hopkins  
 CLASSIFICATION FAO: Areni-Chromic Luvisol(1988) Luvis Xerosol (1974)  
 ST : Arenic ustalfic Haplargid  
 LANDFORM : pediment  
 TOPOGRAPHY : gently undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional dryland farming, crops: sorghum  
 SPECIES : Trees -  
 : Shrubs -  
 : Grasses/forbs -  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: dry 0 - 20, slightly moist 20 - 105 cm  
 SURF. STONES: common gravel  
 EROSION : moderate gully erosion  
 REMARKS: Erosion in field due to ploughing pattern.

SAMPLES: A: 0 - 15 B: 30 - 45 C: 75 - 90

A 0 - 15 cm Yellowish red (5YR 4/7) (moist) and yellowish red (5YR 5/8) (dry), loamy sand to sandy loam, very weak fine to medium subangular blocky structure, slightly hard, friable, very few fine angular slightly weathered quartz fragments, non calcareous, few fine to medium roots, clear smooth boundary.

Bt1 15 - 75 cm Dark red (2.5YR 3.5/6) (moist), sandy clay loam, weak to moderate medium angular blocky structure, friable, common medium pores, few fine angular slightly weathered quartz fragments, non calcareous, few fine roots, clear wavy boundary.

Bt2 75 - 105 cm Dusky red (2.5YR 3.5/1) (moist), sandy clay loam, moderate to strong medium angular blocky structure, friable, patchy thin clay cutans, common medium pores, frequent fine to medium angular slightly weathered quartz fragments, non calcareous, few fine roots, clear wavy boundary.

C 105 cm + dominant fine to medium angular slightly weathered quartz fragments.

GRID : NF-864-807  
 COORD: 21-50-32-S 27-50-04-E  
 DATE : 13/10/88  
 LAND ELEMENT : levee  
 MICRO TOPOGRAPHY: low hummocks  
 VEGETATION: Nil  
 AGRO CLIM.ZONE: 2D3  
 ELEVATION : 821 m  
 SNR: aridic to ustic  
 POSITION: lower part  
 SLOPE : 0.5 - 3 % straight  
 GRASSCOVER: 30 - 70 %  
 ROCK TYPE: gneiss  
 ROCK OUTCROP: none  
 GEOL.UNIT: Basement complex  
 DRAINAGE : well drained  
 HUMAN INF: ploughing

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 2001

SAMPLE DEPTH	pH	EC m	CaCl2	ms/cm	ppm	weight %	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)	vcS	cS	mS	fS	vfS	csi	fSI	Clay	CEC-clay	METH	PRETR
						<-----	<-----					----->	%	%										meq/100gr		
A	0	15	7.4	0.1	B	21	0.0	0.00	11.7	9.9	2.8	0.8	0.0	29.2	100	0.0	0	0	88	0	0	0	7	5		
B	30	45	7.8	0.1	B	24	0.0	0.00	18.7	12.4	10.2	0.4	0.1	16.6	100	0.0	0	0	85	0	0	0	7	8		
C	75	90	7.4	0.2	B	23	0.0	0.00	21.3	18.6	9.9	0.4	0.1	16.9	100	0.0	0	0	75	0	0	0	7	18		

Soil Survey of Botswana FAC/BGT/85/011

last changed : 03/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

Profile: BE 0902 Unit: G 06b Status: 1

SHEET : 2228B4  
 LOCATION : Along Sherwood-Pontdrif road.  
 AUTHOR(S) : T.D.Mafoko J.Maembolwa  
 CLASSIFICATION FAO: Haplic Lixisol(1988) Luvisc Xerosol (1974) petric phase  
 ST : Typic Haplargid  
 LANDFORM : plain  
 TOPOGRAPHY: almost flat  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: commercial grazing  
 SPECIES : Trees - Colophospermum mopane (dom.) Combretum apiculatum  
 : Shrubs - Colophospermum mopane (dom.) Combretum apiculatum  
 : Grasses/forbs-  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: dry 0 - 100 cm  
 SURF.STONES: very few gravel  
 EROSION : nil

GRID : PE-844-191  
 COORD: 22-25-34-S 28-47-28-E  
 DATE : 17/02/89  
 LAND ELEMENT : not applicable  
 MICRO TOPOGRAPHY: even  
 VEGETATION: dense savanna  
 POSITION: intermediate part  
 SLOPE : 0.5 - 1 %  
 GRASSCOVER: 30 - 70 %  
 ROCK TYPE: granite  
 ROCK OUTCROP: none  
 GEOL.UNIT: Basement complex  
 DRAINAGE : moderately well drained  
 HUMAN INF: nil

REMARKS: Profile is identical to BE0204.

SAMPLES: A: 0 - 20 B: 30 - 50 C: 80 - 100

A 0 - 20 cm Very dark grayish brown (10YR 3/2) (moist) and dark brown (7.5YR 3/4) (dry), sandy loam, weak fine to medium subangular blocky structure, slightly hard, common very fine to fine pores, few fine rock fragments, non calcareous, common fine roots, clear smooth boundary.

Bt1 20 - 80 cm Dark reddish brown (2.5YR 2.5/4) (moist) and dark reddish brown (5YR 3.5/4) (dry), sandy clay loam, moderate medium to coarse subangular blocky structure, hard, broken thin clay cutans on pedfaces, common fine to medium pores, frequent fine rounded quartz fragments, non calcareous, few fine to medium roots, clear smooth boundary.

Bt2 80 - 100 cm Dark reddish brown (2.5YR 3/4) (moist) and dark red (2.5YR 3/6) (dry), common coarse distinct clear yellowish-brown mottles, sandy clay loam, massive structure, very hard, continuous thin clay cutans on pedfaces, common fine to medium pores, very frequent fine rounded quartz fragments, non calcareous.

Soil Survey of Botswana FAO/BOT/85/011

Last changed : 18/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: BE 0902

SAMPLE DEPTH	pH	H2O CaCL2	EC mS/cm	P ppm	m P	C C	N weight %	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR				
																vcS	cS	mS	fS	vfS	csi				fSi	Clay	meq/100gr	
A	0	20	5.7	4.8	0.0	B	4	0.4	0.00	3.6	2.1	0.9	0.2	0.1	0.2	92	0.0	11	21	19	16	5	3	6	19	11	H	O
B	30	50	6.0	5.3	0.0	B	1	0.3	0.00	4.6	2.4	1.2	0.1	0.5	0.5	91	0.0	13	23	18	12	5	3	6	19	18	H	N
C	80	100	7.5	6.2	0.1	B	1	0.1	0.00	6.8	4.6	1.9	0.1	3.0	0.0	100		11	21	16	12	6	4	5	25	25	H	N

Soil Survey of Botswana FAO/BOT/85/011

last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PHYSICAL PROPERTIES

PROFILE: BE 0902 UNIT: G 06b

Location : Along Sherwood-Pontdrif road  
 Drainage : moderately well  
 Parent material : in situ weathered  
 Classification : Luvic Xerosol Luvic Xerosol phase

Horizons : A ( 0 - 20 cm): SL Bt1 ( 20 - 80 cm): SCL Bt2 ( 80 - 100 cm): SCL

INFILTRATION

No.	Basic (cm/hr)	a	n
1	26.3	0.44	0.99
2	15.4	0.55	0.86
3	19.4	0.49	0.92
4			
5			

METHODS: Infiltration:

double ring infiltrometer for cumulative time of 4 hrs. "a" and "n" are constants in equation "F=at<sup>n</sup>", where F = cumulative infiltration (cm) and t = elapsed time (min).  
 Bulk Density: oven dry, mean value of 5 measurements. (cl) = estimated on clods; (co) = estimated on core samples.  
 Moisture Retention: 1 bar tension and below: on core samples or clods (see bulk density); more than 1 bar tension: on crushed samples from fine earth fraction (< 2mm).  
 Structure Stability Index: relative collapse of larger pores (in the 1-2 mm fraction of surface soil) on slow and fast wetting. Values range from 0.00 (completely unstable) to 1.00 (completely stable) for well structured soils (no single grains).

SURFACE STRUCTURE STABILITY INDEX: 0.77  
 PERCENTAGE SINGLE GRAINS (1-2 mm): 67%

DEPTH (cm)	BULK DENSITY (g/cc)	WATER CONTENT (weight %)
A 0 - 20	1.44 (co)	11.20 10.59 9.36 7.54 6.7 5.9 5.2 5.1
B 20 - 80	1.51 (co)	13.30 12.10 11.03 9.29 8.3 6.8 6.3 6.2

REMARKS:

Soil Survey of Botswana FAO/BOT/85/011

last changed: 21/12/89

Print date: 21/01/91

SOIL PROFILE DESCRIPTION

SHEET : 2127D4  
LOCATION : IR14 7km from Mmadinare , 500m from Letlhakane riv.  
AUTHOR(S) : M.A.Hopkins  
CLASSIFICATION FAO: Areni-Chromic Luvisol(1988) Arenic Luvisol Xerosol (1974)  
ST : Arenic ustalfic Haplargid  
LANDFORM : pediment  
TOPOGRAPHY: gently undulating  
SURF. CHAR: no sealing, no cracks, nil evidence of salt,  
LAND USE: traditional grazing  
SPECIES : Trees - Acacia tortillis subs. heteroacantha (dom.)  
: Shrubs -  
: Grasses/forbs -

PARENT MATERIAL: in situ weathered  
MOIST. COND: dry 0 - cm  
SURF. STONES: none  
EROSION : nil

REMARKS:  
SAMPLES: A: 0 - 20 B: 30 - 50 C: 80 - 95 D: 120 - 135

0 - 32 cm Dark reddish brown (5YR 3/4) (moist) and yellowish red (5YR 4.5/6) (dry), loamy sand, weak medium subangular blocky structure, soft, non sticky, non plastic, many fine pores, non calcareous, many fine to medium roots, gradual smooth boundary.  
32 - 70 cm Dark red (2.5YR 3/6) (moist) and red (2.5YR 4/6) (dry), loamy sand to coarse sandy loam, weak fine subangular blocky structure, slightly hard, slightly sticky, slightly plastic, non calcareous, common medium roots, gradual smooth boundary.  
70 - 100 cm Dark red (2.5YR 3/5) (moist) and red (2.5YR 4/6) (dry), sandy clay loam, massive structure, hard, slightly sticky, slightly plastic, few fine angular quartz fragments, non calcareous, few termite/ant activity, few medium roots, diffuse boundary.  
104 - 150 cm Dark red (2.5YR 3/5) (moist) and red (2.5YR 4/6) (dry), sandy clay loam, massive structure, hard, slightly sticky, slightly plastic, few fine angular quartz fragments, non calcareous, few termite/ant activity, few coarse roots.  
150 - 170 cm Dark red (2.5YR 3/5) (moist) and red (2.5YR 4/6) (dry), sandy clay loam, few fine angular quartz fragments, few termite/ant activity, few coarse roots.  
170 - 235 cm Strong brown (7.5YR 5/8) (moist), loamy sand.

Soil Survey of Botswana FAO/BOT/85/011  
last changed : 03/12/90 print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 2004

SAMPLE DEPTH	pH	EC mS/cm	CaCL2	EC mS/cm	P ppm	C weight %	N weight %	CEC <	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						
																vcS	cS	mS	fS	vfS	cSi	fSi
A 0	7.2	0.0 B 17	0.0	0.00	6.0	2.6	12.5	0.4	0.1	16.5	100	0	0	85	0	0	0	2	14			
B 30	7.4	0.0 B 23	0.0	0.00	10.4	6.0	13.2	1.5	0.2	60.0	100	0	0	87	0	0	0	3	10			
C 80	7.3	0.0 B 24	0.0	0.00	11.7	8.4	22.4	2.8	0.0	51.0	100	0	0	86	0	0	0	2	12			
D 120	7.3	0.1 B 24	0.0	0.00	13.0	5.0	10.5	0.3	0.0	11.5	100	0	0	83	0	0	0	3	14			

Soil Survey of Botswana FAO/BOT/85/011

Last changed: 13/12/90

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

SOIL PROFILE DESCRIPTION

Profile: SP 0145 Unit: S 13a Status: 3

SHEET : 2128C4  
 LOCATION : Mosalakwane 13 km of Bobonong.  
 AUTHOR(S) : A.Remmelzwaal K.Verbeek K.Kgatlwane J.Maemboelwa  
 CLASSIFICATION FAO: Areni-Petric Calcisol(1988) Petrocalcic Arenosol (1974) petrocalcic phase  
 ST : Arenic Paleorthid  
 LANDFORM : plain  
 TOPOGRAPHY: undulating  
 SURF. CHAR: slight sealing, no cracks, nil evidence of salt,  
 LAND USE: traditional grazing  
 SPECIES : Trees -  
 : Shrubs - Acacia tortillis subs. heterocantha (dom.)  
 : Grasses/forbs-  
 PARENT MATERIAL: in situ weathered  
 MOIST. COND: dry 0 - 35 , slightly moist 35 - 80 cm  
 SURF.STONES: none  
 EROSION : slight sheet erosion

GRID : PF-337-712  
 COORD: 21-57-50-S 28-17-50-E  
 DATE : 14/07/88

LAND ELEMENT : ridge  
 MICRO TOPOGRAPHY: low hummocks  
 VEGETATION: open shrub savanna

AGRO CLIM.ZONE: 3B4  
 ELEVATION : 716 m  
 SNR: aridic  
 POSITION: crest  
 SLOPE : 1 - 2 % convex  
 GRASSCOVER: 30 - 70 %

ROCK TYPE: sandstone  
 ROCK OUTCROP: none

GEOLOG.UINT: Basement complex  
 DRAINAGE : somewhat excessively drained  
 HUMAN INF: borrow pit

REMARKS: Parent material is poorly sorted sandstone; clay content analyses is too high.

SAMPLES: A: 0 - 20 B: 20 - 35 C: 35 - 55 D: 60 - 80

- A 0 - 20 cm Dark reddish brown (5YR 3/4) (moist) and yellowish red (5YR 4/5) (dry), sand to loamy sand, very weak medium to coarse subangular blocky structure, slightly hard, friable, common very fine to fine pores, very few fine rounded slightly weathered quartz fragments, non calcareous, few termite/ant activity, common very fine to fine and few fine roots, clear smooth boundary.
- Bt1 20 - 35 cm Dark reddish brown (5YR 3/3.5) (moist) and reddish brown (5YR 4/3.5) (dry), loamy sand, very weak coarse to very coarse subangular blocky structure, soft to slightly hard, friable, patchy thin clay cutans on pedfaces, many very fine to fine pores, very few fine angular slightly weathered quartz fragments, non calcareous, few termite/ant activity, common very fine and few fine to medium roots, clear smooth boundary.
- Bt2 35 - 80 cm Dark reddish brown (2.5YR 3/4) (moist) and reddish brown (2.5YR 4/3.5) (dry), loamy sand to sandy loam, weak medium to very coarse subangular blocky structure, slightly hard, friable, broken thin clay cutans on pedfaces, many very fine to fine pores, very few fine angular slightly weathered quartz fragments, non calcareous, few termite/ant activity, few very fine to fine roots, abrupt irregular boundary.
- Crnk 80 cm + Light gray (10YR 7/2) (moist) and white (10YR 8/1) (dry), strongly coherent massive structure, extremely hard, no cutans, cemented, no pores, no rock fragments, extremely calcareous, no biological features, no roots.

Soil Survey of Botswana FAO/BOT/85/011

last changed : 03/12/90

print date: 21/01/91

STANDARD SOIL ANALYSIS RESULTS

PROFILE: SP 0145

SAMPLE DEPTH	pH	H2O CaCl2	EC mS/cm	EC m	P ppm	m	C	N	CEC	Ca	Mg	K	Na	EXAC	PBS	CARBO	Particle size (weight %)						CECclay	METH	PRETR			
																	weight %	<----->	meq/100gr soil	%	%	vcS				cS	mS	fS
A	0	7.0	6.0	0.1	B	12	0.3	0.00	5.8	11.4	4.2	0.1	0.0	0.0	100			0	6	7	65	0	7	4	12	37	H	N
B	20	7.2	6.1	0.0	B	5	0.2	0.00	7.1	12.1	4.6	0.1	0.0	0.0	100			0	7	4	35	31	9	1	14	44	H	N
C	35	7.4	6.3	0.0	B	4	0.2	0.00	6.9	12.6	5.0	0.1	0.0	0.0	100			6	6	7	32	28	8	2	13	49	H	N
D	60	7.6	6.5	0.1	B	4	0.1	0.00	7.2	3.4	1.0	0.4	0.2		69			7	7	8	32	26	8	1	14	50	H	N

Soil Survey of Botswana FAO/BGT/85/011

Last changed : 28/09/89

Print date: 21/01/91

EC : Electrical Conductivity m : method ... A = saturated paste B = 1:2.5 in water

P : Available Phosphorus determination m : method ... O = Olsen B = Bray

C : Organic Carbon determination Walkley-Black method

N : Total Nitrogen determination Kjeldahl method

CEC and bases : Ammonium acetate method

EXAC : Exchangeable acidity extracted with KCl

CARBO : Free Carbonates by destruction with HCl

PART-SIZE DETERMINATION METHOD: H = Hydrometer Method, P = Pipette Method, \* = Not Known  
 PRETREATMENT: O = Organic Matter, F = Free Iron Oxides, C = Carbonates, S = Soluble Salts N = None

*Printed By Information Section  
Ministry of Agriculture  
Private Bag 003 Gaborone, Botswana*