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SOIL MAPPING AND ADVISORY SERVICES
BOTSWANA

EXPLANATORY NOTE ON THE LAND SYSTEMS MAP OF BOTSWANA

FOOD & AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

REPUBLIC OF BOTSWANA

UNITED NATIONS DEVELOPMENT PROGRAMME

GABORONE, DECEMBER 1990

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EXPLANATORY NOTE ON THE LAND SYSTEMS MAP OF BOTSWANA

by

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1 INTRODUCTION

Within the overall Government development objective that the Soil Mapping and Advisory Services Project (BOT/85/011) should improve the basis for medium and long term planning of agriculture and rural development, a national soil map of Botswana was produced as a first step.
Institutions involved in national planning require soil information in condensed form to identify regional differences in resource endowment.
However at an early stage of development of the National Soil Map, it proved necessary to produce a separate map based on physiographic units that contains additional information on landforms, topography and vegetation.
The production of such a map also fits the SADCC programme of mapping the landforms of the SADCC region to facilitate transfer of technology between member states.
The combination of the soil map and the land systems map provides an ideal basis for the inventory of physical resources in Botswana, and for their eventual inclusion in a Geographical Information System.
Last but not least, the land systems and soil maps serve an educational purpose, allowing a quick overview of the land resources in Botswana.

It should be emphasized that although the initial idea was to produce a land systems map at the same scale as the soil map (1/1 000 000), the former has been printed at scale 1/2 000 000 for technical and financial reasons.

2 THE LAND CLASSIFICATION SYSTEM

The system adopted for the classification of land in Botswana is developed by the Division of Land Resources and Regional Survey of the Commomwealth Scientific and Industrial Research Organisation in Australia (Christian and Stewart 1953; Perry, 1962). A similar approach was used earlier by Bawden and Stobbs (1963) for the study of then Eastern Bechuanaland. Later the same methodology was proposed for reconnaissance surveys in Jordan by Mitchell and Howard (1978).

The land systems approach is a hierarchical, sub-divisive classification system, where physiography, geology, geomorphology and topography are retained as diagnostic criteria.
The term land system is defined as a tract of land that is homogeneous according to certain pre-conceived criteria. A land systems classification is a hierarchical subdivision of land according to these criteria. The term land unit is regarded as a general term to be used when referring to a homogeneous unit of land.

For Botswana following hierarchical classification for reconnaissance studies is proposed :

<u>Table 1</u>

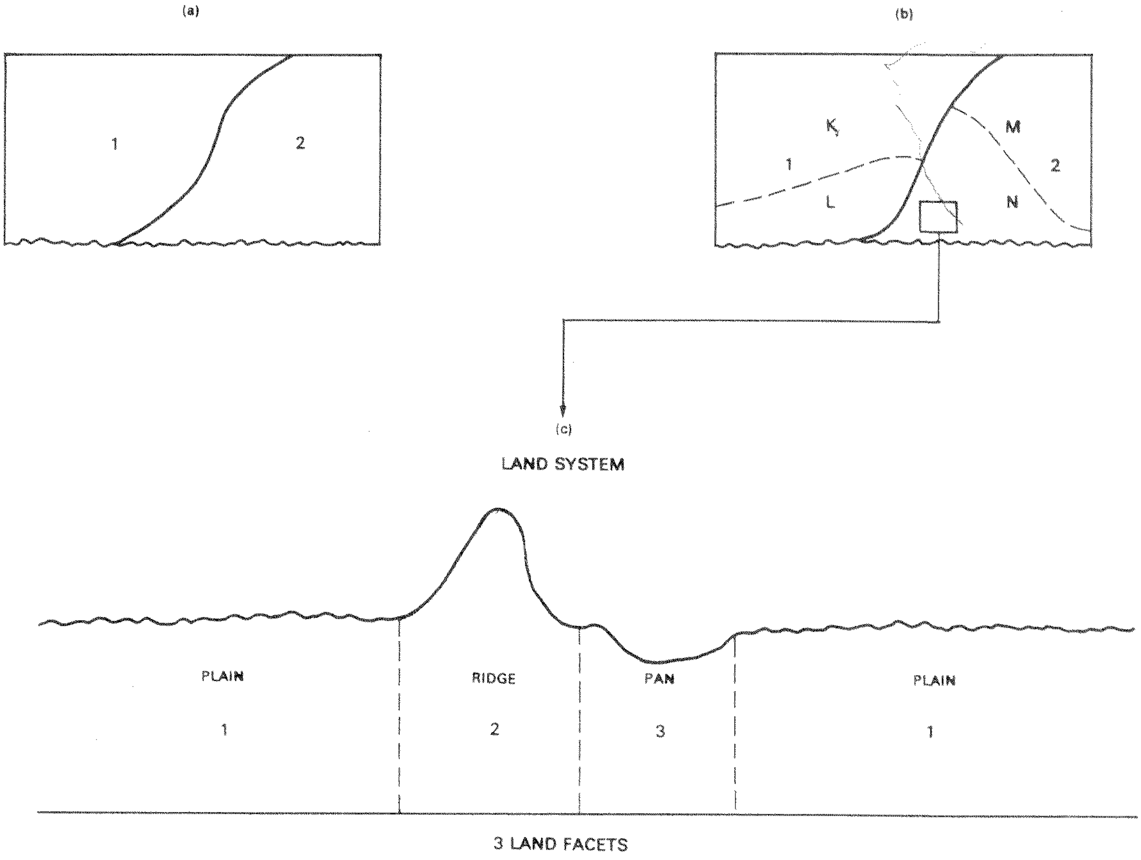
THE LAND SYSTEM APPROACH

land unit	paramount discipline to identify unit	description
land division	physical geography	Gross landform expressive of a continental structure; i.e. a major physiographic unit.
land region	geology	Surface form expressive of a lithological unit or a close lithological association having everywhere undergone geomorphic evolution.
land system	geomorphology, topography	Landform pattern of geographically and geomorphologically related smaller land units, which are recurrent in this land unit.

The smallest land unit that can be mapped at the working scale of 1/2 000 000 is the land system. The land system coincides here with a land catena. It represents a land unit with a predominantly uniform geology, geomorphological and topographical pattern, and has characteristic soil and vegatation associations. An example is given in figure 1.

A further subdivision into land facets, which show a characteristic soil and vegetation association might be established after comparing the national soil map and vegetation map with the land systems map.

It is sometimes possible to recognize one additional higher level namely the land zone. This unit is generally expressive of major climatic zones. As previous climatic cycles have had much more influence on landform and soil formation than the actual climate, this land unit is not retained for classification purposes. A very general description of actual climate in Botswana is given in section 4.



(a) Rural area divided into two land divisions

(b) The same area divided into four land regions

(c) One Land System occurring in land region N. Note that the Land System (c) can be subdivided into three land facets.

Figure 1: Subdivisive land classification

3 SOURCES OF INFORMATION.

The subdivision of the area into major physiographic units, determining the different land divisions, is done by satellite imagery interpretation. The full coverage of the country at a scale of 1/250 000 was available on Landsat MSS bands 4,5 and 7. Most of the satellite images were also acquired at the scale of 1:1 million. The boundaries of the land divisions were mostly clearly visible on the images.

The information for the identification of the land regions, based on lithological units, is collected from previous field documents on reconnaissance soil maps of Botswana, and from the photo-geological map of Mallick et al (1981). In the Botswana Soil Legend (Remmelzwaal 1988), the first or main unit distinction is based on parent material and rock type. These main units are well reflected in the soil maps, and they can be used for identifying land regions. The photo-geological map (scale 1/1 000 000) is based on 1:250 000 Landsat imagery interpretation. This map is very useful for land classification, especially in the sandveld, because the authors adopted a morphogenetic subdivision of the surface deposits.

The delineation of the land systems is based on several sources of information. The soil reconnaissance reports of Botswana (see above) generally include a chapter on landscapes. Much effort has been given to the landscape development of the hardveld, which consequently is very comprehensively represented in these documents. In order to put these landscapes in a broader, national context, several modifications have been made without sacrificing the amount of detail.
Large areas of Botswana, especially the Southwest and Central Kalahari are not covered by reconnaissance soil surveys. For this part, representing 35% of the total surface, intensive satellite imagery and aerial photo interpretation (scales varying from 1:50 000 to 1:70 000) and additional numerous field checks were necessary.
The Bawden and Stobbs (1963) land systems classification of the eastern part of Botswana (representing less than 20% of the extent of Botswana), gives valuable information. However the major disadvantage of latter system is that the land units are identified more in terms of geographical position and less in terms of geomorphological features.

Soils information is derived from the National Soil map of Botswana (De Wit, Nachtergaele, 1990).
Vegetation data characterizing the different land systems are extracted from the vegetation survey of Botswana (Bekker and De Wit, 1990).

4 CLIMATE

Although the actual climate in Botswana is not directly related to landform development and soil formation, it is very important for crop growth and natural vegetation distribution.
Climate has been widely discussed in previous work (Blair Rains and McKay, 1963 ; Pike, 1971 ; Sims, 1981 ; Vossen, 1989).
However no comprehensive climatic map has been established for the country.
Recently Dambe (1987) worked out an agro-climatic zones approach, based on the length of the growing season, its frequency of occurrence, the number of dry days within the growing season, and the length of the humid period (see fig. 2).
It should be noted that following definitions apply :

growing season : the length of the growing season is equal to the length of the growing period if one growing period occurs, or equals the total length of the growing periods when two or more growing periods occur plus the number of dry days

growing period : the start of the growing period is assumed when precipitation exceeds half the potential evapotranspiration. The end of the period is assumed when precipitation falls below half potential evapotranspiration plus a number of days required to evaporate an assumed 100mm of soil moisture reserve when available

humid period : the period during a growing period when precipitation exceeds full potential evapotranspiration

dry days : days during the growing season when no soil moisture is available and rainfall is less than half the potential evapotranspiration

The following six broad agro-climatological regions can be retained :

Shakawe - Kasane (1B1, 1B2)

This region is characterized by a relative long reliable growing season of 101-120 days, with less than 20 dry days. Drought resistant crops such as sorghum can be grown without irrigation.

Gumare - Ghanzi - Maun (2C2, 2C3)

This region borders south of the Shakawe-Kasane region. It is characterized by a shorter growing season of 81-100 days, with 21-30 dry days. The length of the humid period is 20-40 days, with an occurrence of less than 50%. Sorghum can be grown without irrigation, but the risk of crop failure is higher than in the previous region.

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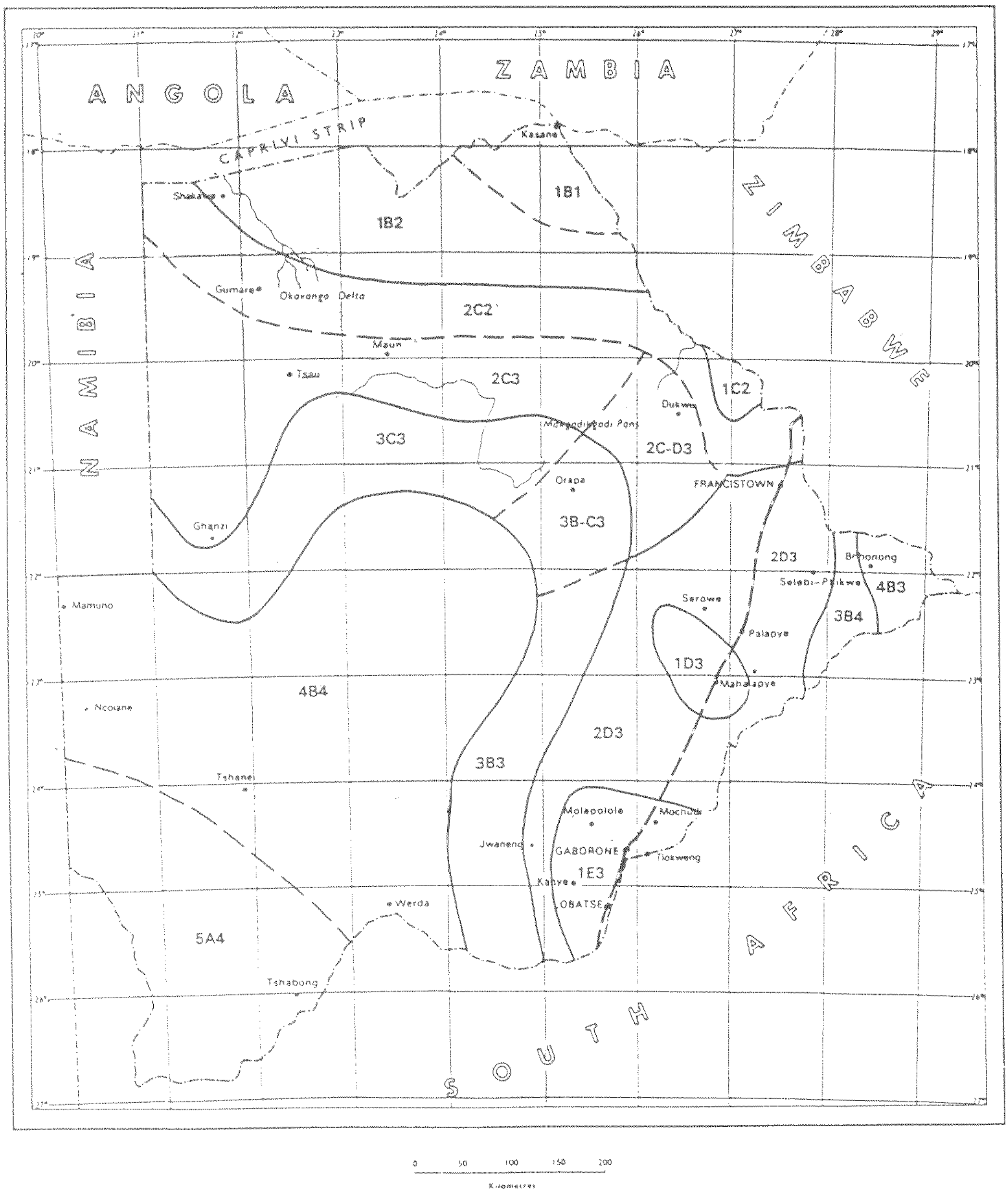

Length of Season

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

Number of Dry Days within the Season

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

Length of Humid Period

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

Figure 2 Agro-Climatic Zonesof Botswana (Dambe, 1987)

Francistown - Palapye (2D3)

This principle agro-climatic region of the hardveld shows a length of growing season of 81-100 days, but with 31-40 dry days, implying that the growing season can frequently be split up in several shorter growing periods. The length of the humid period is 20-40 days, with an occurrence of less than 50%. The growth of rainfed sorghum is very unreliable and low yields and high risk of crop failure might be expected.

Jwaneng - Orapa - Tobane (3C3, 3B3, 3B4)

This region can be considered as a transitional zone between the more humid regions 2 and 3 and the arid region 5. The length of the growing season varies between 61 and 80 days, with 11-30 dry days. The humid period does not exceed 40 days in more than five out of ten years. Conditions for rainfed sorghum are very marginal to unsuitable.

Tshane - Bobonong (4B3, 4B4, 5A4)

This region can be considered as the most arid of Botswana. With a length of growing season of less than 60 days, it is unsuitable for rainfed sorghum.

Gaborone -Mahalapye - Maitengwe (1C2, 1D3, 1E3)

This region is scattered over the hardveld and is characterized by microclimates, originating from local abrupt discontinuities in topography (e.g. Shoshong hills near Mahalapye). Although the length of the growing season is 101-120 days, it can be interrupted by 21-50 dry days. This can lead to two or more shorter growing periods, which might result in unreliable crop growth, low yields and a high risk of crop failure.

Characteristic climatic diagrams for the agro-climatic regions (except for Jwaneng - Orapa - Tobane where no synoptic station is situated) are shown in figure 3. The diagrams show monthly averages of temperature, precipitation and potential evapotranspiration. They are compiled with data collected by the Meteorological Services of Botswana (1984).

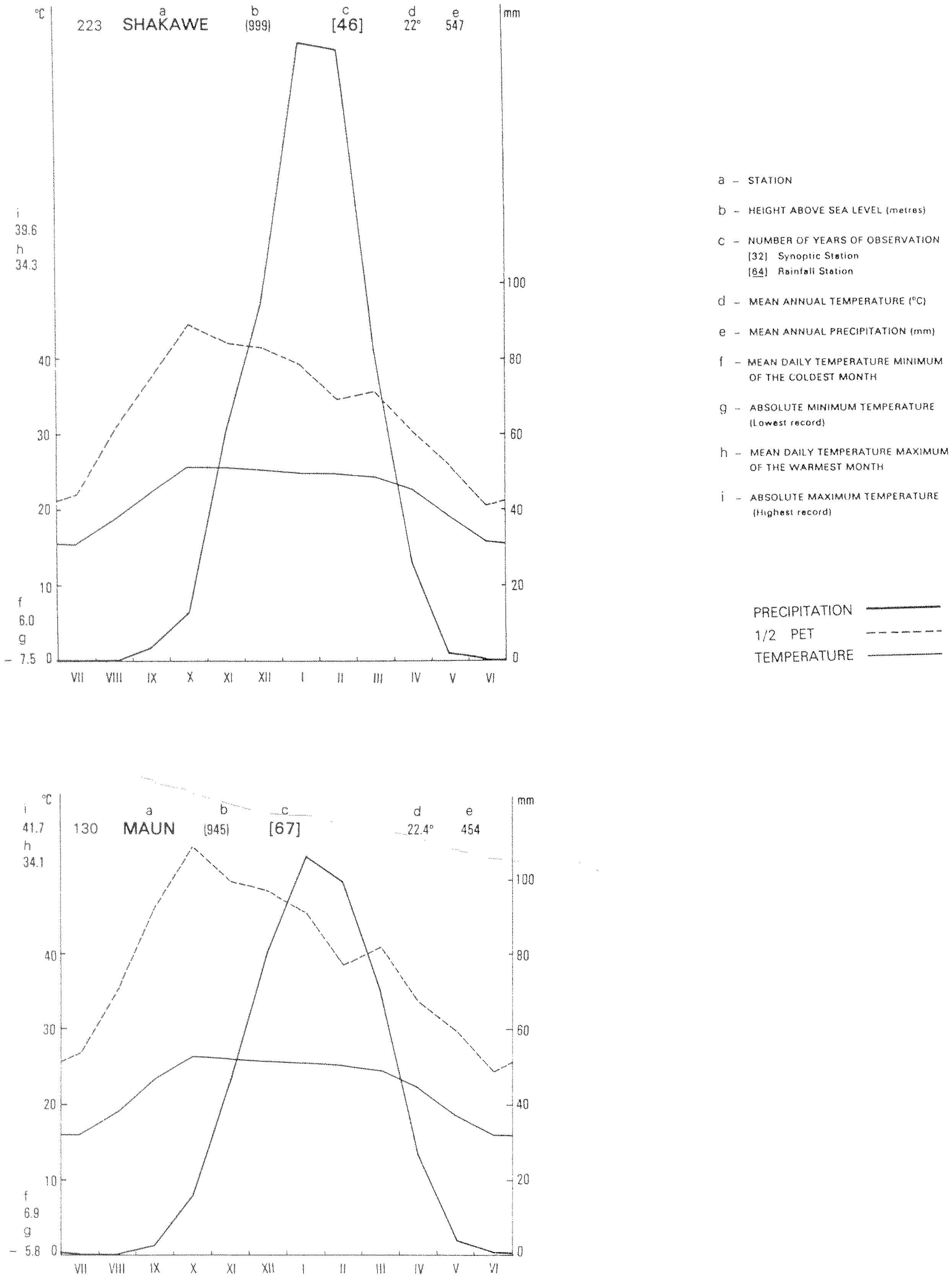

Figure 3: Climatic diagrams of synoptic stations in Botswana

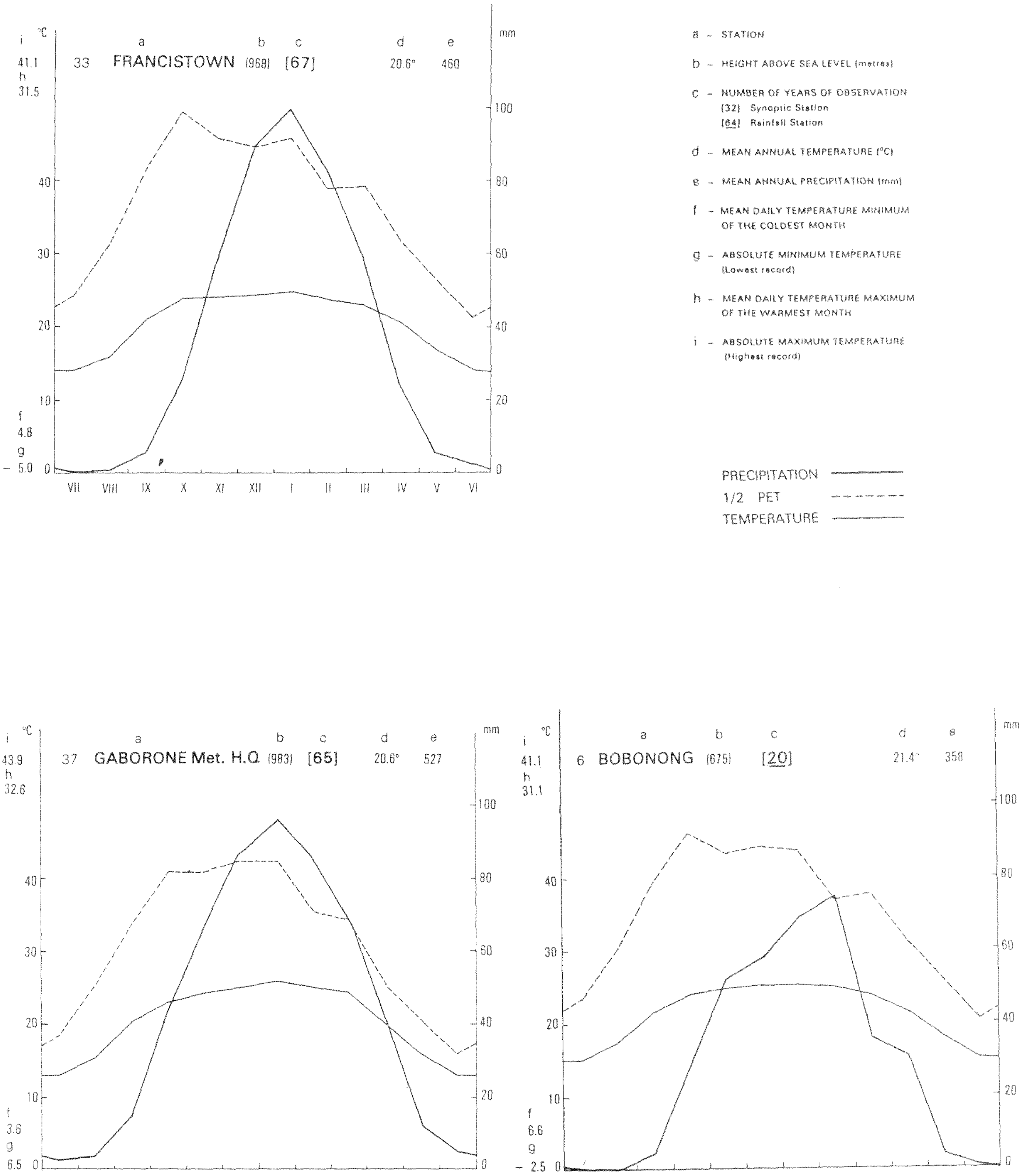

Figure 3: continued

5 THE LAND UNITS OF BOTSWANA

5.1. Land Divisions

Land divisions are gross landforms expressive of a continental structure. They coincide with the four major physiographic units which can be recognized in Botswana : the hardveld, the sandveld, the lacustrine system and the alluvial system (see fig. 4).

5.1.1. The Hardveld (H)

The hardveld can be described as a structural surface developed on mostly Precambrian rocks, occuring in the eastern part of Botswana. It coincides more or less with the late Tertiary and Quaternary erosion surface, as defined by Bawden and Stobbs (1963). The Tertiary surface is an almost flat to gently undulating plain with occasional hill ridges. Due to an uprising of the land surface along the Kalahari-Rhodesia axis (King 1963), and followed by a renewed erosion cycle, the upper catchments of the Shashe-Ramokgwebana watershed became dissected. The eastern boundary of the Tertiary erosion surface is marked by a break of slope to relatively more dissected valleys and undulating plains. The break marks the limit of the encroachment of the Quaternary erosion cycle up the river valleys. The hardveld is thus characterized by mostly active erosional surfaces and some depositional areas related to old and recent riverbeds. The boundary between the hardveld and the sandveld is characterized by another erosion scarp. Sometimes this scarp is very clear (Serowe scarp), sometimes it is indistinct and the eastward extension of the sandveld merges gradually into the hardveld (e.g. near Dibete).

5.1.2. The Sandveld (S)

The sandveld represents the area which is mainly covered by Kalahari sands. It is generally assumed that Kalahari sands are predominantly of late tertiary aeolian origin (Rogers 1936, McConnell 1955). Boocock and Van Straten (1962) mention four different types of Kalahari deposits; the Kalahari sands cover most of them. Bailleul (1975) stresses that part of the Kalahari sands may be formed in situ from underlying sandstones.

In late Cretaceous times an extensive erosion surface was cut in the Precambrian and Karoo rocks which now underlie the Kalahari deposits (McConnell 1955). Due to an elevation of the edge, a basin was established serving as a recipient for the surroundings and prohibiting the transport of materials. During the mid Tertiary another erosion surface was formed. An active erosion cycle flattened the entire surface. Alternatively in dry periods, sand was blown into the area and dunes developed. The reworking of the deposits under a sucession of humid and dry climates resulted in a complex pattern of landforms. Old longitudinal dune systems are alternating with relatively flat sandplains and more recent dune formations. A lot of pans or playas are distributed in the sandveld, mostly in the younger dune areas. As their formation is directly related to surface Kalahari sands, they are considered to be part of the sandveld and not of the lacustrine system.

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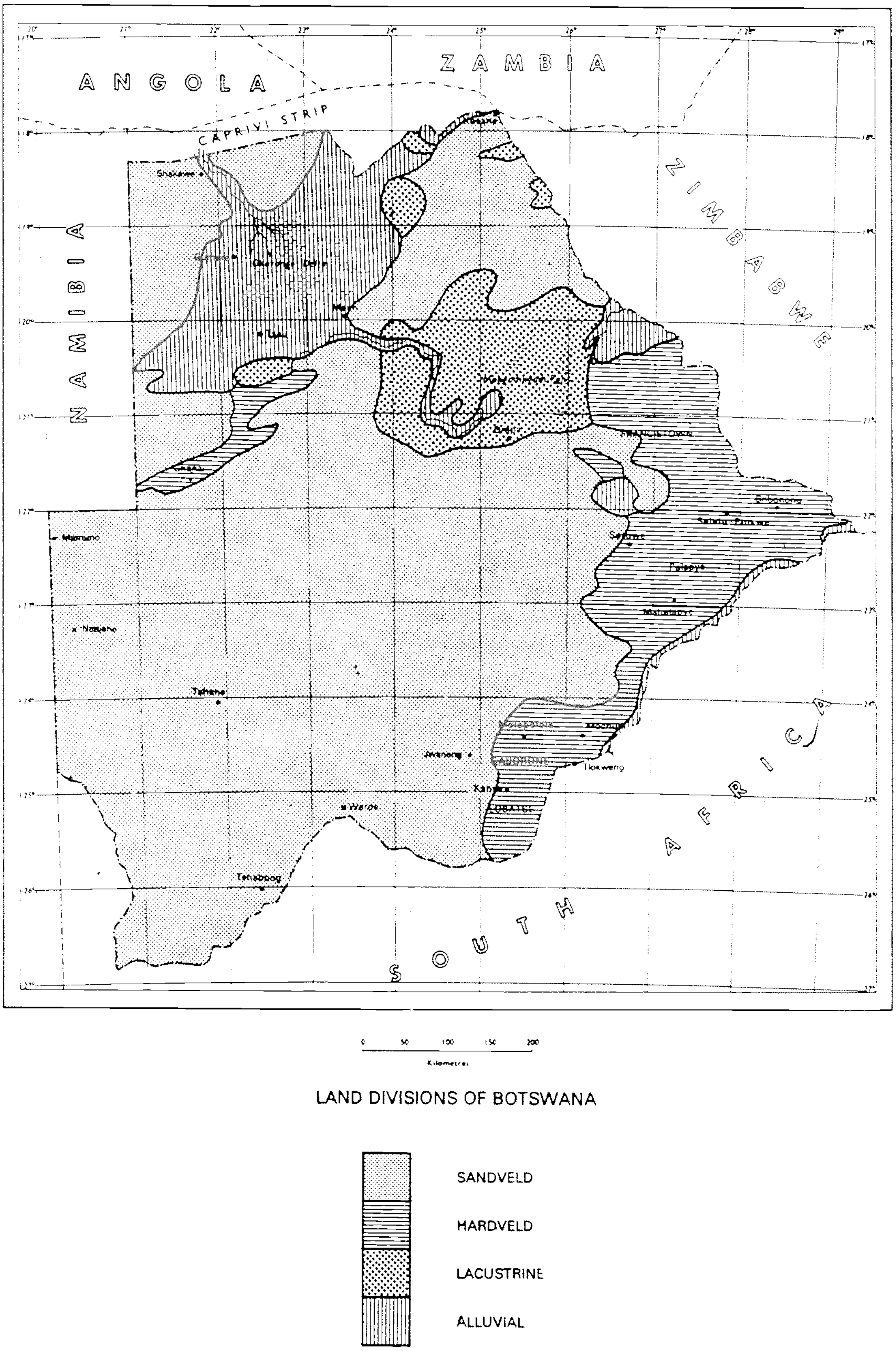

Figure 4: Land Divisions of Botswana

5.1.3. The Lacustrine System (L)

In the lacustrine system, three major developments can be recognized in Botswana : Lake Ngami, the Mababe depression and the Makgadikgadi depressions. They can be easily detected on the Landsat imageries. Lake Ngami is ponded against the Ghanzi ridge, probably by downthrown movements on the Okavango Graben marginal fault (Mallick et al 1981). The lake was probably fed by rivers draining from the southwest, and possibly the Okavango.
The Mababe depression appears also to be fault-bounded. It lies on a slightly tilted block between two north-west downthrowing faults. The depression received floodwaters from distributaries of the Okavango and the Linyanti-Chobe.

The history of the Makgadikgadi lacustrine system is very complex and it is not our aim here to develop all the theories of its development, which are well described by Breyer (1986) and Bailleul (1979). During the late Tertiary and Quaternary time, a tectonic activity along a northeast axis altered the flow of the major rivers. Block faulting probably caused the formation of the Makgadikgadi basin. The depression was filled by the inflow of several rivers during the more humid periods to form the lake. During the late Quaternary age, different morphological processes modified the outlook of the depression deposits. The alternation of humid and dry periods led to the formation of different lacustrine terraces. During the dry periods the deposits were reworked by wind activity and resulted in dune formation. Also several recessional strandlines can be observed. It must be mentioned that the highest terrace of the Makgadikgadi complex, as described by Breyer (1986) is not considered here as a lacustrine system because the aeolian sandcovers are too thick. This terrace must thus be considered as part of the sandveld.

An additional lacustrine development occurs near Pandamatenga, in the depressions bordered by longitudinal and transverse dunes.

5.1.4. The Alluvial System (A)

In the alluvial system two major forms can be recognized, namely the wide valley floors and the alluvial spreads. The distribution of wide valley floors is relatively unimportant in Botswana; the Limpopo, the Boteti and the Linyanti-Chobe can be mentioned as examples.

The wide valley floors in the Kalahari, like the Okwa river and its tributaries are mostly infilled with aeolian sand; actually they are part of the sandveld. The major alluvial spread is the Okavango delta. The Okavango Rift is an alluvium filled graben structure. The sedimentation has been from three sources (Mallick et al 1981). The southwestern part was filled by rivers draining from the south and west, which have long been dry. Another part of the delta receives alluvium from the active Okavango and Linyanti rivers, which are perennial. Active deposition in swamps on the alluvial fan of the Okavango river is encroaching across the older alluvium to the south-west. The Okavango and Chobe alluvium coalesces in the north-east of the rift. The valley in which the Okavango river flows before reaching the head of the fan is probably controlled by faults.

The much smaller coalescing fans of the Nata river and its tributaries occur north-east of the Makgadikgadi depression and continue into the depression. Formerly the Nata river flowed north-westerly to the Nata fault, forming wide alluvial fans overlying the Karoo strata.
By a renewed movement of the fault the Nata river turned more westerly (Mallick et al 1981).

The alluvial spreads of the Moeneyana river occur in front of the boundary scarps between the sandveld and the hardveld.

5.2. Land Regions

A land region is a surface form expressive of a lithological unit or a close lithological association having everywhere undergone geomorphic evolution. The lithological unit or lithological association should be interpreted in terms of parent material or rock type from which the soils are derived, like aeolian sand, basalt, granite etc... A land region encompasses a range of surface forms.
It is not the intention here to describe the geology of Botswana, that having been done very concisely in previous works (Mallick et al 1981).
The main aim is to make relationships between the lithological units and the landscape development.

5.2.1. Solid rocks on the Hardveld

The following solid rocks can be distinguished on the hardveld:

Amphibole-rich meta-basic rocks (Ha)

Mostly meta-basalt lavas (amphibolites) with prominent ironstone layers and minor ultramafic schists, serpentinites and meta-sediments. Occurring locally near Francistown and Chizwina. Gently undulating to undulating plains with occasionally hilly outcrops are characteristic

Basalt (Hb)

Most of the basalts are associated with the basaltic lavas of the Karoo Supergroup. They give rise to a distinct landscape in the east of the country and to the scarps of the Serowe area. To the western margin of the hardveld, they are overlain by aeolian deposits and rarely show rock outcrops. Some outcrops of Central District are related to methamorphosed basic and ultrabasic rocks of the Basement Complex. Undulating plains with few hill ranges developed on this basalt-like rock.

Dolerite (Hd)

The basic intrusive rocks, mostly dolerite, sometimes gabbro are of various ages and can be associated with the Pre-Karoo group. Sloping lands with pediments and hill ranges are characteristic.

Sedimentary rocks (Hc)

The sedimentary rocks, mostly outcropping in Central District, belong to the Palapye supergroup. Limestone, quartzite and greywacke are the most common rock types; they are all weakly affected by metamorphism. Most of the hill groups in the hardveld consist of this type of rocks; they are associated with pediments.

Sandstone (Hs)

Three types of sandstone can be recognized. The sandstones of the Waterberg group, mostly occuring in the southeast of the country are coarse-grained. Gently undulating plains with few inselberghs can be found on this rock type.

The Karoo sandstones, including the Cave sandstone, are younger in age and are mostly found on the western fringes of the hardveld. They are often covered by aeolian sand deposits. There is a common distinction between the Cave sandstone and the older Karoo strata, based on their superficial cover.
The Cave sandstone is a fine-grained red aeolian sandstone, and weathers to produce thick regolith sand very similar to the aeolian sand of the Kalahari. This contrasts with the regolith of the older, water-laid Karoo strata, which also commonly bear superficial calcrete. Vast flat plains are developed on this kind of sandstone.

The Ghanzi sandstone is a fine grained, arkosic rock type, and occurs on the Ghanzi ridge, which is flat with some escarpments.

Granitic gneiss (Hg)

The largest part of the hardveld is covered by granitic-gneiss and associated rocks from the Pre-Cambrian Basement complex. The granitic gneiss is associated with migmatites, granulites, paragneisses and older undifferentiated granites. Flat to undulating eroded plains are developped on these rocks. Sometimes paragneisses can be differentiated from the rest of this rather complex group, because they give rise to a topography consisting of many low parallel ridges. Due to this complexity, the term granitic-gneiss has been used for the acid rocks of this complex.

Granite (Hi)

The Gaborone granite differs from the granites and acid gneisses of the Basement complex in that it has a very coarse grained porphyritic structure. It gives rise to a higher proportion of medium textured soils developed on undulating plains.

Acid volcanic lavas (Hv)

The acid volcanic lavas of the Kanye group are mainly composed of felsitic material and porphyry. The outcrops of these rocks form hill ranges in the south east of the country

Dolomite (Hn)

Dolomites of the Damara group occur in the north east. They are very restricted in extent and comprise hills with pediments.

5.2.2. Parent material in the Sandveld

In the sandveld, three types of parent material can be recognised :

Aeolian sand deposits (Sa)

The deep aeolian sand deposists cover the largest part of the sandveld. They can be correlated with the Kalahari beds as defined by Boocock and Van Straten (1962).
In the Central Kalahari basin the Kalahari beds seldom exceed 90m in thickness. Greater thicknesses over 150m have been recorded, particularly in the vicinity of fossil drainage grooves in the headwaters of the Molopo river in the south east of the country.
These beds have been formed under a terrestrial environment and show marked variation in detail both laterally and vertically. When they are treated as units distributed over a wide area, both lithology and the general succession are however remarkebly constant. The different landforms, which will be discussed later, are mainly developed under recent aeolian and fluviatile influence.

Superficial aeolian deposits over solid rock (Sc, Ss, Sb, Sd)

The superficial aeolian deposits over solid rock are mostly occuring on the western fringe of the hardveld. They must be considered as a transitional zone between the hardveld and the aeolian sand deposits.

Flat plains are mostly characteristic for these areas. A differentiation has been made between the nature of the rocks on which the sand has been deposited , i.e. sandstone, basalt, dolomite and calcrete. Sometimes the deposits are difficult to separate from the sand developed on the Karoo sandstone.

Partly submerged aeolian deposits (Sm)

Small in extent, these lands are occurring in the northern part of the country. They are typical transitional zones between the sandveld and the lacustrine system of the Mababe depression and the Pandamatenga plains. They can be considered as lacustrine reworked sandplains.

5.2.3. Materials of the Lacustrine System

In the lacustrine system, two major different materials can be distinguished :

Major lake and depression deposits (Ll)

They are associated with the lacustrine depositional areas of the Mababe depression, lake Ngami and the Makgadikgadi depression. The latter is by far the most extensive. Although there is a wide range of deposited materials, from sands to clays, no subdivision can be made at this level of the classification. Landscape formation is related to successive transgressions and regressions during the Quaternary, combined with recent aeolian activity which will be briefly discussed later. A common feature of the deposists is that they are vertically well developed.

Superficial lacustrine deposits on sandstone (Ls)

The superficial lacustrine deposits on sandstone occur at the eastern and southern fringes of Sua Pan. They must be considered as a transitional zone between the hardveld and the lacustrine system. Extensive areas of Karoo sediments, especially sandstone, are overlain by quaternary lacustrine deposits.

Lacustrine vlei deposits (Lv)

The lacustrine vlei deposists are representative for the clayey deposits of Pandamatenga. They occur in flat depressions bordered by longitudinal and transverse dunes. The clays overlie Karoo basalts.

5.2.4. Materials of the Alluvial System

In the alluvial system two main materials can be recognized : the recent alluvial deposits which are regularly flooded, and the old, fossil alluvium, which is more elevated.

Recent alluvial deposits (Ar)

The recent alluvial deposits are mainly found in the Okavango delta and on the floodplains of the major rivers like the Boteti, the Limpopo, and the Linyanti-Chobe. The Okavango delta shows perennial and seasonal swamps. The morphology depends on continually migrating channels and varying waterlevels with time. Apart from the open water areas, different deposits can be found ranging from sand, which is the most common, to clay. On the flat areas a distinct microrelief has been developed. The river floodplains are mostly rather flat.

Fossil alluvial deposits (Af)

This type of alluvium occurs in places which are currently no longer flooded. In the eastern part of the country, near Maitengwe, these alluvial deposists are flat.
A more varying landscape can be found on the fossil alluvium of the Okavango. A pattern of old channels is separated by gently undulating areas and depressions. Relief inversion is a common feature.

5.3. Land Systems

A land system is a landform pattern of geographically and geomorphologically related smaller land units (land facets),which are recurrent in this land unit.
The land systems of Botswana are identified by combining the different geomorphological features and their respective topography.

Following topographical classes are retained (Remmelzwaal and Van Waveren 1988) :

class	slope (%)
flat	0 - 0.5
almost flat	0.5 - 2
gently undulating	2 - 5
undulating	5 - 8
rolling	8 - 16
hilly	> 16

The following geomorphological forms and features are recognized and retained for the the land systems classification. They are grouped together in function of the major physiographic units they are occuring in.

5.3.1. Geomorphological forms and features related to the Hardveld

The landforms of the hardveld can be divided into two broad categories : the erosional surface resulting from the continual removal of the products of weathering, and the depositional surfaces resulting from the accumulation of material.
The erosional surfaces can be further divided into the upland plains, and the valleys. As these latter make integral part of the landfacet "plain", and as they are to small to map individually, they are not retained at this level of mapping. Under the depositional surfaces we can consider broadly the alluvial terraces and the floodplains. The vast depositional surfaces are described under "Alluvium". The minor terraces and floodplains have also to be considered as part of the landfacet "plains".

Following geomorphological forms/features can be recognized :

Plains

The plains of the hardveld have to be considered as structural plains; they are the result of different erosion cycles, as mentioned by Bawden and Stobbs (1963).

Their topography, which is an important characteristic to subdivide the plains, is narrowly related to the type of underlying rock type. On a granitic gneiss stratum, corresponding with the late Tertiary erosion cycle, the plains are mostly almost flat to gently undulating. On sandstone a wide range of topographies can be recognized, from flat to rolling. The plains on basalt, which are more related to Quaternary erosion cycles, are gently undulating to undulating, and well dissected.

Hills

They are occurring on a wide range of lithological formations. The hills can be considered as remnants of the early Tertiary cycle of erosion.

Hilly areas

Hilly areas are recognized in Ramokgwebana on the granitic gneiss complex. These areas are very dissected probably due to upwarping of the land surface and renewed erosion.

Escarpments

Mainly occurring west of Serowe, these scarps mark the break between the late Tertiary land surface and the Kalahari plains.

Kopjes

Kopjes or inselbergs are prominent steep-sided residual hills rising abrupt from the surrounding erosion plains. They occur mostly on the granitic gneiss Basement Complex.

Pediments

Smooth pediment slopes have developed on granitic gneiss and on dolerite at the foot of large outcrops, with a very distinct break in slope between the rock and the pediment.

Plateau

Elevated areas of comparatively flat land which is commonly limited by an abrupt descent to lower plains. The plateaus are mostly dissected and associated with pediments.

Ridge

A relatively narrow elevation on Ghanzi sandstone, which is flat of topography with edging slopes towards the sandveld.

Eroded valleys

Recognized mainly as valleys of the Limpopo river and tributaries, which have mainly incised the rocks of the Basement Complex. It is a landform with generally a variable slope towards a major drainage line.
These valleys are subject to an actual erosion phase. Different land facets can be observed, but cannot be mapped at the working scale : terrace, floodplain, valley bottom, levee, backswamp.

Fossil valleys

Fossil valleys are relics of old drainage lines formed during earlier pluvial periods. More characteristic for the sandveld, these type of valleys are rather limited in extent on the hardveld. They must be considered more as depositional valleys than as valleys with an active erosion phase.

Alluvium

Alluvium in the hardveld must be regarded as a flat depositional landform, and not as a parent material for soil development. As most of the alluvial flats cannot be represented at the working scale, they are considered to be associated with the plains, and are not retained separately.

5.3.2. Geomorphological forms and features related to the Sandveld

Plain

The plains occurring in the sandveld are the result of aeolian sand accumulation. They are mostly flat to almost flat, rarely gently undulating.

Parabolic dune

A dune having in ground plan approximately the form of a parabola, with the concave side toward the wind. They are often the result of accumulation of blown sand of pans and depressions.

Longitudinal dune

Longitudinal steepsided ridges with knife-like crests. They lay parallel to each other in vast complexes. Although the original topographic elevation of the dunes has in many places been largely disappeared, the original distribution of the sand ridges is well preserved. They are associated with the interdune hollows where finer washed-in materials and calcrete can be recognized.

Linguoid dune

Very low small ripples with an irregular pattern formed by wind activity. Two different patterns of linguoid dunes can be observed. In the western part of the Kalahari, near the Namibian border, sets of linguoid dunes are occurring in north-south oriented strings; they are associated with almost-linked elongated pans dammed behind the dunes. In this area the curved cross elements of the dunes are convex towards the south. In east-central Botswana fairly well-preserved linguoid dunes are more isolated, with crests forming an elongated cluster.

Reticulate dune

Remnants of former transverse dune ridges over which the younger linear dune ridges pass with little or no deflection. The dunefield is not uniform but consists of numerous units of reticulate dunes differing from neighbouring units in spacing, orientation and size. They are bounded by long terminal ridges, indicating southerly transport of the sand units as a whole, but the reticulate pattern behind them may result from conflicting wind directions.

Transverse dune

Transverse dunes are wide ridges, between 1 and 2km apart, between 10 and 20m high, rather sinuous and bifurcating and trending generally north. It appears that the interdunals are sites of water accumulation, forming small pans; calcrete can be expected at shallow depth. These dunes are formed by light and moderate winds, blowing from the east; they require a considerable sand supply.

Sand mound

These are irregular mounds of reddish sand, probably representing alab ridge sand somewhat redistributed by later, more northerly winds. The mounds are rising above the flat sandplains.

Pan

In southern Africa any depression which holds water after rains is called a pan. Compared with the sense given to a playa - the flat central parts of depressions, which may be ephemerally or seasonally flooded - the popular meaning of the term pan is thus more general. Although all pans are to some extent originating by deflation, several pan types can be recognized.

Longitudinal and transverse dunefield pans are commonly south and west of the Makgadikgadi depression. Those in the longitudinal dune troughs are usually elongated along the troughs and are probably remnants of drainage systems which utilised the interdunals during subsequent wetter periods. They usually lack any marginal dune, since they involved only minor recent sand movement to partially block the former drainage channels. The pans in the inter-transverse hollows are entirely analoguous but have a tendency to be elongated north-south parallel to the dunes.

The calcrete-rimmed pans are occurring in a belt east-west from the Namibian border to Sekoma, along the southern limit of the eroded alab ridges.
These pans of deflation have all calcrete (calcrete can often be recognized as an outcrop or has only a very thin sand cover), sometimes associated with silcrete at their margins, usually forming small cliff features. They normally have at least one large or multiple or complex parabolic dune on the leeside. In some cases longitudinal dunes begin to develop from the leeward faces of the parabolic dunes.

Stringed pans can be recognized in an area of north-south elongate dune ridges, south of the sand mounds. The pans lie north of, and more ponded behind the linguoid dunes. It appears most likely that the north-south interdune troughs were used as part of a tributary network draining into the Nosop river during a wet period, and that pans represent remnants of the drainage system which was modified by partially blocking linguoid dunes during a subsequent more arid period. Although few pans are present in the reticulate dune-field of south-west Botswana, the position of former pans, now covered by sand, can be seen behind the dunes.

The pans in central-southern Botswana are generally circular and of deflation origin. They vary substantially in size and development. Probably the youngest and smallest are pans developed by blockage of run-off behind small linguoid dunes. Somewhat older are similar small pan hollows which have been slightly deepened by deflation, and which now have a small parabolic dune on the lee-side. They lack a wide rim of calcrete but are otherwise comparable to the calcrete-rimmed pans. Some pans in fossil valleys occur along dune-controlled former drainage channels and so are analoguous to the inter-longitudinal dune pans.

Fossil river valleys

The fossil river valleys of the Central-Kalahari, especially the Okwa river, have transported water for centuries.
It has been suggested by McConnell (1959) that the river valleys originated after the Cretaceous planation, and that the present system has established itself in late or post Tertiary times by reincision of the old drainage lines. Under an arid climate the valleys are completely infilled with aeolian sand. In various places these deposits have been reworked into minor dune forms.
The southern fossil rivers, like the Molopo, have been known to flow in recent times in it's upper reaches, but the aeolian sand deposits are extensively spread out.

5.3.3. Geomorphological forms and features related to the Lacustrine System

Plain

Especially recognized in the Makgadikgadi depressions, the lacustrine plains correspond with the 929-908 masl terrace, mentioned by Breyer (1986). These plains are flat to occasionally gently undulating. The terrace is formed during the Holocene by lacustrine deposition. After recession of the lake during a dry period, isolated lakes with their own shore dynamics were formed. Aeolian processes and calcrete formation became widespread.
Together with the plains are also considered the lake bottoms and fossil floodplains.

Salt pans liable to flooding

These flat depressions are the last remnants of the lake. Some parts show perennial water, other parts are covered by thick salt deposits. The pans have not been reworked by aeolian or fluvial erosion.

Pans

Reference is made here to the pans occurring in the lacustrine plains. They represent the lower parts of the plains and must be considered as fossil lake bottoms. Some of them can be seasonally ponded. The lake bottoms stricto sensu are flat. In the bigger pans, like Rysana pan, the lake bottoms are reworked by aeolian activity, and dunes can be observed.
Remnants of fossil strandline features are clearly visible.

Shoreline

Gently undulating sand ridges formed under humid periods by the wave action of vast water masses.
These strandlines are common in Makgadikgadi, Mababe and Lake Ngami. Most of them are situated on the west side of the depressions,what can be explained by waves formed by eastern winds. That coincides with the direction of the longitudinal dunes.

Ridges of reworked lacustrine deposits

These elevations are vestiges of older, more subdued sand ridges probably marking older shoreline positions.
They are possibly predating the later stages of development of the longitudinal dune system.

Fossil lagoon

An aeolian reworking of the Gidikwe ridge blocked the flow of the Boteti river in the Makgadikgadi depression. A shallow lagoon was formed on the western side of the shoreline. After a breakthrough in the Gidikwe ridge, the lagoon dried out and the reworked and redeposited aeolian sands formed the almost flat plain or fossil lagoon. On this plain the Gidikwe lineations can be observed. Grey (1976) showed that the material forming the lineations differed from dune sand and he suggested that they were formed subaqueously behind the shoreline. They involve no discernible topographic variation.

Barchan dune

They are mainly observed in the south western part of Ntwewe pan. These dunes are windblow accumulations of lacustrine deposits during a very dry period. Meanwhile climatic conditions have changed and the original dunal model has been affected by flooding.

Parabolic dune

See above under sandveld

5.3.4. Geomorphological forms and features related to the Alluvial System

Perennial swamp

The swamps coincide with the northern part of the Okavango delta. This part of the delta is flooded continuously. It has a dendritic and anastomasing channel system, and shows lagoons, oxbow lakes, floodplains and scattered islands (Verbeek 1988).

The morphology of the delta depends on continually migrating channels and varying water levels with time. The general topography is flat, but a more undulating microrelief can be found around the islands.

Delta floodplain

The delta floodplain has similar characteristics as the swamps, but the flooding frequency is less. The islands are representing a relatively major extent. The waterflow is related to the floodplains and the sediment transport, mostly sand, occurs through the channels. Channel blockages and diversion of water through other systems is frequent. This flat delta floodplain with a distinct microrelief, coincides with the seasonal swamp described by Verbeek (1989).

Fossil delta floodplain

The fossil delta floodplain of the Okavango presents a pattern of channels separated by gently undulating areas and depressions, unaffected by the present floodlevel. According to the bed aggradation model of McCarthy et al (1988), relief inversion has occurred with former channels found standing as ridges in the landscape.

River floodplain

Major river floodplains are mainly occurring in the north of the country : Linyanti, Chobe, Boteti river. The floodplain of the Chobe river is narrow on Botswana's territory. It is mainly flooded through backflow of the Chobe. To the east the floodplain becomes larger. The Linyanti floodplain is separated from the Okavango fossil floodplain by the Linyanti fault. Some overflow may occur and mixed alluvial deposits are thus obvious. The Boteti river connects the Okavango delta with the Makgadikgadi depressions. The valley is much larger than required by the contemporary flow regime. Extensive layers of silcrete and calcrete occur on both sides. On either side of the river a zone of alluvial reworked sandveld occurs with locally sunken depressions. The northern river floodplains show the typical pattern of levee, backswamp, terrace and plain.

The only major river floodplain in the southern part of the country is the Limpopo floodplain. Forming the border between Botswana and South-Africa, it exists mainly of disconnected fragments, contained within loops of the river. Several parts of the valley are very narrow and rocky; other parts show a clear floodplain development with wide terraces and levees, especially near the confluence of the Limpopo and the Shashe.

Alluvial fans

Alluvial fans are cone-shaped alluvial deposits made by a stream where it runs out onto a level plain or meets a slower stream. The fans of the middle Nata river and tributaries occur north east of the Makgadikgadi depression above the 950 masl contour and continue into the depressions as alluvial flats and terminal fan of the Nata river. Tectonic movement caused probably a deflection of those rivers. The fan is flat and characterized by clayey deposits on sandstone.

The fan north of Serowe is formed by the Moenyena river, which rises from the basaltic scarpments. The sharp increase in channel width and decrease in slope gradient is clearly visible. The terminal fan of the Boteti river debouches also into the Makgadikgadi depression. It is elongated eastwards probably due to a recession of the lake. A mixture of alluvium and lacustrine material can be found, and it is not clear where the boundary between these two systems exactly is. The alluvial fans entering the Mababe depression are much smaller.

Alluvial flats

The occurrence of alluvial flats is confined to the upper catchments on the high parts of the hardveld. The textures of the deposits are directly related to the sources of the material. Most alluvium is found in association with other sediments and rocks.

6. VEGETATION

6.1. Methodology

In order to typify each land system in terms of vegetation, an intensive study of the vegetation of Botswana has been carried out (Bekker and De Wit, 1990).
After consulting existing publications and vegetation maps, each land system was preliminary defined by a structural vegetation type, dominant or prominent woody-, grass- and forb species, and grass cover.
Structural vegetation types are distinguished according to vegetation structure which is considered as a complex of plant life forms, vertical stratification of plant biomass and its horizontal coverage within these strata (Mueller-Dombois and Ellenberg, 1974).
Dominant species control a vegetation community by their presence and canopy cover. Prominent species are characteristic for a certain community, but they are not necessarily dominant.
In a next step approximately 3500 field observations stored in the Botswana Soil Database were processed. The locations of the releves were plotted on the land systems map and lists of structural vegetation types and species occurring in each land system were drawn up.
In a further stage preliminary vegetation characteristics were updated and adjusted by comparing literature data with field observations.
For each land system the most widespread structural vegetation type was determined. As two or sometimes more types occur in one land system, a range is given. Note that the most common structure is given first.
The listed dominant and prominant species were principally obtained from the characteristic structural vegetation type(s).
Vegetation associations are the fundamental units for describing the land systems. They form a typical combination of species with a range of structural vegetation types and a specific ecological occurrence (land region, parent material, soil group, meso climate). Associations are marked by their most dominant and prominent species.
It should be noted that associations can be regrouped in alliances. Although this procedure has been followed for the vegetation classification of Botswana (Bekker and De Wit, 1990), it has not been retained for the land systems map.

For describing the vegetation structure of the land systems, structural vegetation described by Remmelzwaal and Van Waveren (1988) was regrouped into seven classes (see table 2).

Table 2

Vegetation structures retained for the land systems classification

classes land systems	classes Remmelzwaal&Van Waveren		definition
Swamp (S)	S	Swamp	Hydrophytic grasses, sedges and aquatic species
Grassland (GR)	GR	Grassland	Grasses, subordinate forbs, no woody species
Forbland (FL)	FL	Forbland	Herbaceous plants predomonant
Shrub savanna (SS)	SL	Low shrub savanna	Predominantly low shrubs, scattered moderately dense
	SLD	Dense low shrub savanna	Low shrubs approx. a few crown diameters apart
	SLO	Open low shrub savanna	A few isolated low shrubs
	SS	Shrub savanna	Predominantly shrubs, scattered moderately dense
	SSD	Dense shrub savanna	Shrubs approx. a few crown diameters apart
	SSO	Open shrub savanna	A few isolated shrubs
Savanna (SA)	SA	Savanna	Scattered trees and shrubs, moderately dense
	SAD	Dense savanna	Species approx. a few crown diameters apart
	SAO	Open savanna	A few isolated trees and shrubs
Tree savanna (ST)	ST	Tree savanna	Predominantly trees, scattered moderately dense
	STD	Dense tree savanna	Trees approx. a few crown diameters apart
	STO	Open tree savanna	A few isolated trees
Woodland (W)	W	Woodland	Continuous tree layer, crowns usually not touching. Understorey may be present.

It should be emphasized that the mapped land systems are land catenas which can comprise several land facets which are too small to be mapped at the working scale (e.g. the land system "longitudinal dune system" consists of dunes and interdunal depressions).When different vegetation communities are are recognized on different land facets within the same land system, typifying species are given for the land system as a whole, and not for the separate land facets. When a land system occurs in different regions, and consequently the vegetation composition is different, a distinction is made by adding a different geographical name to the land system.

6.2. Regional vegetation distribution

The vegetation of Botswana changes from the southwest to the northeast from (low)shrub savanna to tree savanna and woodland due to the increasing precipitation towards the northeast. Simultaneously an increase in tree species is observed to the northeast.
The most widespread sandveld association is found in the centre of the country and consists of *Terminalia sericea*, *Lonchocarpus nelsii / Acacia erioloba*. This association reaches its southern limit around the Tropic of Capricorn. To the east it extends towards the hardveld and the northern boundary is formed by the mopane-line south of the Makgadikgadi Pan system. In the west the association is found along the Namibian border up to the Caprivi Strip.
Typical sandveld species are *Acacia haematoxylon*, *A.luederitzii*, *Boscia albitrunca*, *Terminalia sericea*, *Lonchocarpus nelsii*, *Bauhinia petersiana and Baphia massaiensis*. *Acacia haematoxylon* is only found in the south-west of the country. *Terminalia sericea* and *Lonchocarpus nelsii* occur mainly north of the line Ncojane-Hukuntsi-Werda, while *Bauhinia petersiana* and *Baphia massaiensis* appear north of 20° South.

The vegetation of the Chobe Region is also developed on sandveld. Offshoots of the miombo woodlands invade the country from Zambia and Zimbabwe. The vegetation in this area can be considered as a transition between the northern miombo woodlands and the southern Kalahari savannas.
Representative hard wood species are: *Baikiaea plurijuga*, *Pterocarpus angolensis*, *Guibourtia coleosperma*, *Amblygonocarpus andongensis*, *Erythrophleum africanum*, *Brachystegia sp.*, *Julbernardia globliflora* and *Isoberlinea sp.*

The vegetation of the hardveld in the east is more diverse than the sandveld, because of a larger range in parent material, soils and climate. The hardveld carries a variety of associations with as most frequent species: *Peltophorum africanum*, *Acacia tortilis*, *Combretum apiculatum*, *A.nigrescens* and in the north *Colophospermum mopane*.

The Makgadikgadi lacustrine system is mainly covered by grasslands with halophytic species, from which *Odyssea paucinervis* is dominant. Islands of Hyphaene palms are common, as well as *Adansonia digitata* (Baobab) trees, solitary or as clumps.

The Okavango Delta forms a very complex ecosystem itself. Swamp, island and floodplain associations can be recognised. Most typical species are *Cyperus papyrus*, *Phragmites australis* and a variety of aquatic species in the swamps, *Phoenix reclinata*, *Hyphaene petersiana*, *Ficus sycomorus*, *Garcinia livingstonei*, *Lonchocarpus capassa*, *Diospyros mespiliformis* and *Combretum imberbe* on the islands and grass and sedgelands on the floodplains.

Colophospermum mopane (mopane) is one of the most typical tree and shrub species of hot, low-lying, eastern and southern Africa. It often occurs in pure stands and grows on a large variety of soils with textures ranging from sand to clay and depths from shallow to deep.
Colophospermum mopane does only occur in the northern portion of Botswana. With the data retrieved from the Botswana Soil Database and from literature a mopane-line could be established, which demarcates the occurrence of this

species. A line drawn between Martin's Drift and the Mokgware Hills forms the southern boundary. The mopane-line can be followed from the Mokgwane Hills in north-eastern direction until a point west of Serule. From there the line runs to the north-west to an area south of Sowa Pan and Ntwetwe Pan up to Lake Xau in the west. The mopane-line surrounds the Pans and the associated shoreline features in the west, which are free of the species. At 18.5° south it runs eastwards to the Zimbabwean border. Just north of Stoffels Pan mopane reoccurs and the line runs south of the Mababe Depression, via the eastern bank of the Thamalakane River towards Lake Ngami. From there it runs south of the Okavango Delta, surrounding the perennial swamp. *Colophospermum mopane* occurs along the delta fringes and on the fossil alluvium. The mopane-line excludes the dune system located along the Caprivi Strip (although the species is recorded in some interdunal depressions, Smith 1990, personal communication) and hits the Kwando River at the Namibian border.

7. LOCATION

In order to locate a specific land system on a topographic map, a location name is added to each land system. If a specific land system occurs scattered in different geographic positions, every major occurrence is defined by a corresponding name. Mostly names of villages, settlements, national parks and game reserves, rivers, important well- known pans are used.
If there occurs more than one distinct vegetation structure/composition within the same land system, this is also indicated by a different location name.

8. SOILS

Each land system is characterized by a range of different soils. The information was obtained by overlying the national soils map on the land systems map. The occurring soils mentionned in the legend are indicating the dominant subgroups.They are classified according to the FAO/UNESCO/ISRIC Revised Legend of the Soil Map of the World (1988).

9. THE LAND SYSTEMS MAP

9.1. Topographic base

The land systems map of Botswana was prepared on the basis of the 1/1 000 000 topographic map produced by the Ministry of Surveys and Lands. For financial and technical printing reasons, the final printed version of the land systems map is presented at a scale of 1/2 000 000. Thus the map consists of one sheet only.

9.2. Mapping units and symbols

A mapping unit consists of a land system which is the equivalent of a land catena. The smaller sub-divisions of the land, the land facets, are not presented at the working scale. If the latter occur they are described in the definition of the land system.

Map unit symbols explain the land system as follows : the first letter (capital) indicates the land division (S for Sandveld, H for Hardveld, A for Alluvium and L for Lacustrine). The second letter (lower case) stands for the land region, if possible (e.g. a for deep aeolian deposits, b for basalt).
The different land systems within the same land region are separated by adding a number to the mapping symbol.

9.3. Legend

The descriptive legend accompanying the land systems map and presented in annex 1 is in table form and shows the hierarchical classification up to the land systems level. It gives additional information on vegetation, soils, location and the extent of each land system.
The abbreviations used for vegetation structure and species are given in Van Waveren and Remmelzwaal (1988); those of the soil sub-groups in De Wit and Nachtergaele (1990).

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APPENDIX 1

Legend of the Land Systems Map of Botswana

Land Division	Land Region*	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km^2)	Mapping Symbol
		undulating to rolling longitudinal dune system	Nosop	SS	AHA, RGT	ARo	5260	Sa1
			West Ngamiland	SA	TMS, LON, AER	ARo	8300	Sa1
		undulating to rolling reticulate dune system	Gemsbok park	SA	AME, ALU, BSA	ARo	12430	Sa2
		almost flat to gently undulating plain with undulating reticulate dunes	Mosomane	SA	AME, ALU,BSA	ARo	8030	Sa3
		almost flat plain with few pans	Bosobogolo	SA	AME, ALU, BSA	ARo	9450	Sa4
			SE Ngamiland	SS/SA	CLM, TMS, LON	ARl, ARo	2700	Sa4
			Chobe	W/SA	PTA, BKP	ARh,ARo,LVf,LVh	1740	Sa4
		almost flat plain with undulating to rolling sand mounds	X'Choi	SS/SA	TMS, LON, AER	ARo	7650	Sa5
		almost flat to gently undulating stringed pan system	Rambuka	SS	CTA, RHT	ARo	1540	Sa6
		flat to almost flat plain with broad fossil valleys	Molopo	SS	AME, ALU, BSA	ARl, ARo, CLp	11580	Sa7
		almost flat to gently undulating plain with major calcrete rimmed pans	Kangwa	SA	AME, ALU, BSA	ARl	9380	Sa8
Sandveld	Aeolian sand deposits	flat to almost flat plain with depressions	Ncojane,Groot Laagte Letiahau	SS/SA	TMS, LON, AER	ARh, ARl, ARo	31180	Sa9
		flat to almost flat plain with major calcrete rimmed pans	Mabutsane, Ukwi	SS/SA	AME, ALU, BSA	ARl, ARo	27630	Sa10
		flat to almost flat plain with calcrete depressions	Mabuasehube game res.	SA	AME, ALU, BSA	ARo	8260	Sa11
			Kutse	SA/SS	TMS, LON, AER	ARl, ARo	8520	Sa11
		undulating transverse dune system	Kedia	SA	TMS, LON, AER	LVh	2220	Sa12
		flat to almost flat plain	Makopong	SA	AME, ALU, BSA	ARl, ARo	12130	Sa13
			Mazeamanong	SA	TMS, LON, AER	ARl,ARO	37460	Sa13
			Chobe South	SS/SA	TMS, LON	ARh,ARl,ARo,CLh,LVh	10000	Sa13
			Chobe	ST/SA	PTA, BKP	ARh	760	Sa13
			Kule/Ncojane	SS/SA	TMS, LON, AER	ARo	18520	Sa13
		almost flat to gently undulating longitudinal dune system	West Ngamiland	SA	TMS, LON, AER	ARh, ARo	15340	Sa14
			Tshauxaba	SS/SA	CLM, CO	ARh, ARl, ARo, LVk	2640	Sa14
			Xaoxwe	SA	TMS, BPM, PEA	ARl,ARo	2800	Sa14
		flat to almost flat fossil valley system	Okwa-Quoxo	SS/SA	TMS, LON, AER	ARh,ARl,ARo,CLh, CLp, LPe, LVf, LVk, RGe	24780	Sa15
		almost flat stringed linguoid dune system	Gope	SA	TMS, LON, AER	ARo	6620	Sa16

Land Division	Land Region	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km^2)	Mapping Symbol
		almost flat plain with eroded longitudinal dunes	Lone Tree	SS/SA	TMS, LON, AER	ARl, ARo	22780	Sa17
			South Ngamiland	SA/SS	TMS, LON, AEB	ARh, ARl, ARo	10460	Sa17
			Stoffels pan	SA/SS	TMS, LON, PTA	ARh, ARo	6700	Sa17
		almost flat to gently undulating eroded parabolic dune system	Shorobe	SS/SA	TMS, LON, CO	ARh, Clp, LVh	2380	Sa18
		undulating parabolic dune system with fossil rivers	Deception	SS/SA	TMS, LON, CTA	ARh, ARl, CLl	6760	Sa19
	Aeolian sand deposits	gently undulating to undulating parabolic dune system	Nxai pan north	ST	CLM, CO	ARl, ARo	240	Sa20
		almost flat to gently undulating plain	Chobe	W/SA	PTA, BKP	ARo	3460	Sa21
		gently undulating transverse dune system	SE Ngamiland	SS/SA	TMS, LON, CO	ARh, ARl, ARo	3440	Sa22
		almost flat plain with fossil rivers	Rooibok	SS/SA	TMS, LON, AER	ARh,ARl,ARo,CLh,CLl RGe	7840	Sa23
Sandveld	Superficial aeolian sand deposits on calcrete	flat to almost flat plain	Tshane	SS/SA	TMS, LON, AER	ARo, LPe, RGe	1515	Sc1
	Superficial aeolian sand deposits on sandstone and other sedimentary rocks	almost flat plain	Khakhea	SS	TMS, LON, AER	ARo	150	Ss1
		gently undulating to undulating plain	Mararaleng	SS/GR	AME, ALU, BSA/STU	ARo, RGe	930	Ss2
	Superficial aeolian sand deposits on basalt and sedimentary rocks	flat plain with minor valleys	Dibete	SA	TMS, ATO, AME	ARl, ARo, LVk	3250	Sb1
		flat to gently undulating valleys with associated plains	Lephephe	SA	TMS, ATO, AME	ARl,ARo,LPq,LVf,LVk	4740	Sb2
		flat to gently undulating plain with mixed alluvium	Morupule, Makobela	SA	CLM, ANG, COA	ARl,ARo,CLh,CLp,LPe LPq,LVf,LVx	5960	Sb3
		almost flat to gently undulating plain with occasional valleys	Gatlhaba	SS/SA	TMS,ATO,ZIM	ARl,ARo,CLh,CLp,LPe LVk,LVx,RGe	2720	Sb4
		almost flat plain with hills and	Mokhomma	SS/SA	TMS, ATO, ZIM	ARo, CLp	460	Sb5

Land Division	Land Region	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km^2)	Mapping Symbol
		ridges						
		flat to almost flat plain	Makoba	SA	TMS, LON, AER	CLp	6080*	Sb6
			Letlhakane	SA	CLM, TMP	CLp,LPe,LVk		Sb6
Sandveld	Superficial aeolian sand deposits on dolomite and sedimentary rocks	almost flat to gently undulating plain	Aha	SA	TMS, LON, AER	ARo	440	Sd1
	Partly submerged aeolian sand deposits	almost flat plain with major pans	Ngwezumba	SA/W	CLM, TMS, COI	ARh,ARo,LVf,LVh	1200	Sm1
		almost flat to gently undulating longitudinal dune system	Betsha	SA	CLM, TMS, LON	ARh,ARl,ARo	4240	Sm2
Hardveld	Amphibole - rich meta-basic rocks	undulating plain with occasional hill ranges	Francistown	SA	CLM, ANG, COI	LVx,Rgc,VRe	800	Ha1
		gently undulating plain	Chizwina	SA	CLM, ANG, COI	LVx,VRe	440	Ha2
	Basalt	dissected undulating plateau	Bobonong	SS/SA	CLM, ANG, COA	LVh,LVk,RGc,RGe	3020	Hb1
		escarpments with associated undulating plains	Serowe	SA	CLM, ANG, COA	RGe	280	Hb2
		gently undulating plain	Pandamatenga	SA	CLM, ANG, COI	RGe	200	Hb4
		almost flat plain with associated alluvium	Saasane	SA	CLM, ANG, COI	ARl,CLh,LPe,LVf,LVx	1200	Hb5
			Serowe	SA	CLM, ANG, COA	LVk,LVx,VRe	420	Hb5
	Sandstone	dissected undulating plateau with escarpments	Point Drift	SA/ST	CLM, ANG, COA	CLp,LVk,RGe	730	Hs1
		undulating plain with isolated	Mokoro	SA	CLM, ANG, COA	ACh,ARl,LPq,LVx,LXf	1120	Hs2
		hills and flat alluvium	Bonwapitse	SA	COA, ANG, ATO	ARl,LPq,LVf,LVx	800	Hs2
		gently undulating to undulating plain with flat alluvium	Kudumatse	SA	COA, ANG, ATO	ARl,LVf,LVk	1040	Hs3
		almost flat to gently undulating plain with occasional kopjes and fossil valleys	Malotwana	SS/SA	PEA, ATO, TMS	ACh,ARl,ARo,LVf,LVk LVx,LXf	5320	Hs4
		hills with transitional undulating to hilly escarpments	Mochudi - Molepolole	SA	PEA, ATO, TMS	LPq	460	Hs5
		flat to gently undulating plain	Sese	SA	CLM, ANG, COA	CMc,LVh,LVx,LXh	1700	Hs6

Land Division	Land Region	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km^2)	Mapping Symbol
		flat to almost flat plain	Dukwe	SA	CLM, ANG, COI	CLh,LPe,LVk,LVx,RGc	1260	Hs7
		flat to almost flat ridge with escarpments	Ghanzi	SS/SA	AME, TMP, CTA	ARh,ARl,ARo,CLh,LPe LPk,LPq	9920	Hs8
		gently undulating to undulating plain with eroded valleys	Selebi-Phikwe	SA	CLM, ANG, COA	LPq,LVh,LVx,LXf, LXh, RGd,RGe	13270	Hg1
		dissected undulating plain with associated pediments	Tewane	SA	COA, ANG, ATO	LVh,LVx,PLe,RGe	1280	Hg2
		flat to gently undulating pediments	Mahalapye	SA/ST	COA, ANG, ATO	LVf,LVh	640	Hg3
		almost flat to gently undulating plain with eroded valleys	Shakwe	SA	COA, ANG, ATO	ARo,LVx,LXf,LXh,RGe	4360	Hg4
	Granitic greiss	undulating to rolling plain with frequent kopjes and almost flat pediments	Maope	SA	CLM, ANG, COA	LVh,LXh	1350	Hg6
Hardveld		rugged hilly areas	Ramokgwebana	ST	CLM, ANG, BUA	CMo,LVx,LXh,RGd,RGe	1480	Hg7
		gently undulating plain with occasional kopjes	Shashe	ST	CLM, ANG, BUA	LVg,LVx,RGd,RGe	10400	Hg8
		flat to almost flat plain	Matsitama	ST	CLM, ANG, COI	CMc,CMo,LVf,LVk,LVx RGd,RGe	5240	Hg9
		almost flat to gently undulating plain	Olifants Drift	SA	AEB, ATO, BSA	LVk,LVx,LXf,LXh	800	Hg10
		gently undulating valleys with almost flat pediments	Ramotswa	SS/SA	PEA, ATO, AKA	RGe	660	Hg11
		gently undulating plain with fossil valleys	Mmathethe	SS/SA	PEA, ATO, AKA	ARo,CLl,LPq,LVh,LVk LXh,RGc,RGe,VRe	3920	Hg12
	Dolerite	hills with flat alluvium and almost flat pediments	Shoshong	SS	COA, ANG, ATO	LPq,LVk,LVx	1560	Hd1
		almost flat to gently undulating pediments	Mahetwe	SS/SA	PEA, ATO, TMS	LVf,LVk,VRe	680	Hd2
	Dolomite and sedimentary rocks	hills with associated almost flat to gently undulating pediments	Aha	SA	TMS, LON, AER	CLp,LPq	200	Hn1
	Acid volcanic lavas	hills with undulating pediments	Kanye	SA/SS	PEA, ATO, ZIM	LPq,LVg,LXf,RGe	1620	Hv1

Land Division	Land Region	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km²)	Mapping Symbol
	Granite	almost flat to gently undulating plain with kopjes and associated pediments	Gaborone	SS/SA	PEA, ATO, TMS	ARo,LPq,LVx,LXf, LXh,RGe	3660	Hi1
		undulating plain with occasional kopjes	Magotlhwane	SS/SA	PEA, ATO, ZIM	ACh,LXh	560	Hi2
	Sedimentary rocks	hilly dissected plateau with pediments and associated alluvium	Palapye	SA/ST	CLM, ANG, COA	LPq,LVf,LVg,LVh LVk,LVx,LXf	3800	Hc1
Lacustrine system	Major lake and depression deposits	flat salt pans liable to flooding	Sowa-Ntwetwe pan	GR	ODP	FLe,SCg,SCh	8670	L11
		flat to almost flat plain with major pans	Maditsenyane	GR/SA	ODP/CLM, TMP, HYP	ARc,ARh,CLh,CLp,LPe LPk,LVk,RGe	5620	L12
		flat to almost flat lake depression with associated shorelines and plains	Lake Ngami shore	FL	SB, ASF	CLh	1700*	L14
			Lake Ngami flats	SS/ST	TMS, LON, AER	ARh,GLk		L14
		almost flat fossil lagoon	Sunday pans-West Mababe	SA/SS	TMS, LON, AER	ARh,CLh,CLp,LPe,LVh	8780	L15
		flat to almost plain with associated shorelines	Chobe enclave	GR/SA	CHG, SES/HYP, LOC, PHR	CLh,GLk,GLm	440	L17
			Mababe depression	SS/W	CLM, ATO	ARh,CHk,GLm,LVg,LVh LVk	2720	L17
		flat to almost flat plain with associated shorelines and major pans	Tsigara	GR	ODP	ARh,CLp,GLk,LPe,RGe	19290*	L18
			Nata-Odiakwe	SS	CLM, TMS, COI	ARh,CLh,CLp,LPe,LPq,LVk		L18
			Gweta	SS/SA	CLM, HYP,ADD	ARh,ARc,CHl,CLh,CLp,LPe LPq,LVk		L18
			Bushmenpits-Rakops	SS/SA	TMS, LON, AER	ARh,CLh,CLp,LPe,LVh		L18
	Superficial lacustrine deposits on sandstone	flat to almost flat plain	Mhatane	SS	CLM, TMS, SCC	CLh,CMc,GLk,LPe	2680	Ls1
	Vlei deposits	flat plain	Pandamatenga	GR/ST	HPF, SES/CLM, ANL	ARo,GLk,LVf,LVg,LVk LPe,VRe	2240	Lv1
Alluvial system	Recent Alluvial deposits	flat to almost flat river floodplain	Limpopo	SS/ST	ATO, COE, LOC,	CMc,CMv,LVk	760	Ar1
			Boteti	S/SS/SA	PHA/ATO, AER, TMP	ARh,CLp,FLc,FLe,SCh SNh	2160	Ar1
			Linyanti - Chobe	GR/SA/W	CND, PAM/COI, AER, CLM	ARg,ARh,GLm,LVk	1200	Ar1

Land Division	Land Region	Land System	Location	Vegetation structure	Vegetation dominant species	Soils	Extent (km^2)	Mapping Symbol
		flat to almost flat fan	Puongwe	SA/ST	CLM, TMS, COI	CMc,CMv,LVk,VRe	1760	Ar2
Alluvial system			Mababe	GR/SA	CND, CEC/ATO, COI	ARh,GLe,LVh	560	Ar2
	Recent alluvial deposits	flat fan with sand ridges	Maitengwe	SA	CLM, TMS, DRC	ARh,ARl,ARo,CLh,CMo GLk,LVg,LVx,VRe	4240	Ar3
		almost flat depression	Modipane	SS/SA	AEB, ATO, BSA	VRe	320	Ar4
		alluvial flats	Dikabeya	SA	CLM,TMS,SCC	LVk,LXf	440	Ar5
		flat to almost flat delta floodplain	Okavango delta	GR/SA/W	IMC, SES/HYP, GAL, LOC	ARg,ARh,FLe,GLe, LVg, LVk,PHg	11840	Ar6
		flat perennial swamps	Okavango delta	S/SA/W	CPP, MIJ/HYP, GAL, PXR		6250	Ar7
	Fossil alluvial deposits	almost flat to gently undulating delta floodplain	North Ngamiland	SA/W	CLM, TMS, LON	ARh,LVh,LVk	11760	Af1
		flat to almost flat delta	West Ngamiland	SA	TMS, LON, AER	ARh,LVh	16440*	Af2
		floodplain	Etsha - Toteng	W	COI, AER, CLM	ARh,LVg,LVh,LVk,PHg		Af2
		flat to almost flat river floodplain	Shakawe	SA	TMS, LON, BPM	ARh	420	Af3

* the extent of the entire land system

APPENDIX 2

Codes used in the Land Systems Map of Botswana

Vegetation species codes

Trees and shrubs

ADD	Adansonia digitata
AER	Acacia erioloba
AEB	Acacia erubescens
AHA	Acacia haematoxylon
AKA	Acacia karroo
ALU	Acacia luederitzii
AME	Acacia mellifera
ANG	Acacia nigrescens
ANL	Acacia nilotica
ATO	Acacia tortilis
BKP	Baikiaea plurijuga
BPM	Baphia massaiensis
BSA	Boscia albitrunca
BUA	Burkea africana
CTA	Catophractes alexandri
CLM	Colophospermum mopane
CO	Combretum spp.
COA	Combretum apiculatum
COI	Combretum imberbe
DRC	Dichrostachys cinerea
GAL	Garcinia livingstonei
HYP	Hyphaene petersiana
LOC	Lonchocarpus capassa
LON	Lonchocarpus nelsii
PEA	Peltophorum africanum
PXR	Phoenix redinata
PHR	Phyllanthus reticulatus
PTA	Pterocarpus angolensis
RGT	Rhigozum trichotomum
RHT	Rhus tenuinervis
SCC	Sclerocarya caffra
TMP	Terminalia prunioides
TMS	Terminalia sericea
ZIM	Ziziphus mucronata

Grasses and sedges

CEC	Cenchrus ciliaris
CHG	Chloris gayana
CND	Cynodon dactylon
CPP	Cyperus papyrus
HPF	Hyparrhenia filipendula
IMC	Imperata cylindrica
MIJ	Miscanthus junceus
ODP	Odyssea paucinervis
PAM	Panicum maximum
PHA	Phragmites australis
SES	Setaria sphacelata
STU	Stipagrostis uniplumis

Forbs

ASF	Asclepia fruticosa
SB	Sesbania spp.

Vegetation structure codes

S	Swamp
GR	Grassland
FL	Forbland
SS	Shrub savanna
SA	Savanna
ST	Tree savanna

Soil unit codes

ACh	Haplic Acrisol
ARc	Calcaric Arenosol
ARg	Gleyic Arenosol
ARh	Haplic Arenosol
ARl	Luvic Arenosol
ARo	Ferralic Arenosol
CHk	Calcic Chernozem
CHl	Luvic Chernozem
CLh	Haplic Calcisol
CLl	Luvic Calcisol
CLp	Petric Calcisol
CMc	Calcaric Cambisol
CMo	Ferralic Cambisol
CMv	Vertic Cambisol
CMx	Chromic Cambisol
FLc	Calcaric Fluvisol
FLe	Eutric Fluvisol
GLe	Eutric Gleysol
GLk	Calcic Gleysol
GLm	Mollic Gleysol
LPe	Eutric Leptosol
LPk	Rendzic Leptosol
LPq	Lithic Leptosol
LVf	Ferric Luvisol
LVg	Gleyic Luvisol
LVh	Haplic Luvisol
LVk	Calcic Luvisol
LVx	Chromic Luvisol
LXf	Ferric Lixisol
LXh	Haplic Lixisol
PHg	Gleyic Phaeozem
PHl	Luvic Phaeozem
PLe	Eutric Planosol
RGc	Calcaric Regosol
RGd	Dystric Regosol
RGe	Eutric Regosol
SC	Gleyic Solonchak
SCh	Haplic Solonchak
SNh	Haplic Solonetz
VRe	Eutric Vertisol