SOILS of the SHOROBE AREA

By
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Food and Agriculture Organisation of the United Nations with the Government of the Republic of Botswana
This technical note is one of a series of working papers, technical data or interim reports prepared during the course of the UNDP/ST/FAO Botswana Project. The conclusions and recommendations given in this note 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 the Project.

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SOILS OF THE SHOROBE AREA

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1.1 Abstract
The soil investigations were carried out to collect background information for appraisal study for improved agricultural production in the area.

The area is at present cultivated under the "molapo" system of farming and is in general well suited for further development.

The survey included the medium and fine textured soils encountered in the river valleys.

Although the absolute fertility level of the soils is not high compared with other productive soils in Botswana, these alluvial soils compare favourably with regard to organic matter and their soil climate.

With additional fertilisation and improved farming practices it is anticipated that high yields of maize, sorghum and of rice may be obtained. The latter particularly on the finer textured soils. In addition vegetables and cotton are expected to do well.

The total area considered suitable for molapo cultivation in the Shorobe areas comprises approximately 15000 acres.

1.2 Introduction
Fieldwork in the area was performed during the second half of January 1971 by the FAO Pedologist and his part time counterpart.

Although the map presentation is on a 1:12,500 scale the survey is on reconnaissance level. The soils encountered are closely related to their physiographic position.

The molapo soils are all of alluvial origin and have a high potential for improved "irrigated" farming.
1.3 Acknowledgements
The cooperation of the agricultural officer in Maun and of the agricultural demonstrator during execution of the survey in the Shorobe area are warmly appreciated.

1.4 Summary of conclusions and recommendations
The encountered molapo soils are classified as young alluvial soils; horizonation due to pedological processes is limited.

Due to their origin textural variation of the soils is considerable in horizontal and vertical direction. On this level of survey a number of soil associations are recognised. Their main criteria for soil mapping is based on their texture.

The textural nomination is derived from the USDA-7th appr. classification. It comprises of the following textural families for the molapo soils: sandy, coarse and fine loamy and clayey.

Although each of these families are suitable for further improvements regarding their agricultural use, the following comments are made:

It is recommended that:
1. The clayey soil families be used for rice* cultivation with maize as secondary crop, and cotton as a non-food crop.
2. On the fine loamy soils maize, sorghum and vegetables be cultivated.
3. The coarse textured soils be used for sorghum and vegetables.

*(Rice may be grown on coarser textured soils as long as enough water can be provided.)
4. N.P.S. fertilizer be applied together with an
application of some trace elements such as Fe and
eventually Zn and Cu.
5. Detailed soil surveys be undertaken in those areas
recommended for intensive development.
6. The quality of the bunds be improved and simple
sluices be introduced for a better floodwater
control.
7. The tsetse fly be eradicated in the area.
8. General access to the area be improved.

2. The Environment

2.1 Location
The Shorobe village is situated 34 km. (21 miles) north-
east of Maun on the road to the Moremi game reserve;
appr. latitude is 19°50'S and longitude 23°40'E. The
survey area is roughly triangular in shape and is
situated to the west of the main village; its northern-
northwestern boundary is the tsetse fly control fence
and the non flooded upland; its southwestern boundary
being the Santantadibe River and its (south) eastern
boundary is formed by the left bank of the Thamalakane
River.

The total surveyed area comprises approximately
13,694 acres + 20,432 acres = 34,126 acres (13,650 ha).

2.2 The Climate
A sub-tropical transitional to semi-arid climate is
encountered in this part of Botswana with distinct
winter and summer seasons.

Most of the rain falls between mid-October and mid-April.
Convective rains are dominant thus increasing the
irregularity in precipitation for a given area. The
amount of rain days (0,2 mm) and wet days (1,00 mm) are
52,9 and 43,5 per annum respectively.

The dominant wind direction is easterly to northeasterly.
Some important climatological data are summarised in Table 1. They are derived from the meteorological station at Maun and cover 43 years (1923 - 1965).

The highest temperatures occur during October and November and the lowest temperatures occur in June-July. Groundfrost may be encountered on occasion in low-lying areas during the winter season.

The relative humidity is highest during the second half of the wet season (January-March; 45% at 14.00 hrs local time). For the remaining part of the year it is low (30%) and particularly so from August to October (21% at 14.00 hrs local time Maun).

Evaporation data for open water, a short green crop and wet bare soil have been calculated for a ten year period (1958 - 1968) from meteorological data recorded at Maun. These estimates of potential evaporation were calculated by the Penman or combination formula incorporating recent modifications on a ten-daily basis and full details are given in the Project Technical Report No. 1 "The Agro-climatology of Botswana" by J.G. Pike. In general, the compiled values of potential evapotranspiration from a short green crop refer to a crop not exceeding one meter in height. For crops up to two meters in height the values shown should be multiplied by a varying factor from 1.10 to 1.30 dependent upon and increasing with the stage of growth.

Only in one month of the year, January, does rainfall exceed evapotranspiration but with the good water holding capacity of the molapo soils and the advent of annual flooding during the dry season, the rainfall/evaporation ratio is not a crucial factor in crop production.

The water source is depending on the climatic conditions in Angola and the subsequent flow of the Okavango River into the swamps. In normal years the floodwater reaches...
Table 1

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<th>Item</th>
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<td>172</td>
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<td>Short green crop</td>
<td>151</td>
<td>131</td>
<td>129</td>
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<td>75</td>
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<td>Wet bare soil</td>
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<td>121</td>
<td>119</td>
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<td>Annual rainfall</td>
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<td>25</td>
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<td>24.8</td>
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<td>Mean of daily max. T</td>
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<td>9.6</td>
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<td>8.6</td>
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<td>The Northern State Lands, Botswana</td>
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<td>by A. Blair Raines and A.D. McKay.</td>
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The Agroclimatology of Botswana
(UNDP (SP) FAO Botswana Project)
the survey area in May. This might either be through direct inflow of the Santantadibe River or is backflow from the Boro River or both. The Gomoti River seldom contributes to the inflow into the area. The peak water level is reached in August-September after which it starts to recede.

The water is retained on the land by simple earth dykes without sluices. Cultivation of the land begins as soon as the water has disappeared from the soil surface and farming devices can be applied.

2.3 Physiography
The geomorphological processes that lead to the genesis of the present landscape are at present poorly defined and the explanation depends largely on evidence found in other parts of northwestern Botswana. However it seems acceptable that the area is a part of the proto-Okavango run prior to the formation of the entire delta after reviewing the new cartographic evidence and hydrological information.

The original almost west-east orientation of the drainage lines which may possibly be the remnants of an alab dune formation and consequently of the areas between them (interflumes) changes its direction towards northeast-southwest going eastwards. This change is evident 2-3 km westwards of Shorobe and is also clearly noticeable in the course of the Gomoti River.

The old delta and swamp area in which the Santantadibe River is the main water course has known a number of dry and wetter periods in its history. The dry periods are reflected in old barchan and parabolic dune formations, consisting almost entirely of white fine sand. In the survey area these dunes are only encountered in the extreme west near Xuxao. Their original shape is distorted but they indicate either a dominating westerly or easterly wind. The second evidence of a dry period(s) is formed
by the occurrence of calcrete. Although it is unlikely that this accumulation was formed by pedological processes but rather in a lacustrine environment. Its present extremely hard indurated occurrence suggest high evaporation rates. Calcrete underlies the majority of the "islands" in the survey area. Their general direction follows the trend as described above.

The "islands" are elongated in form and the typical ones have a depressional area in the centre. (See Fig. 1) This may have been caused by deflation. Some of the forms however do suggest barchan or parabolic dune formations. This suggestion is supported by the occurrence of fine sand overlying the calcrete.

It is thought that sand dunes may be superimposed on top of the old calcrete formations, which could have acted as initiators for the dune formation.

The following sequence of events is visualised in the area:
1. formation of unconsolidated materials of Post-Karoo age, possible in a lake like environment;
2. subsequent hardening of the material during a dry climate phase;
3. erosion of the land surface by streams (after tectonic movements caused enough relief energy) mainly in easterly and northeasterly direction;
4. deposition of fine, Kalahari type sands during a dry phase since Tertiary and younger;
5. subsequent flooding and erosion of the existing landscape in which tectonic movements caused a change in surface drainage towards the southwest in the eastern part of the area;
6. sedimentation of younger mainly fine textured sediments in the water courses in recent and present times. Due to the water regime coarser textured deposits are likely to be found in narrow drainage lines, while the finer textured sediments are encountered in broad river channels and backwaters and at the bottom of the deeper channels.
fig.1 - CROSS SECTION ISLAND

auger depth in cm
scale 1:12,500

22 21 20
19 18 17

22 21 20
19 18 17

22 21 20
19 18 17

22 21 20
19 18 17

22 21 20
19 18 17

22 21 20
19 18 17

22 21 20
19 18 17

auger depth in cm
scale 1:6250

black to very dark grey(ish brown) fine sandy loam
brown to pale brown fine sandy loam
greyish brown sandy clay
dark grey loamy fine sand

all island soils strongly calcareous

w. siderius
The island represented occurs on the road between Shorobe and Gabamochao. Soils and vegetation are given below:

<table>
<thead>
<tr>
<th>Auger</th>
<th>Soil Family</th>
<th>Vegetation</th>
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</thead>
<tbody>
<tr>
<td>17</td>
<td>Sandy</td>
<td>open grassland of <em>Eragrostis superba</em>, <em>Cynodon dactylon</em> and <em>Phragmites mauritanus</em>.</td>
</tr>
<tr>
<td>18</td>
<td>Coarse loamy</td>
<td>mixed woodland of <em>Terminalia prunoides</em>, <em>Combretum imberbe</em>, <em>C. herroences</em> and <em>Grewia bicolor</em>.</td>
</tr>
<tr>
<td>19</td>
<td>Clayey</td>
<td>very open short woodland of <em>Acacia tortilis</em> and <em>A. giraffae</em>; grass cover of <em>Cynodon dactylon</em>.</td>
</tr>
<tr>
<td>20</td>
<td>Coarse loamy</td>
<td>mixed woodland of <em>Lonchocarpus capassa</em>, <em>Combretum imberbe</em> and a few <em>Colophospermum mopane</em>; common <em>Panicum maximum</em> grass.</td>
</tr>
<tr>
<td>21</td>
<td>Coarse loamy</td>
<td>dense mixed woodland of <em>Acacia giraffae</em> and <em>Combretum imberbe</em>.</td>
</tr>
<tr>
<td>22</td>
<td>Sandy</td>
<td>open grassland of <em>Cynodon dactylon</em> and <em>Phragmites mauritanus</em>.</td>
</tr>
</tbody>
</table>
At present the area is characterised by the calcrete formations, which remnants are of equal height above the bottom of the river floodplains (up to 10 m).

Permanent water (swamp) is only encountered in the southwestern part of the region; the overall drainage is south to southwest.

2.4 Natural vegetation
For detailed vegetation descriptions reference is made to the tables attached to the figures 1, 3 and 4 in the text. On the provisional vegetation map of Botswana the whole area is indicated as "swamp grassland - 12a". This is only true in the far west of the survey area where permanent water is encountered.

In the flooded areas a reed and grass vegetation is indeed encountered of which the dominant species are Leersia lexanara, Phragmites mauritanus and Cynodon dactylon. In less wet molapos the common weeds, ferns and grasses are Cynodon dactylon, Digitaria eriantha, Ampelopteris prolifera; Digitaria milanjiana.

In flooded but not cultivated areas one may find Digitaria milanjiana, Panicum maximum, Cynodon dactylon, some Phragmites mauritanus and palm trees (hyphaene). On sloping ground towards the island normally a very open woodland to grassland is encountered. The main species are Cynodon dactylon, Digitaria milanjiana, Leersia lexanara, Eragrostis superbe; palm trees are common.

On the higher ground, which is not subject to flooding, a (dense) mixed woodland occurs especially on the edges of the islands (see Fig. 1).
Dominant trees are: Lonchocarpus nelsia; Pappea capensis; Croton megalobotrys; Lonchocarpus capassa; Combretum herr; Acacia giraffae; Garcinia livingstonei and Combretum imberbe.

Colophospermum mopane and Terminalia prunoides are occasionally encountered. Common grasses are Panicum maximum, Cynodon dactylon and Eragrostis superbe. West of the survey area on the higher ground the dominant vegetation is a Colophospermum mopane woodland.

2.5 Present land use and human activity
Cultivation in the region is almost exclusively practised in the molapos where the common crops grown are maize, sorghum, water melons and pumpkins. Only at a very few places was some dryland cultivation encountered on the islands. Crops included sorghum, beans and peas.

The general level of agricultural management is very low, which is demonstrated in the poor seed distribution resulting in a poor plant population, the absence of intensive weeding, the nonapplication of fertilizers where necessary, etc.

Often lands are not ploughed and planted because of the lack of draft animals and/or tractors. This partly results from the tsetse fly infestation in most of the area.

Other sources of income and agricultural activity concern the breeding of donkeys, the holding of some cattle and goats. The condition of the animals is in general poor. A number of people are occasionally employed by Safari Companies.

2.6 Other (Communication and water supply)
The Shorobe village can be easily reached by a fairly good road, which only in the wet seasons may cause some delay in places. In the dry season a few sandy spots
may cause trouble for saloon cars. Transport in trucks (1 ton upwards) is recommended. Access into the survey area is possible over a limited number of car tracks, however these may become impassible during the floods and occasionally during rain.

There are numerous cattle tracks in the region that are widely used by the inhabitants. Local transport by sledge and donkey cart is common.

During high water, boats can be used in most of the rivers and molapos for local transport.

Water in the region is obtained from open pools in the molapo or shallow wells. The water supply in the Shorobe village is maintained by a deep well.

3. Method

3.1 Survey methods

The area is covered by aerial photography of two kinds. In September 1967 the Shorobe region was flown on a 1:500 scale and in 1969 the area was covered by 1:40,000 aerial photography.

All photographs are printed on semi-matt, double weight paper.

For this survey the 1967 photography was used as it shows greater detail.

Prior to the fieldwork a photo-interpretation was carried out. The following broad units were recognised: non-flooded dune formations; non-flooded islands; depressional areas in the islands; distinct sloping ground to the molapos; permanent water (swamp); areas likely to be flooded but not cultivated; flooded molapos (includes signs of past and present cultivation) and non-flooded molapo.
14.
The ground survey was carried out on reconnaissance level during which each of the above mentioned geographical units were checked on soil conditions. In general a good correlation between the photo interpretation and the soils encountered exists.

Afterwards two maps were compiled (Shorobe North and Shorobe South) from the 1967 photography as an uncontrolled mosaic. The odd numbered photographs were used only; they include for Map 1 from North to South and East to West the following photographs:

Run BT 9 photo's 185 - 193
  " BT 8 " 087 - 079
  " BT 6 " 081 - 075
  " BT 2 " 201 - 195
  " BT 8 " 101 - 107

and for map 2 (Shorobe South):

Run BT 9 photo's 185 - 177
  " BT 8 " 079 - 073
  " BT 6 " 073 - 069
  " BT 2 " 191 - 193
  " BT 8 " 109 - 111

The map in this report is a reduction to 1:25.000 of the two maps mentioned above. The number of augerings is 54, two soil pits were dug each one 1 - 2m wide and 2 m deep unless rock was encountered. The total number of samples taken from the pits is 11 and from the augerings 35.

3.2 Laboratory methods
All samples were analysed at the soil laboratory at Content Farm - Gaborone. Analyses results of trace elements were made available by G. Nilsson, former FAO plant pathologist in Botswana. The properties of the saturated paste are determined only if the electrical conductivity of the 1:5 suspension is more than 100 Umhos/an.

Particle sizes according to the U.S.D.A. limits.
4. Soils
4.1 General properties of the soils
4.1.1 Physical and chemical properties

The pedological development of the soils which is commonly demonstrated by the different soil horizons is poor. Physical structure is sometimes encountered in the finer textured soils, however the remaining soils have no visible structure and are classified as apedal.

For the mapping of the soils and their combined properties the textural family groupings based on the U.S.D.A. August 1964 - 7th approximation has been applied (See Fig. 2).

In addition their physiographic position and the soil colour is used.

The latter has commonly a 10 YR hue, occasionally a 7.5 YR hue is encountered. Chroma's are low, less than 1.5, for most of the topsoils and the fine textured soils. In this case the value is not more than 4 (range between 2-4).

In the coarser textured soils values may be as high as 5 and chroma 5. All references to soil colour in the text and drawings are related to moist colours.

The consistency for the sandy family is loose dry and moist and non-sticky, non-plastic wet. For the coarse and fine loamy textural families the consistency varies between very friable to firm moist; soft to slightly hard dry and are usually slightly sticky and slightly plastic when wet. For the clayey family the consistency is very hard dry, firm to friable moist and slightly sticky and very plastic when wet.

The permeability of the soils and related drainage are closely dependent on the textural variations in the soil, structural development and type of clay.
fig-2; Textural classification for soil family groupings (---)

source: USDA, 7th Appr. 1964.

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Text to Fig. 2.

Texture classes for family groupings:

1. Sandy family: sands and loamy sands coarser than loamy very fine sand;

2. Coarse loamy family: with less than 18 per cent clay: csl, sl, fsl and 1;
   with less than 18 per cent coarser than very fine sand (including coarse fragments): lvfs and sil;

3. Fine loamy family: with more than 18 per cent clay:
   scl, sl, fsl and 1;
   with more than 18 per cent clay but less than 35 per cent clay;
   and more than 15 per cent coarser than very fine sand (including coarse fragments):
   vfasl, sl, l, scl, cl, si, cl;

4. Coarse silty family: with less than 18 per cent clay but less than 15 per cent coarser than very fine sand (including coarse fragments): lvfs, vfasl, sil, si;

5. Fine silty family: with more than 18 per cent clay but less than 35 per cent clay;
   and less than 15 per cent coarser than very fine sand (incl. coarse fragments): vfasl, sil, sicl, l, cl;

6a. Clayey family (fine): with more than 35 per cent clay but less than 60 per cent clay:
    cl, sicl, c, sic; sc;

6b. Clayey family (very fine): with more than 60 per cent clay

Clarification of the symbols: 

v = very
f = fine
s = sand(y)
1 = loam(y)
sicl = silt(y)
c = clay
As molapos may be flooded for several months yearly the water availability for plant growth depends largely on the above mentioned two factors. No drainage problem is expected in the sandy and coarse loamy family; although saturated with water quicker than the finer textured soils the drainage of free water and the evaporation provide a fast removal of water. This seems largely also the case with soils of the fine loamy family.

Most stagnant water is encountered in areas where fine textured soils occur (clayey family). The soil colour may be dark grey throughout because of reduced soil conditions.

In better drained clay soils, caused usually by more defined structure, strong brown mottles are observed in the subsoil. This colour due to oxidation of iron-compounds is usually encountered in a greyish matrix (7.5 YR 5/6 versus 10 YR 5/1). Although saturated soil conditions are unfavourable for many plants they are well suited for rice cultivation.

Analyses results of the different soils are given below in the following textural groupings:

1. soils of the flooded molapos
   a) fine loamy family

2. soils of the non-flooded
   a) coarse loamy
   b) fine loamy
   c) clayey

3. soils of flooded not cultivated molapos
   a) sandy

4. soils of non-flooded islands
   a) sandy

1a) In the soils of the flooded molapos as indicated on the 1967 photography the dominant sand fraction is fine sand (0.10 - 0.25 mm). Fine sand and very fine sand take up usually 50% of the sand fraction. The percentage coarse sand is less than 5% throughout. The percentage of silt varies between 7 - 14%.
19.

This amount varies irregularly through the soil with depth. The clay percentage is normally between 10 – 20 in the top soil but may double within 100 cm to between 20- 35%. As such the texture of the top-soil is a fine sandy loam that changes in the sub-soil to a (sandy) clay loam.

The pH (CaCl$_2$ and H$_2$O) usually increases with depth with 0.6 – 1.5 point.

The pH CaCl$_2$ is lower than the pH H$_2$O as in the CaCl$_2$ suspension the places of a number Hydrogen cations are taken up by calcium cations.

The pH CaCl$_2$ therefore ranges from strongly to moderately acid and from slightly acid to neutral (all values between 5.5 - 7.0).

The pH water ranges from slightly acid to mildly alkaline (all values between 6.1 - 7.8). The EC$_e$ value is always less than 1 and the ESP value 5 or less. Therefore the soils are classified as non-saline and non-alkaline.

The amount of P$_2$O$_5$ is very variable in the soils but decreases significantly with depth. The average P$_2$O$_5$ content is 26 ppm. The percentage C is high when compared with non-alluvial Botswana soils; but also a decrease in carbon percentage with depth is encountered. The average topsoil value is 3.00% and for the subsoil below 1%.

2a) Soils of the coarse loamy family in the non-flooded molapos have also fine sand as the dominant sand fraction. The combined fine sand and very fine sand fraction varies between 50 - 60%. The percentage of coarse sand is less than 5% throughout.
The silt percentage ranges between 10 - 15% and the clay percentage varies between 10 - 15% clay. There is a slight increase of clay with depth. The pH $\text{CaCl}_2$, which is comparable to the pH of the soil paste, ranges from moderately acid to neutral (all values between 6.0 - 6.7). The pH water is usually 1 point higher than the pH $\text{CaCl}_2$. The former range from neutral to mildly alkaline pH 6.8 - 7.8.

The $E_{ce}$ values are below 1 and the ESP is 5 or less; the soils are non-saline and non-alkaline.

The amount of $P_2O_5$ in the topsoil varies between 10 - 17 ppm (average 13) and the percentage carbon between 3.28 - 1.20% (average 2.02%). The amount of C decreases considerably with depth. Dominant cations are Ca and Mg.

2b) Fine loamy soils of non-flooded molapo areas have also fine sand as dominant sand fraction. However the combined percentage of fine and very fine sand is less than 50% in the subsoil.

The silt percentage varies between 5 - 15% and the clay percentage between 17 - 37%. However the weighted average of the clay fraction in the control section (from 20 - 100 cm) is between 18 - 35%.

The pH $\text{CaCl}_2$ ranges from slightly acid to neutral (all values between 6.2 - 6.7). The pH water ranges from neutral to mildly alkaline.

The soils are non-saline and non-alkaline with respect to their low $E_{ce}$ and ESP values. The average percentage C is 1.44% (range from 1.02 - 1.86), but is less than 1% in the subsoil. The amount $P_2O_5$ in the topsoil varies from 6 - 13 (average 10); it increases irregularly with depth. Clay/S value ratios are less than 7 and the dominant cations are Ca and Mg.

21/...
21.

2c) The *clayey family* of the molapos has usually a fine sandy loam texture in the top 20 - 30 cm.

The weighted average of the clay percentage in the control section from 20 - 100 cm may range from 35 - 60% clay but usually varies between 40 - 50% clay.

The silt percentage ranges between 12 - 20%. Subsoil textures include clay loams, clays and sandy clays.

The pH values are variable but are commonly slightly higher than in coarser textured soils.

The pH CaCl₂ varies from 6.6 - 7.6 (neutral to mildly alkaline); the pH water ranges from neutral to moderately alkaline. However ECₑ and ESP values indicate non-saline and non-alkaline conditions. The percentage carbon ranges from 2.56 - 3.0, average 2.8%.

The average P₂O₅ content is 13 in the topsoil and 4 in the subsoil.

The clay/S value ratio is less than 7 and the percentage CaCO₃ low. Dominant cations are calcium and magnesium.

3a) The soils of the *flooded but not cultivated molapos* belong generally to the sandy soil family groupings.

The combined percentage fine sand and very fine sand ranges between 50 - 60%.

The clay percentage is from 2.8% - average 5%; the silt percentage is less than 5%.

The pH CaCl₂ ranges from moderately acid to very strongly alkaline (6.0 - 9.5).
The pH water varies from neutral to very strongly alkaline (7.0 - 10.3).

The dominant cations are Na and Ca. The EC_e value is more than 12 within 90 cm depth and the ESP is more than 20 within 90 cm depth.

The soils are therefore classified as highly saline and highly alkaline.

The percentage carbon is less than 0.5% throughout and the amount of P_2O_5 in ppm decreases from 13 in the topsoil to 4 in the subsoil. The dominant anions are Cl^- - SO_4^{2-} - HCO_3^- . Salts as NaCl, Na_2SO_4 and NaHCO_3 are likely to be encountered.

4a) On the higher not flooded grounds the dominant textural family is sandy. Fine sand is the dominant sand fraction. The combined fine sand and very fine sand percentage is between 60 - 80%. The clay percentage ranges between 2 - 10% clay and the silt percentage between 2 - 4%.

The pH values vary irregularly in the soils, the following values are given: pH CaCl_2 from 6.5 - 7.4 (slightly acid to mildly alkaline) and also from 6.2 - 6.3 (slightly acid).

The pH water may range from 7.3 - 8.6 to 7.1 - 7.5 (neutral to strongly alkaline).

The percentage of CaCO_3 can be as high as 30% in the (deep) subsoil. Normally the percentage CaCO_3 increases regularly with depth.

The dominant cation is Ca; the EC_e is less than 1 and the ESP 5 or less within 90 cm depth.
The percentage of C is less than 0.5% throughout and the amount of \( P_2O_5 \) which may average as 17 ppm in the topsoil decreases to less than 5 ppm in the subsoil.

The clay/S values are less than 7 throughout.

The occurrence of a coarse loamy and a clayey molapo is illustrated in the Figures 3 and 4 respectively.

It will be noted that the local farmer has in general adapted his crops for different soil conditions. Maize on the finer soils which have a higher moisture retention capacity and have also a higher inherent fertility and sorghum on the coarse textures soils, which have a lower moisture availability and are also less fertile.

The Tables 2 and 3 summarise some of the most important data for the different soil family groupings as encountered in the area.

4.1.2 Trace elements

Trace elements were analysed on the present samples and a number of data are available from samples taken in February 1968.

The latter data are summarised in Table 4. The table is made up of 10 analyses results from cultivated molapo. The data under "RV" are the recommended values, the last line represents one sample taken in grassland molapo that showed extreme deficiencies in nitrogen and sulphur. Also included are the pH water and the electrical conductivity (EC\(_e\)) of the extract in numbers/cm. As a general guide to the status of trace elements in the area from the topsoil it is seen that Fe is commonly deficient and that also N,P,S, Mn and B, Cu and Zn are too low.
fig.3: CROSS SECTION SHOROBE MOLAPO

Legend:
- very dark grey to black fine sandy loam
- dark grey to (v) dark greyish brown fine sandy loam
- loamy fine sand
- very dark grey clay
- blocked by calcrete
- ca+ and ca+++ slightly and strongly calcareous resp.
Text to Fig. 3.

The molapo taken is located 500 m NNW of the agricultural plot in Shorobe.

The soil and vegetation (including crops) information reads:

<table>
<thead>
<tr>
<th>Auger</th>
<th>Soil Family</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>coarse loamy family</td>
<td>Dense woodland of <em>Croton megalobotrys</em>; <em>Lonchocarpus capassa</em> and palm trees (Hyphaene); dense cover of <em>Panicum maximum</em> grass.</td>
</tr>
<tr>
<td>2</td>
<td>coarse loamy family</td>
<td>open woodland of <em>Combretum harr</em>; <em>C. Imberbe</em> with a dense grass cover of <em>Cynodon dactylon</em>.</td>
</tr>
<tr>
<td>3</td>
<td>coarse loamy family</td>
<td>open reedland of <em>Phragmites mauritianus</em>.</td>
</tr>
<tr>
<td>4</td>
<td>coarse loamy family</td>
<td>open grassland of <em>Digitaria eriantha</em> with sorghum cultivation.</td>
</tr>
<tr>
<td>5</td>
<td>coarse loamy family</td>
<td>open grassland of <em>D. eriantha</em> with cultivation of sorghum and pumpkins.</td>
</tr>
<tr>
<td>6</td>
<td>coarse loamy family</td>
<td>as 5 with sorghum, pumpkins, melons and <em>Ampelopteris prolifera</em>.</td>
</tr>
<tr>
<td>7</td>
<td>fine loamy family</td>
<td><em>A. prolifera</em> and <em>Phragmites mauritianus</em> with cultivation of maize, sorghum, pumpkins and melons.</td>
</tr>
<tr>
<td>8</td>
<td>sandy family</td>
<td>reedland of <em>Phragmites mauritianus</em>.</td>
</tr>
<tr>
<td>9</td>
<td>sandy family</td>
<td>open grassland of <em>Digitaria milanjiana</em>, <em>Cynodon dactylon</em> with some short shrub of <em>Acacia giraffae</em> and <em>Combretum imberbe</em>.</td>
</tr>
<tr>
<td>10</td>
<td>sandy family</td>
<td>mixed woodland of <em>Pappea capensis</em>; <em>Lonchocarpus nelsia</em>; <em>Croton megalobotrys</em> and palm trees; grasses include <em>P. maximum</em>; <em>Leersia lexanara</em>.</td>
</tr>
</tbody>
</table>
fig.4  CROSS SECTION GABAMOCHAO MOLAPO

<table>
<thead>
<tr>
<th></th>
<th>23 auger</th>
<th>24</th>
<th>25</th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>100</td>
<td>200</td>
<td>300</td>
</tr>
</tbody>
</table>

metres

---

east  

---

west

---

depth in cm

---

legend

- black fine sandy loam
- dark grey to dark greyish brown fine sandy loam
- dark grey loamy fine sand
- black sandy clay
- dark grey clay
- ca ++ and +++ moderately and strongly calcareous resp.
The clayey molapo was sampled just south of Gabamobcho. Soil and vegetation descriptions are:

<table>
<thead>
<tr>
<th>Auger</th>
<th>Soil family</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Coarse loamy family</td>
<td>boundary of open woodland of <em>C. imberbe</em>; <em>Garcinia livingstonei</em> and <em>A. giraffae</em> with <em>Cynodon dactylo</em>on grassland.</td>
</tr>
<tr>
<td>24</td>
<td>clayey family</td>
<td><em>Phragmites mauritanus</em> and maize cultivation.</td>
</tr>
<tr>
<td>25</td>
<td>clayey family</td>
<td>as 24.</td>
</tr>
<tr>
<td>26</td>
<td>coarse loamy family</td>
<td>as 24 on the fringe of the cultivated area.</td>
</tr>
</tbody>
</table>
Table 2
Properties of soils of non-flooded mafapo areas.

<table>
<thead>
<tr>
<th>Textural family</th>
<th>2a Coarse Loamy</th>
<th>2b Fine Loamy</th>
<th>2c Clayey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>0-20</td>
<td>20-100</td>
<td>0-20</td>
</tr>
<tr>
<td>% f+v.f sand</td>
<td>60</td>
<td>54</td>
<td>56</td>
</tr>
<tr>
<td>% silt + v.f sand</td>
<td>17</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>% clay</td>
<td>10</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>pH CaCl₂</td>
<td>6.3</td>
<td>6.4</td>
<td>6.2</td>
</tr>
<tr>
<td>pH water</td>
<td>7.3</td>
<td>7.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Dominant cation</td>
<td>Ca+Mg</td>
<td>Ca+Mg</td>
<td>Ca+Mg</td>
</tr>
<tr>
<td>Clay/S value</td>
<td>&lt;7</td>
<td>&lt;7</td>
<td>&lt;7</td>
</tr>
<tr>
<td>% CaP₂O₅ ppm</td>
<td>2.02</td>
<td>0.41</td>
<td>1.44</td>
</tr>
<tr>
<td>ECₑ</td>
<td>1.0</td>
<td>n.d</td>
<td>1.0</td>
</tr>
<tr>
<td>ESP</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Very fine sand (0.05 - 0.1 mm) is treated as silt for family groupings.

The groups la and 2b may be combined to visualise the potential of the mafapo soils belonging to the fine loamy family.
Table 3

Properties of flooded molapo soils - fine loamy (1a); flooded but not cultivated areas (3a); and non-flooded higher ground (4a).

<table>
<thead>
<tr>
<th>Soil family</th>
<th>Property</th>
<th>Depth in cm</th>
<th>% f+v.f.s</th>
<th>% Si+v.f.s</th>
<th>% C</th>
<th>pH CaCl₂</th>
<th>pH Water</th>
<th>Dom. cation</th>
<th>Clay/S</th>
<th>% C</th>
<th>P₂O₅ ppm</th>
<th>ECₑ</th>
<th>ESP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a - fine loamy</td>
<td>0-20</td>
<td>52</td>
<td>18</td>
<td>14</td>
<td>5.7</td>
<td>6.4</td>
<td>Ca</td>
<td>&lt;7</td>
<td>3.00</td>
<td>26</td>
<td>n.d</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-100</td>
<td>49</td>
<td>15</td>
<td>27</td>
<td>6.2</td>
<td>7.1</td>
<td>Ca</td>
<td>&lt;7</td>
<td>0.18</td>
<td>3.6</td>
<td>0.4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3a - sandy</td>
<td>0-20</td>
<td>57</td>
<td>12</td>
<td>2</td>
<td>6.0</td>
<td>7.2</td>
<td>Ca,k</td>
<td>&lt;7</td>
<td>0.20</td>
<td>13</td>
<td>n.d</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-100</td>
<td>52</td>
<td>12</td>
<td>7</td>
<td>8.9</td>
<td>9.2</td>
<td>Na,Ca</td>
<td>&lt;7</td>
<td>0.14</td>
<td>4</td>
<td>8.2</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>4a - sandy</td>
<td>0-20</td>
<td>72</td>
<td>10</td>
<td>7</td>
<td>6.8</td>
<td>7.8</td>
<td>Ca,Na</td>
<td>&lt;7</td>
<td>0.34</td>
<td>17</td>
<td>0.8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-100</td>
<td>69</td>
<td>10</td>
<td>7</td>
<td>6.7</td>
<td>7.7</td>
<td>Ca,Na</td>
<td>&lt;7</td>
<td>0.13</td>
<td>2</td>
<td>0.8</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

All values given are averages, the possible range is given in the text.
Table 4

<table>
<thead>
<tr>
<th>Element</th>
<th>Values</th>
<th>pH</th>
<th>Ec</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>S</th>
<th>Ca</th>
<th>Mn</th>
<th>B</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td></td>
<td>8.0</td>
<td>2.1</td>
<td>7</td>
<td>23</td>
<td>216</td>
<td>260</td>
<td>16.5</td>
<td>1120</td>
<td>0.25</td>
<td>0.33</td>
<td>4.9</td>
<td>2.0</td>
<td>21</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>7.4-</td>
<td>1.2-</td>
<td>5-</td>
<td>11-</td>
<td>105-</td>
<td>155-</td>
<td>5-</td>
<td>525-</td>
<td>0.1-</td>
<td>0.15-</td>
<td>2.6-</td>
<td>1.0-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.4</td>
<td>2.5</td>
<td>14</td>
<td>120</td>
<td>350</td>
<td>280</td>
<td>50</td>
<td>1300</td>
<td>0.4</td>
<td>0.40</td>
<td>7.6</td>
<td>3.5</td>
<td>8.40</td>
</tr>
<tr>
<td>RV</td>
<td></td>
<td>6-7</td>
<td>1-2</td>
<td>300</td>
<td>120</td>
<td>300</td>
<td>250</td>
<td>200</td>
<td>1000</td>
<td>10</td>
<td>1-2</td>
<td>50</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>Grassland</td>
<td></td>
<td>6.9</td>
<td>0.52</td>
<td>3</td>
<td>16</td>
<td>95</td>
<td>100</td>
<td>8</td>
<td>250</td>
<td>1.4</td>
<td>0.20</td>
<td>5.8</td>
<td>3.0</td>
<td>35</td>
</tr>
</tbody>
</table>
Fertilization with sulphate of ammonia and 1% iron sulphate, the latter mainly in "yellow" areas, are recommended. Small amounts of Zn and Cu may also increase yields.

In soils with a P deficiency the lowering of the soil pH can be tried as more P is released at a lower pH.

Although the amount of Ca is not too high when taken by itself, compared with the other elements available in too low amount, the concentration of Ca is often not favourable.

This makes the other trace elements as Fe, Mn, Cu and Zn much less readily available to the plant.

The trace element analyses done on the present samples are represented in Table 5.

The data indicate a true deficiency in iron (Fe) which is confirmed by the other figures in Table 4.

The other concentrations are low but not restricting initial plant growth.

No molybdenum (Mo) was analysed, although there are indications that there is a deficiency in this trace element.

Biological activity in the soils increases the ripening of the soil material in due course.

At present clearly visible action is caused by ants and mice. Lack of oxygen during flooding limits the effective oxidation period. Under reduced conditions sulphides may develop in an acid environment. Especially the heavier textured soils may be effected.
### Table 5

<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Depth in cm</th>
<th>pH CaCl₂</th>
<th>% CaCO₃</th>
<th>Fe</th>
<th>S</th>
<th>Mn</th>
<th>Zn</th>
<th>Cu</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a-fine loamy, flooded molapo</td>
<td>0-23</td>
<td>5.7</td>
<td>nil</td>
<td>1.8</td>
<td>5</td>
<td>11</td>
<td>1.5</td>
<td>3.8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0-20/30)</td>
<td>(5.5-</td>
<td>(0.2-</td>
<td>(4-</td>
<td>(10-</td>
<td>(1.3-</td>
<td>(1.9-</td>
<td>(7-</td>
<td>(4.6-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.9)</td>
<td>4.6)</td>
<td>7)</td>
<td>12)</td>
<td>1.8)</td>
<td>7.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a-coarse loamy, non-flooded molapo</td>
<td>0-20</td>
<td>6.3</td>
<td>nil-1</td>
<td>0.7</td>
<td>8</td>
<td>9</td>
<td>1.8</td>
<td>2.3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0-10/30)</td>
<td>(6.0-</td>
<td>(0.4-</td>
<td>(5-</td>
<td>(6-</td>
<td>(1.2-</td>
<td>(1.6-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.7)</td>
<td>1.2)</td>
<td>13)</td>
<td>15)</td>
<td>2.4)</td>
<td>3.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30/60-90/120</td>
<td>6.5</td>
<td>nil-2</td>
<td>0.5</td>
<td>5</td>
<td>4</td>
<td>1.7</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.4-</td>
<td>(0.2-</td>
<td>(4-</td>
<td>(1-</td>
<td>(0.4-</td>
<td>(0.9-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.6)</td>
<td>0.9)</td>
<td>7)</td>
<td>7)</td>
<td>2.9)</td>
<td>1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b-fine loamy, non-flooded</td>
<td>0-14</td>
<td>6.3</td>
<td>nil</td>
<td>0.5</td>
<td>2</td>
<td>5</td>
<td>0.7</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0-10/18)</td>
<td>(6.2-</td>
<td>(0-</td>
<td>(3-</td>
<td>(0.5-3</td>
<td>(0.7-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3)</td>
<td>4)</td>
<td>7)</td>
<td>0.9)</td>
<td>1.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-70</td>
<td>6.7</td>
<td>nil</td>
<td>1.1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>1.4</td>
<td>-</td>
</tr>
<tr>
<td>2c-clayey, non-flooded molapo</td>
<td>0-20</td>
<td>6.5</td>
<td>0-1</td>
<td>0.7</td>
<td>4</td>
<td>7</td>
<td>0.6</td>
<td>2.1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>20-100</td>
<td>6.6</td>
<td>0-1</td>
<td>0.5</td>
<td>3</td>
<td>3</td>
<td>0.7</td>
<td>3.7</td>
<td>-</td>
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<tr>
<td></td>
<td>100-120</td>
<td>7.6</td>
<td>5-15</td>
<td>0.7</td>
<td>5</td>
<td>5</td>
<td>2.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3a-sandy, flooded, non-cultivated</td>
<td>0-23</td>
<td>6.0</td>
<td>nil</td>
<td>0.4</td>
<td>4</td>
<td>4</td>
<td>0.3</td>
<td>0.6</td>
<td>-</td>
</tr>
<tr>
<td>4a-sandy islands</td>
<td>0-17</td>
<td>6.7</td>
<td>0-nil/2</td>
<td>0.4</td>
<td>12</td>
<td>8</td>
<td>1.0</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>(0-15/20)</td>
<td>(6.2-</td>
<td>(0.3-</td>
<td>(6-</td>
<td>(3-</td>
<td>(0.9-</td>
<td>(1.2-</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>7.3)</td>
<td>0.5)</td>
<td>18)</td>
<td>13)</td>
<td>1.0)</td>
<td>1.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40-107</td>
<td>6.4</td>
<td>0-nil/2</td>
<td>1.0</td>
<td>3</td>
<td>3</td>
<td>0.9</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(30/50-105/110)</td>
<td>(6.3-</td>
<td>(0.3-</td>
<td>(1-</td>
<td>(0.8-</td>
<td>(0.9-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.5)</td>
<td>1.6)</td>
<td>5)</td>
<td>1.8)</td>
<td>1.0)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>105-160</td>
<td>8.1</td>
<td>30</td>
<td>0.7</td>
<td>5</td>
<td>3.7</td>
<td>1.1</td>
<td>0.8</td>
<td>-</td>
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</tbody>
</table>

**NOTE:**
1) Figures are mean values; data in brackets give range;
2) trace elements in ppm air dry soil.
4.2 The soil classification and mapping legend

The amount of organic carbon in the topsoil is too low to qualify for a humic A and also the thickness criterium is not satisfied.

As such the topsoil horizons are qualified as orthic. Although stratification of the soil material is observed in places, at other sites it is not readily visible. For the present however all molapo soils are classified as belonging to the young stratified alluvium and are grouped according to their texture. The soils of the upland areas contain not enough sand to classify as Regic sand. The subsoil may qualify as a brown apedal or yellow apedal B horizon. (Form XXVIII - series 34, 37, 39.) The overlying topsoil diagnostic horizon is Ochric. However in some areas stratification may occur not caused by water but by wind action. Soils belonging to the clayey textural family group can develop in direction of the Firm Gley subsoil diagnostic horizon. (Form XXVI - series 2.)

In this survey soils of the molapo areas are preliminary indicated as alluvium and soils of the islands as a mixture of alluvium and windblown materials.

The map legend is a combined present land-use, physiographic and soils legend, summarised in Table 6.

Table 6. The map legend

<table>
<thead>
<tr>
<th>Map Symbol</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soils of the flooded molapos: association of fine loamy textural family and the clayey family, non-saline; non-alkaline.</td>
</tr>
<tr>
<td>2</td>
<td>Soils of the non-flooded molapos: association of coarse and fine loamy and clayey families, non-saline, non-alkaline.</td>
</tr>
<tr>
<td>3</td>
<td>Soils of flooded non-cultivated areas: association of sandy and coarse loamy families; strongly alkaline and saline.</td>
</tr>
<tr>
<td>4</td>
<td>Soils of non-flooded islands: association of sandy and coarse loamy family with inclusions of fine loamy and clayey soils in depressions.</td>
</tr>
</tbody>
</table>
5. Interpretation of the survey data for irrigated land use.

5.1 Land classification

For detailed descriptions of the land capability classes one is referred to Technical Note No. 11, Part II.

A resume of the land capability reads as follows:

Map symbol 1 and 2: Suitable
" " 3 and 4: Non-suitable

5.2 Land use recommendations

The classification of the individual soil family groupings for irrigated land use can be stated as follows (all other factors being suitable).

Clayey family: This textural group has a relatively high inherent fertility level and good water availability properties; their main limitation is slow drainage when clays are too firm in consistency and structural development is limited. For the present the very fine clayey family is classified as Class 2 and the clayey family (fine) as Class 1 land; a wide variety of climatically adapted crops can be grown, they include rice, maize, cotton, sorghum, vegetables.

Fine loamy: Although somewhat lower in fertility, the water holding and drainage properties of this family are considered good; they are classified as Class 1 land; a wide range of crops can be grown such as maize, rice, cotton and a variety of vegetables.

Coarse loamy: Mainly on the basis of their coarser texture and related nutrient status and water potential are these soils classified as Class 2 land; the crop range is somewhat narrower but may include sorghum, millet and vegetables.

Sandy family: These soils are marginal for irrigated land use mainly on the basis of their textural composition; they belong to Class 3 land; the adaptibility of the crop is restricted; but orchards of citrus trees could be established, vegetables and "seed" potatoes can be grown.
6. **Appendix I**

6.1 **High level soil classification and correlation**

The proposed classification is preliminary as the amount of available soil data of the area is limited.

The classification is therefore subject to revision. Correlated with other classification systems the soils belong to:

<table>
<thead>
<tr>
<th>Legend</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order Entisols, Suborder Fluvents and Aquets; Great Group Typic and Vertic.</td>
<td>7th Appr. U.S.D.A. 1967</td>
</tr>
<tr>
<td>Eutric Fluvisols (Te)</td>
<td>Soil Map of the World Legend, 1970</td>
</tr>
<tr>
<td>Juvenile soils on Recent Deposits: Bo-on riverine and lacustrine alluvium, Me-not differentiated halomorphic soils</td>
<td>Soil Map of Africa, d'Hoore, 1964</td>
</tr>
<tr>
<td>IV A(i)-(iii) Young soils on fairly recent material A-Hydromorphic soils of recent fluvial material (i) seasonally flooded (iii) perennially flooded</td>
<td>Provisional Soil Map of Botswana (1959)</td>
</tr>
<tr>
<td>Soil Forms XXVIII and XXVI</td>
<td>Botswana Taxonomic Classification, 1970</td>
</tr>
</tbody>
</table>
6.2 Selected bibliography

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Washington, D.C. U.S.A. August, 1964