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FIELD DOCUMENT 1

Soil Mapping and Advisory Services

Botswana

SOILS AND LAND SUITABILITY OF THE BORO–SHOROBE AREA

FOOD & AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

REPUBLIC OF BOTSWANA

GABORONE, 1989

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SOILS AND LAND SUITABILITY OF THE BORO-SHOROBE AREA

by

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Gaborone, 1989

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.

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INTRODUCTION

The Soil Mapping Project is currently mapping the soils of the Shorobe melapo area at scale 1:50 000. Detailed studies are being carried out in the Mazanga and Xhwaa sample are (also pilot areas for the Molapo Development Project). In the sample areas about 50 soil pits have been described and sampled; more than 100 soil pits were dug in the remaining part of the mapping area. The most characteristic ones were sampled.

At present topographic data, flood regime data and soil physical dta are not available. A reinterpretation of the soils data will be necessary, when studies concerning the above mentioned subjects have been completed.

This report is a contribution to the present discussion on land use alternatives for the area.

FAO/UNDP/Government of Botswana. Soil Mapping and Advisory Services Project. Soil and Land Suitability of the Boro-Shorobe area. Prepared by G. J. Rhebergen, Maun June 1985. Updated and completed by K. Verbeek and F. Nachtergaele, Gaborone April 1989.

66 pages, 4 tables, 6 figures, 1 map.

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ABSTRACT

This report presents the results from the semi detailed soil survey of the Boro-Shorobe area at a scale 1:50 000. Chapter 1 describes the general characteristics of the area. Chapter 2 discusses the soils that occur in the area in more detail, while in Chapter 3 the land is evaluated for Molapo and large scale irrigation farming.
Typifying soil pedons with analyses, and a detailed land suitability classification are given in the appendices. A soil map is attached.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

- The current land suitability for molapo farming (both improved traditional and commercial) ranges from moderately suitable (S2) to very marginally suitable (S4) for maize, and from highly suitable (S1) to marginally suitable (S3) for sorghum.

After major improvements the land suitability of most areas can be improved by one class.

- The suitability for irrigated farming is marginal to very marginal for most areas. Only the more sandy area offer better possibilities. The most limiting land quality is 'land drainability' which is determined mainly by the permeability of the subsoil.

- The islands are not suitable for arable farming for the larger part; only the deep sandy edges could be used, but the suitability is marginal to very marginal for most crops.

- The fertility of the regularly flooded alluvial plains is medium to high; available phosphorous remains however low to very low.

- The calcic horizon which was found in the subsoil of some alluvial plains, indicates the low percolation rate of floodwater (if any) to deeper groundwater.

- A yearly increase of the sodium content, measured as the Exchangeable Sodium Percentage (ESP) has been observed in the alluvial plains, which can be attributed to the yearly floods. Successive years of high floods, resulting in a high groundwater table may attribute considerable to the sodification problem.

It is recommended that:

- a hydrological study is carried out which should cover among others the following subjects:

  - salt balance
  - soil physical studies in particular
  - the permeability of different soil types
  - effect of the proposed water resevoir on the groundwater level
  - groundwater movement

- remote sensing techniques be used to study the extent and the duration of the floods.

- the technical and economic feasibility be studied of a land use types based on flood recession (to control salinity and sodicity) but with supplementary sprinkler irrigation.

- the impact of flooding out of a permanent water resevoir of alluvial plains without a surface drainage component on the salinity and sodicity of the soils be studied.

1 GENERAL DESCRIPTION OF THE AREA

1.1 LOCATION, COMMUNICATIONS

The survey area is situated northeast of Maun between the Boro river and Shorobe village. The Buffalo fence forms the western boundary and the edge of the sandveldt the eastern boundary. (Figure 1)

The mapped area covers approximately 500km^2, consisting of alluvial plains (melapo) and islands.

The area is accessible by means of the Maun-Shorobe road, running along the eastern boundary of the survey area. Accessibility is very limited during the flood period (June-November)

1.2 CLIMATE

Basic climatic data are given in Table 1. Rainfall data of thirty nine consecutive years were combined with other climatic parameters (22 years record) and processed in FAO headquaters in Rome, Italy. Evapotranspiration (Penman method) was calculated and growing period analysis carried out (see Table 2).

Table 1

CLIMATIC DATA OF MAUN STATION

Station 68032: Maun

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
P (mm)	120.7	115.0	74.1	25.4	4.6	1.2	0.1	1.0	3.1	17.0	55.1	80.1
T-Mean(C)	25.6	25.2	24.6	22.5	18.6	16.0	16.0	19.1	23.5	26.4	26.2	25.8
T-Max (C)	31.6	31.4	31.3	29.9	27.5	25.0	25.1	28.3	32.2	34.1	33.0	32.1
T-Min (C)	19.5	18.9	17.8	15.0	9.6	6.9	6.9	9.8	14.8	18.6	19.4	19.4
T-day (C)	27.8	27.4	27.0	25.1	21.7	19.1	19.2	22.3	26.6	29.2	28.7	28.1
T-night(C)	23.7	23.1	22.1	19.5	14.8	12.1	12.1	15.3	20.2	23.7	24.0	23.8
Ed (mbar)	20.4	20.2	18.3	14.4	9.9	8.4	8.0	8.0	8.7	11.7	15.3	18.6
RH-mean(%)	62	63	59	53	46	46	44	36	30	34	45	56
U (m/sec)	1.8	1.7	1.6	1.3	1.3	1.4	1.6	1.7	2.0	2.2	2.2	2.0
n/N (%)	61	63	69	78	89	87	88	90	84	75	66	62
Rg(cal/cm^2/ day)	349.1	401.8	477.3	553.5	624.3	618.9	619.7	613.8	549.3	463.0	377.0	336.
ET-PENMAN (mm)	105.2	105.1	135.7	137.8	145.6	134.0	143.7	159.4	171.7	171.6	130.0	108.

The following definitions apply:

Total moisture period equals the length of the growing period, when one growing period occurs, or equals the total lengths when two or more growing periods occur in one hydrological year.

Growing period: the period of the year in days when available water temperature regime permits crop growth.

Normal growing period: the start of a normal growing period is assumed when precipitation exceeds half the potential evapotranspiration. The end of the period is assumed when precipitation falls below full evapotranspiration,

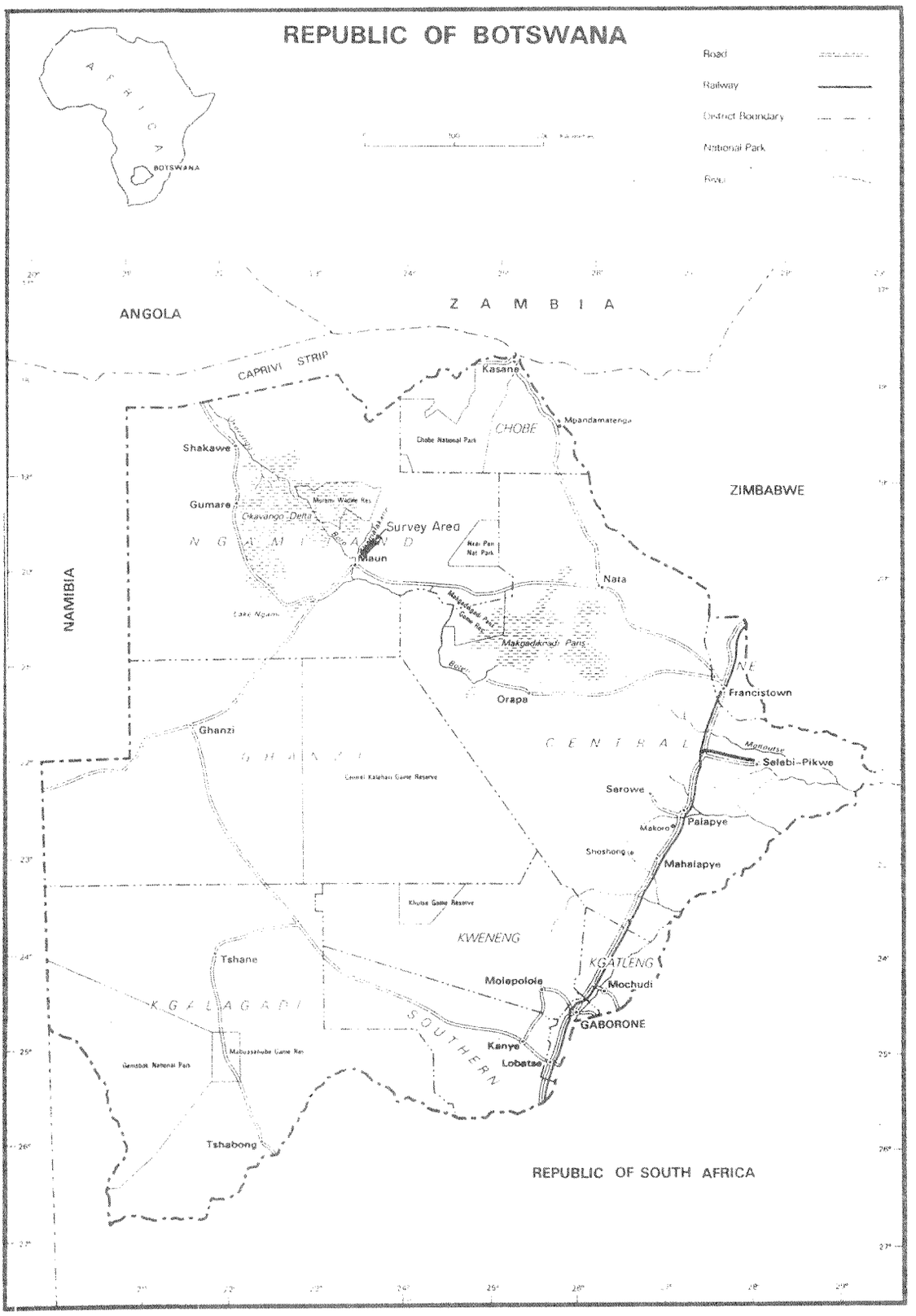

Figure 1 : Location of the survey area

plus a number of days required to evaporate an assumed 100mm moisture reserve when available.

Intermediate growing period: the start of an intermediate growing period is assumed when precipitation exceeds half the potential evapotranspiration. Precipitation does not exceed full potential evapotranspiration and there is no moisture reserve. The end is assumed when precipitation falls below half potential evapotranspiration.

Humid period: period in days during a normal growing period when precipitation exceeds full evapotranspiration.

Table 2

AGRO-CLIMATIC ZONES OF BOTSWANA

Zone	Station	Mean Total MOISTURE PERIOD		Mean Total HUMID PERIOD		PROBABILITY LENGTH TOTAL MOISTURE PERIOD (%)				MEAN PRECIPITATION (mm)	
		1944 1982	1936 1982	1944 1982	1936 1982	<70D	70-99	100-130	>130d	1944 1982	1936 1982
I	KASANE	139	135	74	74	3	7	25	65	680.6	660.9
II	SHAKAWE	116	111	46	38	15	15	35	35	535.4	504.9
	MAUN	106	100	49	49					496.2	512.7
III	GABORONE	101	105	26	31	25	30	20	25	535.4	504.9
IV	MAHALAPYE	106	98	30	23	30	30	15	25	473.9	463.6
	SEROWE	-	89	-	36					-	463.0
V	F'TOWN	75	81	22	26	45	20	29	15	463.4	496.2
VI	GHANZI	64	64	14	16	45	30	15	19	432.4	439.1
VII	BOBONONG	-	-	-	-	-	-	-	-	-	307.1
VIII	RAKOPS	-	56	-	13	60	30	5	5	-	366.3
	TSHANE	-	57	-	14					-	375.8
IX	TSHABONG	39	40	6	5	80	10	5	5	294.2	309.1

A general map of the agro-climatic zones in Botswana is presented in Figure 2.

In the more recent agro-climatic classification of Botswana, the study area is located in zone 2C2, corresponding with a growing season length of 81 to 100 days with 21 to 30 days being dry within the season. The length of the humid period has been calculated as being between 21 and 40 days with a probability of occurrence of 50 - 74%.

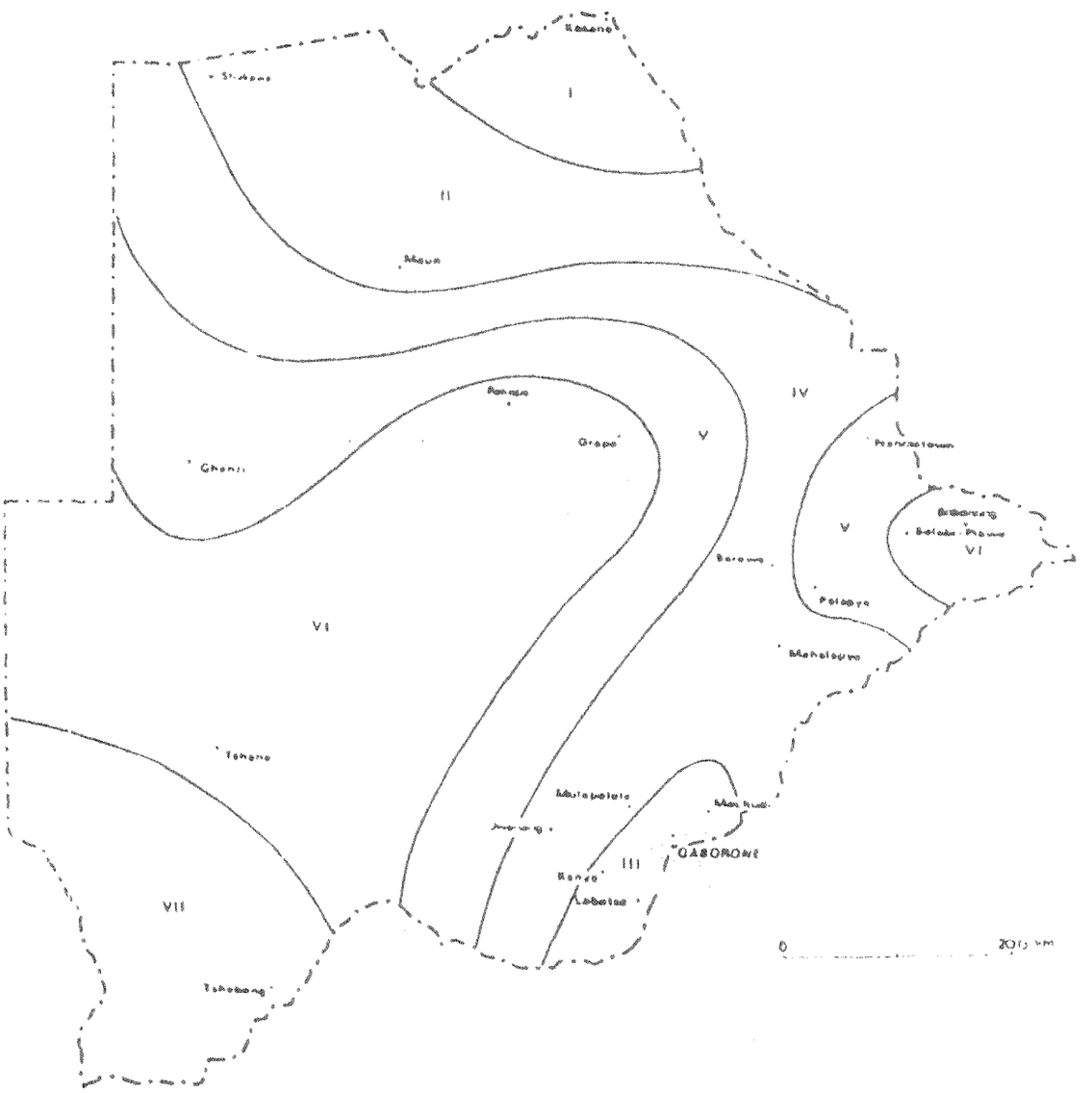

Table 2

	Climatic zone	precipitation (approx.mean)	probability length moist.period >90d.
I	Kasana	600-700mm	90 %
II	Maun-Shakawe	500-600	75
III	Gaborone	500-550	55-60
IV	Mahalapye-Serowe	450-500	50
V	Francistown-Ghanzi	400-450	35-40
VI	Bobonong-Rakops-Tshane	300-400	20
VII	Tshabong	200-300	10-15

Figure 2 : Agro-climatic zones of Botswana

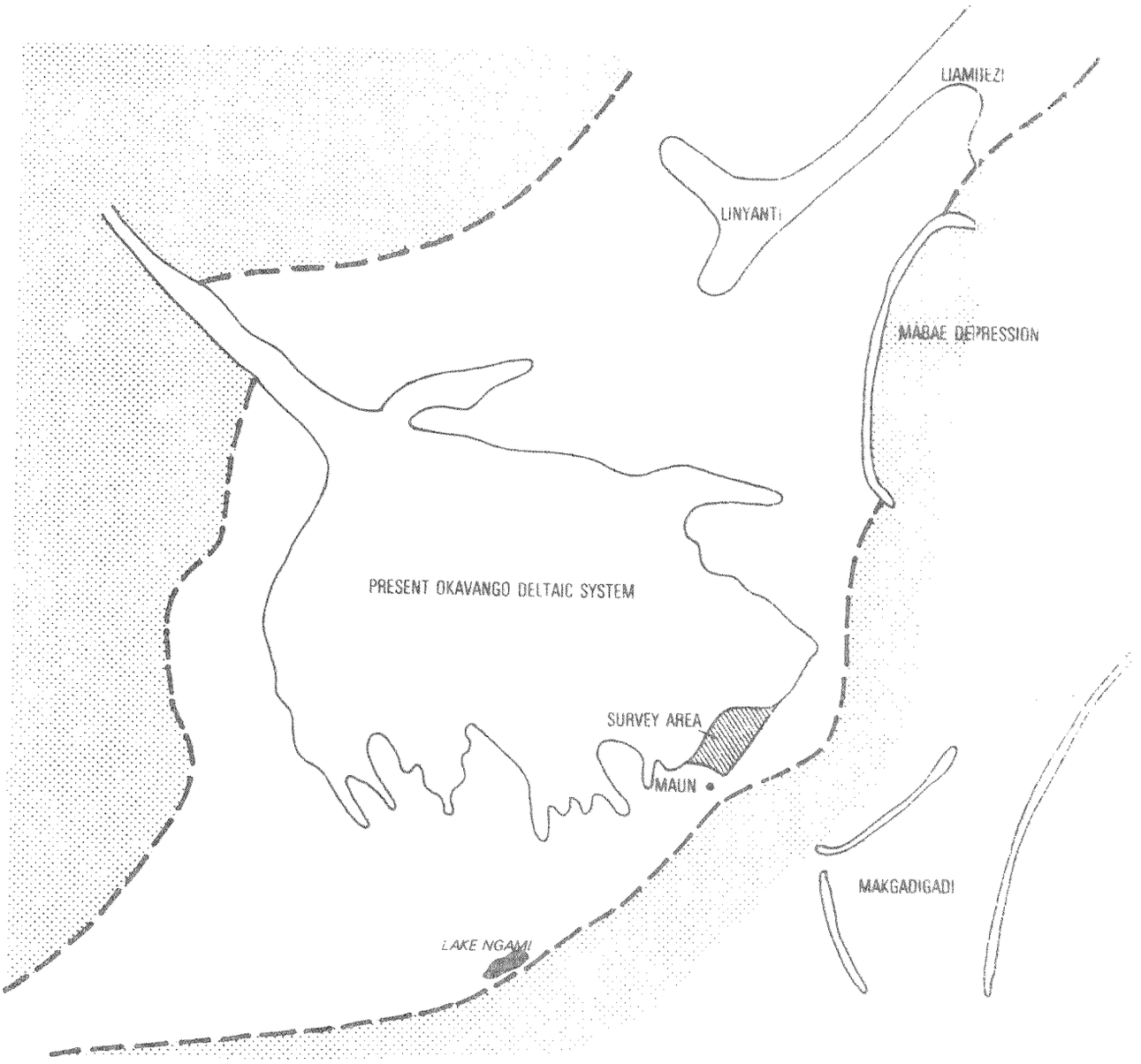

Fig 3: EXTENSION OF PRESENT AND ANCIENT ALLUVIAL SYSTEMS

1.3 PHYSIOGRAPHY

1.3.1 Geology

The survey area is situated between two fault lines: the Kunyere and the Thamalakane fault.

Superficial deposits of considerable thickness consisting of windblown sands (Kalahari beds) and alluvial sediments are overlying the rocks of the Kgwebe Formation.

The Kalahari beds have been reworked by fluvial and deltaic processes and sandy clay and clay has been deposited in the alluvial plains of the survey area.

1.3.2 Geomorphology

The mapping area is situated at the eastern fringe of the Okavango deltaic system. The present deltaic system and at least part of the older alluvial system were deposited in an eolian landscape (see Figure 3). Remnants of the longitudinal dune system can be found in the survey area. The alluvial plains occupy the former interdune depressions and the present islands are remnants of the dunes. The shapes of these features were modified by fluvial and deltaic processes.

Deposition took place in a subsiding basin, confined by faults. There are indications that the fluvial and deltaic deposits reach considerable thickness in some places. As recent and subrecent sediments were deposited in an eolian landscape, the thickness of these deposits does probably not exceed 10m. Deposits found at greater depth (more than 20-30m) must be part of a much older alluvial system.

A schematice cross-section through an island and an alluvial plain is shown in Figure 4.

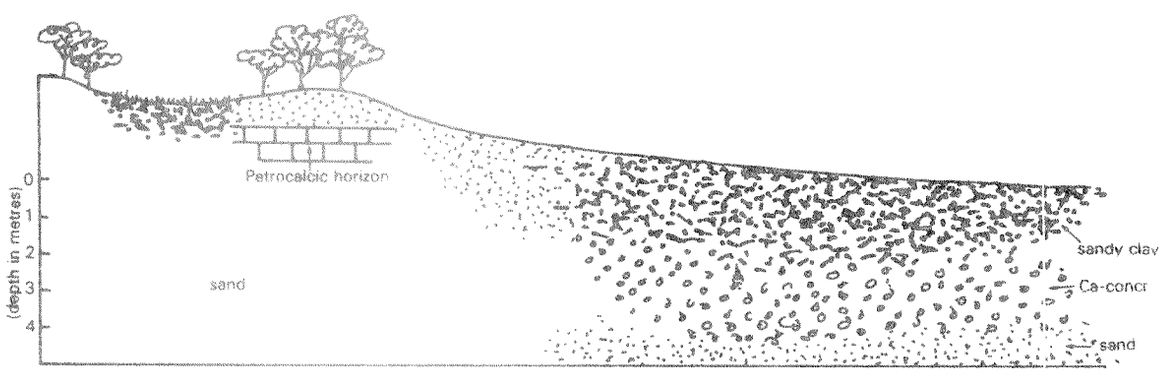

Fig 4: CROSS SECTION THROUGH AN ISLAND AND AN ALLUVIAL PLAIN IN BORO-SHOROBE

Calcic horizons were found in the alluvial plains at a depth of 1.5-2m. It occurs as soft powdery lime, but also as concretions. A petrocalcic horizon has not been found in the alluvial plains.

1.3.2 Hydrology

Understanding of the hydrology of the survey area is most essential before sound recommendations can be given on land use alternatives.
As hydrological studies are being carried out by the Molapo Development Project, only some preliminary conclusions are given here (pers. comm. R. Roostee, Molapo Dev. Proj.):

- an average flood recession in Xhwaa molapo of 10mm/day can be assumed, out of which 6mm through evaporation and approximately 4mm infiltration.

- the sandy clay loam to sandy clay soil material in the alluvial plains can store about 150mm/m of water.

- studies are being carried out to find out if any percolation to deeper groundwater occurs. If not then the salts remain in the upper 3 meters. If percolation does occur salt transport to deeper groundwater takes place. The amount of water percolating, if it occurs, will probably not exceed 1mm/day. A salt balance of the area can only be made when results of the hydrological study are available.

1.4 VEGETATION

The different vegetation types clearly reflect variations in environmental conditions such as : soil pH, drainage, flood regime, etc.

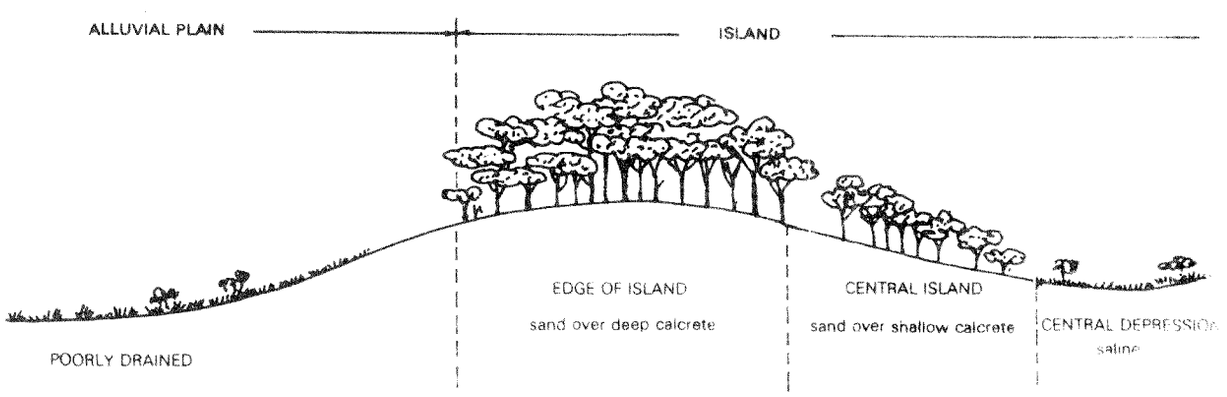

Fig 5: VEGETATION ON DIFFERENT TERRAIN TYPES

The most common species are listed below:

1. along edges of islands

trees :	*Lonchocarpus*	shrubs	*Diospyros lyciodes*
	Ficus sycomorus		*Diospyros mespiliformis*
	Combretum imberbe		*Grewia flava*
	Combretum hereoense		*Grewia bicolor*
	Kigelia africana		*Dichrostachys cinerea*
	Albizia harveyi		*Maytenus heterophylla*
	Acacia sieberana		*Ximenia americana*
	Acacia hebeclada		
	Ziziphus mucronata		
	Croton megalobotrys		

2. centre of islands (not depressions):

trees:	*Colosphermum mopane*	shrubs	*Pluchia leubnitzii*
	Maytenus heterophylla		*Blumea gariepina*
	Hyphaene ventricosa		
	Acacia tortillis		
	Combretum imberbe		
	Combretum hereoense		

3. central depressions:

shrubs: *Acacia tortillis*
halopithic grasses

4. alluvial plains:

grasses: *Asclepias fruticosa*
Vernonia glabra
Ziziphus mucronata (on anthills)

pioneer species after periods without floods

Acacia tortillis
Acacia erioloba
Combretum imberbe

2 SOILS

2.1 Soil Classification

The soils are classified following the FAO/Unesco system with amendments made by the Soil Mapping Project. Classification is also made according to Soil Taxonomy (USDA, 1975) , and FAO/Unesco (1988).

Soil profile description sheets together with the soil analyses results are presented Appendix 1.

For definitions of diagnostic horizons and properties reference is made to previous project reports and to the legend of the soil map of the world (FAO, 1974).

The FAO definition of hydromorphic properties was changed and brought into line with the definitions of Soil Taxonomy. This implies that some soils, which would be classified as Calcic Gleyic Luvisol according to the present FAO/Unesco system, are now classified as Calcic Luvisol. A soil with chromas between 1 and 2 without mottling does not classify as hydromorphic. The revised definition should read as follows:

In soils having an argillic B horizon immediately below the plough layer or an A horizon that has moist colour values of less than 3.5 when rubbed, one or more of the following.

(a) moist chromas of two or less;
(b) mottles due to segregation of iron;
(c) iron-manganese concretions larger than 2mm;

combined with one or more of the following:

(i) dominant moist chromas of 2 or less in coatings on the surface of peds accompanied by mottles within the peds, or dominant moist chromas of 2 or less in the matrix of the argillic B horizon accompanied by mottles of higher chromas (if hues are redder than 10YR because of parent material that remain red citrate-dethionite extraction, the requirement for low chromas is waived).

(ii) moist chromas of 1 or less on surface of peds or in the matrix of the argillic B horizon

(iii) dominant hues of 2.5Y or 5Y in the matrix of the argillic B horizon accompanied by distinct or prominent mottles.

The most important differentiating criterion applicable in the **alluvial plains** is the development of the B-horizon. Fluvisols do not show any B-horizon development, neither of a cambic-B nor of an argillic B. Gleysols have a weakly developed cambic B (structure) horizon. Luvisols generally have a weakly to moderately developed argillic B horizon often in combination with a calcic horizon.

The **islands** are underlain by calcrete (both soft and hard). At the edges they are covered with sand (Calcic or Petrocalcic Arenosol or Eutric Arenosol where the calcrete is too deep). In the central depressions sodic and saline conditions occur. The soils are more clayey and are both calcic and sodic/saline: Calcic Luvisol, sodic phase.

2.2 The Soil Units

In the alluvial plains soil types mostly occur as complexes. Boundaries are very gradual and can probably shift in time depending on changes in the floodregime. Some dry years may be followed by a succession of high floods; Eutric Gleysols may then change into Eutric Fluvisols.

Islands in the alluvial plains are indicated separately on the soil map when the area exceeds two ha. Islands smaller than two ha are generally omitted and they can be considered as minor inclusions in the alluvial plains. An association of soils occurs on the islands as the relation between the soil type is known, but can not be mapped at the scale used. The association is indicated with the capital X. It should be noted that not necessarily all the soil types of the association occur on evey island. The central depression may be absent or the deep sandy edge, characterized by high trees.

Soil units recognized in the survey area are listed below. Details are given on occurrence, soil characteristics and typifying pedons. Particular attraction is paid to the flood risk.

Selected profiles are given in Appendix 1, with standard analytical results. Information on all other soil profiles described during this survey are available from the Botswana Soil Database.

SOIL ON ALLUVIAL DEPOSITS

A7 **FAO:** Gleyic Luvisol, partly sodic (1974)
Gleyic Luvisol/Stagnic Luvisol (1988)
ST : Mollic Ochraqualf

Description: Deep to very deep, poorly to imperfectly drained, dark gray to grayish brown, sandy clayloam to clay.
Topography: Flat
Profiles: MA108, 122
Occurrence: In saucer shaped depressions, at some distance from the water source and the slightly sloping areas on the plains. Frequent flooding occurs, but is probably of short duration. These soils occur often in complex with Eutric Gleysols (A31a and b)
Characteristics: Their structure is weak to moderate subangular and angular blocky in the argillic horizon and a prismatic structure occurs in places. ESP values noted are moderate and in the range of 2 to 8%.

A7a As A7, but sandy loam texture
Profile: MA 201

Occurrence: The occurrence of these soils increases towards the Junyere fault line, as generally the soil texture becomes more sandy deeper into the delta. They occur also on somewhat higher positions in the floodplain.
Characteristics: The structure of the argillic horizon is massive to very weak subangular blocky. Between the A and the B horizons a white sandy layer (or pockets) may be found, with a thickness ranging from twenty to fifty centimeters. This layer is considered as windblown deposits on alluvial materials. ESP levels are more than 6 in places (sodic phase).

A7b **FAO:** Calcic Gleyic Luvisol, partly sodic (1974)
Calci-Gleyic Luvisol, Calci-Stagnic Luvisol (1988)
ST : Mollic Ochraqualf

Description: Deep to very deep, poorly to imperfectly drained, dark gray to grayish brown, sandy loams to clay.
Topography: Flat.
Profiles: MA 114, 115, 247
Occurrence: On the slightly higher parts of the alluvial plains, Floods occur only sporadically.
Characteristics: The structure of the argillic horizon is massive to moderately subangular blocky, in some places weakly prismatic. ESP values often exceed 6% (sodic phase), whilst an increased salinity level, compared to other A7-soils, is observed. The electrical conductivity remains below 4 m5/m.

A9 **FAO:** Calcic Luvisol, partly sodic (1974)
Calcic Luvisol/Luvic Calcisol (1988)
ST : Typic Haplustalf

Description: Deep to very deep, imperfectly to moderately well drained, dark brown to dark grayish brown, sandy clayloam to clay.
Topography: Flat to gently undulating
Profile: MA 143, 15, 174
Occurrence: This soil occurs on the higher parts of the alluvial plains and on the edges of islands. It also occurs on the alluvial plains without flood risk. These soils are very rarely flooded. They occur in complex with Gleyic Solonetz (A5)
Characteristics: These soils have an argillic horizon with a weak subangular blocky to massive structure. ESP can be high to very high (sodic phase). Chromas of the Bt horizon range from one to two.

A9a As A9, but sand to loamy sand over sandy loam to sandy clay loam. (Arenic Haplustalfs in Soil Taxonomy, Arenic Calcic Luvisol in FAO (1974).
Profile: MA 25

A24 **FAO:** Eutric Fluvisol (1974)
Eutric Gleysol/Eutric Fluvisol (1988)
ST : Mollic Aeric Haplaquent and/or Mollic Fluvaquent.

Description: Very deep, poorly to imperfectly drained, dark grayish brown to black, sandy clayloam to clay.
Topography: Flat
Profiles: MA 16, 19, 31, 32, 39, 102, 103, 110, 123
Occurrence: These soils occur in the lowest parts of the alluvial plains, often in saucer-shaped depressions. They are flooded for very long periods. They occur in complex with A31a (Eutric Gleysols). When the soils dry out for a considerable period, cracks develop.
Characteristics: The structure is massive, the consistency is very hard to extremely hard when dry. Mottling occurs from a depth of 80cm onwards. A calcic horizon is present at a depth of 150cm or more. The ESP remains generally below 4%.

A24b **FAO:** Arenic Eutric Fluvisol (1974)
Gleyic Arensols/Areni-eutric Fluvisol (1988)
ST : Aquic Quartzipsamment, Mollic Psammaquent, Mollic Haplaquent.

Description: As A24, but sand to loamy sands.
Topography: Flat
Profiles: MA 7, 23, 38, 118
Occurrence: As A24
Characteristics: Massive to structureless

A31a **FAO:** Eutric Gleysol (1974)
Eutric Gleysol (1988)
ST : Mollic Aeric Haplaquept

Description: Very deep, poorly to imperfectly drained, dark grayish brown to black sandy clayloam to clay.
Topography: Flat
Profiles: MA 2, 3, 4, 5, 22, 135, 104
Occurrence: The soils occur in the same or slightly higher positions as the Fluvisols. They flood regularly and for long periods.
Characteristics: Their structure is weak to moderately prismatic, breaking into a very weak subangular blocky structure. Hydromorphic properties are present within 50cm from the surface. A calcic horizon is present at a depth of 150 cm or more. These soils are non sodic.

A31b **FAO:** Eutric Gleysol (1974)
Eutric Gleysol (1988)
ST : Mollic Haplaquept

As A31a, but with a sandy loam texture.

A40 **FAO:** Eutric Arenosol, partly sodic (1974)
Eutri-Haplic Arenosols (1988)
ST : Ustoxic Quartzipsamment, Typic Ustipsamment

Description: Deep to very deep, moderately well to well drained, gray to white, sand to loamy sand.
Topography: Flat to gently undulating
Profile: MA 237

Occurence: These soils occur on the intermediate levels of the alluvial plains, they are rarely flooded. They also occur as a transition to the Sandveld.
Characteristics: Structureless; ESP levels may be high.

SOILS ON LACUSTRINE DEPOSITS

L11 **FAO:** Calcic Arenosol, sodic phase (1974)
Calcic Arenosol (1988)
ST : Aridic Ustochrept

Description: Deep to very deep, well to somewhat excessively drained, brown to pale brown, fine sand to loamy fine sand, having a calcic horizon, and calcareous between 0-15cm.
Topography: Almost flat to gently undulating.
Profile: MA 117
Occurrence: These soils occur in the central depressions (pans) of the islands.
Characteristics: The soil structure is very weak subangular blocky to structureless; the calcic horizon is massive, transitions to a petrocalcic horizon occur. Some characteristics of a Bt horizon may be present (some clay increase and/or pressure of clay cutans). ESP is generally high. (>8%).

L24a **FAO:** Calcic Luvisol, sodic phase, partly saline (1974)
Calcic Luvisol (1988)
ST : Typic Haplustalf

Description: Very deep, imperfectly drained, very dark grayish brown to brown, sandy clay loam to clay.
Topography: Flat to gently undulating.
Profile: MA 106
Occurrence: As L11
Characteristics: These soils have a weak subangular blocky structure which is never prismatic nor columnar. An extremely high ESP (%) is common, while relatively high EC values are also observed, (ms/m). A calcic horizon is always present with both soft powdery lime and nodular concretions. A transition to a petrocalcic horizon is noted in places.

SOILS ON COARSE GRAINED SEDIMENTARY ROCKS

S13 **FAO:** Calcic Arenosol (1974)
Calcic Arenosol (1988)
ST : Aridic Ustochrept

Description: Moderately deep to very deep, well to somewhat excessively drained, yellowish red to grayish brown, sands and loamy sands, having a

calcic horizon.
Topography: Flat to undulating.
Profile: MA 13.
Occurrence: Between the central depression and the edge of the islands.
Characteristics: As L11

S13a As S13 but with a petrocalcic horizon.

S17 **FAO:** Eutric Arenosol (1974)
Eutri-Haplic Arenosol (1988)
ST : Ust(ox)ic Quartzipsamment or Typic Ustipsamment

Description: Deep to very deep, well to somewhat excessively drained, light yellowish brown to dark grayish brown, fine sands to loamy fine sands. Non calcareous between 50 and 100cm.
Topography: Flat to undulating.
Profile: MA 44.
Occurrence: Mainly occurs along the edges of the islands.
Charactertistics: The structure of the top soil is very weak subangular blocky and becomes structurless in the subsoil. A calcic horizon may be present at a depth of more than 125 cm.

2.3 Profile development and floodregime

There is no clear relation between floodregime and soil development. Important aspects are the duration and the frequency of the floods. These depend on:

1. the distance from watersource (Thamalakane, Boro or Santantadibe river)

2. the shape of the alluvial plain (saucer shaped basins retain floodwater for a very long period).

3. elevation.

Areas which receive floodwater almost every year and for a long period are characterized by soils without profile development (Fluvisols) or by soils with a weak cambic B horizon (Gleysols). The basins are often saucer shaped.

Gleyic Luvisols (A7) can be found in areas which are frequently flooded for a short period. An argillic B horizon develops under conditions of repeated alternated wetting and drying to near-desiccation (Wilding et al, 1983). These conditions occur in:

1. the slighlty higher areas (lower floodlevel and shorter duration)

2. flat, not saucer shaped alluvial plains, which fall dry very quickly.

3. areas at greater distance from the watersource, so that the floodlevel is lower and duration shorter.

Calcic Luvisols (A9) are found in the higher areas of the alluvial plains. The floods are very infrequent and the floodlevel is low. These conditions occur on the terrace-like areas bordering some islands, and on higher areas at greater distance from the watersources. As the wetting and drying cycle is infrequent (most years being dry) the argillic B horizon is not well developed. The calcic horizon is evidence of the yearly net upward movement of capillary water. Whether salts are also deposited and to what extent is not yet established.
The calcic horizon which is found in the lowest part of Xhwaa molapo at a depth of approximately 1.50m is most probably related to the floodregime, specifically to the amount of water infiltrating.

It has been shown by Yaalon (in Wilding, et al, 1983) that the top of a calcic horizon is an exponential function of the mean annual precipitation. (see Figure 6)

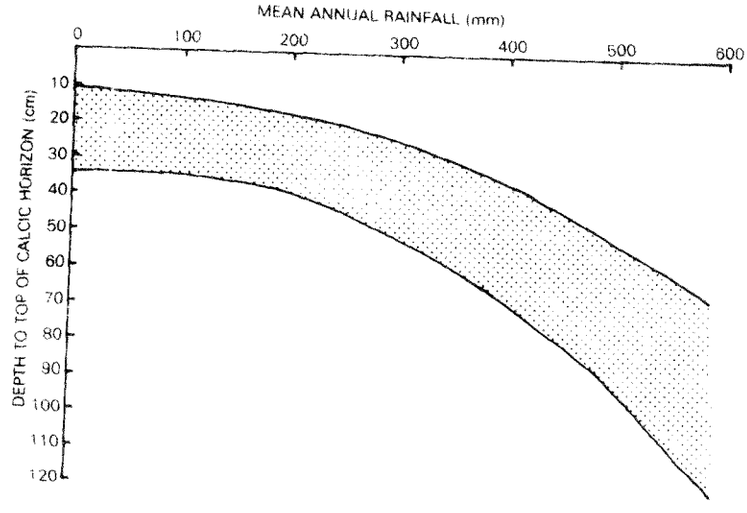

Figure 6. Depth to the calcic horizon as a function of mean annual precipitation (after Yaaloon, in: Wilding, et al, 1983)

In the molapo environment the floodwater has to be added to the precipitation. It can be concluded that floodwater infiltration plus precipitation is not adequate to leach the carbonates from the subsoil.

The following hypothesis can be made to explain the widespread presence of a calcic horizon in the subsoil of the alluvial plains of the survey area:

> It can be observed in several places in the delta, especially along the Boro channel, that at least some areas are flooded by rising groundwater rather than by surface flow. It seems that the flood is partly spreading through groundwater. Groundwater levels in the eastern fringe of the delta seem to fluctuate with the floodlevel in the upper delta. Groundwater levels being low in years with low floods and high in years with high floods. During years with a high groundwater table, evapotranspiration takes place throughout the year on the islands resulting in high salinity and a petrocalcic horizon; in the alluvial plains of the survey area evapotranspiration takes place from a high groundwater table in addition to the infiltrated flood- and rainwater, resulting in the formation of a calcic horizon in the subsoil. During years with low floods percolation in the alluvial plains is extremely slow; as a result, carbonates, deposited by evapotranspired groundwater, are not washed out beyond a certain depth (1.5-2m).

2.4 Salinization/Sodification

At present the edges of the alluvial plains show clear signs of sodification and salinization. The Exchangeable Sodium Percentage (ESP) exceeds 6, but remains mostly below 15. Sodification often goes together with the formation of a calcic horizon.

In the centre of the depressions (Fluvisol-Gleysol complex) a yearly increase in ESP in the topsoil is noticeable after flood recession caused by evaporation of floodwater and susbsequent evapotranspiration of the infiltrated water. When a new flood spreads over the area most of the accumulated sodium and salts are dissolved; some are transported through deep percolation. After flood recession the ESP increases to roughly the pre-flood level. In this natural system an equilibrium exists between sodification/salinization and floodregime and ESP and salinity remain at acceptable levels.

It is obvious that side effects will occur when the natural conditions are changed.

At present four land use types are under consideration:

- traditional molapo farming
- improved traditional molapo farming
- commercial molapo farming
- medium to large scale irrigated farming

The first three land use types make use of a modified flood regime. The amount of floodwater in a basin and the length of flooding is controlled by a system of sluices and bunds. Side effects, if any, will be limited and correction can be made, as the floodlevel can be controlled and the natural equilibrium can be restored at any time.

Irrigated farming does not make use of floods. Fertilizer inputs will be necessary to maintain high production levels. Residual salts will accumulate in the (top)soil. Leaching into the subsoil is impossible due to the very low infiltration rate. Flushing of the area by means of a high flood results in a reduction of the cropping time and an increase in production cost (2 crops per year will not be possible). It is also doubtful whether a high flood level is available when needed.

In conjunction with the formation of the calcic horizon, as described in section 2.3, sodification/salinization can take place. Due to low (ground)water levels these processes can not be studied adequately at present. However a definite answer has to be found before any development plans can be made.

3 LAND EVALUATION

3.1 Introduction

The proposed system is based on the FAO publication: "A Framework for land evaluation" (1976). The framework gives the principles and concepts on which land suitability evaluation is based, and indicates overall strategies for their application.

The Botswana system evaluates different land units for relevant existing, arable farming land use types, as defined by agronomists. Emphasis has been put on sorghum growing under different management levels. Sorghum represents more than 50% of the planted area, and is traditionally the first nutritional source in the rural areas. Several alternative crops, which are actually cultivated at a smaller scale than sorghum, have been proposed and can be evaluated: maize, millet, dolichos, cowpeas and sunflower. In the light of further rural development, other crops under different management levels have to be identified and potential new uses have to be described.

For the location of arable land, a qualitative land evaluation system has been recommended. The suitability is expressed in qualitative terms only, based on physical elements, without specific estimates of outputs (crop yields), inputs, costs and returns.

The systems is worked out according to the limitations approach. The limiting effect of each land quality is evaluated using an ordinal scale.

The system refers to current suitability. Minor land requirements which use common practice for the defined land uses are outlined.

3.2 Land use types

Four land use types can be distinguished in the survey area. Descriptions of the types read as follows:

LAND USE TYPE: Traditional Molapo Farming

Molapo farming is the cultivation of channels and floodplains ("melapo") immediately after the floods have receded (flood recession cultivation). Molapo farming is often practised in combination with dryland farming and communal grazing.

Produce:	Maize, sorghum, water melon, pumpkin, groundnuts
Yields:	600 kg/ha grain
Market orientation:	Subsistence, occasional sale of surplus
Size of holding:	2-10 ha; area cultivated depends on availablitiy of draughtpower, extent and time of flooding/flood recession and rainfall
Capital intensity:	Very low

Credit facilities:	None
Labour intensity:	Low to moderate
Farm power:	Oxen, donkeys, mules; occasionally a tractor may be hired for ploughing
Technical Knowledge:	Knowledge of traditional farming only
Management practices:	Location of fields may vary from year to year, depending on time and extent of flood; no fencing; very limited bunding to protect fields against flooding after planting; broadcasting; multi-cropping; no fertilizer.
Infrastructure requirements:	None
Land tenure system:	Communal

LAND USE TYPE: Improved Traditional Molapo Farming

Produce:	sorghum, maize, cucurbits and other
Yields:	1500 to 2500 kg/ha grain
Market orientation:	subsistence and partly commercial
Size of holding:	4 - 10 ha
Capital intensity:	Low
Credit facilities:	Government institutions
Labour intensity:	Moderate to high
Farm power:	Mainly animal (oxen, donkeys, mules); occasionally a tractor may be hired for ploughing
Technical Knowledge:	Good knowledge of modern farming practices
Management practices:	Permanent cultivation of land protected by (fenced) bunds with inlet structure; improved seeds, monocropping, modest application of fertilizer or manure; proper weeding; row planting
Land tenure:	Communal
Infrastructure:	Adequate extension service; depots for supplies (seeds, fertilizer); adequate market/storage; bridges crossing channels

LAND USE TYPE: Large scale commercial molapo farming

Produce:	maize, sorghum, sunflower and others
Yields:	2500-4500 kg/ha grain
Market orientation:	commercial
Size of holding:	more than 50 ha
Capital intensity:	moderate
Credit facilities:	commercial banks and government
Labour intensity:	moderate
Farm power:	engine
Technical knowledge:	good knowledge of molapo farming and machinery essential
Management practices:	permanent cultivation of land protected by bunds with inlet structures. Farming operations mechanized.
Land tenure:	communal; communal with long term lease
Infrastructure requirements:	enough flood water available every year; good access to markets and/or storage facilities; good access to supplies and mechanical skills/workshops if not present on the farm. Adequate technical advise.

LAND USE TYPE: Medium to Large Scale Irrigated Farming

Produce:	Food crops (including rice) and industrial crops
Yields:	4 - 10 ton/ha grain
Market orientation:	Commercial
Size of holding:	20 - 200 ha
Capital facilities:	Government and commercial banks
Labour intensity:	Moderate to high
Farm power:	Engine
Technical Knowledge:	High
Management practices:	Advanced irrigation techniques, unlimited inputs as long as net return is expected
Source of water:	Large weirs, dams, high-yielding boreholes, perennial swamps
Infrastructure requirements:	Easy access to markets or adequate storage facilities; easy access to agricultural expertise or on-the-farm skilled manager. Easy access to mechanical expertise/ workshop or on-the-farm facilities
Land tenure system:	communal; communal with long term lease

3.3 Land Suitability Classification

Four categories of decreasing generalization are recognized: Orders, Classes, Subclasses and Units.

Orders: There are two orders: Suitable(s) and Non-suitable (N)

Classes: Within order (S) are four classes:

S1 highly suitable: Land which is expected to be highly productive for the defined use. High returns amply justify required inputs. No significant limitations.

S2 moderately suitable: Land which is expected to be moderately productive for the defined use. Moderate returns justify required inputs. Limitations reduce crop yield 10 - 25% and/or increase recurrent costs for production and conservation.

S3 marginally suitable: Land which is expected to have a low productivity for the defined use. Yield benefits are just high enough to justify required inputs. Limitations reduce crop yield 25 -50% and/or considerably increase costs for production and conservations.

S4 very marginally suitable: Land which is expected to have a very low productivity for the defined use. It is doubtfull whether yield benefits alone justify required inputs. Severe limitations reduce crop yields with more than 50% and/or considerably increase costs for production and conservation.

Seasonal cultivation of land classed as S4 will, over a long period, not be profitable in terms of money. However, part of this land is used and will be used, if only periodically, for the following reasons:

a. economic considerations do not play a role, or only a minor one, in traditional dryland farming. Very low yields are justified in this concept;

b. due to the highly erratic rainfall, yields in some years are relatively high and (dryland) farming is justified;

c. considerations other than economic, such as employment and self-sufficiency, justify strongly reduced crop yields.

Within order (N) are two classes:

N1 currently unsuitable land: Land with very severe limitations which at present cannot be corrected economically.

N2 permanently unsuitable land:

Subclasses: Land suitability subclasses reflect kinds of limitations. They are indicated by lower-case letter, symbolizing the kind of limitation (e.g. subclass S2e: limitation caused by erosion).

Only the limitations(s) determining the suitability class are shown, with a maximum of three.

Classes S1 and N2 have no subclasses.

Units: Land suitability units are subdivisions of subclasses, indicated by arabic numbers, following a hyphen (e.g. S2e-1). The units differ from each other in their production characteristics or in minor aspects of their management requirements.
Land suitability units are used in detailed studies only.

Current and Potential Suitability:

The current suitability refers to the suitability for a defined use of land in its present condition, without major improvements. Minor improvements which are common practice for the defined land use are included.

Potential suitability refers to the suitability for a defined use of land after specified major improvements have been completed.

3.4 Preliminary suitability assessment

A final land suitability evaluation can only be made when all the analitical data and the results of the hydrological studies are available. A preliminary qualitative assessment involving a few land qualities will be presented here.

3.4.1 Molapo farming (improved traditional and commercial)

Only the regularly flooded areas and the areas with a potential for regular flooding will be considered.

The following soils can be found in the alluvial plains: Eutric Fluvisol, Eutric Gleysol, (Calcic) Gleyic Luvisol, Calcic Luvisol (see description of soil types, section 2.2).

The land qualities which can limit the suitability of the land for molapo farming are:

(m) moisture availability
(n) nutrient availability
(f) absence of damaging floods
(o) oxygen availability
(p) absence of pests and diseases
(t) absence of toxic substances
(w) workability
(x) adequacy of topography
(y) adequacy of flooding

The land qulaity which caused the most severe limitation determines the final suitability class.

(m) moisture availability

Moisture availability in the alluvial plains is determined by the amount of floodwater, the duration of the flood, climate and soil characteristics. The amount of floodwater and the duration of the flood largely depend on the topographic position (distance from the water source) and the shape of the basin (plain or saucer shaped).
It has been shown by data from the Molapo Development Project (unpublished) that a flood duration of two months is necessary to bring the moisture content of sandy clay profile to field capacity over a depth of 1m.
On plain, but slightly sloping areas the duration of the flood is often limited (estimated at 1 to 3 months), because of rapid recession. In saucer shaped depressions the duration of the flood and the amount of floodwater increased towards the centre of the depression (estimated duration of the flood is 3 to 6 months).

It should be noted that in sandy soils (soil type A24b, A31b and A7a) percolation to deeper groundwater will occur; to what extent is not (yet) known. Therefore a larger portion of the infiltrated water (as compared to the more clayey soils) is not available for evapotranspiration during the croppping season. Also the available water holding capacity (AWHC) is lower (estimated at 70 - 110 mm/m) as compared to the sandy clay soils (A24, A31a and A7) with AWHC of 150-220mm/m.

Although the average infiltration is 4mm/day, it has been observed that the total amount of infiltrated water does not exceed 450mm (unpublished data R. Roostee, M. D. P.). In some Fluvisols the total amount of infiltrated water (after a long flood of at least 3 months) did not exceed 200mm.

In soil type A7 ((Calcic) Gleyic Luvisol) the average depth of the seasonally wetted profile is considered to coincide with the depth of the Bt-horizon. This depth generally varies between 60cm and 100cm. The average total amount of infiltrated water is therefore estimated at 90-220mm.

The effective rainfall for the Maun agro-climatic zone is estimated at an average of 400mm per cropping season (80% of the mean annual rain).

The total amount of water available for evapotranspiration during a cropping season is estimated in table 3 using the above mentioned approximations and following the methodology described in the System of Land Evaluation (Venema and Rhebergen, 1985).

Table 3

SUITABILITY CLASSIFICATION IN RELATION TO MOISTURE AVAILABILITY

		MOISTURE AVAILABILITY					SUITABILITY CLASS			
topography	soil type	flood duration (month)	AWHC mm/m	inf.water avail. for evapotr (mm)	eff rain (mm)	total AW grow.seas (mm)	imp.trad molapo farm maize	imp.trad molapo farm sorgh.	commercial molapo farm maize	commercial molapo farm sorgh.
	A24, A31a	3-6	150-220	200-450	400	600-800	S2	S1	S2-S3	S1-S2
saucer shaped depression	A7, A9,A31a	1-3	150-220	90-220	400	490-620	S2-S3	S1-S2	S3	S2
	A24b, A31b	3-6	70-150	70-250	400	470-650	S3	S2	S3-S4	S2-S3
plain, slightly sloping	A31a, A7 A9	1-3	150-220	90-220	400	490-620	S2-S3	S1-S2	S3	S2
channels	A24b	1-6	70-150	high gwter table	400	>500	S2-S3	S1-S2	S3	S2

AWHC = Available Water Holding Capacity; AW = Available Water

The suitability classification has been downgraded to account for the probability of a total moisture period below average ($^{+}$-30%) and for the probability of a very low or absent flood (not enough data available, but estimated at 10%).

(n) nutrient availability

The nutrient availability is assessed, considering the amount of exchangeable calcium, magnesium, potassium, phosphorous and the CEC. The availability of nitrogen is estimated, using the organic carbon percentage as an indicator. A correction for pH is made (if necessary) depending on the type of crop.

It can be concluded that the nutrient availability ranges from medium to high (see System of Land Evaluation for calculation procedure; Venema, Rhebergen, third draft 1985). In the lower parts of the frequently flooded areas (soil type A24, A31a,b, part of A7) the nutrient availability is highest; however the availability of phosphorus generally remains low. In the slightly higher areas nutrient availability is medium (A7, A31a,b, A7b, A9); phosphorus availibility is low to very low and the Ca/Mg ratio is often unfavourable (>10).

(f) absence of damaging floods

Damging floods can occur in the channels during years of excessive rainfall. The frequency is considered to be low (once every 5-10 years).

(o) oxygen availability

oxygen availability is mainly a function of drainage. When only the drainage during the cropping season is considered, soil types A24 and A31a are imperfectly drained and the ponding hazard is estimated at 1-7 days every 6-10 years. The centre of some depressions will be more poorly drained. Other soil types will have a better drainage and present less or no limitations to most crops.

The suitability of crops sensitive to waterlogging (maize) will be limited most.

(p) absence of pests and diseases

Quantification of this land quality is difficult, because of the great variety of pests and quick (spatial and seasonal/yearly) changes in distribution and intensity. Therefore no suitability rating will be given.

On average however there seems to be considerable damage and the input to improve the situation will be moderate to high (in terms of labour and/or capital).

(t) absence of toxic substances

The following characteristics are considered in the suitability evaluation:

1. salinity (chlorides, sulphates, carbonates)
2. sodicity
3. calcium carbonate percentage

Salinity ratings in the alluvial plains are very low and will, under natural conditions, not limit crop production. Electrical conductivity of the saturated soil paste remains below 2mmhos/cm at 25^{o}C.

Sodicity; the exchangeable sodium percentage (ESP) is used as the indicator of sodicity. When the ESP of the topsoil exceeds 6 adverse effects on crop production can be expected.

Along the edges of the alluvial plains, irrespective of the soil type, ESP values of 4-8 have been found after flood recession. Under natural conditions the ESP is not expected to increase to much higher levels.

Calcium carbonate; the $CaCo_3$ percentage is not included in the standard chemical soil analyses. A quantitative assessment can therefore not be given. Soils with a shallow calcic or petrocalcic (A9a, A9) have some limitation for the two land use types.

(w) workability

In the alluvial plains the ease with which the soil can be cultivated mainly depends on the consistence of the soil. A large portion of the alluvial plains has a sandy topsoil. In the lower parts the sandy topsoil is often absent; the clayey topsoil has a sticky consistence when wet and is hard to very hard when dry, causing a moderate limitation to improved traditional

molapo farming with animal traction. In the case of mechanized farming, either improved traditional or commercial, the limitation wil be less or absent.
Soils with a sandy texture throughout will not cause workability limitations.

(x) adequacy of topography

This land quality can not be assessed quantitatively because of absence of topographic data. The main characteristics are the shape of the basin which is to be bunded and the meso-micro within that basin.

(y) adequacy of flooding

More data have to be made available to assess the adequacy of flooding (extension of the flood, frequency and duration). Remote sensing techniques could be used to gather part of the information (extension of the flood and duration).

Land suitability Classification for improved traditional and commercial molapo farming.

The current land suitability is indicated on the land suitability classification sheets as well as the potential land suitability. The potential land suitability refers to the suitability after the recommended improvements have been carried out. It should be noted that no economic considerations have been taken into account. For both land use types only mechanized farming is considered. The suitability classes have to be downgraded in the case of animal traction.

Moisture availability and oxygen availability are the most critical limitations under natural conditions. Soil physical studies have to be carried out before final recommendations for improvements can be given; especially in areas where flood frequency and duration is sufficient, but where total infiltration is limited (part of unit A24, A31a).

The creation of a permanent water resevoir would offer the possibility to increase the moisture availability in areas with a short and somewhat irregular flood (part of unit A7, A7b, A9, A31a,b). However, the impact of such a resevoir on the watertable of the area has to be studied. A high groundwater table would be detrimental to the area as salinization is likely to occur.

Oxygen availability problems can be expected in areas with low infiltration rates after heavy rainfall. Shallow drainage systems have to be designed to improve the surface drainage.

Under natural flood conditions excess floodwater is drained out of the area, carrying dissolved salts. When a permanent water resevoir is present no surface drainage is possible, unless pumping is introduced. The impact of flooding without a surface drainage component on the salinity/sodicity of the soils will have to be studied. Depending on the results of such study the frequency of excess flooding followed by surface drainage can be calculated and measures can be taken.

3.4.2 Medium to large scale irrigated farming

It is assumed that enough water of good quality is available throughout the year for irrigated farming and that floods are kept out of the farm area by bunds.

Most land quality ratings as discussed in section 3.4.1 also apply for irrigated farming. Land quality (m) moisture availability and (y) adequacy of flooding are not applicable.

The most important land quality limiting the suitability for irrigated farming is (d), soil drainability.

Soil drainability refers to the internal drainage of the soil which should neither be impeded, resulting in a high groundwater table and accumulation of toxic salts, nor very rapid, resulting in a loss of irrigation water.

Internal drainage is mainly a function of infiltration rate, permeability and depth of groundwater table.

Table 4

INTERNAL DRAINAGE CRITERIA

rating	minimum depth to groundwater table (cm)	1/ infiltration rate (cm/h)	2/ permeability cm/h
1	>200	>2	0.5-6
2	120-200	0.8-2	0.2-0.5 6-12
3	75-200	0.3-0.8	0.05-0.2
4	<75	<0.3	<0.05

1/ infiltration defined as entrance of water into saturated topsoil (0-25 cm)

2/ permeability defined as percolation rate of least permeable horizon within 150cm from the surface

The soil characteristic with the lowest rating determines the final soil drainability rating.

The minimum depth to the groundwater table varies following topographic position and distance to the water source. Not enough data are available for adequate quantification.

The infiltration rate is generally considered high as most areas are covered with a sandy topsoil.

The permeability of soils with a sandy clay texture is generally severly limiting the drainability (soil type A24, A31a). The available data indicate a permeability of less than 0.02cm/h. It is recommended that permeability tests are carried out for soil types A31b, A7, A7b, and A9, as permeability rates are probably higher in well structured Luvisols (A7, A7b) and in more

sandy soils (A31b).
It is evident that the soils with a very low permeability are at best marginally suitable for irrigated farming, while the soils with sandy loam or coarser textures offer better possibilities.

It is recommended that special attention is given to the area east of Boro-Xasanare river junction (soil type A31b and A7a). Soil drainability is expected to be more favourable; care has to be taken as high ESP levels have been found.

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APPENDIX 1.

SOIL PROFILE DESCRIPTIONS

Profile Symbol	Soil Unit	Soil Classification
MA108	A7	Gleyic Luvisol
MA122	A7	Gleyic Luvisol
MA201	A7a	Gleyic Luvisol
MA114	A7b	Calcic Gleyic Luvisol
MA115	A7b	Calcic Gleyic Luvisol
MA174	A9	Calcic Luvisol
MA25	A9a	Arenic Calcic Luvisol
MA123	A24	Eutric Fluvisol
MA35	A31a	Eutric Gleysol
MA104	A31a	Eutric Gleysol
MA237	A40	Eutric Arenosols, sodic phase
MA117	L11	Calcic Arenosols, sodic phase
MA106	L24a	Calcic Luvisol, sodic phase
MA13	S13	Calcic Arenosol
MA44	S17	Eutric Arenosol

SOIL PROFILE DESCRIPTION | Profile: MA 0108 Unit: A7 Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo area.
AUTHOR(S): G.Baert K.Verbeek
CLASSIFICATION FAO: Abrupti-Gleyic Luvisol(1988) Gleyic Luvisol (1974)
ST : Aeric Ochraqualf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: traditional grazing
SPECIES : Trees -
: Shrubs - Acacia sp. (dom.)
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 120 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-21-S 23-37-10-E
DATE : 14/02/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: open shrub savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: higher part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: From 60cm on:oxidation along rootchannels. Slightly calcareous along rootchannels from 15cm on.

SAMPLES: A: 0 - 15 B: 30 - 50 C: 90 - 110

A 0 - 15 cm 10YR 2/1.5 (moist) and 10YR 3/1.5 (dry), fine sandy loam, moderate medium and coarse subangular blocky structure, slightly hard to hard, common very fine and fine pores, non calcareous, abrupt irregular boundary.

Btg 15 - 60 cm 10YR 3/1 (moist) and 10YR 4.5/1 (dry), sandy clay, moderate very coarse prismatic falling apart into moderate angular blocky structure, extremely hard, broken moderately thick clay cutans on pedfaces, common very fine and fine pores, non calcareous, few very fine and fine roots, clear wavy boundary.

BC 60 - 120 cm 10YR 3.5/2 (moist) and 10YR 4.5/2 (dry), very weak angular and subangular blocky structure, extremely hard, few very fine and fine pores, non calcareous, very few very fine and fine roots,

STANDARD SOIL ANALYSIS RESULTS

PROFILE: MA 0108

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------û					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	15	6.6	6.0	0.4	6	0.9	13.7	8.5	1.5	0.8	0.3	81	0	1	10	54	9	4	5	17	61	H	A
B	30	50	7.6	6.9	0.5	2	0.1	21.7	14.2	3.3	1.4	0.5	89	0	1	9	41	6	2	3	38	56	H	A
C	90	110	7.6	6.7	0.3	1	0.1	19.0	13.3	3.0	1.4	0.3	95	0	1	10	42	6	3	5	33	56	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0122 Unit: A07 Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo area, 2.5km NW from MDP camp..
AUTHOR(S): G.J.Rhebergen G.Baert K.Verbeek B.Kopelo
CLASSIFICATION FAO: Orthi-Gleyic Luvisol(1988) Gleyic Luvisol (1974)
ST : Mollic Ochraqualf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: strong sealing, no cracks, nil evidence of salt,
LAND USE: traditional Molapo farming
SPECIES : Trees -
: Shrubs - Acacia sp. (dom.)
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: moist 0 - 100 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-39-S 23-36-20-E
DATE : 27/08/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: open shrub savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: higher part
SLOPE : 0 - 0.5%

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: Bleached sand grains on ped surfaces in Bt2 horizon. Btl and Btl slightly calcareous along rootchannels. Not regularly flooded molapo.

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

A 0 - 15 cm 10YR 3/1 (moist) and 10YR 4/1 (dry), sandy clay loam, weak medium to very coarse subangular blocky structure, firm, non calcareous, common very fine and fine roots, clear smooth boundary.

Btg1 15 - 65 cm 10YR 2.5/1- (moist) and 10YR 3.5/1- (dry), sandy clay, moderate coarse and very coarse angular and subangular blocky structure, very firm, broken moderately thick clay cutans on pedfaces, non calcareous, few very fine and fine roots, clear smooth boundary.

Btg2 65 - 110 cm 10YR 4/1- (moist) and 10YR 5/1- (dry), sandy clay loam, weak very coarse subangular blocky structure, very firm, broken thin clay cutans on pedfaces, non calcareous, very few very fine and fine roots,

STANDARD SOIL ANALYSIS RESULTS

PROFILE: MA 0122

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	meq/100gr soil					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	6.8	6.0	0.0	4	0.8	18.6	10.3	2.5	1.3	0.2	77	0	5	8	46	8	4	6	24	66	H	A
B	30	50	7.6	7.0	0.7	1	0.1	20.8	12.2	3.0	1.3	0.5	82	0	1	6	45	7	1	4	37	55	H	A
C	80	100	7.7	6.9	0.0	1	0.1	17.9	10.0	2.5	1.1	0.4	78	0	1	8	44	6	4	4	33	53	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0201 Unit: A07a Status: 2

SHEET : 1923D3
LOCATION : Boro molapo area.
AUTHOR(S): K.Verbeek
CLASSIFICATION FAO: Gleyic Luvisol(1988) Gleyic Luvisol (1974)
ST : Mollic Ochraqualf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: moderate sealing, no cracks, nil evidence of salt,
LAND USE: traditional grazing
SPECIES : Trees -
: Shrubs - Acacia sp. (dom.)
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: moist 0 - 100 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-52-59-S 23-31-24-E
DATE : 20/03/85

LAND ELEMENT : channel
MICRO TOPOGRAPHY: even

VEGETATION: open shrub savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: intermediate part
SLOPE : 1 - 2 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: Bt2 slightly calcareous along rootchannels. Cracks starting under A, few millimetres wide. Oxidation along rootchannels in Bt1 and Bt2.

SAMPLES: A: 0 - 20 B: 30 - 50 C: 70 - 90

A 0 - 20 cm 10YR 3/1 (moist) and 10YR 4.5/1 (dry), fine sand to loamy fine sand, very weak medium and coarse subangular blocky structure, very friable, non calcareous, common roots, clear wavy boundary.

Bt1 20 - 70 cm 10YR 3.5/1 (moist) and 10YR 5.5/1 (dry), fine sandy loam, very weak very coarse prismatic structure, very firm, non calcareous, few roots, gradual smooth boundary.

Bt2 70 - 100 cm 10YR 4/1- (moist) and 10YR 5/1- (dry), fine sandy loam, very weak very coarse prismatic structure, very firm, non calcareous, no roots,

STANDARD SOIL ANALYSIS RESULTS

PROFILE: MA 0201

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	7.4	6.3	0.0	2	0.5	5.9	6.4	0.8	0.4	0.1	100	0	1	10	58	13	6	6	7	57	H	A
B	30	50	7.5	6.5	0.4	2	0.1	7.7	7.2	1.1	0.4	0.2	100	0	1	10	54	13	5	5	13	54	H	A
C	70	90	7.6	6.4	0.3	1	0.1	12.7	10.6	2.0	0.6	0.2	100	0	1	9	47	10	10	6	18	69	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0114 Unit: A07b Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo area.
AUTHOR(S): B.Kopelo G.Baert
CLASSIFICATION FAO: Calci-Gleyic Luvisol(1988) Calcic Gleyic Luvisol (1974)
ST : Mollic Ochraqualf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: traditional grazing
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 100 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-59-S 23-38-09-E
DATE : 20/02/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: intermediate part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: From 18cm on: oxidation is along rootchannels. Bleached sand grains along structure elements.

SAMPLES: A: 0 - 15 B: 25 - 45 C: 80 - 100

A 0 - 18 cm 10YR 2/1 (moist) and 10YR 3/1 (dry), sandy clay loam, hard, non calcareous, common very fine and fine roots, clear wavy boundary.

Btg 18 - 50 cm 10YR 3/1 (moist) and 10YR 3.5/1 (dry), sandy clay to clay, weak prismatic structure, very hard, patchy thin clay cutans on pedfaces, very few fine spherical soft calcareous white nodules, slightly calcareous, few very fine and fine roots, gradual wavy boundary.

Btgk 50 - 100 cm 10YR 4.5/1 (moist) and 10YR 5.5/1 (dry), clay, moderate medium and coarse subangular and angular blocky structure, extremely hard, patchy thin clay cutans on pedfaces, frequent fine spherical hard calcareous white nodules and frequent fine spherical soft calcareous white soft segregations, strongly calcareous, very few very fine and fine roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0114

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	15	6.7	6.1	0.0	4	1.2	17.0	13.2	2.3	0.2	0.2	94	0	0	6	39	10	10	9	26	46	H	A
B	25	45	8.0	7.3	0.3	1	0.2	21.1	13.6	5.2	0.9	0.2	94	0	0	5	30	7	5	7	45	45	H	A
C	80	100	8.9	8.0	0.3	1	0.1	25.1	37.1	9.0	0.4	0.2	100	1	1	2	11	5	2	16	62	40	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0115 Unit: A7b Status: 1

SHEET : 1923D3
LOCATION : Xhwaa molapo area.
AUTHOR(S): G.Baert B.Kopelo
CLASSIFICATION FAO: Calci-Gleyic Luvisol(1988) Calcic Gleyic Luvisol (1974)
ST : Mollic Ochraqualf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: traditional grazing
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 110 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-58-S 23-38-12-E
DATE : 20/02/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: intermediate part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: Thin layer of white sand between A and Btg. Oxidation along rootchannels in Btg1.

SAMPLES: A: 0 - 15 B: 25 - 45 C: 60 - 80 D: 100 - 120

A 0 - 15 cm 10YR 2/1 (moist) and 10YR 3/1 (dry), fine sandy loam, very weak medium subangular blocky structure, slightly hard, common very fine and fine pores, non calcareous, common fine roots, clear smooth boundary.

Btg1 15 - 55 cm 10YR 3/1 (moist) and 10YR 4/1 (dry), few fine distinct sharp yellow mottles, sandy clay to clay, weak medium subangular blocky structure, very hard, patchy thin clay cutans on pedfaces, few fine pores, non calcareous, few very fine and fine roots, gradual smooth boundary.

Btg2 55 - 100 cm 10YR 4/1 (moist) and 10YR 5/1 (dry), few fine distinct clear yellow mottles, sandy clay to clay, weak medium subangular blocky structure, very hard, few fine pores, non calcareous, few fine roots, clear wavy boundary.

Cgk 100 - 110 cm 10YR 5/1.5 (moist) and 10YR 6/1.5 (dry), few fine distinct clear yellow mottles, clay, strongly coherent massive structure, extremely hard, few fine pores, few fine spherical soft calcareous white nodules, strongly calcareous, very few very fine and fine roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0115

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	meq/100gr soil					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	15	6.6	5.8	0.0	3	1.3	15.9	8.2	1.4	1.0	0.1	67	0	1	9	46	9	6	10	20	54	H	A
B	25	45	7.7	7.0	0.3	1	0.1	20.0	12.3	2.9	1.0	0.3	83	0	0	6	29	6	2	5	52	38	H	A
C	60	80	8.0	7.2	0.3	1	0.1	19.1	15.8	2.9	0.2	0.5	100	0	0	6	27	6	1	5	55	34	H	A
D	100	120	8.5	7.7	0.2	1	0.1	22.4	22.6	3.4	0.2	0.6	100	0	0	4	20	5	6	4	61	36	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0174 Unit: A09 Status: 2

SHEET : 1923D3
LOCATION : Chinese rice farm.
AUTHOR(S): G.J.Rhebergen B.Kopelo
CLASSIFICATION FAO: Calcic Luvisol(1988) Calcic Luvisol (1974)
ST : Typic Haplustalf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: medium scale irrigated farming
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: slightly moist 0 - 100 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: - - 0-S - - 0-E
DATE : 26/03/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION:

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: intermediate part
SLOPE : 0 - 0.5%

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: ploughing

REMARKS: Rice field, poor crop perfomance.

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

A 0 - 20 cm 10YR 3/2 (moist) and 10YR 4/2 (dry), loamy fine sand, weak medium and coarse subangular blocky structure, slightly hard, slightly calcareous, common roots, abrupt smooth boundary.

Bt 20 - 50 cm 10YR 4/2 (moist) and 10YR 5/2.5 (dry), fine sandy loam, very weak coarse and very coarse subangular blocky structure, hard, moderately calcareous, few roots, gradual smooth boundary.

Btk 50 - 100 cm 10YR 4/2 (moist) and 10YR 5/2.5 (dry), sandy clay loam, very weak coarse and very coarse subangular blocky structure, very hard, patchy thin clay cutans on pedfaces, frequent fine spherical soft calcareous white soft segregations, strongly calcareous, very few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0174

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	7.3	5.2	0.2	4	0.2	6.9	6.1	0.9	0.3	0.3	100	0	1	18	61	6	2	1	10	59	H	A
B	30	50	7.5	6.3	0.1	4	0.1	11.0	8.1	1.4	0.3	0.4	93	0	1	17	55	6	3	4	15	73	H	A
C	80	100	8.6	7.7	0.7	1	0.0	13.3	18.5	2.4	0.5	0.5	100	0	1	16	51	6	2	3	20	66	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0025 Unit: A09a Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo area.
AUTHOR(S): G.J.Rhebergen
CLASSIFICATION FAO: Areni-Luvic Calcisol(1988) Arenic Calcic Luvisol (1974) sodic phase
ST : Arenic Haplustalf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no sealing, no cracks, nil evidence of salt,
LAND USE: traditional Molapo farming
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 100 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-46-30-S 29-38-06-E
DATE : 15/05/84

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: higher part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : moderately well to imperfectly drained

HUMAN INF: ploughing

REMARKS: Position: edge of alluvial plain

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

A 0 - 20 cm 10YR 3/1 (moist) and 10YR 4/1 (dry), fine sand to loamy fine sand, very weak medium subangular blocky structure, slightly hard to hard, moderately calcareous, common roots, clear smooth boundary.

Btk 20 - 60 cm 10YR 3/2 (moist) and 10YR 4/2 (dry), loamy fine sand, strongly coherent massive structure, very hard, strongly calcareous, few roots, gradual smooth boundary.

Ck 60 - 100 cm 10YR 4/3 (moist) and 10YR 6/2 (dry), fine sand, massive structure, hard, frequent fine irregular soft calcareous white soft segregations, slightly calcareous, very few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0025

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	8.2	7.3	0.1	1	0.2	2.7	2.3	0.4	0.7	0.0	100	0	3	26	55	6	1	4	5	35	H	A
B	30	50	9.6	8.4	1.3	1	0.2	4.1	12.1	0.9	1.1	2.1	100	0	3	28	50	5	1	3	10	34	H	A
C	80	100	8.9	7.5	0.1	1	0.1	2.5	2.9	0.6	0.5	0.4	100	0	2	26	55	6	1	3	7	31	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0123 Unit: A24 Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo.
AUTHOR(S): G.J.Rhebergen G.Baert K.Verbeek B.Kopelo
CLASSIFICATION FAO: Orthi-Eutric Gleysol(1988) Eutric Fluvisol (1974)
ST : Mollic Haplaquent
LANDFORM : alluvial plain
TOPOGRAPHY: rolling
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: improved Molapo farming, crops: sorghum, maize
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: moist 0 - 270 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-50-S 23-35-09-E
DATE : 27/02/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: lower part
SLOPE : 0 - 0.5%

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly to poorly drained

HUMAN INF: ploughing

REMARKS: 3.80m depth groundwater reached by augering.

SAMPLES: A: 0 - 20 B: 40 - 60 C: 90 - 110 D: 140 - 160 E: 190 - 210 F: 240 - 260

A 0 - 20 cm 10YR 2/1 (moist) and 10YR 3.5/1 (dry), sandy clay loam, weak medium and coarse subangular blocky structure, very hard friable, common very fine and fine pores, non calcareous, common very fine and fine roots, clear smooth boundary.

Cg1 20 - 70 cm 10YR 3/1 (moist) and 10YR 4/1 (dry), few fine faint clear reddish-brown mottles, sandy clay loam, strongly coherent massive structure, firm to very firm, few very fine and fine pores, non calcareous, few fine roots, gradual smooth boundary.

Cg2 70 - 170 cm 2.5Y 3/2 (moist), many fine distinct clear reddish-brown mottles, sandy clay loam, strongly coherent massive structure, firm, few very fine and fine pores, non calcareous, no roots, gradual smooth boundary.

Cgk 170 - 270 cm 2.5Y 5.5/2 (moist), many fine faint clear reddish-brown mottles, sandy clay loam to sandy clay, strongly coherent massive structure, friable, few very fine and fine pores, frequent fine irregular hard and soft calcareous white nodules, strongly calcareous, no roots,

STANDARD SOIL ANALYSIS RESULTS

PROFILE: MA 0123

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	meq/100gr soil					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	6.4	5.8	0.0	12	1.4	20.0	9.6	1.9	1.8	0.2	68	0	1	10	46	7	4	8	25	57	H	A
B	40	60	7.3	6.5	0.0	3	0.1	18.2	9.3	2.3	1.2	0.5	73	0	1	9	43	7	5	7	30	60	H	A
C	90	110	6.6	5.8	0.0	1	0.1	15.0	6.2	1.8	1.1	0.5	64	1	1	13	49	6	4	3	23	63	H	A
D	140	160	7.2	6.7	0.0	2	0.1	19.3	10.3	2.1	1.4	0.4	74	0	1	11	44	6	5	4	29	65	H	A
E	190	210	8.0	7.6	1.1	0	0.1	23.9	53.7	3.5	1.4	0.6	100	0	1	7	29	6	6	11	39	60	H	A
F	240	260	8.5	7.7	0.3	0	0.0	18.3	48.4	3.2	0.8	0.2	100	1	1	10	42	7	4	6	29	64	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0035 Unit: A31a Status: 2

SHEET : 1923D3
LOCATION : Mazanga molapo.
AUTHOR(S): G.J.Rhebergen
CLASSIFICATION FAO: Eutric Gleysol(1988) Eutric Gleysol (1974)
ST : Mollic Haplaquept
LANDFORM :
TOPOGRAPHY: flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: improved Molapo farming
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 120 cm
SURF.STONES: none
EROSION : moderate accumulation by water

GRID : - -
COORD: 19-48-30-S 23-33-44-E
DATE : 26/06/84

LAND ELEMENT : not applicable
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: lower part
SLOPE : 0 - 0.5% concave

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : poorly drained

HUMAN INF: nil

REMARKS: Ah contains less humus than MA0032.Bg and Cg oxidation along rootchannels.

SAMPLES: A: 0 - 200 B: 0 - 0 C: 0 - 0

Ah 0 - 20 cm 10YR 3/2 (moist) and 10YR 4/2 (dry), loamy fine sand to fine sandy loam, very weak medium subangular blocky structure, hard, common very fine and fine pores, non calcareous, common roots, abrupt wavy boundary.

Bg 20 - 80 cm 10YR 3/1- (moist) and 10YR 4/1- (dry), sandy clay, very weak very coarse angular blocky structure, very hard, common very fine and fine pores, non calcareous, few roots, gradual smooth boundary.

Cg 80 - 120 cm 10YR 4/1- (moist) and 10YR 3/1- (dry), sandy clay to clay, strongly coherent massive structure, very hard, non calcareous, very few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0035

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	meq/100gr soil					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	200	5.8	5.2	0.0	2	0.9	9.1	6.7	0.8	0.5	0.2	90	0	0	8	63	8	2	4	14	40	H	A
B	0	0	5.9	5.2	0.0	3	0.1	20.0	14.7	2.5	1.4	0.4	95	0	1	9	39	6	3	5	38	51	H	A
C	0	0	6.6	5.9	0.0	1	0.1	22.8	16.9	2.8	1.6	0.3	95	0	0	7	36	7	4	6	41	55	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0104 Unit: A31a **Status: 2**

SHEET : 1923D3
LOCATION : Xhwaa molapo.
AUTHOR(S): K.Verbeek G.Baert
CLASSIFICATION FAO: Orthi-Eutric Gleysol(1988) Eutric Gleysol (1974)
ST : Mollic Haplaquept
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: improved Molapo farming, crops: maize
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: moist 0 - 110 cm
SURF.STONES: none
EROSION : slight accumulation by water

GRID : - -
COORD: 19-45-47-S 23-37-40-E
DATE : 14/02/85

LAND ELEMENT : flood plain
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: aquic

POSITION: higher part
SLOPE : 1 - 2 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: ploughing

REMARKS: On contact Ap-Bg1 2cm thick layer of bleached sand. Bg1 oxidation along rootchannels

SAMPLES: A: 0 - 5 B: 0 - 0 C: 0 - 0

A 0 - 18 cm 10YR 2/1 (moist) and 10YR 3/1 (dry), sandy clay loam, weak medium and coarse subangular blocky structure, friable, non calcareous, few very fine and fine roots, abrupt smooth boundary.

Bg1 18 - 75 cm 10YR 3/1 (moist) and 10YR 3.5/1 (dry), sandy clay loam to sandy clay, weak coarse and very coarse subangular blocky structure, very firm, non calcareous, few very fine roots, clear smooth boundary.

Bg2 75 - 110 cm 10YR 3/1 (moist) and 10YR 3.5/1 (dry), common fine distinct clear yellowish-brown mottles, sandy clay, strongly coherent massive structure, very firm, non calcareous, very few roots,

0 cm +

STANDARD SOIL ANALYSIS RESULTS

PROFILE: MA 0104

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	5	5.7	5.4	0.0	0	2.9	22.0	15.0	1.0	2.2	0.3	84	0	1	10	39	6	7	13	25	42	H	A
B	0	0	6.8	6.1	0.0	4	0.1	15.3	11.4	2.2	0.7	0.2	95	0	1	11	37	5	5	9	32	47	H	A
C	0	0	6.9	6.1	0.0	2	0.1	17.4	12.8	1.1	2.8	0.4	98	0	1	10	31	5	4	10	39	44	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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: MA 0237 Unit: A40 Status: 2

SHEET : 1923D3
LOCATION : Santantadibe molapo area.
AUTHOR(S): G.Baert K.Verbaek B.Kopelo R.Kelebemang
CLASSIFICATION FAO: Haplic Arenosol(1988) Eutric Arenosol (1974) sodic phase
ST : Ustic Quartzipsamment
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: no apparent management system
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: alluvium
MOIST. COND: dry 0 - 80 cm
SURF.STONES: none
EROSION :

GRID : - -
COORD: 19-49-18-S 23-31-21-E
DATE : 29/05/85

LAND ELEMENT : not applicable
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: higher part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS:

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

A 0 - 10 cm 10YR 2.5/1 (moist) and 10YR 4/1 (dry), loamy sand, weak medium subangular blocky structure, soft, non calcareous, common roots, gradual smooth boundary.

Ac 10 - 30 cm 10YR 3/1 (moist) and 10YR 4.5/1 (dry), fine sand, weakly coherent massive structure, soft to slightly hard, non calcareous, few roots, gradual smooth boundary.

C 30 - 80 cm 10YR 4/1 (moist) and 10YR 6/1 (dry), fine sand, weakly coherent massive structure, slightly hard, non calcareous, very few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0237

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil -------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	10	6.5	5.6	0.0	2	1.1	11.0	8.2	1.0	0.4	0.4	91	0	2	23	47	7	7	8	7	96	H	A
B	10	30	6.7	5.8	0.0	2	0.5	5.9	4.5	0.5	0.3	0.4	97	0	2	28	50	7	4	7	3	118	H	A
C	50	70	6.8	6.1	0.0	1	0.0	3.6	2.2	0.3	0.2	0.3	83	0	2	28	51	8	4	4	3	120	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0117 Unit: L11 Status: 2

SHEET : 1923D3
LOCATION : Khwaa molapo area.
AUTHOR(S): G.Baert B.Kopelo
CLASSIFICATION FAO: Calcic Arenosol(1988) Calcic Arenosol (1974) sodic phase
ST : Typic Ustochrept
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt, bleached sand on surface
LAND USE: traditional grazing
SPECIES : Trees - Hyphaene ventricosa (dom.)
: Shrubs - Hyphaene ventricosa (dom.)
: Grasses/forbs-
PARENT MATERIAL: lacustrine reworked aeolian
MOIST. COND: dry 0 - 120 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-56-S 23-38-22-E
DATE : 20/02/85

LAND ELEMENT : island
MICRO TOPOGRAPHY:

VEGETATION: open savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: intermediate part
SLOPE : 0 - 2 % convex

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : well drained

HUMAN INF: nil

REMARKS: Transition between island and molapo. Repeat analyses to check for saline phase (paste) and soluble salts to calculate SAR.

SAMPLES: A: 0 - 20 B: 40 - 60 C: 90 - 110

53

A 0 - 23 cm 10YR 3/1 (moist) and 10YR 3.5/1 (dry), fine sand, very weak medium subangular blocky structure, soft to slightly hard, common very fine and fine pores, strongly calcareous, common fine and medium roots, clear wavy boundary.

C 23 - 70 cm 10YR 4.5/1 (moist) and 10YR 5.5/1 (dry), fine sand to loamy fine sand, massive structure, slightly hard to hard, common very fine and fine pores, strongly calcareous, very few fine roots, clear wavy boundary.

Ck 70 - 120 cm 10YR 4.5/ 1 (moist) and 10YR 5.5/ 1 (dry), fine sand to loamy fine sand, massive structure, slightly hard to hard, common very fine and fine pores, few fine spherical soft calcareous white nodules, strongly calcareous, very few fine roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0117

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil -------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	20	8.8	7.8	0.2	6	0.1	4.0	11.3	0.6	0.3	0.2	100	0	1	23	60	6	2	2	6	60	H	A
B	40	60	10.0	8.6	0.5	1	0.0	4.5	33.6	1.6	0.7	1.8	100	0	2	23	55	6	6	1	8	54	H	A
C	90	110	10.2	8.6	1.3	1	0.0	3.8	26.4	0.6	0.6	1.9	100	0	1	23	59	6	1	2	7	53	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0106 Unit: L24a Status: 2

SHEET : 1923D3
LOCATION : Xhwaa molapo.
AUTHOR(S): K.Verbeek G.Baert
CLASSIFICATION FAO: Luvic Calcisol(1988) Calcic Luvisol (1974) sodic phase
ST : Typic Haplustalf
LANDFORM : alluvial plain
TOPOGRAPHY: almost flat
SURF. CHAR: no cracks, nil evidence of salt,
LAND USE: traditional grazing
SPECIES : Trees -
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: lacustrine
MOIST. COND: dry 0 - 10 , moist 10 - 110 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-45-38-S 23-37-47-E
DATE : 14/02/85

LAND ELEMENT : island
MICRO TOPOGRAPHY: even

VEGETATION: grassland

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: lower part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : imperfectly drained

HUMAN INF: nil

REMARKS: Depression on island. Repeat EC, check for saline phase.

SAMPLES: A: 0 - 10 B: 20 - 40 C: 80 - 100

A	0 - 15 cm	10YR 5.5/1.5 (moist) and 10YR 6.5/1 (dry), fine sand to loamy fine sand, weak medium subangular blocky structure, slightly hard, strongly calcareous, few roots, abrupt smooth boundary.
Btk1	15 - 50 cm	10YR 4/2 (moist), common coarse distinct diffuse black mottles, sandy loam, weak coarse and very coarse subangular blocky structure, firm, broken thin clay cutans on pedfaces, strongly calcareous, few roots, clear smooth boundary.
Btk2	50 - 110 cm	10YR 3/2 (moist), many coarse distinct diffuse black mottles, sandy clay loam, weak coarse subangular blocky structure, very firm, broken thin clay cutans on pedfaces, strongly calcareous, very few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0106

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	10	10.1	8.9	0.7	3	0.2	7.4	12.5	1.0	2.0	6.2	100	0	1	24	46	9	4	7	10	66	H	A
B	20	40	10.4	9.8	1.2	6	0.1	10.9	5.5	0.7	1.5	6.9	100	0	1	10	53	8	3	10	16	64	H	A
C	80	100	10.6	9.2	3.5	28	0.1	14.0	3.1	0.4	1.6	14.0	100	0	1	10	52	7	2	4	24	57	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0013 Unit: S13 Status: 2

SHEET : 1923D3
LOCATION : Xhwaa camp island.
AUTHOR(S): G.J.Rhebergen A.Remmelzwaal
CLASSIFICATION FAO: Areni-Petric Calcisol(1988) Calcic Arenosol (1974)
ST : Typic Ustochrept
LANDFORM : alluvial plain
TOPOGRAPHY: gently undulating
SURF. CHAR: no sealing, no cracks, nil evidence of salt, bleached sand on surface
LAND USE: traditional grazing
SPECIES : Trees - Hyphaene ventricosa (dom.)
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: aeolian pale sand
MOIST. COND: dry 0 - 150 cm
SURF.STONES: none
EROSION : nil

GRID : - -
COORD: 19-46-18-S 23-37-23-E
DATE : 04/05/84

LAND ELEMENT : island
MICRO TOPOGRAPHY:

VEGETATION: open tree savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C2
ELEVATION :

SMR: ustic

POSITION: higher part
SLOPE : 0 - 2%

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : moderately well drained

HUMAN INF: nil

REMARKS: Edge of island. Transition to S13a-Petrocalcic at depth Cmk moderately commented.

SAMPLES: A: 0 - 0 B: 0 - 0 C: 0 - 0

A 0 - 30 cm 10YR 3/2 (moist) and 10YR 4/2 (dry), fine sand to loamy fine sand, weak fine to coarse subangular blocky structure, soft, common very fine and fine pores, strongly calcareous, many and many roots, clear smooth boundary.

Bk 30 - 60 cm 10YR 3.5/3 (moist) and 10YR 6/3 (dry), loamy fine sand to fine sandy loam, very weak fine to coarse subangular blocky structure, soft, common very fine and fine pores, few spherical hard calcareous white nodules, strongly calcareous, many roots, gradual smooth boundary.

Ck 60 - 140 cm 10YR 5/4 (moist) and 10YR 8/3 (dry), loamy fine sand to fine sandy loam, weakly coherent massive structure, soft, few very fine and fine pores, few hard calcareous white nodules, extremely calcareous, common roots, clear wavy boundary.

Cmk 140 - 150 cm 10YR 5/4 (moist) and 10YR 7/2 (dry), massive structure, hard, cemented, extremely calcareous, few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0013

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	ù----- meq/100gr soil ------ù					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	0	8.2	7.5	0.1	1	0.5	7.5	23.5	1.5	1.1	0.1	100	0	1	9	64	9	2	5	10	56	H	A
B	0	0	8.3	7.7	0.1	4	0.1	4.3	26.3	2.0	1.1	0.1	100	0	1	10	62	8	2	5	12	32	H	A
C	0	0	9.2	8.1	0.2	1	0.0	5.1	31.5	1.9	3.2	0.7	100	0	1	14	61	8	3	3	11	48	H	A

Soil Survey of Botswana FAO/BOT/85/011 Print date: 23/03/89

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: MA 0044 Unit: S17 Status: 2

SHEET : 1923D3
LOCATION : Matsaoudi research plot.
AUTHOR(S): G.J.Rhebergen G.Baert
CLASSIFICATION FAO: Eutri-Haplic Arenosol(1988) Eutric Arenosol (1974)
ST : Ustic Quartzipsamment
LANDFORM : sand plain
TOPOGRAPHY: almost flat
SURF. CHAR: no sealing, no cracks, nil evidence of salt,
LAND USE: improved trad. dryland farming
SPECIES : Trees - Colophospermum mopane (dom.) Acacia sp.
: Shrubs -
: Grasses/forbs-
PARENT MATERIAL: aeolian sand
MOIST. COND: dry 0 - 110 cm
SURF.STONES: none
EROSION :

REMARKS:

SAMPLES: A: 0 - 0 B: 0 - 0

GRID : - -
COORD: - - 0-S - - 0-E
DATE : 20/09/84

LAND ELEMENT : not applicable
MICRO TOPOGRAPHY: even

VEGETATION: open tree savanna

ROCK TYPE:

ROCK OUTCROP: none

AGRO CLIM.ZONE: 2C3
ELEVATION :

SMR: ustic

POSITION: higher part
SLOPE : 0 - 1 %

GRASSCOVER:

GEOL.UNIT:
DRAINAGE : somewhat excessively drained

HUMAN INF: clearing

A 0 - 15 cm 10YR 3/2 (moist) and 10YR 4/2 (dry), fine sand, very weak medium subangular blocky structure, loose, non calcareous, common roots, clear smooth boundary.

C 15 - 110 cm 10YR 4/ 2 (moist) and 10YR 5/ 2 (dry), fine sand, weakly coherent massive structure, slightly hard, non calcareous, few roots,

S T A N D A R D S O I L A N A L Y S I S R E S U L T S

PROFILE: MA 0044

SAMPLE	DEPTH		pH		EC	P	C	CEC	Ca	Mg	K	Na	PBS	Particle size (weight %)								CECclay	METH	PRETR
			H2O	CaCL2	mS/cm	ppm	weight %	meq/100gr soil					%	vcS	cS	mS	fS	vfS	cSi	fSi	Clay	meq/100gr		
A	0	0	7.1	6.6	0.1	4	0.2	4.6	3.2	0.2	0.3	0.2	85	0	1	19	64	10	1	0	6	68	H	A
B	0	0	8.0	7.5	0.2	1	0.1	3.8	3.1	0.8	0.4	0.1	100	0	1	18	62	10	1	0	7	48	H	A

Soil Survey of Botswana FAO/BOT/85/011

Print date: 23/03/89

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

APPENDIX 2

LAND SUITABILITY CLASSIFICATION SHEETS FOR SPECIFIC SOIL MAPPING UNITS

LAND SUITABILITY CLASSIFICATION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003

location: Boro-Shorobe area sheet: 1923 C4,D1,D3 date: June 1985

agro-climatic zone: Maun (II) mapping unit: A24, A31a

author: G.J.Rhebergen site characteristics:

remarks: saucer shaped depressions

flood duration: 3-6 months

Regularly flooded alluvial plain; only mechanized farming is considered

			LAND USE TYPE: improved trad. molapo farm.				LAND USE TYPE: commercial molapo farming			
			CROP				CROP			
LAND QUALITY	CODE	RATING	maize	sorghum			maize	sorghum		
accessibility	a	1	S1	S1			S1	S1		
correct temp. regime	c	1	S1	S1			S1	S1		
soil drainability	d	N.A.	-	-			-	-		
resistance to erosion	e	1	S1	S1			S1	S1		
absence of damaging floods	f	1	S1	S1			S1	S1		
conditions for germin.	g	1	S1	S1			S1	S1		
moisture availability	m	1	S2	S1			S2-S3	S1-S2		
nutrient availability	n	1-2	S1-S2	S1			S2	S1-S2		
oxygen availability	o	2	S2-S3	S1			S2-S3	S1		
absence of pests and diseases	p	2-3	no suitability class is given							
availability of water of good quality	q	N.A.	-	-			-	-		
foothold for roots	r	1	S1	S1			S1	S1		
absence of toxic substances	t	1	S1	S1			S1	S1		
workability	w	2-3	S1	S1			S1	S1		
adequacy of topography	x_1	no data								
	x_{11}	N.A.	-	-			-	-		
	x_{111}	N.A.	-	-			-	-		
adequacy of flooding	y	no data								
land drainability	z	N.A.	-	-			-	-		
.....										
.....										
CURRENT LAND SUITABILITY			S2mno-S3o	S1			S2mno-S3mo	S1-S2mn		

RECOMMENDED IMPROVEMENTS:

- soil physical condition (structure, permeability) to improve infiltration of floodwater.
- fertilizer application
- improve surface drainage to avoid ponding

POTENTIAL LAND SUITABILITY			S1-S2o	S1			S1-S2mo	S1		

LAND SUITABILITY CLASSIFICATION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003

location: Boro-Shorobe area

sheet: 1923 C4,D1,D3 date: June 1985

agro-climatic zone: Maun (II)

mapping unit: A24b, A31b

author: G.J.Rhebergen

site characteristics: relatively low areas with higher stream velocities

remarks:
often occuring in narrow alluvial plains between islands; flood duration 3-6 months

			LAND USE TYPE: improved trad. molapo farm.				LAND USE TYPE: commercial molapo farming			
			CROP				CROP			
LAND QUALITY	CODE	RATING	maize	sorghum			maize	sorghum		
accessibility	a	1	S1	S1			S1	S1		
correct temp. regime	c	1	S1	S1			S1	S1		
soil drainability	d	N.A.	-	-			-	-		
resistance to erosion	e	1	S1	S1			S1	S1		
absence of damaging floods	f	1	S1	S1			S1	S1		
conditions for germin.	g	1	S1	S1			S1	S1		
moisture availability	m	1-2	S2-S3	S1-S2			S3	S2		
nutrient availability	n	2	S2	S1			S2	S2		
oxygen availability	o	2	S2	S1			S2	S1		
absence of pests and diseases	p	2-3	no suitability class is given							
availability of water of good quality	q	N.A.	-	-			-	-		
foothold for roots	r	1	S1	S1			S1	S1		
absence of toxic substances	t	1	S1	S1			S1	S1		
workability	w	1	S1	S1			S1	S1		
adequacy of topography	x_1	no data								
	x_{11}	N.A.	-	-			-	-		
	x_{111}	N.A.	-	-			-	-		
adequacy of flooding	y	no data								
land drainability	z	N.A.	-	-			-	-		
.....										
.....										
CURRENT LAND SUITABILITY			S2mno-S3m	S1-S2m			S3m	S2mn		

RECOMMENDED IMPROVEMENTS:
- low available water holding capacity causing moisture availability limitation can not be corrected; therefore potential land suitability equal to current land suitability

POTENTIAL LAND SUITABILITY			S2mno-S3m	S1-S2m			S3m	S2mn		

LAND SUITABILITY CLASSIFICATION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003

location: Boro-Shorobe area sheet: 1923 C4,D1,D3 date: June1985

agro-climatic zone: Maun (II) mapping unit: A24b

author: G,J,Rhebergen site characteristics: stream channels

remarks:
flood duration varying: 1-6 months

			LAND USE TYPE: improved trad. molapo farm.				LAND USE TYPE: commercial molapo farming			
			CROP				CROP			
LAND QUALITY	CODE	RATING	maize	sorghum			maize	sorhgum		
accessibility	a	1	S1	S1			S1	S1		
correct temp. regime	c	1	S1	S1			S1	S1		
soil drainability	d	N.A.	-	-			-	-		
resistance to erosion	e	1	S1	S1			S1	S1		
absence of damaging floods	f	2	S2	S2			S2	S2		
conditions for germin.	g	1	S1	S1			S1	S1		
moisture availability	m	1	S2-S3	S1-S2			S3	S2		
nutrient availability	n	2	S2	S1			S2	S2		
oxygen availability	o	3	S4	S2-S3			S4	S2-S3		
absence of pests and diseases	p	2-3	no suitability class is given							
availability of water of good quality	q	N.A.	-	-			-	-		
foothold for roots	r	1	S1	S1			S1	S1		
absence of toxic substances	t	1	S1	S1			S1	S1		
workability	w	1	S1	S1			S1	S1		
adequacy of topography	x_1	no data								
	x_{11}	N.A.	-	-			-	-		
	x_{111}	N.A.	-	-			-	-		
adequacy of flooding	y	no data								
land drainability	z	N.A.	-	-			-	-		
.....										
.....										
CURRENT LAND SUITABILITY			S4o	S3o			S4o	S3o		

RECOMMENDED IMPROVEMENTS:

- oxygen availability can hardly be improved as channels are lowest spots in the area; potential suitability is equal to the current suitability.

POTENTIAL LAND SUITABILITY	S4o	S3o			S4o	S3o		

LAND SUITABILITY CLASSIFICATION SHEET SOIL SURVEY OF BOTSWANA FAO BOT/80/003

location: Boro-Shorobe area

sheet: 1923 C4,D1,D3 date: June 1985

agro-climatic zone: Maun (II)

mapping unit: A7,A7b,A9,A31a (partly sodic)

author: G.J.Rhebergen

site characteristics: saucer shaped depressions and plain,slightly sloping areas

remarks:
flood duration: 1-3 months
regularly flooded alluvial plain; only mechanized farming is considered

			LAND USE TYPE: improved trad. molapo farm.				LAND USE TYPE: commercial molapo farming			
			CROP				CROP			
LAND QUALITY	CODE	RATING	maize	sorghum			maize	sorghum		
accessibility	a	1	S1	S1			S1	S1		
correct temp. regime	c	1	S1	S1			S1	S1		
soil drainability	d	N.A.	-	-			-	-		
resistance to erosion	e	1	S1	S1			S1	S1		
absence of damaging floods	f	1	S1	S1			S1	S1		
conditions for germin.	g	1	S1	S1			S1	S1		
moisture availability	m	1-2	S2-S3	S1-S2			S3	S2		
nutrient availability	n	2	S2	S1			S2	S2		
oxygen availability	o	2	S2-S3	S1			S2-S3	S1		
absence of pests and diseases	p	2-3	no suitability class is given							
availability of water of good quality	q	N.A.	-	-			-	-		
foothold for roots	r	1	S1	S1			S1	S1		
absence of toxic substances	t	1-2	S2-S3	S2			S3	S2		
workability	w	2-3	S1	S1			S1	S1		
adequacy of topography	x_1	no data								
	x_{11}	N.A.	-	-			-	-		
	x_{111}	N.A.	-	-			-	-		
adequacy of flooding	y	no data								
land drainability	z	N.A.	-	-			-	-		
.....										
.....										
CURRENT LAND SUITABILITY			S3mot	S2mt			S3mot	S2mnt		

RECOMMENDED IMPROVEMENTS:
- increase frequency and duration of flood to increase total available water
- increased flood duration might improve limitation (t)
- fertilizer application
- improve surface drainage to avoid ponding

POTENTIAL LAND SUITABILITY			S2mot	S1			S2mot	S1		

Appendix 3

Area calculation of combinations of associations

Associations	Proposed colour	Area (ha)
A24b	dark blue	470
A24, A24-24B A24-31a, A24-31a-24b	light blue	3300
A31a, A31a-24 A31a-7, A31-7a-40 A31a-40-31b A31a-24-31b A31b, A31b-24 A31b-7, A31b-24 A31b-7, A31b-7a A31b-31a-7 A40-24b, A40-31a	light green	8150
A7, A7a A7-31a, A7-7b A7a-7b, A7a-31b A7-31a-7a A7a-7b-9a A7b-7, A7b-7-9 A40-, A40-7a	dark green	4200
A7a-9-40, A7b A7b-A9, A7b-7-9 A7b-9-9a, A9-7b A9-9a-7b, A9a-7b A40, A40-7b A40-9a, A40-9a-7b	yellow	2750
islands	brown	20750
	TOTAL	39620 na

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