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Sustainable development in Botswana

an analysis of resource management in three communal development areas

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3 RESOURCE POTENTIAL OF THE THREE COMMUNAL FIRST DEVELOPMENT AREAS

3.1 Introduction

The resource base of a given area can be assessed by using a multitude of physical and socio-economic parameters depending on the production sector under consideration. The physical resource base is normally characterised in terms of landscape ecological or environmental elements like climate, relief, soils and hydrology. These elements, together with their interrelationships are closely associated with the success of the major kinds of land use practised in the communal areas (i.e. rainfed arable farming, extensive grazing). The success is either measured in terms of economic yield or more generally expressed in terms of biomass production. Apart from socio-economic factors, the production of biomass depends on a very complex set of interacting environmental variables which can be grouped into three classes:

- prevailing radiation and temperature regime;
- volume of plant available moisture and the time over which it is available; and
- available nutrients.

Estimates of productivity under given environmental conditions can thus be used to assess the natural resource base for a number of actual or intended kinds of land use. Available procedures for estimation of productivity are known as *land evaluation.* The principles of land evaluation which have been widely accepted are described in the "Framework for Land Evaluation" (FAO, 1976). They allow for assessments at various geographical scales, both in qualitative and quantitative terms. Background information on land evaluation procedures is given in Annex I.

3.2 The resource potential of the Chobe CFDA

Climate

In general terms, the Chobe Enclave is characterised by a semi-arid to sub-humid climate with a mean annual temperature of 30°C and an evaporation of some 2300 mm. Most of the mean annual 650 mm of rain falls in the months of October to March/April. Rainfall exceeds the potential evapotranspiration in January.
However, there is little information of the required detail and reliability. Rainfall records cover a rather short period with a relatively large proportion of dry years and are far from complete. Additional climatological information required to determine the growing period (especially potential evapotranspiration (PET) are recorded only in Kasane as from 1983. Jansen and Riezebos (1990) argue that the Kasane records may be considered representative of the Chobe Enclave (table 3.1).
The mean monthly maximum and minimum temperatures for Kasane are given in table 3.1. Lowest maximum and minimum temperatures occur in July. Highest maximum temperatures are in October, which is just before the beginning of the rainy

season. With a lowest mean minimum temperature of 11.2°C, occurrence of night frost is rather unlikely.
The mean monthly relative humidity falls to a minimum in the months of August and September.

Table 3.1 Summary of climatic data for Kasane

	Tma	Tmin	Rhu	Solr	Wspd	Vpd	PET	P
Jan	31.0	20.0	65.2	9.2	1.24	25.3	187.9	161.4
Feb	31.1	19.3	66.8	9.6	1.39	8.0	185.0	136.0
Mar	31.3	19.2	63.6	8.5	1.44	11.7	224.1	96.1
Apr	30.0	17.3	57.4	8.6	1.66	12.5	203.2	24.9
May	28.9	15.1	47.0	7.7	2.00	14.1	157.9	3.7
Jun	26.8	11.7	42.1	7.0	1.87	10.4	136.0	1.5
Jul	26.3	11.2	38.2	7.4	2.11	13.4	145.4	0.0
Aug	28.6	13.0	31.4	8.6	2.30	16.9	183.5	0.2
Sep	33.5	17.3	26.9	9.8	2.50	23.9	224.5	1.6
Oct	33.6	20.2	36.6	9.4	2.33	22.6	278.9	21.3
Nov	32.7	20.2	49.4	9.3	1.66	12.7	211.3	70.5
Dec	31.5	20.0	63.1	8.8	1.47	12.3	195.1	150.5
Year	30.4	17.0	49.0	8.7	1.83	15.3	2332.8	667.7

Source: Balothra, 1987
Tmax = Mean maximum temperature (°Celsius)
Tmin = Mean minimum temperature (°Celsius)
Rhum = Relative humidity (%)
Solr = Solar radiation
Wspd = Wind speed (m/s)
Vpd = Vapour pressure deficit (saturated minus actual vapour pressure)
PET = Potential evapotranspiration (mm)
P = Mean monthly Precipitation (1922-86) (mm)

The quantity of solar radiation is determined by day length, angle of incoming radiation and cloud cover. Despite the higher cloud coverage during summer, the incoming radiation is maximal during this period (table 3.1).
The long term average annual rainfall (1922-1986) is 667.7 mm with a standard deviation of 204.6 mm. The maximal depth of rain ever recorded was 1407 mm during the 1958-1959 season. The lowest annual precipitation was recorded in 1982-1983 (298.7 mm). For the three months period from December to February which covers the growing season, rainfall amounts varied from 1174 mm to only 150 mm. These data allow for the conclusion that rainfall in the Chobe Enclave is rather erratic.
The Penman potential evapotranspiration rates, required for the assessment of the growing period, are based on the results of only four years of recording and are therefore of limited value. The calculated PET in table 3.1 exceeds the mean monthly

rainfall in all months. Using long-term records a slightly more favourable situation comes up where rainfall exceeds PET in January. It must be realised however that the PET is strongly influenced by rainfall. As such the PET may be considered erratic as well.

The length of the growing period is influenced by temperatures which are of some constraint for crop growth during the rainy season in the Enclave. Hence, the length of the growing season can be defined as the average duration of the period over which the mean rainfall is higher than half of the mean potential evapotranspiration. The difference between rainfall and PET provides a first approximation of the deficit, or surplus, of plant available water. Deficits may result in water stress and reduction of yields. "Mean rainfall", however, is a rather theoretical concept in Botswana. A season with average rainfall occurs rarely because the inter-annual variability of rainfall is high. As an indication of the variability the standard deviation can be expressed as a percentage of the mean, yielding the "coefficient of variation" (CV). The higher this CV, the more likely it is that large differences occur between the actual rainfall during a season and the long-term average rainfall.

Table 3.2 Mean rainfall (P in mm) with coefficient of variation (CV) and mean evapotranspiration (PET in mm) for Kasane (period: 64 years)

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Yr
P	1.6	21.3	70.5	150.5	161.4	136.0	96.1	24.9	3.7	667.7
CV (%)	345	106	56	54	63	75	81	175	270	30
PET	170	191	185	166	158	145	152	138	117	1767

Source: Vossen, 1987

Table 3.3 Agro-ecological parameters for Kasane

	Growing season			Humid period			Dry period
	length (d)	start	end	length (d)	start	end	(d)
average (days)	118	25/11	23/03	52	28/12	24/02	15
CV (%)	31	14	11	55	14	14	137
50% (median)	121	25/11	27/03	45	14/01	27/01	8
25% (lower quartile)	88	05/12	04/03	29	20/12	26/02	22

Source: Vossen, 1987

The rainfall and evapotranspiration data in table 3.2 and the data from table 3.3 indicate that the length of the growing season is more than 121 days in one out of two years, and less than 88 days in only one out of four years. On average the season

lasts from the end of November 25th to the end of March. There is an extended humid period in January-February with a 95% chance of occurrence of rain.
A 'normal' growing season must include at least one 10-day humid period, defined as a period in which rainfall exceeds PET. Drought during the growing season can also be described using the concept of "dry period". The duration of a "dry period" is defined as the number of consecutive days with less than 2 mm of rainfall.

Physiography
Based on differences in origin and actual processes, four major physiographic units have been distinguished (fig. 3.1), each having its specific soil types:

- The escarpment with the sandveld area (soil type R).
  The soils developed on basalts are medium-textured and contain gravel. They are moderately fertile but have a limited depth. The soils on the Kalahari sands are deep, sandy and have low natural fertility.
- The colluvial zone (soil type C).
  The soils here have, in general, the same characteristics as on the Kalahari sands on the escarpment but they are deeper and more compact. However, the presence of calcrete layers restricts the rooting depth. (soil units R and C)
- The Chobe flats (soil type CF).
  The soils in the Chobe flats vary with topography. Soils in channels and depressions are medium to heavy textured and have a high organic matter content in the topsoil. Soils in higher positions are light textured and often have a calcic horizon.
- The Chobe and Linyanti floodplains (soil type F).
  The soils in the floodplain vary from sand to clay, depending mainly on the physiographical position. The regularly flooded soils have a high organic matter content and a heavy textured topsoil. The less frequently flooded soils often are light to medium textured with a argillic and/or calcic horizon. Due to the capillary rise of groundwater, salt accumulation may occur as well. The beach ridges, well above flood levels, have sandy soils.

In view of their extension the soils in the Chobe Flats (CF) and the Floodplains (F) are most important.

The hydrology of the Chobe Enclave is a crucial factor in the natural resources potential of the area. In a wet year, large parts of the Floodplains may be flooded thereby restricting the possibilities for arable farming and cattle grazing to higher parts of the area. In the other extreme case, the whole floodplain may be dry after successive drought years and crop production may be low due to lack of water. The hydrology of the area is fairly complicated. The Chobe Enclave is drained by one river, the Chobe, but may receive water from several other open water resources among which the Kwando-Linyanti river system and the Zambezi river. As various sources contribute to the surface water availability in the Enclave, there is a high variation in water levels in relation to the discharge quantities of the various rivers. The most important consequence of the variation in river discharge is the occurrence

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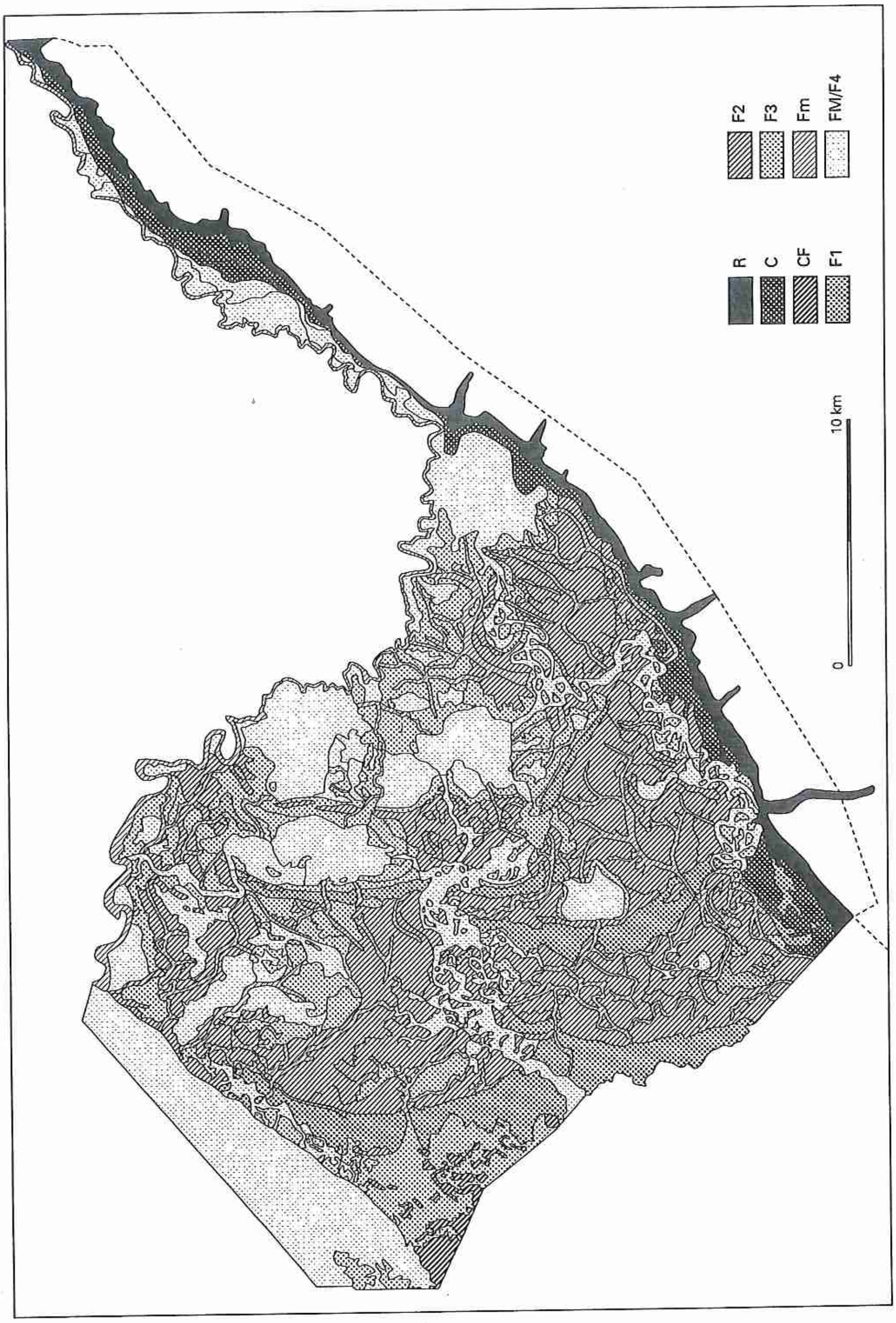


Figure 3.1 Major division of the land units.

of floods. Local people indicate a ten year cycle of high floods but no reliable data is available regarding the extent or the frequency of these floods. If high groundwater levels occur flooding may also be caused by heavy rainfall in the Enclave and adjacent areas during the rainy season (December to March); this in contrast to floods caused by river water which reach maximum levels in April. The backflow of the Zambezi causes a relatively reliable yearly flood east of Kavimba. This is the only part in the Chobe Enclave where so-called molapo farming is practised annually. Molapo farming is an arable farming system in which stored soil moisture is used for crop water requirements after flood recession.

Recognising the importance of these dynamics in relation to agricultural land use a further subdivision of especially the Floodplain soils was necessary. This led to the distinction of:

F1: Soils in the floodplain, high enough to be clear of floods in all years. These soils are mainly situated on the beach ridges and are further characterized by a tree and shrub vegetation.

F2: Soils in the floodplain situated on the intermediate areas. These soils are only flooded during short periods of extreme flooding (e.g. 1 out of 10 years). High groundwater tables result in the accumulation of salts and or carbonates through the process of capillary rise.

F3: Soils in the floodplain low enough to be liable to longer periods of flooding (e.g. 1 out of 4 to 5 years) or high groundwater tables. Most of these soils have a topsoil with a high organic matter content.

F4: Soils in the floodplain in low and very low positions, which are liable to long periods of flooding and are very susceptible to ponding. These soils are very rich in organic matter and lack accumulation of carbonates and salts.

FM: Soils situated in the larger depressions and in the lower parts of the major molapo channels. These soils are subject to ponding after intensive rainfall.

Fm: Soils situated in the small channels all over the Floodplain. As these units are small but elongated the influence of concentrated run-off differs widely. This results in large differences in the water budget. An excess of water in the lower parts is accompanied with a shortage along the edges. The lower part in the middle of the channel is highly organic in contrast with the adjacent edges. The temporarily high groundwater table may result in salt and carbonate enrichment at the surface.

Land suitability assessment for arable farming
As temporal variations in moisture condition largely determine the farming patterns in the Enclave the land suitability assessment for arable agriculture has to include the flood regime of the area. The land evaluation as described in Annex I was therefore

extended to include three different flood scenarios in an attempt to include the dynamics of the area into the land evaluation procedure.

The occurrence of floods is of great importance to the suitability of the area for arable farming. Flooding has three effects on crop production:

1. floods can be advantageous as supplementary water supply in areas where rainfall is not sufficient for crop growth;
2. adversely, the area available for arable farming is reduced; and
3. standing crops may be damaged due to an excess of water.

As the flood regimes in the Enclave are unpredictable and too dynamic to be intrinsically incorporated in a land evaluation through flood ratings, the land evaluation procedure was adjusted to include the flood dynamics by reflecting them in three scenarios: dry, flood and intermediate. The scenarios depict situations with (1) no flood at all, (2) a high flood, and (3) an intermediate receding flood.
Land suitability maps are presented for the dry and flood scenario only.

(1) The dry scenario comprises a year and growing season with no flood at all. Surface water is limited to the eastern part of the Chobe river channel and to some isolated low spots further to the west in the same main channel. Furthermore, a small number of pools exist in small depressions (pans) all over the floodplain. Groundwater levels vary between one meter below surface in the lower areas during the rainy season, to four meter on higher places at the end of the dry season.
Even in this scenario oxygen availability is a common restrictive factor for arable farming in the floodplain. This may be attributed to the fact that soils in the lowest areas have heavy-textured topsoils with low infiltration rates, implying a high risk of waterlogging after heavy rainfall. Furthermore, soils on intermediate levels in the floodplain commonly have a heavy-textured, low permeability horizon in the subsoil; the internal drainage of these soils is poor and may consequently cause oxygen deficiency in the root zone. Given sufficient well distributed rainfall, high yields can be expected from the low lying molapo soils because of their good moisture retention characteristics (supplemented with capillary moisture) and high natural fertility. Results of the land suitability assessment for a variety of crops are presented in figures 3.2 - 3.3.

(2) The flood scenario is based on a high flood water level corresponding with a level of 930.0 meters above sea level. This level coincides with the altitude of the higher parts in the intermediately high areas of the Floodplain which are only flooded during short periods of extreme flooding. The highest water level occurs around the beginning of June which implies that by the start of the growing season, the water level is lowered by 5 months of evaporation and by some surface drainage through the Chobe river. Estimates yield a drop of the water level of roughly 90 cm. Taking account of the topographical position of the various land units in relation to the water level the land suitability for maize and sorghum was rated. Results are presented in figures 3.4 - 3.5.

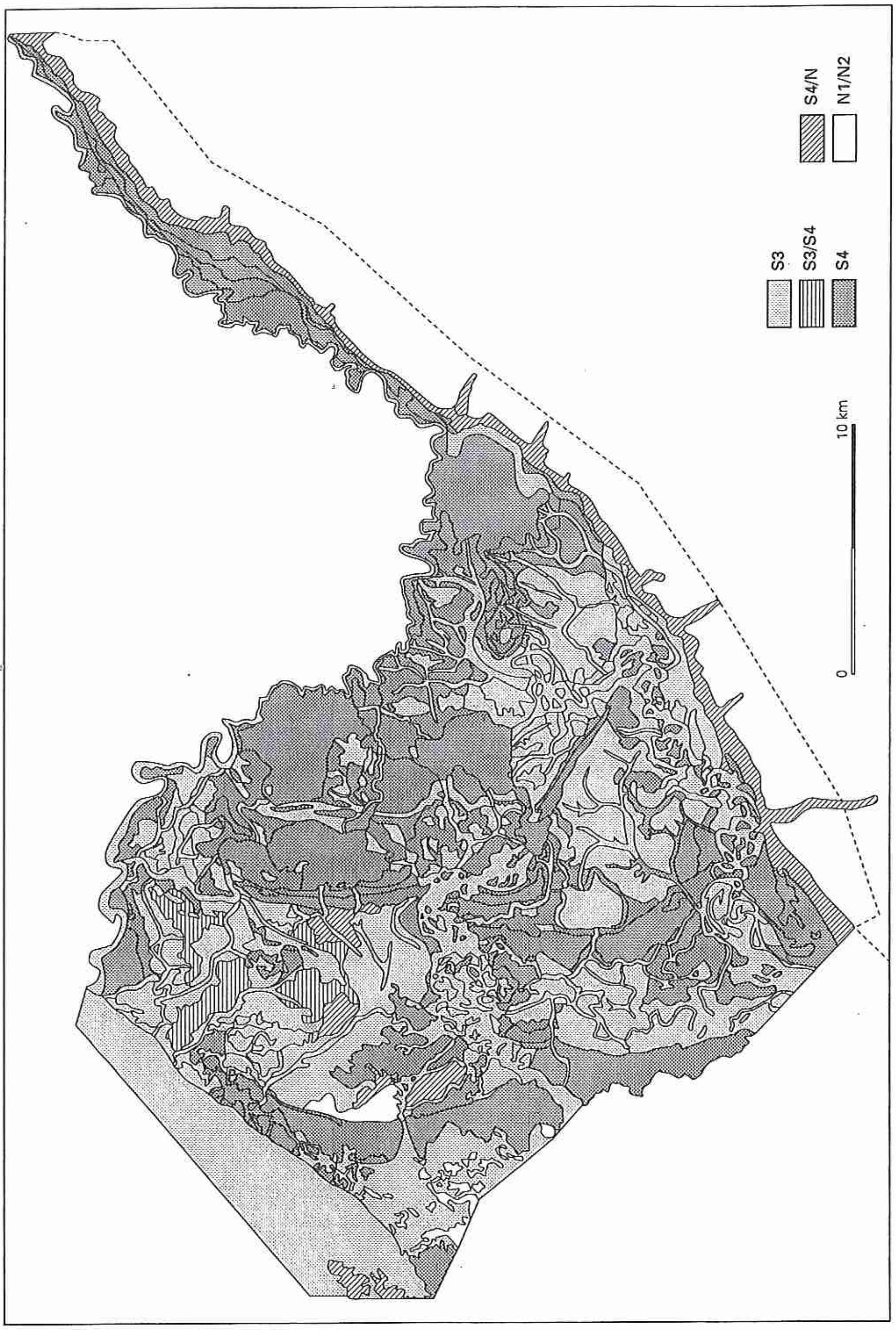


Figure 3.2 Suitability for maize (dry scenario).

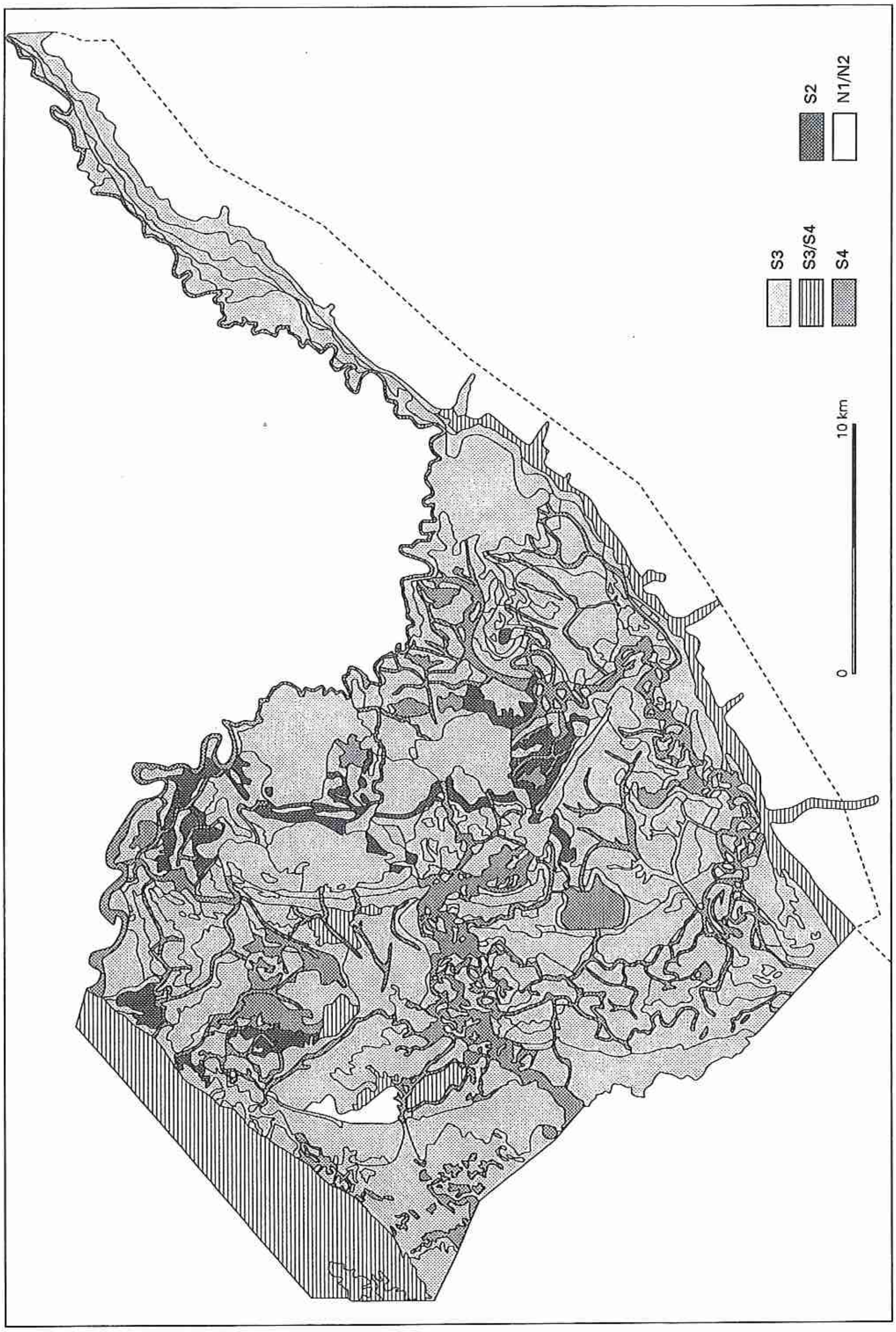


Figure 3.3 Suitability for sorghum (dry scenario).

(3) The intermediate scenario represents the situation a few years after a flood when most of the water would be evaporated. Due to evapotranspiration and precipitation the mean nett lowering of the water level is estimated to be 1.7 m per year. The overall effect is that, two to three years after a high flood, the lowest parts of FM and Fm units (section 3.2.2) are still inundated or at least very wet. The higher parts of these Floodplain units are above the surface water level and may have groundwater levels of roughly between 50 and 100 cm below soil surface. Water availability from rainfall is supplemented by capillary rise in these parts but in more low lying areas oxygen availability is limited.

Summarising the results of the land suitability assessment for three scenarios, it may be concluded that in the dry scenario some soils in the lower floodplain areas have the most favourable conditions for the growth of maize, be it a suitability class of only S3 (marginally suitable) or S4 (very marginally). The major constraint is moisture availability or lack of drainage. The same soils are more suitable for sorghum (S3 or even S2), because of their better resistance to drought.
In the flood scenario the area best suitable for the production of maize (although not better than S3) is found in the highest land units of the Floodplain and in the higher, well drained terraces of the Chobe Flats. The same units have a similar suitability for sorghum, but in addition, other units also have a S3 suitability rating (some R and C units).

Table 3.4 Area distribution (ha) for different crops per suitability class in the Chobe CFDA

crops:	S2	S2/S3	S3	S3/S4	S3/N	S4	S4/N	N1/N2
dry scenario:								
maize	-	-	3256	1186	-	50972	3408	623
sorghum	2182	1186	52045	2476	932	356	-	268
millet	2387	1186	46163	5797	932	2710	-	268
groundnut	2364	1186	44375	5797	932	4498	-	268
sunflower	2270	1186	51958	2476	932	356	-	268
cotton	-	-	5630	11230	-	39771	2547	268
pumpkin	-	-	15400	8429	1793	17853	7520	6267
beans	-	-	15400	8429	1793	17853	7520	6267
intermediate scenario:								
maize	-	-	4	-	-	12363	10385	36693
sorghum	-	-	12363	10314	932	10858	10538	14435
flood scenario:								
maize	-	-	5332	-	-	1282	2547	50284
sorghum	-	-	6614	1610	932	942	9222	40121

Source: Utrecht University, CFDA field survey 1988

In the intermediate scenario best opportunities for growing maize (S3) are found in the intermediately high areas of the Fm unit where the suitability for sorghum is moderate (S2). A very marginal suitability (S4) for maize can be found in R units in the sandveld area, in some C units in the Chobe flats, and in some of the Fm areas. In all of these units the suitability for sorghum production is one class better (S3). A summary of the suitabilities for various crops in relation to the area distribution (in ha) is given in table 3.4.

Land suitability for livestock farming

In relation to the physiography of the CFDA (fig. 3.1) three classes of grassland may be distinguished in the Chobe enclave:

- the grasses in the Floodplain and in the depressions of the Chobe Flats (soil units F and CF)
- the grasses on the colluvial slopes and on the higher parts of the Chobe Flats (soil units C and parts of CF)
- the grasses in the Forest reserve on Kalahari sands (soil unit R).

The first type of area (soil units F and CF) reflects a dynamic environment in terms of hydrology and varies from aquatic grasslands, with reeds and species well adapted to swampy environments. In the same area also species occur which are mostly classified as sweet veld, with grasses which remain palatable in the dry season and do not loose all of their nutritional value. The second class of grassland (soil units C and parts of CF) belongs entirely to the sweetveld. The last class (soil unit R) is covered by sour veld with tall coarse grasses and only few favourable smaller grasses in between. The tall grasses are unpalatable and have a low nutritional value.

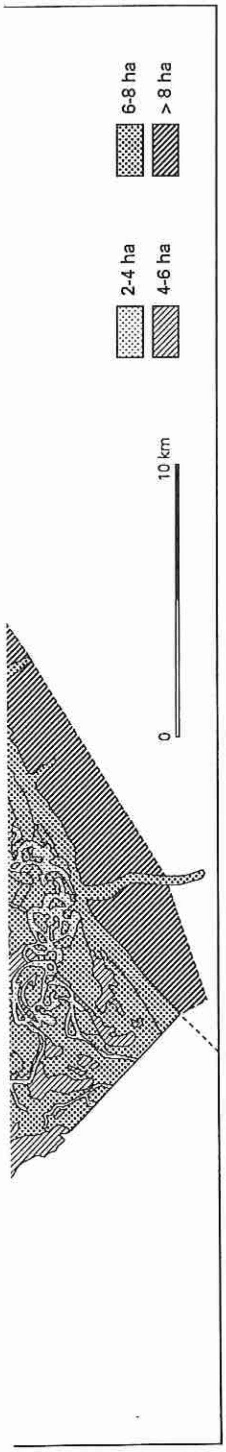
The most important grass species in the Chobe enclave have been divided into 'good', 'intermediate' and 'poor' (Hendzel, 1981), indicating the grazing capacity and rangeland condition.

- The good species are Setaria sphacelata, Panicum coloratum, Cynodon dactylon Chloris gayana and Digitaria species.
- The intermediate species are Eragrostis species, which belong to the so called 'increasers': with increasing grazing pressure their abundance increases too (Field,1976). Their presence is a first sign of disturbance of the ecosystem.
- The poor species comprise Aristida congesta, Pogonarthria squarrosa: both indicating overgrazing (Field, 1976), and still undetermined species locally known as Umbwe grass and in the following referred to as Umbwe.

The potential grazing capacities (PGC) of different units expressed in standard livestock unit (ha/LSU) is presented in the map of figure 3.6.

Generally the PGC varies in the Chobe Flats between 2 ha/LSU and 4 ha/LSU; on the colluvial slopes PGC is 5.4 ± 1.3 ha/LSU and in the forest reserve 15.7 ± 4.3 ha/LSU. A Livestock Unit (LSU) equals one mature animal (tollies/heifers are 0.7 and calves 0.5 LSU).

Figure 3.6 Potential grazing capacity.



The actual grazing capacity has been determined by sampling of sites which were considered representative for the actual state of the rangeland.
In former river channels and the lowest depressions the actual grazing capacity is only slightly different from the potential grazing capacity of roughly 3 ha/LSU. The higher, more sandy units show more difference between potential and actual grazing capacity. In the higher F units (with a potential of $\pm$ 6.0 ha/LSU) the actual capacity was determined as 34 ha/LSU or 27.8 ha/CLSU on a formerly overgrazed area with dominant species Pogonarthria squarrosa and Aristida congesta. Even after four years of abandonment rangeland conditions on these sandy units near the abandoned settlements of Huhuwe and Nchenje have still not recovered from heavy grazing. Apart from a change in species composition by selective grazing of the good and intermediate species, which occurs on every soil type, the roots of the grasses are damaged by trampling. This causes a drop in the amount of perennial grasses in favour of the annuals which are generally worse. The regeneration on sandy soils is slow; the natural fertility is poor and the addition of nutrients, especially nitrogen by rainfall is limited, because the majority of the rainwater percolates to the groundwater without interception by roots. Furthermore water availability in sandy soils is low.
Other areas with large differences between potential and actual grazing capacity are the soil units between Satau and Parakarungu. The Umbwe is limited to areas with high groundwater tables and a sandy subsoil. As Umbwe is not consumed by cattle it causes increased grazing on more palatable species in units which are partly covered by Umbwe grass. The major part of the good and intermediate species in these units are grazed to the ground before they reach the reproductive stage which causes the decrease of desirable species in favour of the unwanted Umbwe. The actual grazing capacity in these units varies from 10.0 ha/LSU on relatively undisturbed places to 100 ha/LSU near cattle treks. Cattle density between Satau and Parakarungu is about one LSU per two ha, which implies a grazing pressure of at least five times the actual grazing capacity.
Very close to Satau and Parakarungu on some of the intermediately high F units with a potential of roughly 6.5 ha/LSU, the grass cover has disappeared leaving a completely bare soil. Grass cover increases with distance to these villages but overgrazing remains visible in a low grass coverage associated with invasion of weeds and shrubs over several kilometers. Heavy trampling has compacted the topsoil considerably, making regeneration of grasses extremely difficult as seeds have no ability to enter the soil. Grazing capacity could not be determined because of the lack of fullgrown grass.
Generally, rangeland conditions in the northern area are often worse than in the southern part of the enclave. All over the northern area many poor species were found on higher parts of the intermediate level units indicating some grazing pressure. The Chobe flats have very good grasslands with a wide variety in grass species, except for a small area around the cattle post Mahozu where the frequency of poor and intermediate species increases. Actual grazing capacities equal the potential grazing capacities from 2 to 3.5 ha/LSU.
In the area west of Kachikau (near Kataba) grasslands are very good with a wide range in species' composition with roughly the same grazing capacity. Rangeland

conditions in the southern area are generally good, except for the areas near the villages of Mabele and Muchenje where the available grazing area is extremely limited by the proximity of the Chobe river and by the presence of arable fields near the settlements.

3.3 The resource potential of the North East District CFDA

Climate

The climate of the North East District CFDA is characterised by the conditions recorded at Francistown and Tshesebe.

The mean monthly maximum and minimum temperatures, potential evapotranspiration and rainfall for Francistown are given in table 3.5. The lowest maximum temperature occurs in June, while the lowest minimum is in July. Highest maximum temperatures are in October and November, just before the beginning of the rainy season. As in the Chobe CFDA, temperature is not a constraint when considering traditional dryland farming. However, for irrigated agriculture night frost, occurring in the winter months (average: 3.3 days), may be a serious threat. Many crops can not stand any frost at all and need special protection.

The PET exceeds rainfall for all months. Rainfall falls short of the evaporative demand (PET). This means that crops which are grown under dryland conditions suffer from waterstress most of the time, resulting in low yield figures.

Table 3.5 Mean monthly maximum and minimum temperature (°C), potential evapotranspiration (PET) and rainfall (P) for Francistown

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max.	31.2	30.1	29.6	27.8	25.9	23.0	23.1	26.1	29.8	31.3	31.3	30.4
min.	18.9	18.3	16.9	13.6	8.4	5.2	4.8	7.9	12.3	16.2	17.7	18.4
PET(mm)	184	157	158	126	107	85	65	127	163	191	181	181
P(mm)	102	82	61	24	7	3	1	1	6	27	59	89

Source: Bhalotra, 1987.

Rainfall data for Francistown are based on 65 years of observation and rainfall data for Tshesebe are based on 27 years of observation. Table 3.6 provides precipitation data together with the coefficient of variation for Francistown and Tshesebe. It appears that the variation of the amount of rainfall in one month is rather high. In addition, much of the rain falls in thunderstorms with a high intensity, causing high run-off volumes which, while inducing soil erosion, are not available for plant growth.