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POTENTIAL VALUE OF LAND AND WATER RESOURCES IN NORTHEAST OTJOZONDJUPA

March 1999

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POTENTIAL VALUE OF LAND AND WATER RESOURCES IN NORTHEAST OTJOZONDJUPA.

A study for the Namibian Ministry of Lands, Resettlement and Rehabilitation by the Summer Desertification Project VII:

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CHAPTER 1: INTRODUCTION

OBJECTIVES OF THE SDP VII TRAINING PROGRAMME

The aim of the 1998-1999 Summer Desertification Programme (VII) was two-fold:

I. to provide training for tertiary-level students in the evaluation of regional land and water resource potential;

II. to establish a methodology of land evaluation appropriate to Namibian conditions both in terms of logistical constraints and in the use of the end-products.

At the request of the Ministry of Lands, Resettlement and Rehabilitation, the SDP focused this year on the potential value of land and water resources in Northeast Otjozondjupa Region, in the area formerly known as Western Bushmanland.

To this end the training programme concentrated on field survey and data transformation techniques within the procedural framework of a land evaluation, in order to provide results of practical value to the process of regional development planning.

LAND EVALUATION FRAMEWORK

To make this section more readable it starts with the definitions of some of the terms most frequently used when describing the concept of land evaluation.

Table 1. Common Land Evaluation Terms and their definitions

Term	Definition
Land evaluation	Estimation of the potential of the land for one or more alternative land uses
Land use	The way the land is used
Land unit	An area within which environmental conditions are assumed to be uniform.
Land system	An area with a recurring pattern of topography, soils and vegetation, and with a relatively uniform climate.
Land quality	Measure of the conditions of the land necessary for the successful application of a given land use.
Land use requirement	Conditions of the land necessary for the successful and sustainable application of a given land use.
Land form	Specific surface feature created by weathering and erosion (i.e. sand dune, river valley, flood plain etc.)
Topography	Surface shape
GPS	Global Positioning System, Makes use of satellites to determine a position on the ground.
GIS	Geographic Information System. Computer software making it possible to analyse spatial information from various sources (i.e. maps, tables)

The 1998 SDP carried out a field study in Western Bushmanland at the request of the Ministry of Lands, Resettlement and Rehabilitation to identify possible development options, which would be environmentally sustainable and economically feasible for the residents of the area. This request was general and therefore open to a number of approaches.

In the planning phase of the programme it was decided that a land evaluation approach would be tested. A land evaluation was assumed to provide a good framework within which environmental information could be gathered, recommendations could be made for sustainable resource development, and all the data could be subjected to an evaluation of suitability for a number of proposed land uses. Presentation of the results could also be made in the form of a multipurpose land suitability map of the area, which may be useful for future planning purposes. In view of the general nature of the request from MLRR combined with the large land area (circa. 81,000km^2) to be investigated, a reconnaissance level land evaluation was carried out with a final mapping scale of 1: 250,000.

Land evaluation can be defined as the process of estimating the potential of land for one or more alternative uses (Young, 1976). There is a great number of different systems of land evaluation, most of them are of local or national scope (Breimer et al., 1986). In Latin America, Beek and Bennema (1974) developed a very flexible land evaluation methodology that can be used for any kind of land use, at any technology level. The technology was adopted by FAO in its "Framework for land evaluation" (FAO, 1976). For this study the guidelines described in FAO (1991) have been adopted, and the steps followed are outlined below and illustrated in figure 1.

The information requirements of a land evaluation depend on the reasons for the evaluation and the scale of the area to be investigated. The reasons for doing a land evaluation usually include an investigation into the suitability of specific land uses proposed for the area. Land units, in terms of their land quality, must be matched against the requirements of the proposed land uses to determine the level of suitability of each land unit.

LAND EVALUATION PROCEDURE

The procedure of the land systems approach to land evaluation made by the SDP was based on the following steps:

1. *To define the objectives of the land evaluation, identify both the beneficiaries and the factors that might influence the future development of the study area.*

This was done at an early stage of the project as a discussion among all the participants of the land evaluation.

2. *To identify the current and potential land use types (LUTs).*

The selection of potential land uses is based on information gathered both from other studies and from information obtained in the field. Each land use has to be described through a set of technical specifications.
S1: very suitable,
S2: suitable,
S3: marginally suitable,
n: not suitable.

For this study, two different land use types were initially identified: dryland cropping and grazing by large stock.

3. *To determine the requirements for each land use type.*

The land use requirements are the conditions of the land necessary for a successful and sustainable application of a given land use. Requirements can include drinking water availability for extensive grazing or, in the case of horticulture, conditions necessary to avoid soil erosion under irrigation.

4. *To descibe land units through soil, water and vegetation surveys.*

To increase the accuracy and save time, the SDP field survey was supported by a large number of maps, aerial photographs and satellite imagery. During the field survey the students sampled the soils, vegetation and water to obtain direct and representative measurements of land and water characteristics. They also conducted a socio-economic survey to obtain information about the current socio-economic conditions and current land uses in the study area. A land unit map was produced from this information.

5. *To rate the land use limitations relevant for present and the potential land uses.*

In this study we did the following rating of each land use:

- The conditions that are suitable for each land use.
- The range of conditions that are below the optimum but still are suitable to some extent.
- The conditions that are unsuitable and unproductive.

6. *To match land use requirements with land use limitations in order to identify areas in the region where:*

- Land and/or water qualities will not support the suggested land use types.
- Land and water qualities would be optimally suitable for each type/combination of land use types.
- Identify the level of technology input needed for the considered land uses to be sustainable.

7. *To present recommendations on regional development options.*

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CHAPTER 2 – ENVIRONMENT

This is not a review of literature and most information was gathered by survey and observation.

THE LOCATION

The study area is situated in Northeast Otjozondjupa Region, in the northeastern part of Namibia. The northern border of the study area follows the southern border of the Kavango Region, which runs along latitude 19°10'S. The eastern border is along 20°E and the southern border is along 20°S. The western border follows the veterinary fence which isolates the commercial areas of the western parts of Namibia from the communal lands of the northeastern parts of Namibia. However, it never stretches further than 19°E to the west.

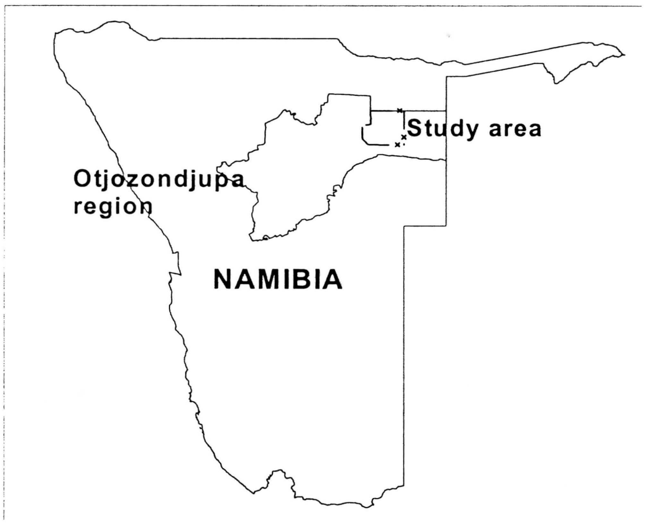

Fig 2.1: The study area in relation to Namibia

The study area falls completely within the borders of the area formerly known as Western Bushmanland, which is a part of the current Tsumkwe district. In the north the Tsumkwe district borders onto the Rundu district, the Kavango and Otjozondjupa region. The border between the Tsumkwe district and the eastern Grootfontein district follows the veterinary fence. In the south and southeast, Western Bushmanland borders on the Okakarara district.

The major settlement in Western Bushmanland is Mangetti Dune, situated in the centre of the study area. The nearest administrative centre is the district capital of Tsumkwe, about 75km east of Mangetti Dune. Grootfontein is the nearest major town, about 150km to the west of Mangetti Dune.

Western Bushmanland lies on a plain of Kalahari sands. The plain covers large areas of southern Africa. The elevation is slightly higher than 1 200 meters above sea level in the Western Bushmanland area. The most significant variations of altitude consist of the omiramba of the Daneib in the southeastern part of the area, and the Omatako in the central to eastern part. The elevation of these incised river-valleys is slightly less than 1 200m. The difference in altitude between the omiramba and the surrounding plains varies from 10 to 50 meters.

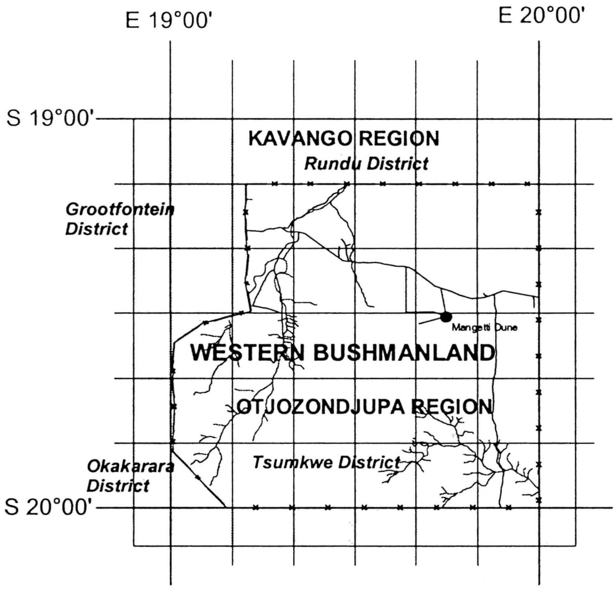

Fig 2.2: The study area with bordering regions and districts

The dominating landform in the study area is large sand drift areas which occur in the central and southeastern parts, known as the Kalahari sands. The Omatako and Daineb mentioned above are also major landforms, being fossil river valleys cutting through the landscape. The Omatako flows (when it flows) in a northeastward direction towards the Okavango River. The Daineb flows southeastwards through Hereroland towards Botswana and the Okavango Delta. There is also an area of complex sand dunes and dune streets in the northwestern part of the study area.

CLIMATE

Table 2.1: Climate data of Western Bushmanland, calculations based on data obtained from Grootfontein and Tsumkwe weather station.

	Jan.	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept.**	**Oct.**	**Nov**	**Dec.**
Average Rainfall (mm)	126.6	128.5	88.4	52.4	3.1	0.7	0.0	0.6	5.9	17.8	48.3	72.3
Max. temperature	30	29	29	28	26	23	24	26.9	30.7	32	32	32
Minimum temperature	18	17	16	13	8.1	4.9	4.4	7.4	11.9	15.7	17	18
Average temperature	24	23	22	20	17	14	14	17.2	21.3	23.9	24	25
Average humidity(%)	55	61	62	55	46	43	40	33	28	29	42	47
Wind speed(m/s)	1	1	0.90	0.90	1	1.3	1.1	1.3	1.3	1.4	1.4	1.2
Sunshine (hour/s)	8.1	7.5	8	8.6	10	10	10	10.4	10.1	9.5	8.7	9.5
Potential evapotranspiration (mm)	149.5	125.5	128	108.5	95.5	81.5	85.5	116	144	172	164	167.5

The rainfall figures of Grootfontein and the rainfall figures of Tsumkwe were used to obtain the average rainfall of Western Bushmanland. It was assumed that the average between these two stations gives a representative value for the rainfall in Western Bushmanland since the study area is situated inbetween stations (Agro-Ecological Zoning Project climate data, 1998). The other climate variables are a monthly average obtained from the Agro-Ecological Zoning Project climate data (1998).

Rainfall in Western Bushmanland differs from year to year. Normally the rainfall starts in October and continues to April. The climate is semi-arid and is characterised by low annual precipitation, periodic droughts of varying severity and high rates of evaporation (Hines 1990, Hitchcock 1992). The evaporation rates are lower from May to July, as indicated in table 2.1. In October the evaporation rates are very high and range from 172mm decreasing to 108.5mm in April. Therefore, conditions for rainfed crop production are extremely marginal.

The average monthly rainfall ranges between zero and 128.5 mm. The average humidity is lowest in September and October just before the rainy season. Most rain falls between November and April in this area, but it should be stressed that annual rainfall usually occurs as discrete seasonal events. As rainfall is the factor limiting the rate of plant production in systems like this, the seasonal, spatial and temporal variability in rainfall is important for management and utilisation of crops and bush vegetation (Hines 1990, Hitchcock 1992)

The region has a warm climate with high temperatures. The maximum daily temperature is 32 °C from October to December. The minimum temperature is 18° C in December to January. During the winter the days are warm and nights are cold. Frost occurs a few nights each year in the lower-lying areas such as the omiramba. The most hours of sunshine are between May to September when there is seldom any cloud cover. The incidence of crop-damaging weather occurs from time to time but is very infrequent (i.e. hail storms experienced during our stay).

GEOLOGY AND GEOMORPHOLOGY

Kalahari Sands

Western Bushmanland lies within the largest aggradational land surface found in Northern Namibia (Loxton, Hunting *et al*, 1971). Aggradation (the process of building up a surface by deposition), that was active during the late cretaceous age (64 Million years ago) resulted in a large scale deposition of aeolian (wind blown) sands. These depositions occur in the north and northeast of Namibia and are referred to as the Kalahari Sandveld. Over geological time increasing differentiation of the wind-blown sands has produced two sand groups that underlie the soils of Western Bushmanland:

- True Kalahari Sands of tertiary age (about 500 million years ago).
- Younger red sands and later redistributed sands.

The wind-blown sands were mostly deposited on a calcrete erosion surface, the calcretes themselves having been previously formed by processes associated with receding water surfaces, probably under increasingly arid conditions.

Extensive areas of massive longitudinal (seif) dunes occur in the northwest of the area, now stabilised by vegetation. The dunes were formed under arid conditions by the action of easterly prevailing winds. This explains why they lie from west to east.

Omuramba Formation

Subsequently in a wetter period, and possibly under climatic conditions similar to the present, water from the central Highlands belt drained east and northeast and dissected those dunes to form the main omuramba systems of Western Bushmanland - the Omatako and the Daneib. Tectonic evidence (movement of continents from their original position to the present) suggests that dissection must have occurred along fault-lines running southwest-northeast in the case of the Omatako, and west-east in the case of the Daneib (Albat, 1991). The Daneib, draining to the east, has been deeply incised into the underlying calcrete. The result is that its valley floor is narrow with increasingly frequent outcrops of calcrete down its length. The northeast flowing Omatako omuramba has also been incised but not as deeply as the Daneib. The result is that its valley floor is broader and flatter, and whereas calcrete can be found near to the surface, outcrops are not as frequent as in the Daneib.

Loxton, Hunting *et al* (1971) report that wind as well as water influenced the form of the omuramba valleys and their environs. Thus, dunes commonly fringe both the Omatako and Daneib. These are more pronounced on southern and eastern banks, indicating the action of northwesterly winds.

Calcretes and Pans

Western Bushmanland lies on a broad, flat watershed situated between the Omatako drainage system to the west and the Daneib system to the east. Ward and Swart (1989), commenting on the geomorphology of the region, report that much of Bushmanland has been a broad stable watershed since about the Mid Tertiary in geological time. This is borne out by the widespread occurrence of calcrete, developed largely in gravels, grits and sands, out-cropping in numerous pan areas found to the south of latitude 19°30' in both Eastern and Western Bushmanland.

The development of a broad stable watershed has promoted the formation of pans where the Kalahari Sand cover is comparatively thin.

Soils

Soils formed on the aeolian sands and calcrete surfaces of Western Bushmanland are discussed in Chapter 5.

NATURAL VEGETATION

The vegetation in Western Bushmanland is classified by Giess (1998) as woodland. The Directorate of Forestry (1997) classified the vegetation of most of the same area and south west Kavango as 78% woodland with trees higher than 5m and 22% as savannah. The woodlands are mostly open and trees are sparsely distributed. Deciduous trees, such as the *Burkea africana* and *Pterocarpus angolensis* are the most dominant. The following vegetation types were found: wooded shrubland, shrubbed woodland, shrubland and wooded grasslands (Chapter 4).

The vegetation distribution is roughly correlated to the following land forms: Omuramba and dune valleys, Omuramba slopes and crests,and the plains of Western Bushmanland. The valleys are dominated by *Acacia spp.* shrubland and some grasslands. *Lonchocarpus nelsii* and *Acacia spp.* occur along the slopes and crest of the Omuramba. Deciduous woodland dominates in most of the other parts of Western Bushmanland with denser woodlands in the northeast becoming less dense towards the south west.

The more common tree species in the area are: *Pterocarpus angolensis*, *Burkea africana*, *Combretum collinum*, *Lonchocarpus nelsii* and *Acacia erioloba*. Other species of trees and shrubs such as *Grewia spp. Acacia mellifera, Acacia fleckii, Acacia erioloba, Terminalia sericea, Boscia albitrunca, Commiphora africana, Baphia massaiensis , Ozoroa gratissimus* and *Rhus tenuiervis* are found. In the open tree savanna a good coverage of climax grasses such as *Brachiaria nigropedata, Anthephora pubescens* and *Schmidtia pappuphoroides* are found (Müller, 1984). Other grass species found are *Panicum maximum, Stipagrostis uniplumis, Anthephora pubescens* and *Eragrostis spp.*

ETHNOBOTANY

The major tree and shrub species that are identified by local San people as important for food, medicine and construction purposes are: *Terminalia sericea* (Silver cluster leaf), *Ochna pulcha* (peeling plane), *Acacia fleckii* (Plate thorn), *Schinziophyton rautanii* (Mangetti tree), *Grewia flavescens* (Sand paper raisin), *Grewia villosa* (Mallow raisin), *Grewia flava* (Velvet raisin), *Boscia albitrunca* (Shepherds tree), *Bauhinia petersiana* (Coffee neats foot), *Baphia massaiensis* (Sand camwood), *Burkea africana* (Wild seringa), *Croton gratissimus* (Lavender fever berry), *Rhus tenuinervis* (Kalahari currant), *Commiphora glandulosa* (Tall common corkwood), *Dichrostachys cinerea* (Sickle bush), *Ozoroa paniculosa* (Common resin tree) and *Strychnos pungens* (Spire–leaved monkey orange) (see Chapter 4 for more details).

WATER RESOURCES IN WESTERN BUSHMANLAND

Hydrogeology

The majority of people living in Bushmanland depend on ground water for survival. Large areas are underlain by semi to unconsolidated strata of Kalahari group of aquifers. This means that underground water is mainly stored in the spaces between fine sand granules. However there may be some localised areas where artesian aquifers can be found. According to State of Environment Report on Water in Namibia (Seely *et.al*, 1998), 'boreholes drilled into the Kalahari aquifer are generally low yielding and produce water of variable salinity'. Based on measurements of the rest water level, the water table becomes deeper from northeast to southwest of the study area. In Western Bushmanland most of the boreholes are located in the low-lying areas of the omiramba where the distance to the rest water level is assumed to be lower.

Water storage

There are no storage dams found and there is no permanent standing water available in this area. Water from the boreholes is stored in reservoirs provided by the Department of Rural Water Supply and Namwater. Water is pumped into and kept in tanks of different sizes ranging from 3 to 100m^3. These tanks are either made of plastic or corrugated iron. Each borehole is normally provided with two small tanks on a tower and a big tank on a stand. In general, smaller storage tanks are used to store water for domestic purposes and larger ones for livestock and at some places, also for gardening (H. Park, pers.comm.).

Water quality

On the basis of TDS (total dissolved solids [mg/l]) data and reference to water quality maps (Interconsult ground water survey, 1993), Western Bushmanland's water is of good quality.

Pans

Larger pans occur more in the southeastern and northwestern parts of Western Bushmanland. All pans are seasonal and therefore do not have water throughout the year.

Regional surface drainage

Sandy sediments in the study area are between the range of 200m-500m thick. The areas with the thickest sand are located towards the centre of the study area; the central area also has the highest altitudes. Rainwater therefore runs off the high ground in all directions and this water is collected in the drainage channels that feed the Omatako-omuramba and Nhoma rivers flowing towards the northeast, and the Daneib river flowing in a southeasterly direction, all of which are ephemeral rivers that are characterized by rare periodic flow.

COMMUNICATIONS

Apart from tourist and government vehicles, a negligible percentage of people living in western Bushmanland drive cars. Most people travel on foot. Almost all the roads that exist in the study area were made by the former South West African Defence Force (SWADF) to access army bases. The main gravel road that stretches east-west across the length of Western Bushmanland serves regional centres like Tsumkwe and Gam in Eastern Bushmanland. The Works/Roads Department services the main roads and it is safe and reasonably comfortable to drive on them. On the other hand they become inaccessible not very far from the main roads. There is a re-growth of vegetation along most of these tracks and this makes it hard for any car to travel on them. Tracks are often sandy and a powerful vehicle is needed. The most frequent natural disaster is veld fires, but they have not had much effect on the roads in the area. There are cut-lines within the study area that were made by borehole drillers to access drilling and exploration sites.

One landing strip exists in the study area which is a short gravel runway for small aircraft (4-6 seater) located south of Mangetti dune. Bushmanland is an area where radio, telephone and television are unheard of. There is no transmission tower or telephone line in the area. The absence of such crucial means of communication has partially contributed to the lack of information reaching the communities within this part of the country.

PRESENT LAND USE

The San communities in the area are dependent on the natural resources. The communities referred to the n!ore system of Eastern Bushmanland which is also their traditional system of land and resource management (Toma and Piek, 1997). Among the J/'hoansi a n!ore is a named place containing various natural resources. Some n!oresi are residential while others are used for hunting and gathering. Each residential n!ore has one or more 'eating place' (m/hosi) which may not be shared with contiguous n!oresi. Each residential n!ore also has an associated 'hunting place' (!age/ho) or direction of usual hunting. These hunting areas are sometimes shared with nearby residential n!oresi. Where 'eating places' are shared, each n!ore inhabitant has a special, but ultimately non-exclusive relationship to the portion of the m/ho closest to their tju/ho (village) (Thoma & Piek, 1997). At present the communities are changing their land use to cultivating crops because of the increasing local population and pastoralists coming in from the outside. As a result of these factors, the pressure on resources is becoming higher and can lead to their depletion. Currently the communities are in the process of establishing traditional authorities to protect the natural resources in Western Bushmanland.

The communities are changing to crop production similar to some other communities in Namibia. They are making fields for planting mahangu (millet), maize, groundnuts and sorghum. The Ministry of Agriculture, Water and Rural Development supplies seeds and assistance. As far as land management is concerned the area is not fenced and because it is communal land, it is open for everyone to settle. When it comes to livestock control and management the community usually combines their livestock herds which are never very big. Children or hired hands herd the livestock. During the rainy season when the fields are planted, the livestock are herded away from the fields. During the dry season the livestock are left alone to graze.

MINISTRIES AND DEPARTMENTS REPRESENTED IN THE AREA

For more information on these government activities see Chapter 7 (Socio-economics).

- Kanovlei Forest Station
- Ministry of Lands, Resettlement and Rehabilitation (MLRR)
- Ministry of Agriculture, Water and Rural Development (MAWRD)
- Agricultural Development Centre at M'kata
- Namibian Police (NAMPOL)
- Ministry of Health and Social Services (MHSS)
- Ministry of Basic Education and Culture (MBEC)

PRESENT ECONOMIC ACTIVITIES IN THE AREA

For more information on these activities see Chapter 7 (Socio-economics).

- Omatako Valley Rest Camp
- Sawmill / Resort
- Luhebo Baskets and Furniture Market
- Shops in Mangetti Dune and Omatako

DESCRIPTION OF TWO TYPICAL VILLAGES

Meduletu Village

Meduletu is a word derived from Oshiwambo meaning "in our land". All the San people living here are from Okongo in Ohangwena region. They came to Mangetti Dune in 1992, under the supervision of a Pastor named Ihuhua Junias who served with the ELCIN mission church. In 1994 they moved to Kukurushe, and from there to Meduletu in 1996. The population of the community is approximately 55. This community appears to be more self-reliant in terms of cultivating (omahangu) when compared to other villages in the area. The village produces most of the omahangu for their own consumption and sells the surplus. They also help the nearby villages with supplies of omahangu i.e. Kukurushe, Kankudi, Mparara and Luhebo. The San people living at Meduletu learned how to cultivate from Owambo people in Okongo.

The community is farming well with omahangu which is their staple food. Their production ranked second after Kankudi, according to the records of omahangu yield for 1998. A possible reason Kankudi ranked 1st might be that some community members from Kankudi attended a course on crop production at M'kata Agriculture Development Center. In 1993, ELCIN donated four head of cattle to the community. Later the Pastor in Meduletu bought two more head of cattle, which are shared among the community members. Water seems to be a problem in this village, because hyenas often damage the pipe that transports water to the village. The nearest school, shop and hospital are at Mangetti dune, approximately 7km away. The people are happy to stay here because their children have access to school, which is free of charge to everyone.

Nhoma Village

Most of the people living in Nhoma have remained hunters and gatherers, except one member of the community who is interested in farming with cattle. The community stated that they prefer to be hunters and gatherers. The MLRR and ADC have confirmed that the people do not seem to be interested in agriculture because of their resistance to clearing bush for cultivation, as requested by MLRR, ADC and MAWRD. As bush food is scarce, they are more dependent on wildlife as their main source of food. The people think the number of wild animals in the area is still enough to support them. The following animals are currently seen: kudu, giraffe, elephant, springbok, duiker, oryx and eland. One of the factors why the residents at Nhoma are not interested in farming with crops is that the elephants in the area frequently destroy their crops.

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CHAPTER 3 - METHODS AND MATERIALS

VEGETATION

Three sites on each soil type were selected in order to examine whether the soil and vegetation types are associated. Altogether we had 16 sites for sampling both plus two extra sites where only vegetation sampling took place. The vegetation type was classified according to the guide from Sweet & Burke (1998), supported by aerial photographs, satellite imagery and three vegetation maps (see Chapter 7) for the classification of the land units.

The vegetation cover was estimated for each site. The percentage cover of trees, grasses and shrubs were classified into percentage ranges e.g. 0-10%, 10- 25%, 25-50% at all the 16 study sites.

At each site a random 20x20m plot was laid out and all trees and shrubs in the plot were identified and counted. Simpson's index was used to express species diversity at each study site: $D=1/\Sigma P_i^2$ (P = proportion of individuals per species per total individuals of the site) (Begon *et al*, 1986). All trees and shrubs commonly used for food, construction or medicine were arranged in species per site.

A ruler was used to measure the diameter breast height (DBH) of trees which were larger than 5cm diameter in the 20x20m plot. All trees, indifferent to species, were arranged and classified into 5cm diameter size classes and graphed. All sites were lumped together to get an indication of overall tree size distribution in Western Bushmanland. For calculating wood production (m^3/ha) all trees with diameter greater than 5cm were used. The volume of wood per hectare was obtained by using the formula $V= \pi r^2 h$ (h = height was assumed to be 1.2m because 1.2m was used by the Department of Forestry (1997) for wood log length).

For the grass biomass a 1x1m quadrant was used which was randomly thrown 5 times in each study plot. The standing perennial grass was cut off 5cm above ground to simulate livestock grazing. The grass was weighed in the field with a pesola. The average grass biomass from the five plots per study sites were converted from g/m^2 into kg/ha. The variance of values around the average were calculated by using the standard deviation. Formula used for carrying capacity = 2700 / Total Dry Mass x 80%.

- 2700 kg/ha = 2.5% - 3% of the bodyweight of one head of cattle is taken to calculate the dry feed per head per annum (2300 – 2700 kg/ha) (deLeeuw & Tothill, 1993)

De Leeuw et al (1993) used 80% of the end of season feed supply and reduced that a further 40% to account for the decreasing biomass during the dry season. Sampling at the sites in Bushmanland was done at the end of the dry season before the growing season started and is therefore already at its minimum biomass. The 40% was therefore not subtracted.

SOILS AND LANDFORMS

Phases of the Soils and Landform Investigation

Information Review

Previous studies of the region were collected and reviewed. Where this information was useful as background data and relevant to land evaluation it was mapped at a scale of 1:250,000 using 1918 Grootfontein of the national topographic map series as a base.

Fieldwork

The fieldwork was designed to verify the accuracy of previous studies of landforms, soil types, associations and complexes carried out from previous work in the area.

The fieldwork was carried out at reconnaisance level in terms of observation density, and a transect approach was adopted. The transects ran as perpendicularly as possible to boundaries between previously mapped units.

Two levels of observation were made in the field, following the guidelines for soil survey and land evaluation set out in UNESCO (1986) and FAO (1991).

- Observation of landforms and land cover were made by driving through the region and cross-checking as many landforms and soil association boundaries as possible and from the information on the prepared maps, aerial photographs and satellite image. This level of observation took place during a pre-fieldwork reconnaissance trip to the area and throughout the fieldwork period.

- Sites for field data collection were chosen in areas representative of the landforms and soils observed during reconnaissance drives and spread over the region as far as accessibility would allow. At these sites, soil pits were dug down to weathered rock in shallow soils, and down to the bottom of the lowest observable horizon where sands underlaid deep soils. This depth was usually in the range of 60-90cm. Auger holes were also made to cross-check soil depths.

At each sampling site three types of observation were carried out and recorded on prepared data sheets:

1. Surface observations to delineate erosion features, evidence of surface drainage, surface sealing, cracking, occurrence of boulders and rock outcrops, surface stones, parent material, topography in terms of elevation, slope % and shape, land system and land facet.

2. Field measurements of cumulative infiltration rate, presence of carbonates and effective depth at each pit site.

3. Soil profile pits were dug at least twice in each soil type and land facet identified. Profile descriptions were carried out to determine horizon and topsoil/subsoil boundaries, texture, structure, colour, handling properties, presence of organic matter, evidence of burning and rooting depths.

Undisturbed samples were taken for laboratory determination of bulk density and organic carbon % at the surface and 10cm, 20cm and 30cm depths. Three samples were taken at each depth per pit.

One bulk (disturbed) sample was taken from each pit at 0-30cm and 30-60cm depths for laboratory determination of free ions, particle size, pH and nitrogen %.

All soil pits were photographed and located by a global positioning system (GPS). Soils were described *in situ* complying with the FAO Guidelines for Soil Description (1977) and by the use of Munsell colour charts.

Laboratory Analysis

Samples were collected for determination of the following soil characteristics by analysis at the Gobabeb laboratory:

- Bulk density and moisture content by mass fraction (for compaction and porosity)
- pH of saturation extract and 1:5 soil-water suspension
- Organic carbon percentage
- Cation exchange capacity (mo/100g)
- Soil fertility status: total nitrogen, total phosphorous, available potassium
- Exchangeable sodium percentage (ESP)
- Calcium carbonate percentage
- Electrical conductivity (ECe) of saturation extract
- Particle size analysis

This turned out to be an ambitious plan. Bulk density and moisture contents were the only measurements successfully completed. Time constraints and lack of experience were the main reasons for not completing the remaining work.

Bulk density and moisture contents were measured gravimetrically. Field infiltration data were adjusted for errors in instantaneous and cumulative water intake measurements, and basic infiltration rates were calculated. Free carbonates were measured in the field by efforvescence in 10% solution of HCl.

Data Processing

In total, the following soil and landform characteristics were measured by field measurement and laboratory analysis:

- Texture (field assessment)
- Colour (moist)
- Structure
- Bulk density
- Free carbonates
- Infiltration rate
- Evidence of burning
- Drainage class

- Depth class
- Erodibility class
- Classification (Binomial system, RSA)
- Topographic context

All results were documented and grouped according to pit location, soil classification and land unit. Summary soil and landform characteristics were compiled for the land evaluation.

Test pit analyses of soils previously sampled in Western Bushmanland were found in the soil survey technical appendices of Loxten *et al* (1971). This information, particularly the chemical data and parameters derived from them (e.g. cation exchange capacities) were used (with caution) alongside the SDP survey data to substitute for the gaps in information during the land evaluation.

POROSITY

Pore sizes

There are different systems of pore-size designation, based either on size or on function of the pores. Jongerius (1957) used classes to describe the observations of pore sizes.

a. Coarse (macro) pores – Their diameters are greater than 0.1mm, aeration and drainage by gravity flow are their main function. They are visible to the naked eye and are the pores in which roots proliferate.

b. Medium (meso) pores - Their diameters range from 0.03mm to 0.1mm, conduction of water by capillary flow is their main function. They are visible at 10 times magnification.

c. Fine (micro) pores - Their diameters are less than 0.03mm, retention and slow capillary flows are their main function. Micropores are not visible, but they can be inferred from observations made from the face of aggregates. The rougher the aggregate surface is, the more micropores there are.

For the soil to allow good root penetration, it should contain an adequate number of pores of >2.5mm diameter; to allow free drainage, at least 10% by volume of the soil in the rooting depth should be composed of interconnected pores > 0.5mm; and for storage of available water, at least 10% by volume of water should consist of pores with diameter ranging from 0.005 to 0.05mm.

How to work out the total porosity

A sample of soil was taken in an undisturbed condition with the cylindrical cutter about 5.5cm diameter and 4cm long. The cylindrical cutter was driven into the soil, dug out and cleaned into a plastic bag. The soil was put in a weight container and then placed in an oven at 105^0 C until the sample was dry (more than 24 hours). The container and the soil was weighed again, the loss of weight was the weight of water in the original sample and the weight of dry soil was obtained from (wt of container + soil) – (wt of container).

The total porosity (total pore space) of a soil is calculated from the bulk density and the particle density. The bulk density is obtained from the weight of dry soil over the volume of the cylindrical cutter. The particle density of most soils is normally assumed to be $2.65 g/cm^3$ (J.R.Landon ,1984). The total porosity is normally expressed as a volume percentage and is equal the volume % water content as saturation:

Total porosity (volume %) = 1 – (Dry bulk density / Particle density) * 100

INFILTRATION RATES

From infiltration measurements, several calculations can be made:

The instantaneous intake rate (IR) - this is the volume of water infiltrating through a horizontal unit area of soil surface at any given instant. It shows, in general, a rapid decline at the beginning followed by a more stable, very slow decline, later.

The average infiltration rate (IR av) – this is the cumulative infiltration (F) divided by the time since infiltration started.

The cumulative infiltration (F) – this is the characteristic which is measured in the field. The measurements are plotted on log-log paper (F against time). Usually a straight line is obtained and therefore the accumulated intake can be represented by the equation F = at *n* where *t* is in minutes; *n* varies from 0.5 to 1.0 and *a*, related to the order of magnitude of the water intake, is given by *a* = F after 1 min. The *n* value for sandy soils (high F value) is usually 0.8 or more; *n* values < 0.5 indicate the occurrence of soil cracks. In moist soils *a* values are lower (and *n* values higher) than the corresponding values in dry soils. It is preferable to express the time in hours (T) because, in this way, it may be easier to visualize the order of magnitude of infiltration. The equation of F expressed in hours can be obtained by computation as follows:

$$F = 0.24\ t\ 0.70 = 4.2\ T\ 0.70$$

The basic infiltration rate – this is the relatively constant infiltration rate which develops after some time during infiltration tests. The time taken to reach this rate is dependent upon soil type.

Measuring infiltration in the field

Infiltration was measured at each sample site. Water had to be brought in large containers from the campsite borehole and the number of measurements was limited to the available water and time. A tin cylinder infiltrometer was used with centimeter intervals marked inside. The cylinder was pushed 12cm into the undisturbed soil surface and the soil around it (but not inside it) was wetted thoroughly. This was to ensure that water would move downwards through the soil and not horizontally after draining down to the bottom of the infiltrometer. Water was poured slowly into the cylinder and at a pre-marked point allowed to drain. A stop-watch was used to measure the time taken for water to drain between 2cm intervals. Water was added to the top mark and the drainage time was taken between the same depth intervals. This was repeated until a constant time was reached between the intervals. All times were recorded on the infiltration form. Sixteen infiltration measurements were made in the field on four soils.

Bulk Density

The method used to sample soil density was the same as the one explained above for soil porosity. At each site three replicates at 0cm, 10cm, 20cm, and 30cm depth were taken. The oven- dry masses of the replicates were summed and divide by the total volume of the cylindrical cutter to obtain the mean bulk density.

$$\text{Bulk density of soil y} = \frac{\text{Weight of soil}}{\text{Volume of soil}}$$

WATER

Interconsult provided a database for the water team, which was originally obtained from the Department of Water Affairs. This database was updated and had information on boreholes of which only 46 occurred in the study area. With the aid of a GPS (GARMIN 12 XL) all the boreholes in that are that were accessible, were located. The local people were of great assistance in directing the team to find a number of boreholes. In most instances it was much easier to find a village, where it was certain there would be a water point nearby. It was not always easy to find boreholes as most roads leading to boreholes further away from the main road were inaccessible by car (4x4). However, an effort was made to find all the boreholes.

When a borehole was found the following were obtained:

- the state of the boreholes, whether in use or not
- rest water level, (the level at which water was at the time)
- water quality, by measuring the total dissolved solids in water with a TDS meter
- usage of water from the borehole
- other geophysical and topographical information

Because the dipper (rest water level measuring instrument) that was used was only 100m in length, it was not possible to obtain the rest water level (RWL) of those boreholes which had a RWL deeper than 100m.

The information gathered from the field was combined with that from other sources and together these formed the bulk of data for the water group. Various methods were used to analyze the raw data obtained. Among the methods used were the Correlation and Regression statistical tests to test for variances between means of different variables. Linear regression analysis between:

- TDS (Mg/l) and rest water level (m)
- Drilled depth (m) and Yield (m^3/h)
- Rest water level (m) and Maximum yield (m^3/h)
- TDS (mg/l) against borehole yields (m^3/h)

After the field data was analyzed, the results obtained were compared with the existing information on water in the study area.

SOCIO-ECONOMICS

Most of the information was obtained from the headmen/women of the villages or from the people who had been in the village for a long period. An introduction of the project was always given prior to interaction, in the language spoken in the village. The interviews were conducted in the form of meetings with the permission from the headmen/women, and every member of the community was welcome to attend. Most of the individual older people were questioned about their personal details as well as about general information.

A GPS (Global Positioning System) was used to determine the position of the village. The cultivated fields were also measured by using a GPS as well as the distances from one villages to another. Some of the community members were asked to help with pacing off cultivated fields. Four wheel drive vehicles were used to reach the villages. The interviews were conducted in English via the translator who could speak most of the San languages which are spoken in the area. In some cases, Oshiwambo and Afrikaans were used in direct communication. Pictures of the villages were taken for comparison.

Procedures at village

The time to conduct the interview that best suited the community was considered before arriving at the village. After arrival at a village we talked to the headman/woman or a Senior person and asked for permission to conduct the interview. Then the community gathered in a central location. The introduction of the project was made prior to the interviews and discussion. The translator clearly spelled out the objectives of the research.

Open-ended questionnaire

After the introduction, group discussion followed, led by the open-ended questionnaires. The questionnaire requested information on personal details, resources, infrastructure and resettlements. Group discussion played a major role among the community, during which ideas or thoughts were collected randomly from the participants. Some people were interviewed individually depending on the number of people present. The minimum time spent at each interview or village was one hour thirty minute, while the maximum time spent was ± 4hours. At some places interviews were conducted from house to house, where houses were far from each other.

Translation

Interviews were conducted with the assistance of a local translator, Piet Nakwa, who speaks most of the San languages in the area. In some cases, English, Afrikaans and Oshiwambo were used as well.

Global Positioning System (GPS)

A GPS was used to determine and mark the position of each village where the interviews were conducted. A GPS was also used to measure the size of plots/cultivated field at some villages.

Procedures with Authorities

Prior to the interviews appointments were made verbally with the following Government Ministries/departments represented in the areas: Ministry of Lands, Resettlement and, Rehabilitation (MLRR) at Mangetti dune; Ministry of Agriculture, Water and Rural Development (MAWRD); Ministry of Health and Social Services (MHSS); Namibian Police Force (NAMPOL); Agriculture Development Center (ADC) at M'kata and the Kanovlei Forestry Station. The same procedure was followed for the Chief of Western Bushmanland. Senior officers of the different Ministries and Departments were approached to provide information about their activities in the area.

Key questions used to obtain the information

Personal details

What is your name?
How old are you?
Are you married?
How many children do you have (boys and girls) and their locations?
Where are you from? How did you come here? Why did you come? When did you come?
Are you happy to stay here?
What is your occupation?

Resources

Where do you get your food?
What types of crops do you grow?
What time of the year do you find natural food?
Where else do you get your food?
Which type of food do you regard as of the most important? The people were asked to rank their food sources.

Infrastructure

What are your water sources?
Is there a school in the village? How many teachers and learners?
Do you have a clinic in the village?
Where do you generate/get your power from?
What is the means of communication in the area?

Housing and Resettlement

What type of houses do you prefer to live in?

Do you prefer to have traditional rather than modern houses?
Do you have incoming people coming to settle in your area?

Problems during the interviews

Although it was planned to interview all men and women, very few women were interviewed, due to their shyness and the anger caused by the empty promises made by previous people working in the area.

The survey was planned to be conducted from house to house but in most cases, the people did not appreciate this approach. In some cases the people expressed their problems instead of responding to the questions asked, i.e. hunger, neglect by government, unemployment and other problems.

MAPPING

All the modified and newly drawn maps were made by hand on tracing paper. In the field this is a simple way of getting a good overview. Also the initial mapping was made in the field, where no computer equipment was available.

The maps compiled during this course are based mainly on existing maps. The method of compiling a map is basically to use tracing paper on top of a map and copy it. The traced copy can be used on top of another map with the same scale and area to see differences or similarities. Corrections can then easily be made to the traced copy. In our case, corrections were often based on information from our own survey.

When two different maps are combined in order to derive new units containing information from both maps, the same method is used. The information in the two maps simply merge or split the map into more/fewer units.

The use of a satellite image was also an important part of the mapping procedure. The sources of the new maps and the methods used for mapping will be presented in this chapter.

Digitizing method

All the maps used were digitized. Also some new maps were traced directly on the computer, such as region borders, water point locations and settlements. The three main reasons we digitized our map were:

- Digital maps can be changed, merged and compiled an infinite number of times without any loss of information.
- All map objects can be linked to databases, storing a lot of information.
- The maps can easily be printed.

The digitizing itself was made on a standard digitizing table. The map to be digitized was placed on the table, and fixed to it. Then the features of the map were transferred into digital coordinates, by placing a digitizing mouse over the selected object and pressing a button for each coordinate to record. The method is similar to drawing using the ordinary computer mouse. The big difference is that the digitizing table recognizes the exact position of the mouse, and therefore maps can be digitized with an error of less than half a millimeter. On a map scaled 1:250 000, the same as all our sources, half a millimeter on the digitizing board equals 125 meters in reality. Compared to the detail level of most of our maps, that error was acceptable.

Map sources

Table 3.1. The following maps were available for use by the mapping group. They were used as working copies and are not provided in the appendix.

Map Sources

Map Ref	Map Name/ title	Map Information	Information source	Laid out by	Date and Place
1	Topography (base map)	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition	LAND TYPES, Namibia Map sheet 2 (FAO, 1984)	S.J Simmonds	October, 1998
2	Surface Drainage	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition		S.J Simmonds	October, 1998
3	Land Types	ompiled from 1:250 000 ToCpographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition		S.J Simmonds	October, 1998
4	Soil Association	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition	R.F Loxton, Hunting & Ass	S.J Simmonds	October, 1998
5	Settlement & Infrastructure	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition		S.J Simmonds	October, 1998
6	Agro-ecological Zones with Growing Periods	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition	FOA/TCP/NAM/6611 (1997)	S.J Simmonds	October, 1998
7	Waterpoint Locations	Compiled from 1:250 000 Topographic sheet 1918 GROOTFONTEIN, Windhoek 1980, 2nd edition	Department of Water Affairs (MAWRD) Borehole database	S.J Simmonds	October, 1998
8	Geology- Bushmanland	Map no 2472/7 ; scale 1:250 000	MLRR	Francois Marais Ass	June, 1983
9	Veld types- Bushmanland	Map no 2472/10 ; scale 1:250 000	Rui Correia	Francois Marais Ass	June, 1983
10	Physiography (sand dunes, Pans, kalkvelds & other velds)	Map no 2472/9 ; scale 1:250 000	R.F Loxton, Hunting & Ass	Francois Marais Ass	June, 1983
11	Bush Map	Compiled from 1:250 000 Map No.2472/N	FOA/TCP/NAM/6611 (1997)	S.J Simmonds	October, 1998
12	Vegetation	Digital copy of vegetation in Western Bushmanland	Directorate of Forestry (MET)	NRSC	?

Satellite Image

The satellite image is a SPOT XS Scene that was obtained from the National Remote Sensing Centre (NRSC) as a paper copy.

Limitations

1. The satellite image, a SPOT XS Scene, was received in May 1993 and that in itself is a limiting factor, because some areas shown on the image have changed since the image was taken. Some of the burned areas on the satellite image have recovered, and would look different on a new satellite image. With the frequent veld fires in the area, some of the densely vegetated areas on the image might have been burned since the image was taken. After a very low rainy season – the deciduous vegetation might have lost its leaves.
2. The upper top right corner of the image is not very clear because of thick smoke from a veld fire in the same area.
3. The resolution of the image is not optimal. Every pixel on the satellite image presents an area of 50m X 50m in reality. The original pixel size in a SPOT XS scene is 20m x 20m in reality. Our scene was resampled by NRSC due to lack of disc space. As a comparison it can be said that a map with the resolution 20m x 20m per pixel contains 6.25 times the information as the same image with the resolution 50m x 50m per pixel.

Table 3.2. Available information on the satellite image

Date	Scale	Area
May , 1992	1: 250000	19 00 S-20 00 S 19 00 E- 20 00 E

Maps compiled

Table 3.3. List of maps compiled by the mapping group, and the map sources (Table 3.1) used for each map. These maps were working copies and are not provided in the appendix.

Map ref	Map name/theme	Source map
A	Geology landforms associations, erosion, vegetation layer dominance	8,3
B	Geology Land types and soil	8,3,4
C	Vegetation	12
D	Vegetation	Satellite Image
E	Vegetation (Veld types)	9
F	Pans, Dunes and Drypans	10
G	Land Systems	2,4,10
H	Vegetation	14, 9 & satellite Image

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CHAPTER 4 – VEGETATION

Likoro Masheshe

INTRODUCTION

This survey attempted to compile the vegetation data for the land evaluation in the formerly known Western Bushmanland. The objective of the vegetation survey was to focus on the potential land qualities, sustainability and appropriate land use to add information to the land evaluation process. The potential land uses identified, were: veldfood, charcoal production and large livestock grazing. For the land evaluation process only large livestock grazing was considered.

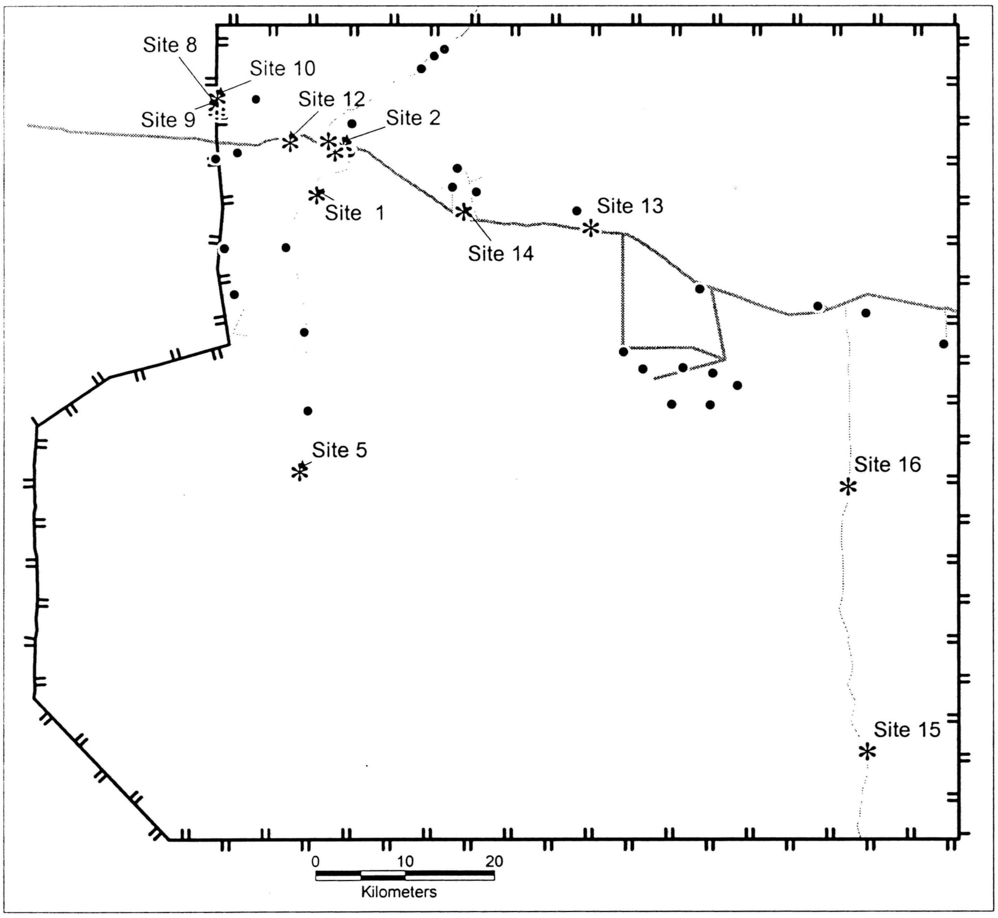

Fig. 4.1. Locations of vegetation and soil sample sites 1-16 (*) and villages (•) in Western Bushmanland.

Table 4.1: All study sites in West Bushmanland and their associated vegetation type, species richness and species diversity (Simpson's Index) in a 20m x 20m plots.

Site	Vegetation Type	Soil	No. Species	Species Diversity
Site 1	Terminalia/Acacia Shrubland	Gaudam		
Site 2	An association of *P.angolensis, C. collinum* and *B. massaiensis* - Shrubbed woodland	Sandspruit	7	5.9
Site 3	Shrubbed woodland with dominant species *Lonchocarpus nelsii*	Gaudam	8	5.7
Site 3A	Shrubbed woodland with *Lonchocarpus angolensis*		10	4.2
Site 4	Shrubbed woodland with dominant species *Acacia erioloba* and other acacias	Okavango	11	7.5
Site 5	Wooded grassland	Okavango	18	3.2
Site 5A	Shrubbed woodland with Acacias		8	4.9
Site 8	Dwarf shrubland with stunted *Burkea africana*	Fernwood	8	3.8
Site 9	Shrubbed woodland with Terminalia, Combretum and Pterocarpus	Sandspruit	12	5.9
Site 10	Shrubland with Acacia and Dichrostachys	Okavango	11	8.7
Site 12	Shrubland with Acacia	Okavango	3	1.3
Site 13	Wooded shrubland with Terminalia, Combretum and Burkea	Fernwood	4	3.6
Site 14	Shrubbed woodland with Pterocarpus, Burkea, Terminalia and Combretum	Fernwood	13	8.6
Site 15	Shrubbed grassland with Acacia, Boscia, Terminalia	Okavango	8	3.2
Site 16	Wooded shrubland with Burkea, Combretum and Terminalia	Sandspruit	11	1.2

Site 6,7 and 11 were located in southern Kavango and not included in the vegetation chapter. At site 3A and 5A only the vegetation in the 20m x 20m plot was sampled and no percentage cover, grass biomass or soil survey was done. Site 1 was next to a cattle post borehole and the disturbance was thought too high for vegetation sampling.

Table 4.2: All study sites in Western Bushmanland and their vegetation cover in percentage.

	Trees (%)	Shrubs (%)	Grasses (%)
Site 2	0-10	10 -25	10 -25
Site 3	0 -10	10 -25	0 -10
Site 4	10 -25	10 -25	10 -25
Site 5	0 -10	0 -10	25 -50
Site 8	0	10 -25	0 -10
Site 9	10 -25	10 -25	0 -10
Site 10	0 -10	0 -10	0 -10
Site 12	0 -10	10 -25	0 -10
Site 13	0 -10	0 -10	10 -25
Site 14	10 -25	25 -50	0 -10
Site15	0	10 -25	25 -50
Site 16	25 -50	10 -25	10 -25

INFLUENCE OF SOIL TYPE ON VEGETATION DISTRIBUTION

The vegetation of Western Bushmanland can be roughly divided into three parts: the drainage systems (omiramba), the dune system and the woodland plains. The woodlands, which have lower grass cover, seem to be associated with the poorer water-holding capacity and lower nutrient content in the soils. Higher grass cover occurs on the more nutrient rich soils of the omuramba floor and in dune streets (Loxton, Hunting and Associates, 1971). The denser woodlands occur in the north east of our study area while the south is more shrubby with a higher grass cover (NRSC map, 1994).

The vegetation is related to the soil types and the land forms (Chapter 5). The percentage cover of trees, shrubs and grasses (Table 4.2) and the species composition (Table 4.1) are probably the best indications of relationships between soils and vegetation. The species richness or species diversity index does not seem to correlate with the soil types (Table 4.1).

Gaudam Soil

The vegetation on the omuramba slope and crest (Site 1, 3, 12 & 3A) on Gaudam soil consists of shrubland and shrubbed woodland (Table 4.1). The dominant trees are a mixture of *Combretum collinum, Lonchocarpus nelsii, Schinziophyton rautanenii* and *Acacia erioloba*. Common shrubs are *Acacia mellifera, Terminalia sericea, Baphia massaiensis* and *Commiphora spp.* The percentage ground cover of shrubs is higher than that of the trees and grasses (Table 2). A calcrete outcrop was recorded at site 12. At this site shrubs like *Acacia spp.* dominated and very few grasses were found.

Okavango Soil

The vegetation types on the omuramba floor (Site 4, 5 & 15) and dune streets (Site 10) vary from shrubbed woodland, wooded shrubland, shrubland to grassland savanna (Table 4.1). The percentage grass cover is high at Site 15 and 5 (Table 4.2) although the grassland areas are never very big. Site 4 has a higher tree cover especially *Acacia erioloba*. *Acacia spp.* dominate with some *Lonchocarpus nelsii* and areas of a variety of shrubs like acacias, *Dichrostachys cinerea, Terminalia sericea*, combretums, *Commiphora africana* and *Bauhinia petersiana*.

Sandspruit & Fernwood Soil

These two soils cover most parts of Western Bushmanland and the vegetation changes from shrubbed woodland, wooded shrubland to shrubbed grassland (Table 4.1). The plant species and vegetation types are very similar on these two soils. Woodland species such as *Burkea africana*, *Pterocarpus angolensis*, *Ochna pulchra, Combretum hereoense* and *Terminalia sericea* dominate. The tree cover varies between 10% and 25% (Table 4.2). Site 8 on the dune slope did not have any large trees because all *Burkea africana* were stunted although the grass cover was good at this site. Leaching of minerals down the slope probably stunted the growth of the Burkea.

ETHNOBOTANY

The people in Western Bushmanland use a range of trees and shrubs for food, construction and medicine. They still depend substantially on veld food for their diet. The following list includes all the species which were found at the study sites (Table 4.3) and their uses (Saar, 1995 & Leger, 1997. The most important food plants to the people ranked by importance are: *Schinziophyton rautanenii* (mangetti tree), *Strychnos pungens* (monkey orange), *Ochna pulchra, Grewia retinervis* (kalahari sand raisin), *Parenaria capensis* (sandapple), *Salacia luebertii* and *Ximenia caffra* (large sourplum) (Saar, 1995). Only at two of our study sites was *Schinziophyton rautanenii* (Table 4.3) present and *Strychnos pungens* at one. No *Strychnos coccoloides* was found. The National Forest Inventory Project (1997) found in an area of 607 949ha (including part of south west Kavango and excluding south west Bushmanland) 0.6 stems/ha of *Schinziophyton rautanenii,* 1.73 stems/ha of *Strychnos pungens*, 0.33 stems/ha of *Strychnos cocculoides*, 1.67 stems/ha *Ochna pulchra* and 0.99 stems/ha of *Boscia albitrunca.* The fruits of these species are harvested mainly in the rainy season from November to January. The mangetti nut is harvested the whole year round which makes it the most important food plant for the San.

These very important food plant species are becoming a rare resource with the increasing number of people in Western Bushmanland (Chapter 7). The solution for a continuing stable food supply could be the cultivation of these plants. Germination experiments have been done at the Kanovlei Forestry Station (Saar, 1995). Biesele *et al* (1979) found Mangetti difficult to grow. They found the best method was to grind the pointed end off the entire fruit until the white embryo is exposed. Germination experiments should be encouraged to continue at the forestry station. Our study site area was far too small to get any knowledge of the distribution of these important plant species. To know to what extent this resource is limited, further studies are recommended. The cause of the apparent decrease in veld food should also be investigated (e.g. increase in livestock and human population or limited distribution of the plants).

Table 4.3: Useful trees and shrubs at 16 sites (20m x 20m, n=1) in Western Bushmanland. (Common names for plant species are given in Appendix A)

SITE	1	2	3	4	5	8	9	10	12	13	14	15	16
Terminalia sericea	15	0	0	0	0	12	12	27	0	6	10	2	16
Ochna pulchra	5	0	0	5	7	10	0	0	0	0	10	0	6
Acacia fleckii	0	4	0	4	5	0	0	0	0	0	0	0	0
Schinziophyto rautanenii	0	0	0	6	0	0	0	8	0	0	0	0	0
Grewia flavescens	0	3	9	1	4	4	0	0	1	0	0	0	5
Pterocarpus angolensis	0	2	0	0	0	1	4	0	0	0	5	0	0
Commiphora africana	0	0	16	10	33	0	0	4	0	0	0	0	0
Grewia flava	0	0	12	0	0	0	4	10	0	0	2	6	5
Boscia albitrunca	0	0	5	1	1	0	0	0	0	0	0	2	0
Bauhinia petersiana	0	0	1	0	38	5	0	0	0	0	6	4	4
Baphia massaiensis	15	13	13	0	0	0	24	0	0	0	12	0	0
Burkea africana	1	1	0	0	0	8	0	0	0	0	11	0	3
Croton gratissimus	0	0	26	0	0	3	2	0	0	0	0	0	0
Rhus tenuiervis	0	0	0	0	0	0	0	0	0	0	0	0	0
Grewia villosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Commiphora glandulosa	0	0	0	0	1	0	0	0	0	0	0	0	0
Dichrostachys cinerea	0	0	0	6	0	0	0	8	0	0	0	0	0
Ozoroa paniculosa	0	0	0	0	0	0	2	1	0	0	0	2	0
Strychnos pungens	0	0	0	0	0	0	0	0	0	0	5	0	0

- *Terminalia sericea* leaves and roots help against stomach pain. The wood is very good for construction. The community uses rope made from the roots.
- *Lonchocarpus nelsii* is used for handles for axes, knives and spoons.
- *Burkea africana.* The leaves are used for stomach pain, pounded bark is mixed with salt to cure nose bleeds and burnt mouths. It is a very strong and hard wood.
- *Acacia erioloba* is used for building purposes, for making pounding sticks to pound maize flour and is a very good fuelwood giving a long lasting fire.
- *Pterocarpus angolensis* roots are used for people coughing blood and the sap is used for open wounds; it is the most important wood for construction and used for axes and knives.
- *Commiphora africana.* Pupae of one of the species of beetle that eat the leaves of the shrub are used by the San to prepare poison arrows.
- *Acacia fleckii.* Rope is made from the roots.
- *Schinziophyton rautanenii*, the whole fruit can be used. The pulp of the fruit is edible raw or stewed. The nut contains one or two kernels, which are edible raw or cooked. Oil is extracted from the nut

and used for cooking or cleaning the body. The nuts can be gathered throughout the whole year, which makes them a staple food. The bark is used for stomach ache. For cosmetic purposes, ash of the bark mixed with water makes the hair softer.

- *Strychnos pungens*. The fruits contain an edible pulp, which is very important for nutrition. It is abundant and easy to collect, very tasty and highly nutritious, and can be harvested from December until May.
- *Ochna pulchra* fruit is very important for people's nutrition. The trees are abundant and it is easy to collect the fruits. These, when black and ripe, can be boiled in water to yield an oil which is used for cooking. The cooked flesh can be eaten as well, which makes the whole fruit very popular.
- *Grewia retinervis* fruit is one of the important ones amongst the *Grewia spp*. They can be harvested almost throughout the whole year. The shrubs are abundant, easy to collect and tasty. However, the kernel cannot be used so that the fruits are not as important as those from *Ochna pulchra*. After being dried, the berries can be stored for a long time and are then soaked or boiled before being eaten. Ropes are made from the roots.
- *Grewia bicolor* fruits are bigger than those of *Grewia retinervis* and therefore more popular. Ropes are made from the roots. *Grewia bicolor* is the only species to be used for arrows, as all other species will break.
- *Grewia flavescens* fruits are eaten fresh or dry and rope is made from the roots.
- *Grewia villosa* fruits are edible and roots used medicinally.
- *Boscia albitrunca* fruits are edible, the roots are used in milk to make it sour and the leaves and roots are used medicinally.
- *Bauhinia petersiana*. The roasted beans are used as a coffee substitute or pounded into a meal to make a palatable porridge. Leaves and roots are used medicinally.
- *Baphia massaiensis*; very strong durable wood used for construction.
- *Croton gratissimus*. The leaves in dried and powdered form are used as a perfume. Leaves and bark are used medicinally. It has very strong, hard wood for construction.
- *Dichrostachys cinerea*; various parts of the shrub are used medicinally. The wood is hard and durable, but very pliant, and is used by the San to make bows.

GRASS AND GRAZING

Table 4.3: Perennial grass standing biomass (kg/ha) average and standard deviation (n=5) in all study sites.

Site	Biomass Average (kg/ha)	Standard Deviation	Carrying Capacity (ha/LSU)
Site 10	0	0	-
Site 12	0	0	-
Site 9	220	192	15.3
Site 13	260	82	13.0
Site 3	374	442	9.0
Site 2	394	346	8.6
Site 14	396	527	8.5
Site 16	460	554	7.3
Site 4	550	237	6.1
Site 15	840	428	4.0
Site 8	910	397	3.7
Site 5	1690	654	2.0

Grass biomass was measured to give an indication of the grass productivity of the different areas of Western Bushmanland. Carrying capacity could be estimated i.e. how many cattle the particular area can support with forage at a sustainable level (Table 4.3.). The biomass consisted of standing dry perennial grass from the last rainy season except for Site 15, where the grass started to resprout and some green grass was included in the biomass calculation.

The Standard Deviation of all sites is very high (Fig. 4.1. & Table 4.3.). The high variation of the grass plots shows the patchiness of the grass distribution in Western Bushmanland. Spatial variability occurs at several levels and is caused by differences in soil type, grazing pressure and incidence of fire resulting in variable grass composition and degree of grass cover (de Leeuw and Tothill, 1993)

The sites 5, 8 and 15 have the highest grass biomass (Fig. 4.2), because these areas have not been grazed heavily. Site 5, in a remote wooded grassland at the bottom of the Omuramba Omatako, has the highest biomass. Site 8 is situated in dwarf shrubland with stunted *Burkea africana* on a dune slope. Site 15 occurs on the same soil as Site 5 in a dune street. The Omiramba and dune valleys seem to have the highest potential for grass biomass production although the areas are not very extensive (observation). Site 10, near the village of Grashoek, was heavily grazed. Site 12 was situated on a calcrete outcrop with low grass cover which has been grazed.

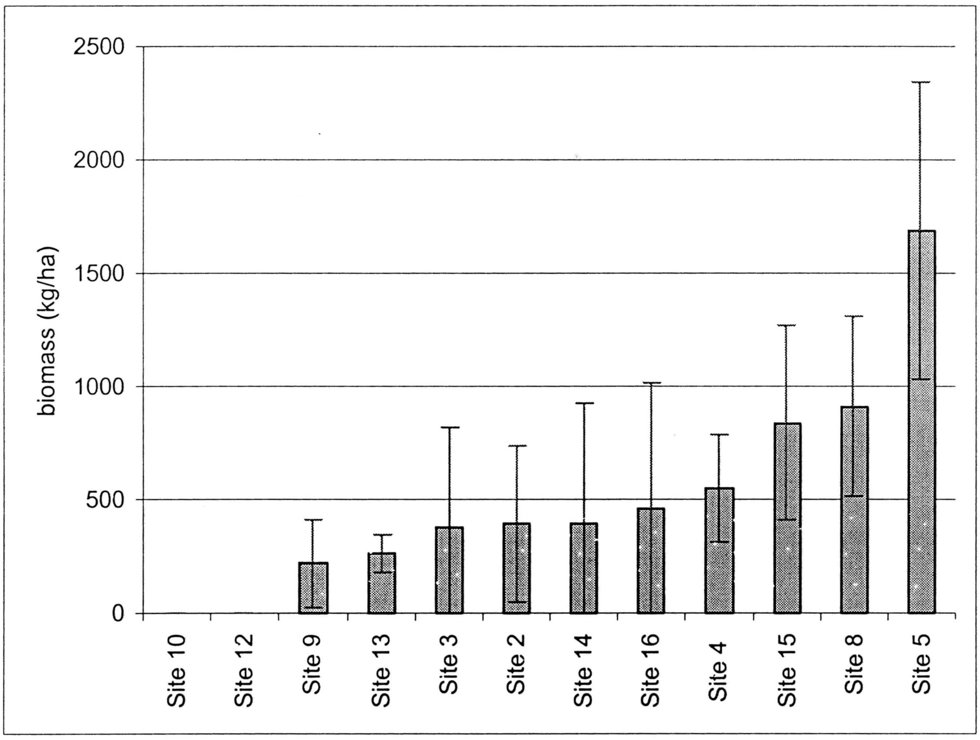

Fig. 4.2: Perennial grass standing biomass (kg/ha) average and standard deviation (n=5) in all study sites.

The present plant communities consist mainly of grazing-tolerant species, shrubs and perennial grasses which are often palatable to livestock. Climax and subclimax grass species such as *Eragrostis spp., Panicum maximum, Anthephora pubescens, Stipagrostis uniplumis* and *Aristida meridionalis* were found in many of the study sites. According to our observations Sites 3, 4, 8, 10 and 12 were grazed by livestock. Sites 3 & 4 were only grazed by horses while the other three sites were probably grazed by cattle. However, we tried to locate our study sites in undisturbed areas with only few livestock so that the animal impact on the grazing area is reduced to a minimum. During our stay there, we only saw cattle a few times. Goats, sheep and horses were very rare. When we visited eastern Bushmanland and Gam the areas seemed severely grazed. The poisonous plant "gifblaar", indicator of overgrazing, was only found at Site 8 in limited numbers. Many of the grasses at our sites were also moribund (dying because they get too little light through standing biomass) and are dying naturally because only some have been grazed. Limited grazing (wildlife or livestock) can be a solution to this problem.

The carrying capacity is the maximum possible stocking rate of herbivores that a rangeland can support on a sustainable basis. Our estimate of carrying capacity is based on the assumption that livestock require a daily dry matter intake using total herbaceous forage productivity as the single criterion to predict the livestock support capacity (Table 4.3.). Biomass quality and feeding value for the livestock are not taken into account. The estimates of our carrying capacity was sampled at the time of the year when the grass biomass is the lowest before the rainy season starts. The carrying capacity formula was adjusted to account for the low biomass at the end of the dry season. Namibia is an arid country and the rain varies over the years and seasons thus we cannot rely on a fixed long-term carrying capacity. The carrying capacities given should therefore be used with caution.

We recommend that grazing in omiramba areas and dune streets be used for limited grazing, based on availability of grass and good shrub species like *Boscia albitrunca, Combretum spp.* and *Acacia spp.*

WOOD PRODUCTION

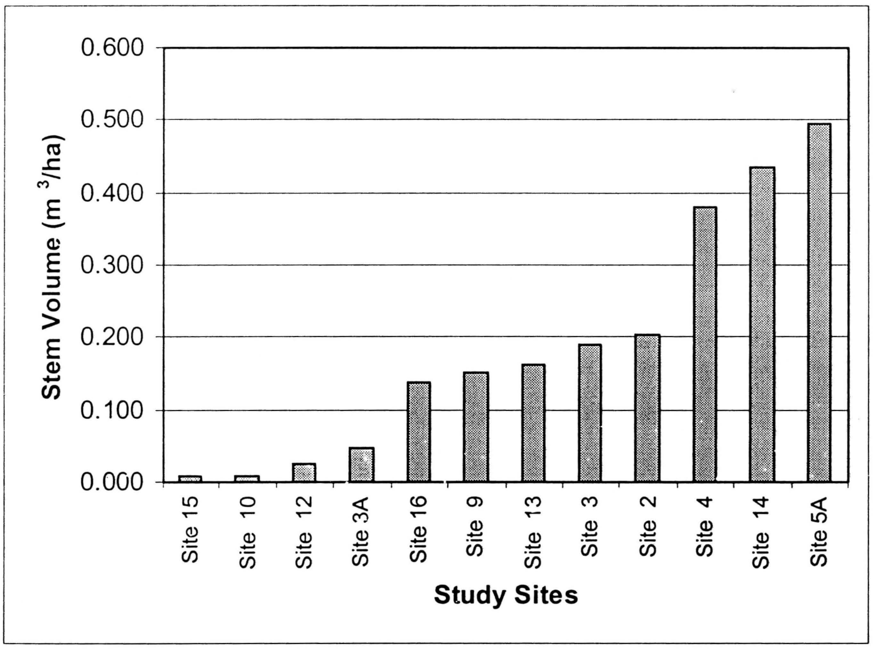

Fig.4.3: Stem volume of all tree species with diameter larger than 5cm (m^3/ha) at 13 study sites (n=1)

All trees, dead or alive, with diameters larger than 5cm were assumed to be a potential source of wood for charcoal production (Fig. 4.3.). By taking a fixed length of 1.2m per tree stem the results are only an approximation of the potential wood production. A more thorough study is recommended if this matter is persued further.

The highest stem volume per hectare was recorded at Sites 5A, 14 and 4, in that order. Sites 4 and 5A were on the Omiramba floors with *Acacia erioloba* (Site 4) and *Acacia mellifera* (Site 5A) contributing most of the wood volume (Fig. 4.3.). Site 14 has woodland trees dominated by *Pterocarpus angolensis* and *Burkea africana.*

Site 16, 9, 13, 3 and 2 have a wood volume between 0.1-0.2m^3/ha (Fig. 4.3). All these sites are shrubbed woodland with species like *Terminalia sericea, Combretum spp., Lonchocarpus nelsii, Pterocarpus angolensis* and *Burkea africana.* Sites 10, 15, 3A and 12 are shrubland with very few trees and Sites 5 and 8 had no trees at all.

The sites with the highest wood volume are those on the Omiramba floors where one finds dense acacia stands. The dense stands of acacias seem to be more productive than the shrubbed woodlands. The acacia stands in the omiramba do not cover big areas (observation) and it would not be sustainable to cut these trees for charcoal production. Denser woodlands in the northeast of Western Bushmanland (NRSC map, 1994) would give a higher wood yield but no sampling was done in that area. According to Cunningham (1997) Western Bushmanland is not classified as bush encroached and other areas of Namibia are therefore more suitable for charcoal production.

The National Inventory Project (Directorate of Forestry, 1997) found that *Burkea africana* has the highest wood volume of 7.57m^3/ha followed by *Pterocarpus angolensis* with 4.4m^3/ha and *Combretum collinum* of 0.89 m^3/ha. Their study area included southwest Kavango and excluded the southern part of Western Bushmanland. They say that most of the stem volume occurs in southwest Kavango especially *Pterocarpus angolensis* forests. They also noted that the dense forests are far away from any roads and it would be uneconomical to harvest those trees.

TREE SIZE CLASS DISTRIBUTION

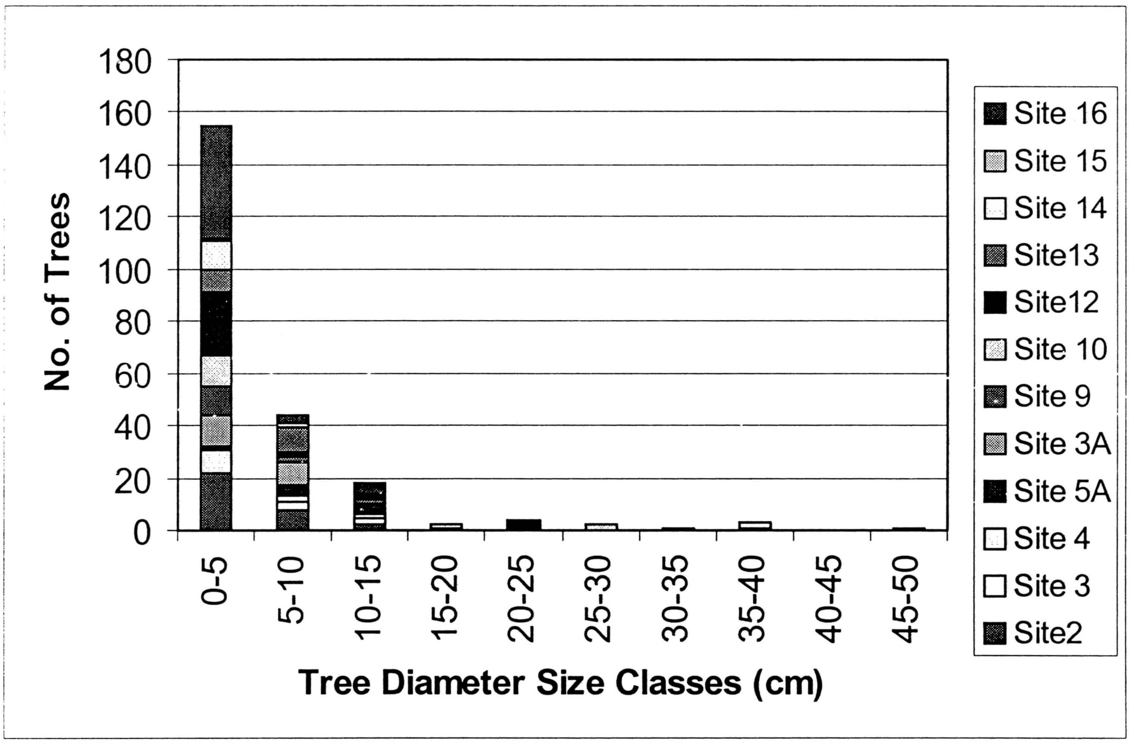

Fig. 4.4: Diameter breast height tree size class distribution in 20 x 20m plots of all tree species.

The size class distribution indicates the number of trees found in each 5cm stem diameter class of all trees in Western Bushmanland (Fig. 4.4). The overall tree population of Western Bushmanland looks healthy with a very high regeneration of small trees. In general the trees of Western Bushmanland are producing a high number of seedlings which will ensure their near future survival.

The larger tree size classes seem to be too low. Frequent fire could be one of the reasons that mature trees are killed. Dead mature trees (probably killed by fire) were found at four sites. Evidence of fire in the past was also recorded at all sites. The National Inventory Project (Directorate of Forestry, 1997) found fire damage on 90% of the trees sampled. But most damage was mild and no damage was recorded for 82% of *Burkea africana* and 34.4% of *Pterocarpus angolensis*. For *Pterocarpus angolensis* the damage is frequent but usually not very serious, though the number of dead and dying trees is high. All *Strychnos pungens* and *cocculoides* (monkey orange) affected by fire were killed (Observation P.W.Festus).

The size-class distribution of *Pterocarpus angolensis* also shows that it has alarmingly few seedlings (Ministry of Forestry, 1997). Fire might be the cause for this poor regeneration killing the seedlings before they can form a protective bark. The Ministry of Forestry (1997) suggests that this species might have problems regenerating because it is growing in its most southwestern distribution area and might experience some limiting factors. The Ministry therefore recommends that *Pterocarpus angolensis* should be protected and cutting should only occur very sparingly.

RECOMMENDATIONS

- Woodland trees are not adapted to frequent burning, although it seems that burning occurs regularly in Western Bushmanland (Simunze Richard, pers.comm.). Compared to the commercial areas on the western border of Bushmanland the communal land has a less dense tree/bush cover and more grass (observation). The cause for this could be less intense grazing by livestock and a higher frequency of fires in Western Bushmanland. The higher biomass of the ungrazed grass would increase the fuel for natural or man-made fires.

  A bush burning policy should be adopted and enforced. We also recommend that the local residents are made aware of the policy and that they be employed to implement it . Simunze Richard at the Kanovlei Forestry Station made us aware of this need and is capable of implementing the policy if he is given support.

- Our sample size was not extensive enough to determine the distribution of the veld food species and we would recommend further studies.

- A conservancy or the equivalent thereof, should be considered in Western Bushmanland to conserve the environment including the veld food on which people still depend.

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CHAPTER 5 - SOILS AND LANDFORMS

Emma Noongo and Ndafuda Shiponeni

OBJECTIVES

The objectives of the soils and landform investigation were:

- To provide information on the soils and landforms of Western Bushmanland at a scale and level of detail suitable for use in the production of a land systems map of the region. The land systems map was used to produce soil management units at 1:250,000 scale to increase manageability of information without sacrificing essential information.
- To provide geomorphological and soils information for input into the land suitability evaluation which will match land qualities against the requirements of specified land uses.
- To verify existing information on the soils and landforms of the region.

INTRODUCTION

Together with data on vegetation, water availability and socio-economic conditions, the compilation of soils and landform data is an essential part of a land evaluation. From this information land units are defined, mapped and characterised in terms of a summary of land qualities contained within each unit.

In view of the large land area (approx. 81,000km^2) to be investigated, a reconnaissance level soils and landform investigation was carried out with a final mapping scale of 1: 250,000.

This chapter presents the results of the soils and landform investigation in several ways by:

1. Giving an overview of the soils found in Western Bushmanland, drawing together information from the field survey and from previous work.
2. Exploring the relationships found between soils and landforms, once more drawing together information from a variety of sources and using the field survey results to verify previous work.
3. Presenting the soils data in three formats (1) the results by sample site, (2) a summary of soil characteristics by soil type, and (3) a further summary of the characteristics by land unit – this is a way of summarizing the information to make it easy to use in a land evaluation.
4. Interpreting the survey results. Where field results need to be supported by other information, this information is supplied by test pit results previously sampled on the same soil types in Western Bushmanland.

BACKGROUND INFORMATION AND SOIL CLASSIFICATION SYSTEMS

Background information on the soils of the region was scarce. Only one document provided information for the region as a whole. This document (Loxton, Hunting *et al,* 1971) reported the findings of a reconnaissance level soil survey carried out over northern Namibia to estimate the potential for irrigation. The survey employed an early approximation of the Binomial System of Soil Classification for South Africa – a system which has since been revised but has not yet been correlated to the standard FAO system (FAO, 1991).

It was not within the scope of the SDP soil survey to attempt to reclassify the soils of Western Bushmanland into the FAO system. Even though this might have become useful background material for future work in the region, to change classification systems would have prevented the use of the previous work for reference in the field. Therefore the survey focused on verifying the boundaries and classifications made using the South African binomial system.

OVERVIEW OF THE SOILS OF WESTERN BUSHMANLAND

The main objective of the soils survey was to describe the soils in relation to landform and topography for eventual classification into land units. The field work therefore concentrated on trying to identify and characterise soils lying on landforms that could be seen on the maps, aerial photographs, the satellite image *and* by field observation.

The use of previous work together with the land systems approach provided useful directions for field sampling strategy. Three land systems were identified: The Omuramba System, The Linear Stabilized Dune System, and the Sandveld Plains.

Having found the land systems, the survey focused on sampling the soils within them. Firstly landform features in each system were identified and then sample sites were randomly located.

The pattern of soils observed in the field was complex. Coarse, medium and fine sands dominated the study area. Darker colours and textures finer than sand could easily be associated with the presence of calcrete, either at the surface or lying at shallow depths. In an area of so many sands the colour variation was one of the ways each sand type could be distinguished from another. Colour differences also appeared to be related to specific landform features such as position on dune and omuramba slopes (foot slope, mid slope, upper slope, crests and ridges), position on the valley floors, and depressions in the Sandveld plains.

According to previous studies, the dominant sands of the area fall into three series – Fernwood, Sanspruit and Gaudam. The distribution of these are described next, in relation to the landforms observed.

Aeolian Sands of Dune Crests and Slopes, Sandveld Plains, Omuramba Ridges and Upper Catchment Boundaries.

Gaudam, Sandspruit and Fernwood sands fall into this category. Grey coloured Fernwood sands - the dominant soil of the region - are widespread over the Sandveld plains and extend in association with yellow Sandspruit sands to the Omatako omuramba ridges and through to the Upper Daneib catchment boundaries.

Red Gaudam sands occur more locally on the Omatako omuramba side slopes and on the upper catchment slopes of the Daneib omuramba. Sandspruit and Fernwood soils can also be found in association with Gaudam soils, although occupying less than 20% of the total land area (Loxton *et al*, 1971).

Sandspruit, together with Fernwood sands, are found on the crests and slopes of stabilised dunes to the west of the region. These soils occur as a complex and in catenary sequence with Okavango and Valsrivier soils. Catenary sequence means that the soils are found in a definite order from the top to the bottom of a slope, which can be explained by processes encouraging the downslope movement of particles and nutrients. The sequence is always the same if the same topographic and geological conditions are there. Field observations indicated that Sandspruit soils occur on dune crests, Fernwood soils are found on dune slopes and Okavango and Valsrivier soils lie on the valley floors.

Gaudam, Sandspruit and Fernwood soils are all characterised by less than 15% clay content. In certain areas, particularly on dune crests, the clay content of Sandspruit soils may be as low as 0-6%. Test pit information also showed that Fernwood soils had only 2-3% clay on the Sandveld plains but when found on the footslopes of dunes, both the clay and silt content was observed to be higher by the 'feel' test. On the omuramba slopes the clay content of the red Gaudam sands is generally slightly higher than both the Sandspruit of the omuramba ridges and the Fernwood soils located near to ridges. This may indicate a downslope transportation of clay particles through sheet wash processes, although it could also indicate that Gaudam soils naturally have a higher clay content than the soils of the omuramba ridges.

Subsoil drainage characteristics differ. All the soils sampled had extremely rapid infiltration rates. The survey results were too high (see interpretation of results) although they did show relatively consistent results in soils of the same series. Of the medium and coarse sand group Fernwood soils showed the slowest infiltration through subsoil zones while Gaudam show the highest. Okavango soils, containing more clay and silt, had the lowest surface infiltration rates. The results were much higher than expected although they were in the order of 8 times lower than the coarser textured soils.

Dark Coloured Soils of Omuramba Floors and Interdune Streets

Okavango soils fall into this group. The B horizons are not well developed and are consequently fairly permeable, considering the texture and nature of clay minerals present. It is common to find calcrete rock underlying these soils in both the omiramba and dune streets. Subsoils are loamy sand to sandy loam containing 6-15% clay and medium sand grain size range (250-500 μm).

As these soils occur in low lying and flat areas of poor drainage, these soils rate a moderate salinity hazard. Available water-holding capacities are good where the clay content is in the 10-20% range. These soils have the best irrigation potential of Western Bushmanland. However, in places these soils overly calcrete at fairly shallow depths. In such cases the irrigation potential will be limited by soil depth. With adequate drainage the moderately deep soils (>50 cm depth) can be irrigated as the underlying calcrete layer is not usually continuous, and not limiting to penetration by roots and water. Under irrigation a ploughsole may develop in these soils. This is a layer of lower permeability caused by the action of agricultural machinery such as ploughs and disks. This should be guarded against by varying the depth of ploughing and avoiding the puddling of the topsoil.

Clay Pan Soils of Active Pans on Omuramba Floors, Interdune Streets and Depressions in Kalahari Sandveld Plains

Valsrivier soils fall into this group. These soils were not found by the field survey although a number of attempts to locate them were made. Two sample sites which were anticipated to be Valsrivier were in fact identified as Okavango series after analysis of field results.

A limited amount of general information on Valsrivier soils was found in the work of Loxton *et al* (1971) who report that Valsrivier soils have a clear transition from a dark coloured surface horizon to an equally dark coloured, dense, extremely hard B horizon. The B horizon is sandy clay loam and, in the omirambas, can be calcareous at depth. These soils have a high salinity hazard and, in many places, they are naturally saline. The immediate subsoil is dense and impermeable while the deeper subsoil, especially in the calcareous zone, is less so. Due to the salinity hazard, clay pan soils should not be developed for irrigation.

Table 5.1 General summary of the soil series found in Western Bushmanland.

Soil Series	General Description	Occurence in Western Bushmanland	Special Problems
Fernwood	Deep, grey sands with less than 6% clay.	Occurs mainly in the Kalahari Sandveld on the plains or as infill in lower slope positions in the dune system	Commonly non-saline; generally very low water-holding capacity; excessive infiltration rate; possible erosion hazard on omuramba ridges
Gaudam	Deep red sands with less than 6% clay.	Common in the Kalahari Sandveld in freely drained sites such as the steeper sloping margins of omiramba.	No salinity hazard; very low water-holding capacity; excessive infiltration rate.
Okavango	Fairly deep, dark greyish brown, sandy loams (6-15% clay) overlying calcrete.	Fairly extensive soils especially where an admixture of weathering products and aeolian sand has occurred in low-lying positions, such as omiramba floors and dune streets.	Moderate to moderately low salinity hazard; moderate water-holding capacity; rapid infiltration rate.
Sandspruit	Deep yellowish sands with less than 6% clay.	Common on dune crests, and found on the Kalahari Sandveld plains in association with the more dominant Fernwood.	Very low to no salinity hazard; low water-holding capacity; very rapid infiltration rate.
Valsrivier	Clay pan soils; dark greyish brown, sandy clay loams with a prominent dense, hard setting B horizon. With depth, subsoil becomes calcareous and less dense.	Not extensive, occurs mainly in low-lying areas often in minor association with Okavango soils in active pan areas of omiramba and dune streets.	High salinity hazard; impeded internal drainage.

Soils and Associated Landforms

Previous Work

Loxton, Hunting *et al,* (1971) suggest that the distribution of soils of the Kalahari Sandveld Region (stretching over large areas of northeast Namibia including Western Bushmanland) can be related to the interactive effects of two factors:

- the depth of the aeolian sand mantle, and
- the degree of relief.

The combination of these two factors have produced a set of landforms with which certain soils can be associated. Subsequent to their deposition on the Tertiary calcretes and other sedimentary rocks, the Kalahari sands were eroded and partially reworked by wind and water. The end results produced landforms varying from flat plains to massive seif dunes, and sand depths varying from more than 50 metres to none at all.

SDP VII Ground Survey Results

Landforms and soils were investigated by ground survey to confirm whether or not the relationships found by Loxton *et al* (1971) would apply to the Western Bushmanland area of the Kalahari Sandveld.

Table 5.2: Combinations of sand mantle depth, surface relief, landform and soils found by the ground survey of Western Bushmanland

Sand Mantle Depth / Relief	Landform	Soil Series
Deep sand mantle and no surface relief	Dune crests	Sandspruit
	Sandveld plains	Fernwood / Sandspruit
Deep sand mantle and marked relief	Omuramba slopes	Gaudam
	Dune slopes	Fernwood
Shallow or no sand mantle and no relief	Omuramba floors	Okavango Valsrivier
	Dune streets	Okavango Valsrivier
	Omuramba Ridges	Gaudam with calcrete outcrops

Three combinations were found from the ground survey. A fourth relationship put forward by Loxton *et al*, (1971), which combines shallow or no sand mantle and marked relief, was not found in the area. Apart from the absence of the fourth relationship, the ground survey results confirmed the findings of the earlier work.

Landform/Soil Associations

The SDP ground survey results were blended with the confirmed information from Loxton *et al*, (1971) to produce a description of landform/soil associations occuring in Western Bushmanland.

Soils on deep sand and no relief
Where the sand mantle is deep, but where there is no relief and where surface drainage is imperceptible, the dominant soils are loose grey sands of the Fernwood series. In this case the soils and soil parent material are both sands of aeolian origin. In places these sands are nearly white in colour under a surface layer (+/- 15cm deep) stained by ash from veld fires. These soils predominate in Western Bushmanland. The largest single block is found in the ephemeral water divide to the east of the northern 'flowing' Omatako omuramba and west of the eastward 'flowing' Daneib drainage system. They are also found on lower dune and omuramba slopes where they frequently occur as recent infill.

Soils on deep sand and pronounced relief
In areas of deep sand where relief is more pronounced and well drained, soil forming (pedogenic) processes have given rise to catenary sequences of red sands (Gaudam) on upper slope positions, yellowish–brown sands (Sandspruit) on mid-slope positions and either grey sands (Fernwood) or heavier dark coloured soils (Okavango) on the bottomlands, depending on the extent to which erosion and deposition processes have acted on the sand mantle in those areas.

The soil survey found that Gaudam soils also occurred on mid-slope positions and that Sandspruit soils in this position are not as common as the previous work suggested. Gaudam soils were found on the dunes bordering the western lateral tributaries of the Omatako omuramba, and dominated the side slopes of both the main Omatako and the Daneib omiramba.

Soils on shallow to moderately deep sand with moderate to no relief
Where relief on deep sand is not pronounced, and where the sand mantle on flat plains is shallow to moderately deep, Sandspruit sands were found. In Western Bushmanland the field survey found that Sandspruit sands occurred on the flatter crests of dunes. They were also associated with Fernwood sands on the Sandveld plains in areas such as the Omatako omuramba ridges, where the sand mantle was locally shallow.

Soils on shallow or no sand mantle and no relief
Flat areas of Western Bushmanland having a shallow or no sand mantle are omiramba floors, pans (whether active, incipient or dry), and interdune streets. In these areas the parent materials include products of calcrete and silcrete weathering which contribute to the darker colours and heavier textures of the soils. The SDP survey found that Okavango soils were widespread on the omuramba floors and interdune streets. At the interface between interdune streets and base slopes, the soil characteristics appeared to be a mixture of Fernwood and Okavango. Soil textures were coarse (similar to Fernwood) although colours were of an intermediate variety between Fernwood and Okavango. Infiltration rates were higher than Okavango, but considerably lower than Fernwood results taken as a whole.

Organization of soils and landform data for land evaluation

The soil results have been organised into three groups for further reference:

Group 1: Individual sample site results are presented in table format according to pit number, soil type and land unit.

Group 2: Soil characteristics from all sites are then condensed and combined with supplementary information available from previous work to produce representative summary tables of the soils found in Western Bushmanland.

Group 3: The data is presented as one table in which land units (i.e. the final mapping units) are described in terms of summary soil and landform characteristics (Appendix B).

Characteristics summarised in Groups 2 and 3 above were used together with those of the vegetation survey to provide information on land qualities for the land evaluation. Information from the water survey were incorporated to describe the land units identified for Western Bushmanland.

INTERPRETATION OF RESULTS

The soils of Western Bushmanland were examined in terms of some of their physical and chemical characteristics. These characteristics were considered to be useful as indicators of soil potential when looking at suitability for different land use types.

This section describes each characteristic, explains its importance as an indicator of soil potential and discusses the results.

Soil porosity

The quantity of pores and their size distribution in a soil are useful general indicators of the physical condition of soils. Because pore characteristics change with seasons, they are not readily quantifiable in their influence on crop productivity. Pores are important features that influence aerating/ventilation, water movement as well as root penetration in soils.

The porosity of soils of Western Bushmanland was found to range between 30 and 60%. The calculation gives only the overall volume percentage of the pore space and does not characterize the size of the individual pores. Unlike bulk density, the results of porosity cannot be used as conclusive evidence for over-compaction problems in soil, but rather as indicators of likely risk. Sands with a total pore space of less than 40% for instance, are liable to restrict root growth due to excessive strength (Harrod, 1975) whilst, in clay soils, limiting total porosity is higher, and less than 50% can be taken as the corresponding approximate value.

Porosity and Nutrient Status

The soil porosity at each site increased with an increase of the soil depth except in Gaudam (over calcrete), Sandspruit and in Fernwood sands. It means that in most of the soils porosity will not limit root penetration. Higher porosity with depth might not be good because too much water will be allowed to drain through the soils without being held in the root growing zones. It also means that the soils will be dry for long periods of the year. If porosity is high (as with the sands of the area), allowing water to drain freely, the water will also drain away water soluble ions which make up the nutrient store in the soil. Porosity in this way might indirectly indicate the nutrient status of the soils. If this relationships is dependable, then it can be inferred that the sandy soils which make up the majority of the soils in the study area must have low nutrient supplies in the horizons near to the surface. Where do the nutrients go to if they are washed down the soil profile? They are translocated to areas further down the soil unless the porosity at depth is also high. In that case the nutrients are washed to depths which are too deep for plant roots to reach. However, long tree roots may still be able to tap these nutrients.

Porosity is high because most of the particles are sand and not silt or clay. Pores are larger between sand particles than between clay particles. Many macropores could be seen either by eye or with a magnifying glass in almost all the soils sampled. There was no difference between pores near the surface or deeper.

Infiltration Rates

Infiltration gives some indication of vertical water movement through a soil. It cannot be used directly to measure permeability as the lateral movement of water should also be considered. However, like porosity, it can serve as a guide to the internal drainage condition of the soil. A slow infiltration rate on flat land might cause pooling and puddling and the creation of pans in the wet season, although water will also be available for plants. A too rapid infiltration will lead to dry soils (a drought in the soil), and the possible leaching of nutrients down to lower horizons. This makes the top horizons less fertile and vulnerable to topsoil removal if nothing is holding the particles together. Clays cause lower infiltration but the particles also stick together.

Treatment of field results

The infiltration rates measured in the field were **very** rapid (up to 180cm/hr). The soil manual (Landon, 1984) indicates that infiltration rates greater than 25cm/hr for sand goes beyond freely draining to excessively drained. Considering the high porosity values it is not surprising that the field measurements were high but this cannot completely account for such high results. Results on the omuramba floors and dune streets were the only field results that matched with amounts indicated in the manual.

The high results could have been obtained as a result of measurement errors as well as naturally high rates. Some of the reasons contributing to higher than expected results were:

- recurrent presence of termite tunnels and ant nests under the soil surface
- presence of many burnt root channels under almost all the soil surfaces on the sand plains, omiramba slopes, dune crests and slopes
- mistakes in reading time intervals
- mistakes in reading depth intervals
- depth interval wrongly marked inside infiltrometer (1.4cm not 2cm)
- not enough water available to reach the constant infiltration level
- mistakes made in judging the constant infiltration rate

The measurements were corrected for wrong markings and basic infiltration rates were produced for all sites. However, the observations were not plotted on log-log paper to derive the cumulative infiltration (F) values.

Even though the infiltration rates were too high for all soils, measurements taken at each site could be grouped into rates corresponding to particle size distribution. The Okavango soils, with the lowest sand and highest clay contents show the slowest basic infiltration rate. This rate (14cm/hr) still indicates well drained soils. Gaudam and Sandspruit sands were all excessively drained wherever the soils were sampled. Fernwood sands showed slightly slower basic infiltration rates although in FAO terminology they would still be "somewhat excessively drained".

Infiltration, Porosity and Nutrient Status

High porosity values will produce internal soil conditions which encourage high infiltration and rapidly drained soils. By what has been said above, there may be a link between high porosity and infiltration values and low shallow horizon nutrient supplies. This is a subject discussed in the next section on soil chemistry.

Bulk density of soil

The overall density of a soil is termed bulk density. It should be clearly distinguished from the density of the solid soil constituents, called the particle density.

The measurements of bulk density are of great importance in soil surveying as guides to soil compaction and porosity. The measurement results are used as indicators of problems of root penetration and soil aeration in all the horizons found. Factors such as moisture content, organic matter level, root penetration, soil texture and cattle trampling can all affect the bulk density. Trampling for example can increase the bulk density, whereas an increase in organic matter will decrease it. An increase in bulk density of soil imposes stresses on plant root systems: the mechanical resistance to root penetration increases, thus reducing the plant's ability to exploit the environment; the air-porosity of the soil decreases, thus restricting the air supply to plant roots and facilitating the accumulation of toxic products; permeability also decreases with increasing density. The typical range of bulk densities found for sands and loams is <1.6 – 1.8; for silts is <1.4 – 1.6.

Bulk densities of the soils of Western Bushmanland

Results of the laboratory analysis show that all the soils have bulk densities in the lowest value range for the soil types. In the case of Okavango soils, found on omiramba floors and dune streets, bulk densities must reflect the higher percentages of silt and clay mixed with the sand particles from the calcrete underlying the soil.

Lower bulk densities than expected in the sands were also found in the samples taken at 10-20cm depths. In these areas of the soil profiles, bands of burned organic matter were observed. It is possible that the concentrations of burned materials (having lower densities than the mineral fraction) may have lowered bulk density in these areas.

Unfortunately it was not possible to confirm the observations by burning off the organic carbon in the laboratory and so we could not test for relationships between the organic carbon content and bulk densities.

Bulk Densities and Erosion

We are quite sure that the study area soils show very little evidence of compaction judging from the bulk density results. The soils are loose in all areas except for omiramba floors and dune streets. This is both good and bad; as long as the vegetation cover remains protective of the soil surface (i.e. the percentage cover does not significally decrease) then the high permeability of the soils will prevent water erosion. In areas such as omiramba crests the sandy soils would be vulnerable to erosion if the vegetation cover was decreased because of the nearness to quite steep and long slopes (up to 5 % steepness).

In flat areas where the vegetation was completely removed (on the Tsumkwe road near the turn off to Mangetti Dune) and bare soil was waiting for cultivation, we observed that high winds caused a lot of top soil to be blown away. From our observations it appears that the sandy soils are in danger of wind erosion if left without vegetation cover or some other means of protection from the effects of wind. Planting lines of trees across the path of the winds would help reduce the problem.

Particle size

Particle size refers to a mechanical analysis and it is used to determine the proportion of different-sized particle is the soil and hence its textural class. In principle the results are also used as basic indicators of soil physical and chemical properties. The soil particles are either held together by electrostatic interaction or by varieties of organic and inorganic substances.

Due to technical problems the particle sizes of the soil were not worked out in the laboratory. Information from the previous studies of the same areas were therefore used. The results of particle size analyses are quoted as percentage by weight of the whole soil.

Table 5.3.1. The particle size distribution (%) of the Okavango soil series at different depths

Depth (cm)	20-50	50-100
Horizon	B2	cl_{ca}
Particle size distribution (%)		
% fine earth	100	100
c. sand	2	1
m. sand	29	26
f. sand	51	61
silt	3	3
clay	14	10

Table 5.3.2. The particle size distribution (%) of the Sandspruit soil series at different depths

Depth (cm)	0-22	22-70
Horizon	A1	B2
Particle size distribution (%)		
% fine earth	100	100
c. sand	13	12
m. sand	36	35
f. sand	44	47
silt	1	1
clay	6	6

Table 5.3.3. The particle size distribution (%) of the Gaudam soil series at different depths

Depth (cm)	22-76
Horizon	B21
Particle size distribution (%)	
% fine earth	100
c. sand	1
m. sand	40
f. sand	53
silt	1
clay	6

Table 5.3.4. The particle size distribution (%) of the Fernwood soil series at different depths

Depth (cm)	0-25	25-78	78+
Horizon	A1	C1	C2
Particle size distribution (%)	100	100	100
% fine earth			
c. sand	0	1	1
m. sand	52	46	43
f. sand	44	50	53
silt	2	0	1
clay	2	3	3

The soils of the study area contain a lot of sand and very little clay or silt. As the percentage clay content affects other properties of soil such as the amount of cations held by the soil, it is important to know how much clay is in the soil in relation to particles of other sizes. This will be discussed in the soil chemistry interpretation.

The Okavango soil has the highest maximum clay percentage, although this is only 14%. Other soil series such as Gaudam and Sandspruit have even less clay - a maximum clay percentage of 6% (both). The Fernwood soil has the least clay content at 3%. All the soils fit into the FAO texture class of Coarse.

INTERPRETATION OF SOIL CHEMISTRY CHARACTERISTICS

Soil chemistry analysis may be done to obtain essential data on soil fertility that will allow the use of a map based on soil characteristics to be used for land management and planning.
In our study, four measurements are used here to describe the soil chemistry characteristics of the four soil types found in Western Bushmanland, (Table 5.4).

Table 5.4: Cation Ratios, Cation Exchange Capacity (CEC), Sodium Absorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) of four soils in Western Bushmanland

SOIL SERIES	Ca:Mg	K:Mg	CEC total	CEC clay	% clay content	SAR(me/l)	ESP(%)
Gaudam	5:3	2:9	2.30	-	6	0	0
Fernwood	1:1	1:2	1.72	65.3	2.7	0.31	2.97
Sandspruit	5:4	1:3	2.08	29.5	6	0.20	2.64
Okavango	3:2	1:15	6.63	57.5	12	0.20	1.58

Cation Ratios

The Ca:Mg and K:Mg ratios are used to explain the relative Magnesium (Mg) content in relation to other ions. Mg deficiency in crops is not only associated with low Mg content in the soil, it is also associated with the presence of large amount of other cations, particularly Calcium (Ca) and Potassium (K).

Increasing Ca:Mg ratios above 5:1, Mg become progressively less available to plants. At these high ratios, the soil structure becomes weaker due to increased deflocculation of the clay particles. Gaudam, Sandspurit and Okavango soils have a Ca:Mg value less than 3:1, the value which according to Landon (1984) inhibits uptake of Phosphorus ions by plants. The approximate optimum range for most crops is 3:1 to 4:1, therefore to improve those types of soils with less than 3:1 values, a considerable amount of Ca should be added to raise the levels to the optimum. Fernwood on the other hand with the ratio of one means that Ca should also be added to the soil because this value indicates the lowest acceptable limit.

Magnesium uptake by plants is inhibited if the K:Mg values in the soil are >2:1, a less than 3:2 value is recommended for field crops. All the four soil types in our study area have a K:Mg ratio which is less than 3:5 and under these conditions vegetables, fruits, greenhouse crops and importantly, field crops can grow.

Cation Exchange Capacity (CEC)

Cation exchange capacity measurements are used in the assessment of the soil potential fertility, and the soil response to fertilizer applications. CEC is defined as the total adsorption capacity of a soil for cations that results from negatively charged clay particles and organic substances.

According to Landon (1984), CEC values which are less than 4me/100g soil indicate a degree of infertility normally unsuitable for irrigated agriculture. Three of the soil types found in Western Bushmanland have CEC values <4me/100g. These soil types are Sandspruit, Fernwood and Gaudam.

From the explanation above, it appears that the sandy soils in Western Bushmanland are infertile due to low CEC values. The CEC values used were the CEC Total which are values related to the **total** soil including clay content and organic matter content of each soil. It would be logical to expect therefore, that if the clay and/or organic matter contents of the soils were low then CEC Total values would also be low.

CEC itself is a property of colloidal fraction of soil, mainly derived from clay and organic matter fractions. Therefore it is essential that CEC values should always take into account the clay content. All soil types found in the area have low clay contents (Table 5.4), and in cases like this CEC values of clay are useful. The Okavango and Fernwood soil types have CEC clay values of >40me/100g, which according to Landon (1984) is classified as very high. Sandspruit, with a 29.5 CEC clay value, is classified as high. In both cases this indicates a good degree of fertility.

The two interpretations of CEC above pose a problem for the land evaluation. If the Total CEC values are used, it can be concluded that the fertility of the soils is very low. However, if the CEC values for just the clay fraction are used, it can be concluded that the soils of the area are fertile. Which values should we use ?

From all the observations made, there is strong evidence of low fertility in the soils especially the sands. Also as the clay content is so low, very few nutrients can be held by the colloidal fraction of the soil. Therefore, the Total CEC values reflect all the other observations more closely than the CEC Clay values do. These are the values that should be used to indicate soil fertility potential.

If organic matter content results had been obtained they could have been used to check for relationships between organic matter and CEC values (CEC Total and CEC Clay).

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio of soil extracts is used in the assessment of sodicity hazards from an increased sodium hazard. A sodic soil has sufficient exchangeable sodium to interfere with plant growth and cause dispersion and swelling of clay minerals. According to Silsoe (1998), soils with SAR in the range of 10-20 are potentially hazardous in this respect. Soils with low clay minerals, higher SAR as well as exchangeable sodium percentage (ESP) can be tolerated. This is because low salt concentration increases the effects of exchangeable sodium on soil swelling. All the four soil types in Western Bushmanland have a relatively low SAR (<1me/L), indicating that there is no problem of sodicity. It would not be a problem to crops if SAR is to rise, as the low clay content in the soil would decrease the hazard of increased sodicity.

EXCHANGEABLE CATION LEVELS

Levels of **Exchangeable Cations** in soil are of greater value than the CEC, because they do not only indicate the existing nutrient status. The level of exchangeable cations is also used to assess balances amongst cations. This is important because many effects such as those of soil structure and nutrient uptake by crops are influenced by the relative cations concentrations as well as by their absolute levels.

We looked at the exchangeable sodium percentage (ESP). Although **Sodium** may in particular circumstances be utilized by some plants as a substitute for Potassium, it is not an essential plant nutrient and therefore its absence or presence in very small quantities is not detrimental to plants. However, this element in significant quantities, has an adverse effect on plants as well as on the physical condition of the soil (Landon, 1984). From Table 5.4 above it can be seen that the soils of the studied area have quite a low **exchangeable Sodium percentage,** in the range of 0-3%. The Okavango and Gaudam soils with an ESP in the range of 0-2%, would not affect the most sensitive crops, as indicated by Landon (1984). Only extremely sensitive crops (deciduous fruits, nuts, Avocado, Cassava and citrus) are affected in soils with ESP in the range which Fernwood and Sandspruit fall. So in Western Bushmanland there is no Sodium problem to prevent growing crops such as wheat, beans or sugarcane as they are not affected by this ESP.

SOIL FERTILITY

The overall fertility level of soils in Western Bushmanland is low. All soil types have a low content of Ca and K in relation to Mg. The low content of sodium however, prevents the soil from becoming sodic, and is thus good for agricultural production.

RECOMMENDATIONS

1. Low overall soil fertility and low clay content
   Because of low clay content in the soil, it is necessary that fertilizers be added to the soil to increase the mineral content of the soil.

2. Wind erosion hazard of fields.
   To minimise the impact of erosion we recommend the establishment of windbreaks to reduce wind velocities over fields. The high rate of wind erosion on some fields and open areas with little ground cover was observed during the field study. The thread of wind erosion is highest at the end of the dry season just before the rainy season starts, when the fields are ready for ploughing.

CHAPTER 6 – WATER

Patrick Lubanda and Nandehasho Nickanor

INTRODUCTION

Boreholes in Western Bushmanland are maintained and owned by different groups. There are two main suppliers of water in the area; the Rural Water Supply and NamWater. NamWater supplies bulk water to larger settlements such as Mangetti dune, Omatako, M'kata, Kukurushe, Rooidaghek and Aasvoëlnes. Rural Water Supply offers its services to people on a more local scale. There are some water pumps that are privately owned and donated by NGOs, for example at Omatako village (BH60, Deon Louw) and Omatako community rest camp (BH 70,WIMSA) respectively.

Appendix C indicates all the boreholes that exist in Western Bushmanland (considered to include a part of Central Bushmanland during the field survey) according to the DWA database. A total of 58 boreholes were found, including one hand-dug well. Thirty boreholes were found in use, thirteen were found not in use and fourteen were not found. Those boreholes that were found not in use included the abandoned boreholes and those which had been drilled and found to be dry. Boreholes that were abandoned were found without water except one (BH 78) which was formerly used by the Roads/Works department and this was sealed at the time of the survey. There are no settlements near these abandoned boreholes. Reports from people in the area indicate that there used to be people living near these abandoned boreholes before they dried up. After they dried up, people moved to areas where there was water nearby. Those boreholes that were found in use were mostly run by diesel engines although there were those that were powered by solar or electric pumps. No one has complained about not having enough water for their needs. However there were complaints about the delay of repairs to boreholes and late delivery of diesel to the communities.

Active boreholes were found mainly along the main gravel road and near to the tracks that connect to the main roads. Boreholes that were not found were those which were difficult to access or may not have existed. Such boreholes had location coordinates that often put them very far away (>50km) from the main road or in densely forested areas where there was very little or no access. Most of those boreholes as indicated in the Directorate of Water Affairs' (DWA) database were far from human settlements (according to people living near the main gravel roads). Most of the boreholes not found were commonly located around the Daneib in the southeast and upper Omatako system in the southwest (Appendix C).

WATER QUALITY

Underground water in the study area is of good quality, in terms of total dissolved solids (TDS), even though there are some places where water has a slight salty taste (Fig. 6.3). When the DWA information is combined with the results from the field survey, three water quality classes are obtained (Fig. 6.1). These are, A, B and C standards (SWA Water Affairs standards). 85% of the water is A-Standard, 6% B-Standard and 9% C-Standard. If only the water from the active boreholes is considered, then 97% of the water in the area is of A-Standard and only 3% is of B-Standard. Most of the active boreholes deliver A-Standard water. This is reflected by the low TDS, which ranges from 100-1165 mg/l. At Rooidaghek, water is of the B-Standard with a TDS of 1600mg/l.

No extensive areas of poor groundwater quality are present. In most areas (since we did no drilling), according to Simmonds (1993) potable water can be located within approximately 5km of a borehole which has intersected unusable water. Little information is available regarding aquifer parameters, which control groundwater distribution. The area can be represented by six Kalahari group sediments from which groundwater is obtained (as defined by the water team, Table 1-legend). The Kalahari group strata constitute a reliable source of generally good quality water except in a few areas: a high TDS was measured from borehole WW23193 (2925 mg/l) and WW6452 (2588 mg/l) in the northwestern and southeastern parts of Western Bushmanland (Fig.6.3.).

Isolated boreholes also intersect artesian water in the Kalahari strata along the Omuramba-Nhoma river systems. Normally a high degree of correlation exists between groundwater level and topography. The results from the study has shown that there is no relationship between any of the measured variables, i.e. TDS and drilled depth; maximum yield and drilled depth; TDS and rest water level; maximum yield and rest water level; TDS and maximum yield. In general groundwater would flow from areas with a higher water table (i.e. areas of recharge) to areas with a lower water table. Where the rest water level in a phreatic Kalahari aquifer is deeper than 20m it is felt that little, if any, direct recharge from rainfall will take place due to the very fine grain size and correspondingly low permeability of the sediment. From the field study, referring to Figure 6.4. one can derive a similar argument. From this representation it is seen that much of the Kalahari has a rest water level greater than 20m. Consequently it is interpreted that substantial recharge must therefore originate from fracture aquifers in bedrock with which the Kalahari comes into contact. This recharge is very slow, possibly taking several hundreds of years for water to move 100km (Interconsult, 1996). The ground water aquifer in the area is probably recharged from two different directions: from the wetter eastern Bushmanland and from the fractured aquifers of Otavi, Tsumeb and Grootfontein areas.

Table 6.1: Water quality standards*.

Standard	**A-standard**	**B-standard**	**C-standard**	**D-standard**
Total dissolved Solids (TDS) (Mg/l)	1500	2000	3000	6000

*Department of Water Affairs, 1971.

The different water standards are suitable for use in the following ways:

A-Standard: Villages with more than 10 000 dwellers.

B-Standard: Villages with less than 10 000 dwellers, public rest camps and holiday resorts and small communities that are supplied by the State with drinking water.

C-Standard: Where the source is only used by a limited number of people such as farms and posts.

D-Standard: Cattle drinking.

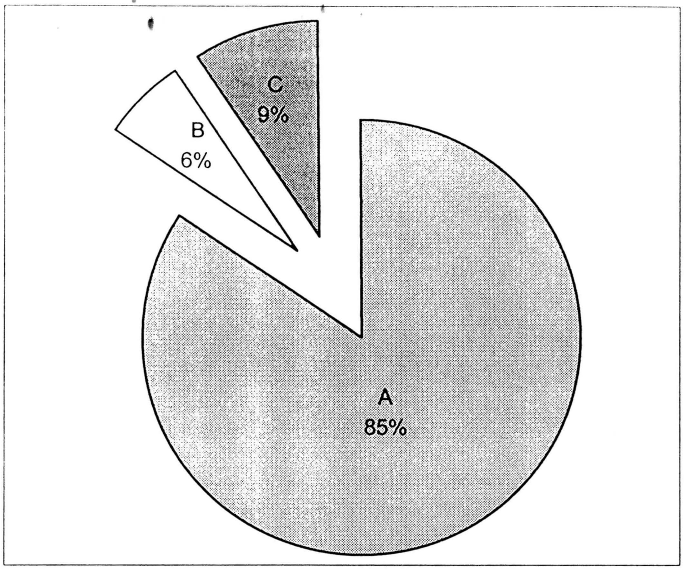

Fig. 6.1. Water quality classification into A, B and C standards in Western Bushmanland.

THE UTILISATION OF WATER

Water is used mainly for domestic purposes (D) (which at some places included schools (S), clinics and hospitals (H) and police (P)), livestock (L) (horses, goats, cattle), research (R), tourism (T) and gardening (G) (Appendix C). At Mangetti dune, water from all three boreholes is meant for human use only (not for livestock), (NamWater caretaker, pers.comm.). Small-scale horticulture (gardening) is practiced at most villages. Some villagers have made small fenced-off plots around the larger storage tanks from which water for irrigation is also obtained. A variety of crops are cultivated in these gardens. (See Appendix C)

Storage of water

In general each borehole is supplied with one big storage tank and two small tanks. There is an exception at places where there are two boreholes located near each other, in such a case the two boreholes normally share the same storage tank. The capacities of the storage tanks vary from place to place and also come in different sizes. The sizes of tanks range from $4m^3$ to $40m^3$. The total storage capacity per village ranges between $4m^3$ to $85m^3$.

Rest water level (as an indication of the water table)

The rest water level could not be measured below 100m because the dipper that we used during the field study was only 100m in length. This made it difficult for the team to determine the rest water level of most boreholes. According to Namibia Ground Water Development Consultants (InterConsult, 1990), the rest water level increases as one moves from east to west of the study area. This is also supported by the results obtained from the field survey (Fig.6.4). The rest water level in this area varies from 28m to 182m and has generally increased in the area during the past years (Fig. 6.2.). The depths of boreholes range from 45m in the east to 505m in the west. The average drilled depth was found to be around 195m. There was one borehole (BH69) in the western part of the study area that was recorded to have been drilled to a depth of 505m but its rest water level was only 35m below ground. This same borehole was said to have developed into a spring (from an artesian aquifer) that was producing hot water (Chief John Arnold, pers.comm.). Compared to others, this borehole

(BH69) has the highest TDS reading recorded in the DWA Database (2925mg/l). At the time when the study was done, this borehole was not in use as the local people have sealed it off with concrete blocks (Chief John Arnold, pers.comm).

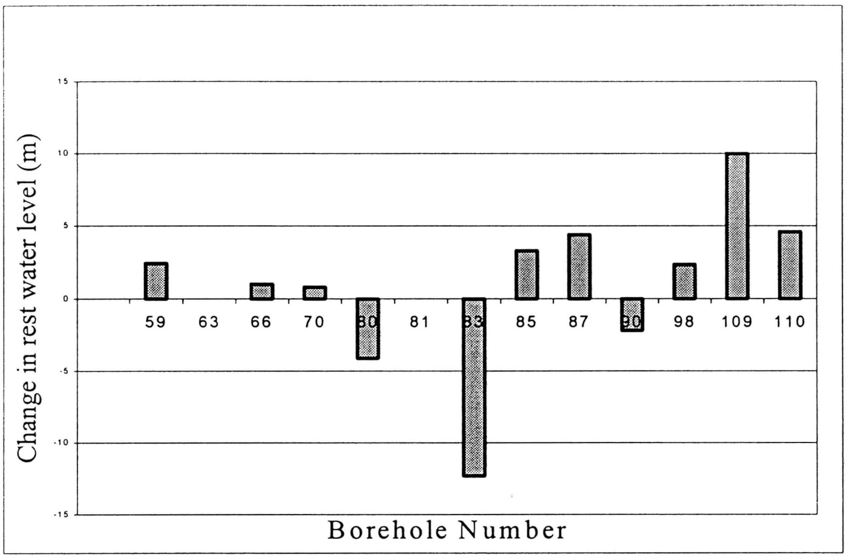

Fig. 6.2. Rest water level change over a certain period of time.

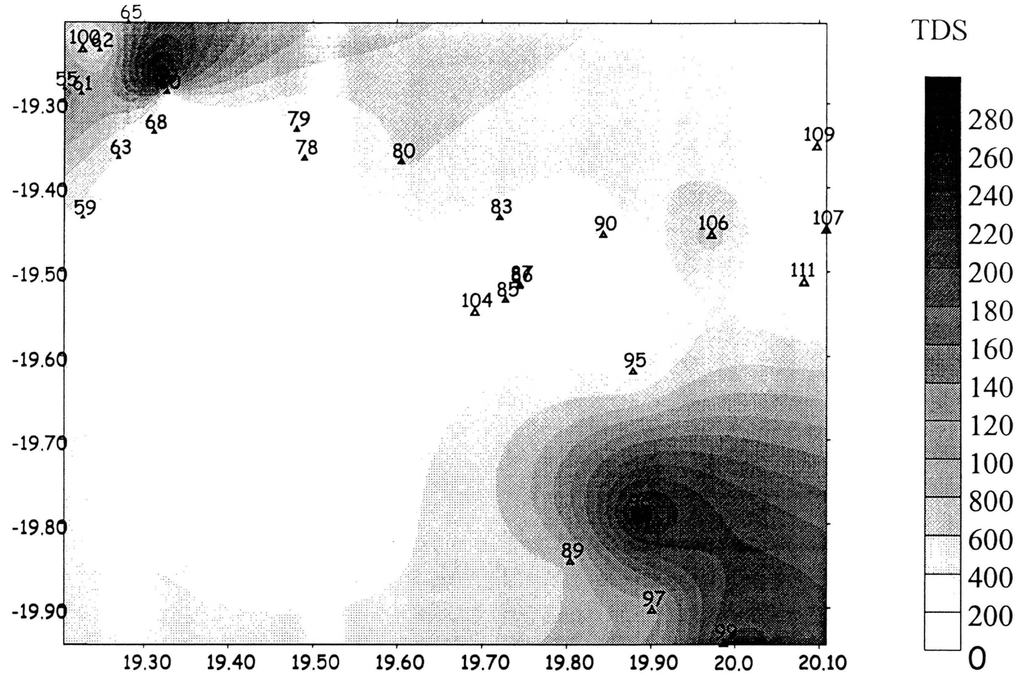

Fig 6.3. TDS levels (mg/l) in western Bushmanland obtained from DWA database and field survey

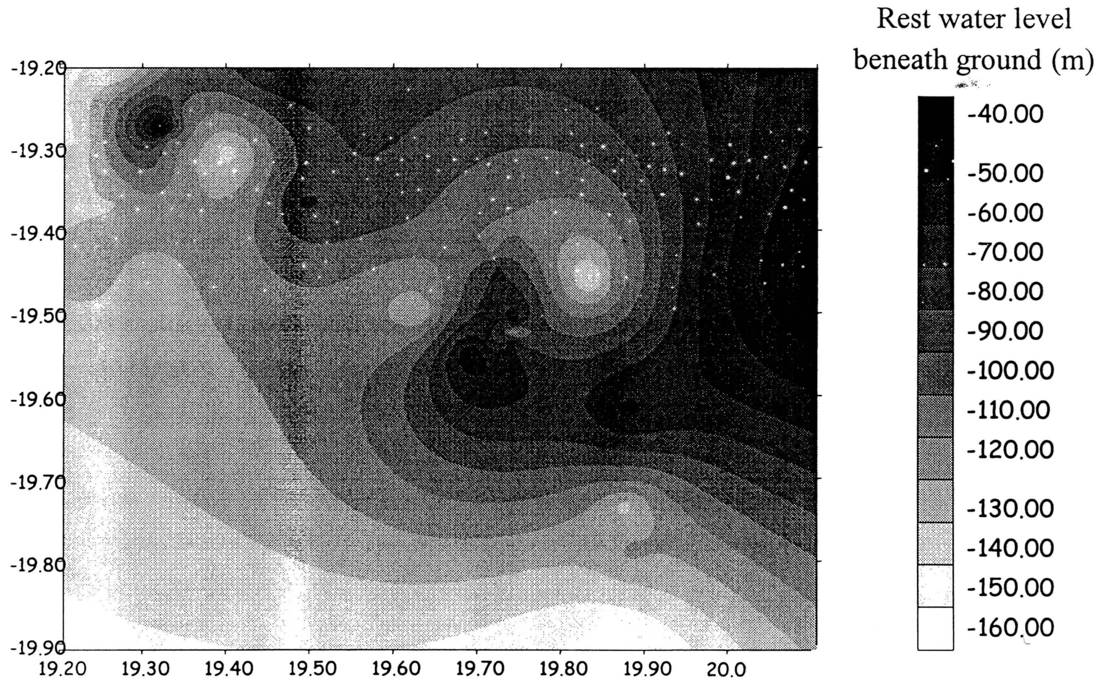

Fig 6.4. Rest water levels in western Bushmanland

WATER YIELD

The yield measurements of only two boreholes were determined in the field; yields for the rest of the boreholes were obtained from the DWA database. As the extraction rate (yield in m^3/h) fluctuates over time, the combined information that produced the results do not necessarily reflect the present state of water available in the study area. Information regarding the saturated thickness and the hydraulic properties of the Kalahari sediment is scarce and no comprehensive, regional resource evaluation of the aquifer has been carried out. In addition, the lack of properly updated yield information with an uncertain population size is increasing the problem even more. Thus at this stage, it is not possible to quote stored reserve figures with confidence. This calls for further research.

WATER AVAILABILITY

Except for administrative centers where there are two to three boreholes found, at most one borehole is commonly shared per village. Given an estimated population size of around 4000 with 30 working boreholes there is a density of 133 people per borehole. Western Bushmanland covers an area of approximately 100 000 km^2. With such a vast area compared to its population, the area can be classified as sparsely populated. The existence of a working borehole always signifies the presence of a settlement nearby i.e. within 3km of a village. Water is a ubiquitous resource in the livelihoods of the communities found in this area. A number of people have left areas where they have lived for many years after the borehole that they depended on dried up, to settle at places where water was available. At present, boreholes are situated along the main gravel roads along which most and major settlements are also located.

GLOSSARY

1. **Rest Water level -**	depth from ground surface to water table.
2. **Phreatic -**	a zone of permanent saturation (relating to the water table).
3. **TDS -**	total dissolved solids, which gives an indication of water quality.
4. **Water Contours -**	lines joining areas of the same water table.
5. **Aquifer -**	strata containing extractable groundwater. The quality may vary, as may the nature of its porosity and permeability.
6. **Water Table -**	the upper surface of a zone of saturation of an aquifer.
7. **Potable Water -**	water that is safe to drink.
8. **Artesian Aquifer -**	an aquifer which contains water under pressure.
9. **Fracture Aquifer -**	an aquifer that forms in hard rock where porosity is developed along interconnecting fissures and other discontinuities.

Quarter-degree areas assumed to have a uniform underlying aquifer*

1. 1919DA-Red, very fine to fine grained often poorly sorted and angular calcareous sand.

2. 1919DB-Red very fine clayey sand, sandy clay, and silt. Often calcareous and siliceous and with fragments of country rock.

3. 1919BD-Similar to 1919DA.

4. 1919AC-Red orange and dark brown or grey, very fine to fine grained sand. Clay contains angular fragments of slitter and calcrete.(Eiseb formation).

5. 1919CB-Darker shades of red, brown, Grey, pink and beige, fine to coarse grained often gritty and gravelly. Poor to moderate sorting and subrounded sand often with interbedded and interstitial silt and clay. Alternating horizons of calcareous and siliceous sand.

6. 1920AA-Red, orange, pink and brown, very fine to fine grained calcareous and siliceous sand. May also contain angular fragments of silcrete and calcrete.

Courtesy of Namibia Groundwater Development Consultants. (Geological Section of the Okavango and Bushmanland)

* Any borehole that falls within one of the quarter degree. Areas listed above will have an underlying aquifer with the properties as described.

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CHAPTER 7 - SOCIO ECONOMICS

Andreas Gazza, Penda Shimali and Rauna Nawa

Until the 20th century, people did not permanently occupy Western Bushmanland. San people probably used it seasonally when sufficient rain supported hunting wildlife and gathering of veld foods such as mangetti nuts. With the introduction of boreholes, villages developed. In the 1970s, the South African (SA) army used this sparsely populated area to develop a major military base. Many San people settled in the area at that time. Other San people were brought to the area as the SA army withdrew from Namibia. After the independence of Namibia, San people continued to be resettled in the area.

The socio-economic situation in the area, with particular reference to the San people, was investigated with an emphasis on four specific topics.

- A characterisation of nineteen of approximately twenty-five villages in the area, and of the people living in these villages.
- The agricultural practices upon which the people in these nineteen villages depend for some of their resource needs.
- An overview of the infrastructure of Western Bushmanland.
- An overview of all food resources used by the people living in Western Bushmanland

The results presented in this chapter represent information gathered from interviews with local villagers.

HISTORY OF VILLAGES AND PEOPLE

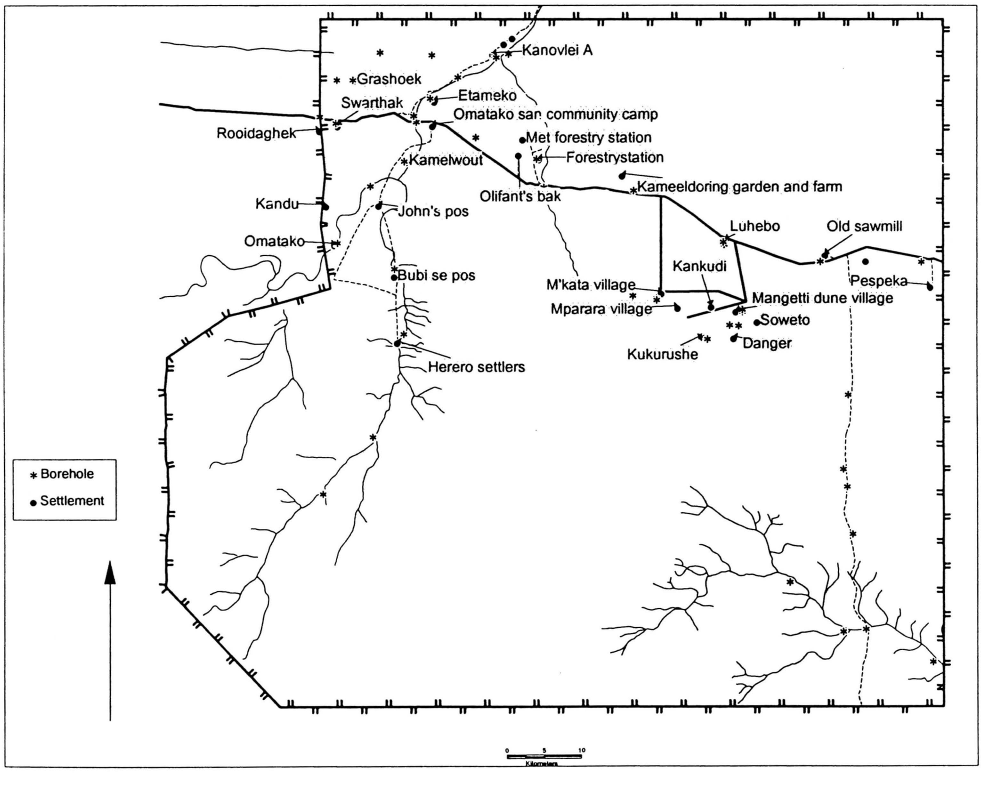


Figure 7.1: The villages visited in Western Bushmanland (♦ villages, ⊗ boreholes, —road)

The nineteen villages visited during this study, can be categorised into three groups based on a combination of their location and their history (Table 7.1 and Figure 7.1).

- The 'Omatako tributaries'. These villages lie in the western half of Western Bushmanland and depend on the seasonal water associated with this fossil watercourse.
- The 'Mangetti Dune Group' of villages comprises 8 villages that developed in association with the army base at Mangetti Dune. Mangetti Dune is now the administrative centre of Western Bushmanland.
- The 'Outlier Group' represents three villages situated northwest and northeast of the two main groups.

The nineteen villages investigated in the area are occupied by people originating from six different places within northern Namibia and south-western Angola (Table 7.1). The people came into the area in many different ways. The South African Army brought some in 1981, others were brought by political representatives of the San while others came with church missions. Background information of people living in the villages was one of the main things that was gathered during the interview (Table 7.2). In addition, information about present movements of people was collected.

Table: 7.1 General description of the villages surveyed

Village groups	**GPS**	**Date visited**	**Origin of people in village**	**Min. no. of people at meeting**	**# of pensioners (M) (F)**
A. Omatako					
Bubi se Pos	19°28'34"S 19°17'57"E	6/12/98	Western Bushmanland	3	3 3
Etameko	19°15'78.7"S 19°20'99.8"E	8/12/98	Mpungu	23	1 1
Kameelwoud	19°20'09.9"S 19°18'50.7"E	6/12/98	Farms	9	2 1
Kandu			Mpungu Angola	64 adult	2 2
Kanovlei A	19°12'25.0"S 19°25'28.1"E	5/12/98	Mpungu	46	1 1
Omatako	19°26'15.1" S 19°13'23.0" E	6/12/98	Angola Omatako	3	20, sexes not identified
Omatako Valley Restcamp	19°17'33.4"S 19°20'52.8"S	16/12/98	Angola Mpungu	5	2
B. Mangetti Dune					
Danger	19°33'02.2"S 19°43'59.4"S	12/12/98	Angola	15	0 0
Kukurushe	19°32'58.4"S 19°41'31.7"S	12/12/98	Kukurushe Tsutsabis Mpungu	±75	3 3
M'kata		16/12/98	Mpungu		
Mangetti	19°31'05.8"S 19°44'09.4"S	11/12/98	Angola Etosha	1	20 not identified
Meduletu		11/12/98	Okongo	±42	1 0
Mparara	19°30'49.7"S 19°39'40.3"S		Mpungu Angola	±40	1 4
Luhebo	19°26'10.6"S 19°43'22.4"E	11/12/98	Angola	28	5 2
Soweto	19°31'51.2"S 19°45'46.5"S	11/12/98	Angola	4	0 0

C. Outliers						
Aasvoëlnes	19°27'02.9"S 20°06'28.7"S	13/12/98	Tsumkwe Aasvoëlnes	7	0	3
Grashoek	19°14'17.6"S 19°14'50.6"E	7/12/98	Tsumkwe Angola Kavango	25	3	5
Nhoma	19°13'47.1"S 20°18'21.7"S	13/12/98	Samagaigai Tsumkwe	±65	1	3

A GPS (Global Positioning System) was used to determine the position of the villages for inclusion in the maps of the area. Just a few older people in Grashoek, Bubipos, Aasvoëlnes and Nhoma mentioned that they had been born in the area. Most of the old people came from Angola, Kavango Region (Mpungu and Samagaigai), Caprivi Region (Omega), Ohangwena Region (Okongo) and the area of Etosha National Park (Outjo).

From the interviews we learnt that 70 people were receiving pensions, of which 28 were female and 22 male (20 were not specified) (Table 7.1.). Yet, this appears not to be a true representative number of the pensioners in Western Bushmanland. The reason seems to be that the residents are not in the possession of the correct identity documents. Most of the people who have settled in the villages for farming purposes arrived after independence. More recently, a number of people moved into the area for agricultural purposes, many under the supervision of ELCIN acting as the implementing agency for the Ministry of Lands Resettlement and Rehabilitation (MLRR).

In each of the nineteen individual villages, a selection of older people were interviewed (Appendix D). Emphasis was placed on past and present movements of people. The maximum number of persons interviewed in depth in a village was nine, while the minimum was one. Detailed records were made for 38 males and 24 females (Appendix D). Males appeared to be more comfortable with interviews whereas females in several villages did not wish to participate in discussions. This could be attributed to the San tradition of having males speak to visitors. At other villages, females contributed the majority of the opinions and information. In these situations, it was noted that the male heads of the households were absent.

All older women and most of the older men were married. It appears that most married people have children (Appendix D). Females appear to marry at a younger age than males (15 years for females, older than 20 years for males). The average number of children per reproductive female is said to be 5.5 (hospital records, Mangetti Dune). As they grow older, young people tend to leave the area, in search of study places, employment or improved living standards. Some people were reported moving within Western Bushmanland in search of veld foods, places in schools and employment.

AGRICULTURE

Agriculture is the dominant way of producing food for the communities, such as irrigated gardens, cultivated dryland cropping as well as livestock farming (Table 7.2). However, there are some villages which cannot produce their food through agriculture due to lack of farming skills. The main livestock that are being farmed are cattle and goats. Dryland crop farming is well practised in most of the villages although not all. Because of the people's different backgrounds, agricultural practices differ from village to village and even within the villages as indicated in the tables below.

Table: 7.2: Number of livestock obtained from interviews/ observations. (+ = Present, but number not known; - = Not known if present or not; 0 = None)

Village groups	# Cattle	#Goats	#Donkeys	#Horse	Ownership
A. Omatako					
Bubi se Pos	+	+	+	+	±80 cattle belong to Paul Haodom- a Haikum tribe. Karuashe Kxao (headman) has cattle as well. there are also Hereros who are farming with cattle. Others own donkeys and horses.
Etameko	11	0	0	0	belong to the community
Kameelwoud	± 30	0	+	+	The cattle belong to one man – of Damara tribe
Kandu	190	0	0	0	Over 180 cattle belong to Allen Garab (Damara). 10 belong to the community.
Kanovlei A	2	0	+	+	1 cow and calf belongs to the community.
Kanovlei B	3 1	0 4	0 10	0 2	owned by the community Mr. Cisou Ngandu
Omatako	±10	15	8	0	Mr John Arnold (chief)
Omatako Valley Restcamp	0	0	0	0	
B.Mangetti dune					
Danger	9	+	0	0	Cattle owned by community donated by ELCIN, while goats belong to the headman
Kukurushe	10	0	0	0	Owned by the community donated by ELCIN.
M'kata	+	+	+	+	Some donated by ELCIN, while others are owned by individuals.
Mangetti	15	0	+	0	Cattle owned by community, donkeys owned by a community member.
Meduletu	4 2	0 0	0 0	0 0	4 owned by the community, Pastor , Junias Haixuxwa.
Mparara					
Luhebo	12	0	0	0	Own by the community, donated by ELCIN.
Soweto	+	0	0	0	Owned by the community.
C. Outliers					
Aasvoëlnes	0	0	0	0	
Grashoek	47	85	0	4	Owned by Mr Thomas Kauchab from Khorixas.
Nhoma	124	0	0	0	103 owned by principle of Aasvoëlnes school, while 21 owned by San women from Tsumkwe.

The people who own large numbers of livestock in the area are those who moved into the area, mainly Hereros, Damara and Kavango. Only 20% of the cattle in Western Bushmanland is owned by the San people living in the area, while the immigrant farmers own 80% of the cattle. Most of the livestock owned by the San people were donated by MLRR through ELCIN. Goats are easily susceptible to the poisonous plants in the area. This keeps the number of goats low in some area where the poisonous plants are common (e.g. Kanovlei A and B, Etameko, Bubi se Pos), mostly Omatako villages.

Table 7.3: Cultivated crops (y = Yes, present; n = No, not present)

Village groups	Mahangu	Maize	Sorghum	Beans	Pumpkins	Water melon
A. Omatako						
Bubi se Pos	y	y	y	y	y	y
Etameko	y	y	y	n	y	y
Kameelwoud	y	y	n	y	y	n
Kandu	y	n	y	y	y	y
Kanovlei A	y	y	y	y	y	y
Kanovlei B	y	y	y	y	y	y
Omatako	y	y	y	y	y	y
Omatako Valley Rest camp	y	y	y	y	y	y
B. Mangetti Dune						
Danger	y	y	y	y	y	y
Kukurushe	y	n	y	n	y	y
Mangetti	y	y	y	y	y	y
Meduletu	y	y	y	y	y	y
M'parara	y	y	y	y	y	y
Luhebo	y	y	y	y	y	y
Soweto	y	y	n	y	n	n
C. Outliers						
Aasvoëlnes	y	y	y	y	y	y
Grashoek	y	y	n	n	n	n
Nhoma	y	y	y	n	n	y

Table 7.3. represents data on the presence or absence of cultivated crops per village. Although most villages do farm with crops not all of them are doing well in terms of yield production. Traditionally, San people are not farmers, although they are trying to cultivate some crops in order to sustain themselves. Villages have different needs for cropping. Those who live far from areas with game and veld food, farm with crops. In addition, not all the villages have the same plot size. Residents at Nhoma village do not farm with crops. The reason given is that they are not interested in doing so, but they are closer to game and veld food areas. Only people from Kavango and one San from Tsumkwe, farm with crops at Nhoma. According to verbal reports in 1998, Kankudi produced 119 bags of mahangu (1 bag weighs approximately 50 kg) and 6 bags of sorghum. Meduletu produced 55 bags of mahangu and 2 bags of sorghum. Mparara produced 29 bags of mahangu, while Kukurushe produced 28 bags of mahangu.

Table 7. 4: Irrigated gardens and food types planted.

Village groups	Food type
A. Omatako	
Bubi se Pos	Pumpkin, onions, cabbage, tomatoes, water melon, beans.
Etameko	None
Kameelwoud	None
Kandu	Pumpkins, onions, cabbages, tomatoes, water melon, beans.
Kanovlei A	None
Kanovlei B	Pumpkins, water melon, beans.
Omatako	Pawpaw, Pumpkins, water melon, beans.
Omatako Valley Rest camp	None
B. Mangetti dune	
Danger	None
Kukurushe	None
Mangetti	Unknown
Meduletu	None
Mparara	None
Luhebo	pumpkins, water melon, beans, sweet potatoes, ground-nuts
Soweto	None
C. Outliers	
Aasvoëlnes	Pumpkins, water melon, beans
Grashoek	Pumpkins, water melon, beans, spinach, onions, tomatoes, bananas.
Nhoma	None

In most of the villages investigated (Table 7.4), pumpkins are doing well compared to other vegetables. The soil seems to be good for vegetables as well as fruits. Some communities who do not have gardens expressed their concern that they are lacking water sources in the area for gardening, e.g. the communities at Soweto and Etamako village.

INFRASTRUCTURE

Gravel roads connect most villages, except the newly established ones like Soweto, Danger, Meduletu and Kukurushe. The existing main roads seem to have been cleared in the early 1970s and were used by the SA army trucks in the area. The power which is generated locally and radio communication is only available in some villages: M'kata, Mangetti Dune, Omatako, Aasvoëlnes and Kanovlei Forestry station.

In the nineteen villages investigated, it is only Mangetti Dune and Omatako village that have schools, clinics and shops. Most villagers rely on the Mangetti Dune hospital and the Omatako clinic. Mangetti Dune is the only hospital in Western Bushmanland. All the villages in the Mangetti Dune Group use Mangetti hospital while villages in the Omatako group make use of the Omatako clinic.

The highest grade of education offered in the area is Grade seven. Teachers in the schools are of tribes other than San. Table 7.5 below shows that there are no secondary schools in Western Bushmanland. Primary schools are found in Grashoek, Kanovlei B, Aasvoëlnes, M'kata and Kukurushe.

Most of the shops in Western Bushmanland are owned by people living there. The following villages have shops: Omatako, Mangetti Dune, Sawmill, Tsumkwe and Rooidak Gate. The principal of Omatako School sells goods to villages like Kanovlei A and B, and at Etameko.

Recently the Government has built houses in the area for the San people. Ten houses were constructed at Kankudi, while five were constructed at Luhebo and ten at Kukurushe. According to the headman of Mangetti Dune, he was not involved in the planning session done by the GRN, neither were the community members. The Headman suggests that houses should to be built at Mangetti Dune. The reason given was that Kankudi, Kukurushe and Luhebo are mainly used for farming purposes. Though houses are finished, the San are not informed about who will be moving into those houses.

Table 7.5: Current infrastructure in Western Bushmanland

Village group	Nearest hospital	Nearest school, Highest grade, Number of teacher (if known)	Nearest shop	GRN New houses
A. Omatako				
Bubi se Pos	Omatako	Omatako	Omatako	None
Etameko	Omatako	Kanovlei	Principal of Omatako sells to them.	None
Kameelwoud	Omatako	Omatako	Omatako	None
Kandu	Omatako	Omatako	Kandu	None
Kanovlei A	Omatako	Kanovlei B	Principal from Omatako sells to them	None
Kanovlei B	Omatako	Kanovlei B Highest grade three Two teachers	Principal from Omatako sells to them	None
Omatako	Omatako	Omatako Highest grade six Six teachers	Omatako	None
Omatako Valley Rest camp	Omatako	Omatako	Omatako	None
B. Mangetti Dune				
Danger	Mangetti Dune	Mangetti Dune	Mangetti Dune	None
Kankudi	Mangetti Dune	Mangetti Dune	Mangetti Dune	10
Kukurushe	Mangetti Dune	Kukurushe Highest grade four Two teachers	Mangetti Dune	10
Mangetti	Mangetti Dune	Mangetti Dune Highest grade seven Seven teachers	Mangetti Dune	None
Meduletu	Mangetti Dune	Mangetti Dune	Mangetti Dune	None

Mparara	Mangetti Dune	M'kata Highest grade seven Seven teachers	Mangetti Dune	None
Luhebo	Mangetti Dune	Mangetti Dune	Mangetti Dune	5
Soweto	Mangetti Dune	Mangetti Dune	Mangetti Dune	None
C. Outliers				
Aasvoëlnes	Tsumkwe	Aasvoëlnes Highest grade six Five teachers	Tsumkwe	None
Grashoek	Omatako	Grashoek Highest grade four Three teachers	Rooidak	None
Nhoma	Tsumkwe	Aasvoëlnes	Tsumkwe	None

MINISTRIES AND DEPARTMENTS REPRESENTED IN THE AREA

Kanovlei Forestry Station

At the Forestry station there are nine households occupied by the Forestry staff that works for the Ministry of Environment and Tourism. Most labourers are from Omatako, Mangetti and Luhebo.

The following activities take place at Kanovlei forestry station:

- Implementation of the forestry extension programme;
- Determining the prices of trees;
- Issuing three permits:
  - for cutting down trees,
  - for transporting the trees/products,
  - for marketing in terms of making crafts.

The staff members at the Forestry station are responsible for controlling fires in the area by means of arranging meetings with communities and by means of law enforcement. Communities burn the veld to maximise visibility during the hunting season. Natural fires also occur in the area (Simune Richard, pers. comm., 1998) although they are not as frequent as man-made fires.

To generate self-income for the San, a bread and sewing project, as well as a training program has been introduced at the Station by a German Development Agency.

Fire control is not the only reason for law enforcement and community meetings. Other objectives are: to control the illegal cutting of trees; to create awareness not to harvest more trees than the resource allows; to promote the planting of fruit trees by distributing Mangetti seedlings to interested villages.

Ministry of Lands Resettlement and Rehabilitation (MLRR) & Ministry of Agriculture, Water and Rural Development (MAWRD)

In Western Bushmanland five staff represent the MLRR. They are all based at Mangetti Dune and consist of: one project manager, a driver, a clerk and two caretakers. The following services are offered to the communities: distribution of diesel for the boreholes, drought relief, ploughing of fields and support of ploughing equipment, and training of the San women in sewing. In most cases, the MLRR work hand in hand with MAWRD. The Department of Water Affairs is based at Tsumkwe and is responsible for servicing boreholes in the Eastern Otjozondjupa region.

The MAWRD gives advice on the ploughing techniques that are most suitable for the conditions in the region. The MAWRD owns two tractors, while the MLRR owns three. Three hectares is the minimum size per household to be ploughed by the MLRR, while additional ploughing is normally done later. The distribution of seeds takes place at the same time as ploughing. A threshing machine is provided during harvesting time, and at the same time an assessment is carried out in the villages by the staff of the MLRR to determine the yields. MLRR staff members visit the communities once a month, unless requested by the community to do so more often. The main plan of the MLRR is to resettle the San people, for example by building them houses and try to make people self-reliant. Currently the MLRR is the ministry that works closest with the people in Western Bushmanland i.e. regular visits and delivering messages to other ministries.

Agriculture Development Centre At M'kata

There are four technicians and five drivers at the ADC. Two drivers are working for the Government (GRN), while the other three are casual. The technicians check up whether the seeds have been used appropriately and supply artificial fertiliser to the communities for free during the ploughing season. They offer yearly courses and workshops to interested target groups of San people. The courses touch various topics like livestock production, crop production and pasture management. ADC is helping the communities with the marketing and transport of the crops produced when the communities wish to do so.

Namibian Police (NAMPOL)

The police station is based at Mangetti Dune. There are five male officers. Four officers are constables and one is a sergeant. Their responsibility is to keep law and order in the area. The most common cases are: food theft and cattle theft, which is normally perpetrated by the San people when food becomes scarce. Hereros are reported to occasionally steal livestock from the farmers in the area. Apart from that, the police at Mangetti Dune are very under-equipped and don't even have a car to patrol the area. Normally, they phone Kanovlei Forestry station to help them with transport in case of an emergency.

Ministry of Health and Social Services (MHSS)

There is a hospital at Mangetti Dune and a clinic at Omatako. The hospital in Mangetti Dune also has a mobile clinic which visits the villages once a month.

Ministry of Basic Education and Culture (MBEC)

There are two literacy schools, as well as primary schools in the area i.e. at Omatako, Mangetti, Grashoek and Kukurushe.

PRESENT ECONOMIC ACTIVITIES

Omatako Valley Rest Camp

The Omatako Valley Rest Camp was constructed in 1995 by the San community on an initiative taken by WIMSA (Working Group Indigenous Minorities in Southern Africa). This was suggested to be a community rest camp to assist the community to generate their own income through employment, craft selling and traditional dancing. According to the information obtained from the community members living near the camp, seven people are currently employed by WIMSA.

Mr. Arnestus Andrinu came to the area in 1995 and is employed as a camp guide with six other employees who mainly assist him with the cleaning of the camp. According to Mr. Andrinu, people living next to the camp can sell their crafts through the camp if they pay a fee to Mr. John Arnold who is the chief of Western Bushmanland. Mr. Arnold is the camp manager and is responsible for collecting the money from the sale of the crafts. He pays the employees N$20 – N$30 every three months, depending on the number of tourists visiting the camp. None of the workers (labourers) knows how much money has been saved so far in the community bank account. They also do not know the exact amount of money generated per month. Other villages do benefit from the camp by bringing their crafts to be sold. People living near the camp also get money by dancing for the tourists. A well known traditional dancing group from Peka (N'homa) is permitted to do their dance at the Restcamp. An amount of N$150 is paid to them by the tourists after watching. The group have to pay N$50 to the camp and are left with N$100. During 1996, the dancing group from Omatako was permitted to dance, during the summer of 1997, a dancing group from Rooidak, and during the winter the Peka (N'homa) dancing group had permission. The WIMSA director Mr Axel Toma, based in Windhoek, visits the employees once a year.

Sawmill / Resort

The Sawmill has been in the area for 15 years under Mangetti dune administration. Recently Mr. Louis Torre suggested that the sawmill should be changed into a resort. Mr Torre, a son OF the previous manager, applied for the resort at the same time as WIMSA. Mr. Torre is still waiting for the permission to occupy the land (P. T. O.). WIMSA is opposing Mr Torre's application and is also waiting for permission to change it into a resort. According to the Mangetti Dune headman, Mr Costa Swau, he gave the business permission for the resort to Mr Torre to operate in the area with a gardening business and for producing planks. The permission was granted by the headman provided that many people from the community are going to be employed (no number was given as to how many would be employed). Currently, the Sawmill is already operating as a resort, but there are no community members being employed that the headman is aware of. A Permission to open a shop and petrol service station at the sawmill was also included in the permit from the headman.

Luhebo Baskets and Furniture Market

Most of the women in the Luhebo village make baskets for selling as a main source of income. The baskets are sold individually without a fixed price. Mrs. Esther Mandjoro and her husband Mr Johannes Chaqwanda have started two businesses for making baskets and furniture (chairs and tables). Mr Chaqwanda, who works for the Ministry of Lands, Resettlement, and Rehabilitation employs one person as permanent staff while others are casual workers employed when there is a need for wood to be cut in the field. Mr. Chaqwanda is sometimes asked by government Ministries to make furniture for them. Due to the lack of transport, selling takes place at the workshop.

Shops

All the existing small shops in Western Bushmanland are owned by community members. Mangetti Dune, which is regarded as a town, has only one small shop which sells little other than alcohol. Two shops are based at Omatako. Mr Deon Louw (Omatako school principle) visits the near-by villages Kanovlei and Etameko on a monthly basis selling his goods. Residents in Kanovlei complained about the high prices of the goods sold by Mr Louw. At most villages there are no shops, therefore the people in the area have to travel long distances to buy their supplies, mainly at Omatako, Mangetti Dune or even Grootfontein.

IMPORTANT RESOURCES SUPPORTING LIFE IN WESTERN BUSHMANLAND

Livestock

Observations made in the villages indicated that the number of livestock varied among villages. At some villages, one individual owned most of the livestock and hired others to herd them. In all villages where this was recorded, the owner was not a San and in most cases he lived outside Western Bushmanland. Where there were small numbers of livestock owned communally amongst the San residents, these were given to them by ELCIN during the first part of the 1990's. It is not clear what proportion of the food or cash income of the San residents comes from livestock but it appears that this proportion is small compared to other resources used.

Wildlife

Wildlife is not commonly found in Western Bushmanland. This appears to be a result of the human and livestock population pressures, lack of access to water and the lengthy presence of the army. Hunting activity in the area was mentioned in only two villages where interviews were conducted. In one village, men were out hunting during the time of the interview. At the village Nhoma, the residents spoke about a gemsbok that had been killed the week before and also about other species they hunted on a regular basis. Traditional hunting equipment was displayed during interviews in several villages. Residents at Nhoma village experienced problems with crops because of the elephants in the area.

Dryland cropping

Dryland cropping was observed in all nineteen villages where interviews were conducted. Mahangu appeared to be the main crop cultivated. As it was the end of the dry season, only stalks were observed in some fields, for example Meduletu and Mparara.

The community at Kandu village talked about large numbers of livestock in the area interfering with crops, while the Nhoma residents complained about cattle that destroyed crops. These belong to the principal of Aasvoëlnes. Aasvoëlnes residents do not allow cattleto be kept there, so the principal's cattle are all at Nhoma.

Veld foods

Veld foods were mentioned as an important resource in all nineteen villages. Through the translator, it was established that mangetti nuts, roots, berries, monkey oranges and spinach were the main veld foods.

Veld foods described by villagers in Western Bushmanland during this study:

Mangetti nuts (*Schinziophyton routanenii*) – used to make an alcoholic brew; oil extracted from seeds; when dry, flesh cooked and eaten with porridge.
Roots: San name -Shung (*Camptorrhiza strumosa*) used as food, while other plants' roots are used as source of water and food(e.g. *Ceropegia multiflora*).
Berries – usually eaten fresh in the field directly from the plant.
Monkey oranges – (*Strychnos pungens* and *Strychnos cocculoides*) fruits collected and flesh eaten without cooking.
Spinach – leaves cooked to make a sauce eaten with porridge.

Both men and women were reported to collect veld foods and several times during interviews, the villagers mentioned groups of women and men being away at that time on collecting trips. Women collecting spinach were observed at Nhoma, Kanovlei B, Mparara and Etameko.

People stated that veld foods were becoming scarce and that they had to walk greater distances to find them. In several instances, people told about moving away from the more densely populated Mangetti area to live in the west where veld food is more abundant. Livestock brought in by outsiders and an increasing number of San people using veld foods were given as reasons for growing scarcity. As a consequence of the scarcity, some people spent up to one week collecting veld foods, although a few hours or one day were also reported. In the case of roots, people said that livestock destroy the growing parts by grazing or trampling, so that they cannot be detected easily.

Government drought relief food subsidies

All nineteen villages receive 'drought relief' food subsidies throughout the year. Some villages stated that they received this food every month while others said that it arrived less frequently. The subsidies consist of maize meal, cooking oil, tinned fish, powdered cool drink, dried fish and sugar, with maize meal being the most important component for daily consumption.

Although these food subsidies are known as drought relief in the area, it appears that subsidies have been provided throughout the year since independence. Currently the government is supplying this food but when ELCIN was working for the government in the area (the early 1990's) they were the distributors. The Ministry of Lands, Resettlement and Rehabilitation themselves took over the distribution after ELCIN left the area while the Office of the Prime Minister is currently co-ordinating the distribution.

An important aspect of these subsidies is the lack of information about their time of delivery. The villagers stated that the expected food subsidies often did not appear or appeared much later than expected. This makes it difficult for them to balance their use of their resources. As a result of no delivery, some villagers have moved to Mangetti Dune in search of food and to await further deliveries to their own villages. Compounding the problems associated with food relief is the great variation from year to year in crop harvests and availability of veld foods.

Table 7.6: Relative importance of five main food sources as indicated by villagers during interviews.

Village group	Crops	Livestock	Veldfood	GRN	Game
A.Omatako					
Bubi se Pos (San)	2	1	4	3	5
Etameko	2	3	1	1	5
Kameelwoud	1	1	2	3	5
Kandu	1	3	3	2	5
Kanovlei A	2	4	3	3	4
Kanovlei B	1	5	2	3	4
Omatako	1	3	4	2	5
Omatako Valley Restcamp	1	5	3	2	5

B. Mangetti Dune					
Danger	1	4	2	1	5
Kukurushe	3	4	2	1	4
M'kata	2	4	3	1	5
Mangetti	2	4	3	1	5
Meduletu	1	3	3	2	5
Mparara	2	3	4	1	4
Luhebo	2	4	3	1	5
Soweto	2	4	5	1	5
C. Outliers					
Aasvoëlnes	4	4	3	1	2
Grashoek	1	3	4	2	5
Nhoma	4	5	1	3	1

Explanation of rankings of importance:
1. high reliance; important source of food
2. medium reliance; important when available
3. medium to low reliance; occasionally used when available
4. lowest reliance; only used as supplemented when available
5. not used.

The difference in response from the A group and B group of villages is of significance (Table 7.6). It may be related to the length of time of residence in the area and the origins of the people living there (A group has lived in the area for a long time; B group resettled from elsewhere in the past 10-20 years)

THE ROLE OF NGOs

Evangelical Lutheran Church in Namibia (ELCIN)

ELCIN on behalf of the Ministry of Lands, Resettlement and Rehabilitation was mainly taking care of education, agriculture and an environmental educational program for the San people to establish a self-reliant community. It was trying to plan and set up a resettlement and rehabilitation programme for Western Bushmanland. They were also aiming to give the demobilised San soldiers an alternative to being transferred to South Africa (Botelle and Rohde, 1991).

Agriculture

ELCIN originally purchased 22 oxen, 14 of which were trained as part of the agriculture extension exercise. The communities received cows and one bull to allow for reproduction and increase of the cattle herd. Due to lack of grazing potential in Grashoek, the community was given two donkeys as draught animals as donkeys are more drought resistant than cattle.

ELCIN employed local people and trained the community members in tree nursery, irrigation activities and agro-forestry. The training is currently under direct government control. ELCIN used one tractor that was handed over to the government.

Education

Both formal and non formal education were considered as prerequisites for achievement of the aims and objectives of ELCIN. The education in Western Bushmanland is currently run by the Ministry of Basic Education and Culture. Two schools were built by ELCIN, one in

Grashoek and one in Kanovlei. A new school is planned to be built in Kukurushe. Four teachers are employed. Eighteen literacy facilitators were trained in sewing. Some people were trained in mechanics, dam building, agronomy, typing, building construction, black smithing and carpentry.

Health

ELCIN was not directly involved with the health sector since health services are provided by the Ministry of Health and Social Services through the clinic at Tsumkwe and the health centre at the Mangetti Dune hospital. At the Mangetti Dune hospital they also operate a mobile clinic which visits all the settlements in the program area on a weekly basis.

Working Group Indigenous Minorities in Southern Africa (WIMSA)

WIMSA is currently involved in developing and maintaining a tourist camp site in the Omuramba Omatako along the main road between Grootfontein and Tsumkwe. They are working closely with Mr. John Arnold, Chief of Western Bushmanland, to establish a conservancy in the area. However, John Arnold, and consequently WIMSA are viewed with suspicion by some communities in the area.

CONCLUSIONS

Any kind of development to be implemented in Western Bushmanland should take the following aspects into consideration: ethnicity, population growth and regulation, resource economics, disease and the political situation.

Veld food has been the main staple food for the San people in Western Bushmanland. Veld food subsistence depends on availability and abundance, influenced by the presence of livestock.

All settlements are dependent upon Government drought food relief. Without this supplement or help, San people would starve or move in and out of Western Bushmanland to areas where there are better living standards.

Most of the livestock in the villages are normally owned by outsiders and not by the San people who have been in the area longer. Cattle seem to be the dominant livestock in all the villages visited. The cattle owned by the San people were donated by ELCIN in the early 1990s. Adding more livestock is unappealing to many San because increased livestock will interfere with crop production and especially with veld food gathering. Farming operations including livestock may be less sustainable than those dependent only on crop production and veld food gathering.

Grade Seven is the highest school grade in Western Bushmanland, based at Mangetti Dune and at M'kata. None of the school teachers belong to the San community.

There is a high unemployment rate. The highest rank occupied by most San people in Western Bushmanland is that of labourer and only few San people are employed in the Government Ministries or departments represented in the area.

San people used to hunt wild animals in the area with bow and arrows, but because of the number of people moving in the area, the number of wild animals has declined. The modern hunting equipment used by non-San people has also contributed to the decline of some game species in the area.

The lack of proper communication between the communities and the GRN Ministries, dealing with the ploughing service, normally causes delays in the services. Radio communications are only available at: Mangetti Dune, Omatako, M'kata, Aasvoëlnes and Kanovlei Forestry station.

Finally, the development of these areas to accommodate additional immigration cannot be cost-effective because the region is heavily dependent upon outside support, and additional people will reduce the capacity of the area to be self sustaining.

REFERENCES

Botelle A and Rohde R. 1995. *Those who live On the Land, A Socio-economic Baseline Survey for Land Use Planning in the Communal Areas of Eastern Otjozondjupa.* Ministry of Lands, Resettlement and Rehabilitation. Windhoek, Namibia.

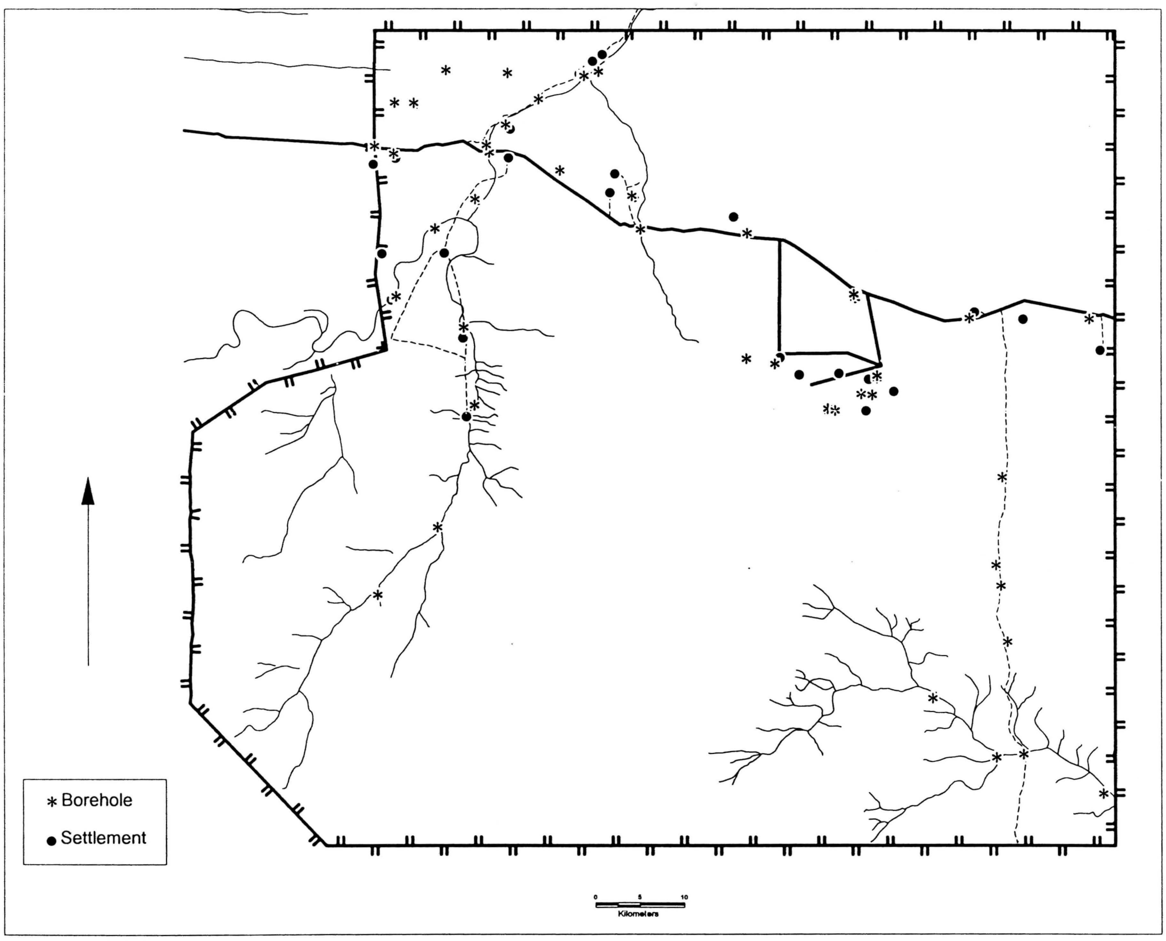
CHAPTER 8 - MAPPING UNITS FOR LAND EVALUATION

Vazembua Muharukua and Jonatan Persson

MAPS PRODUCED DIGITALLY USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

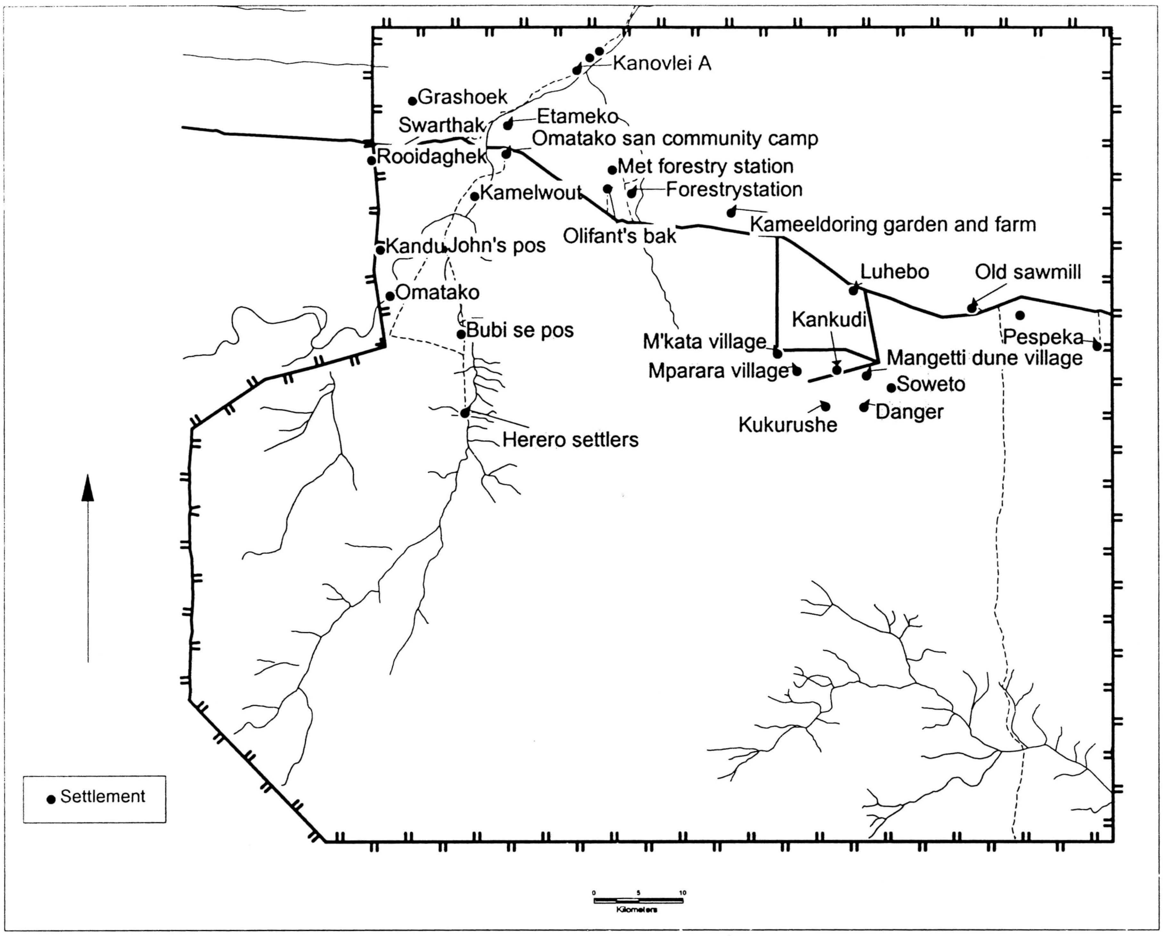
Map production methods

1. Water point Map



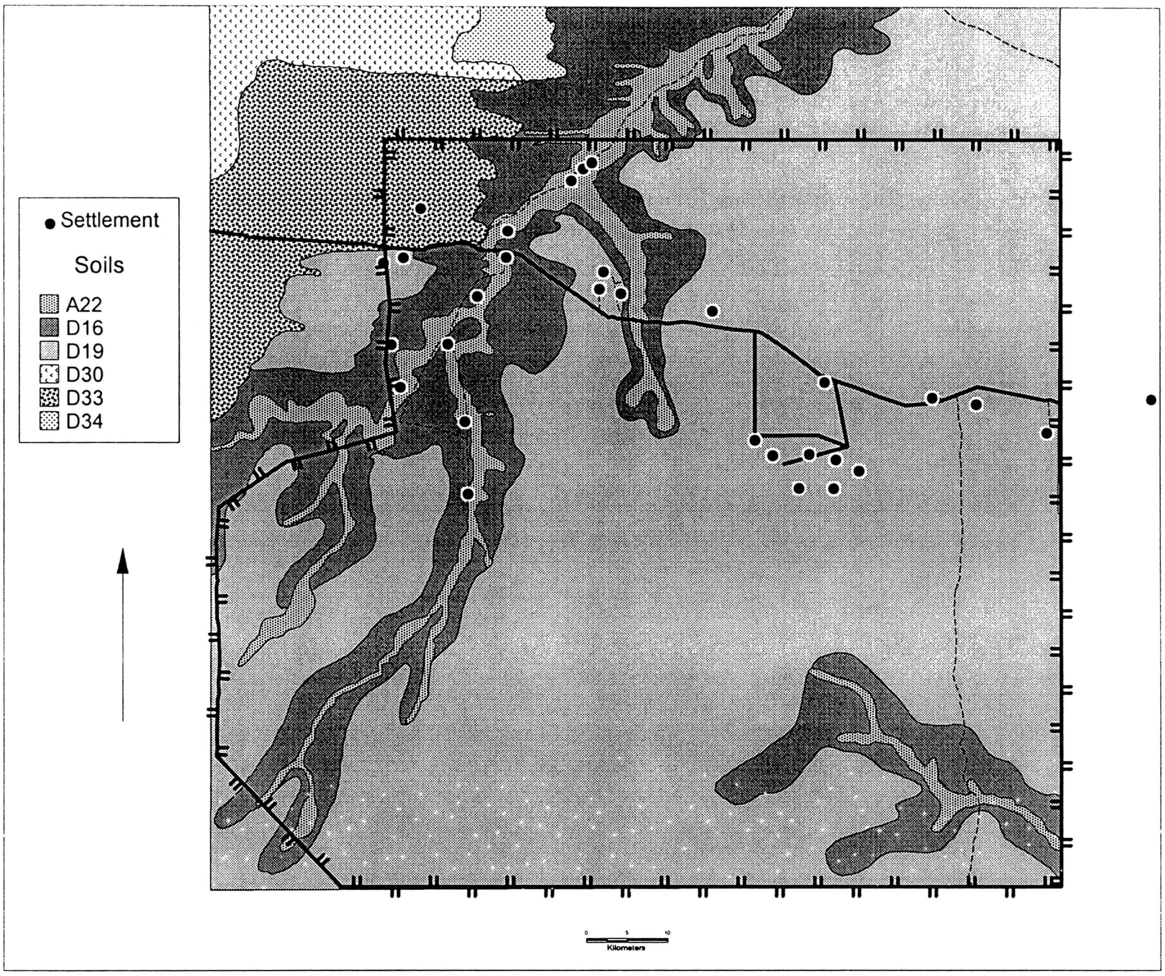
This map shows all the water points in Western Bushmanland. The map is based on GPS coordinates that were taken by the water group during the field survey. The map was simply made by inserting the coordinates and all the information we had about each borehole into the computer.

2. Infrastructure Map



This is a map of the infrastructure of the study area. It shows settlements roads and tracks. It was digitized without editing.

3. Soils Map



The soils map shows all the different soils in the area. It is a digital copy of the Soils Map. The soils have also been confirmed by sampling.

4. Land Systems Map

While mapping the area we defined three major land systems.

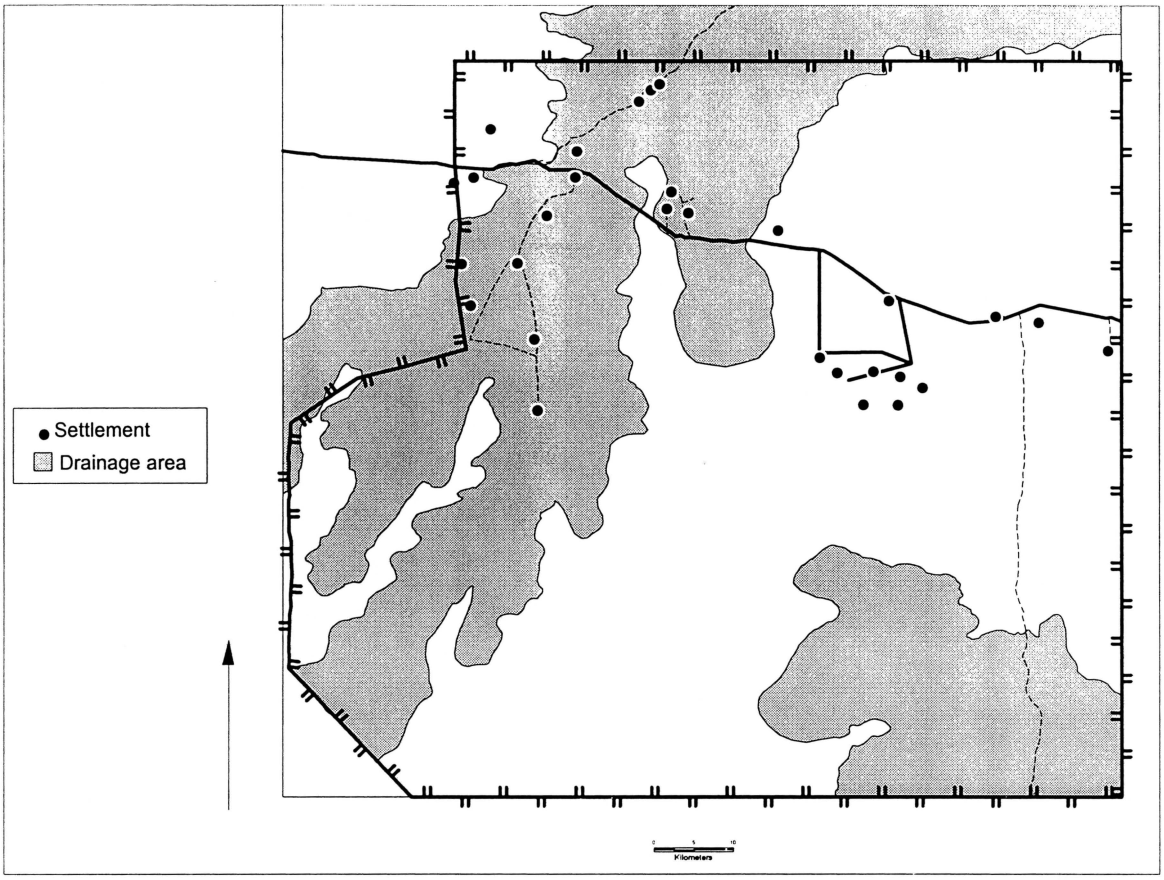
- Complex Dunes and Streets.
  This land system is in the north west of the study area. It was based on the dunes that stretch in an east-west direction from the commercial lands into the study area. The dune system goes all the way to the Omatako omuramba, but the dune area close to the omuramba is slowly turning into a part of the omuramba drainage system. Therefore the eastern border of the dune system is limited by the Omatako omuramba drainage system and not by the dunes.

- Omiramba System
  This consists of the drainage areas of the Daineb and Omatako omiramba. The slopes on the riversides and the omiramba crests also fall within this system. Basically, the drainage system map sets the borders of this land system.

- Sandveld Plain Area
  It is the largest land system and stretches from the northeast down to the south west. It is very flat, but it still forms a divide between the two omiramba systems in the study area.

Please see Map 7, Land Unit Map for reference.

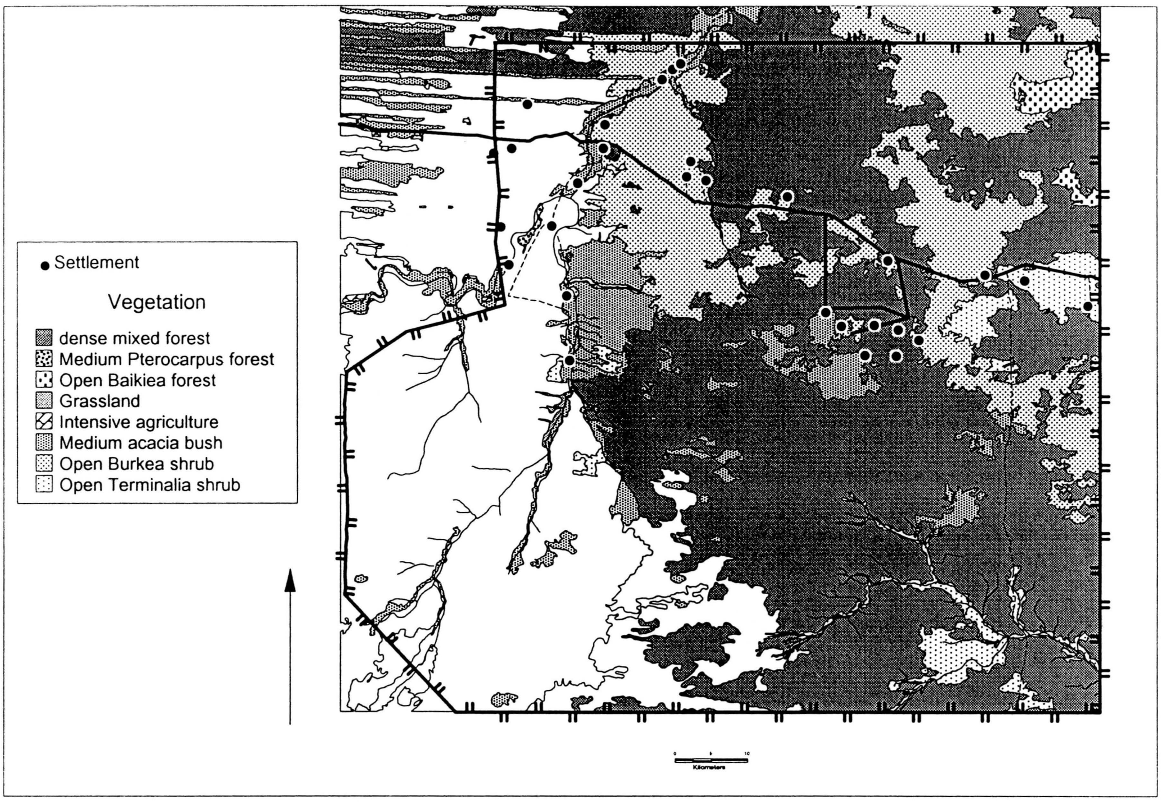
5. Drainage Areas Map



This map is a compilation of two other maps. They are the Drainage Lines Map, and the Topography map. It was compiled by tracing the drainage lines, and then connecting the tips of the drainage lines with topographic elevation lines. The resulting areas around the omiramba were the slightly sloped areas, which provides the omuramba with water.

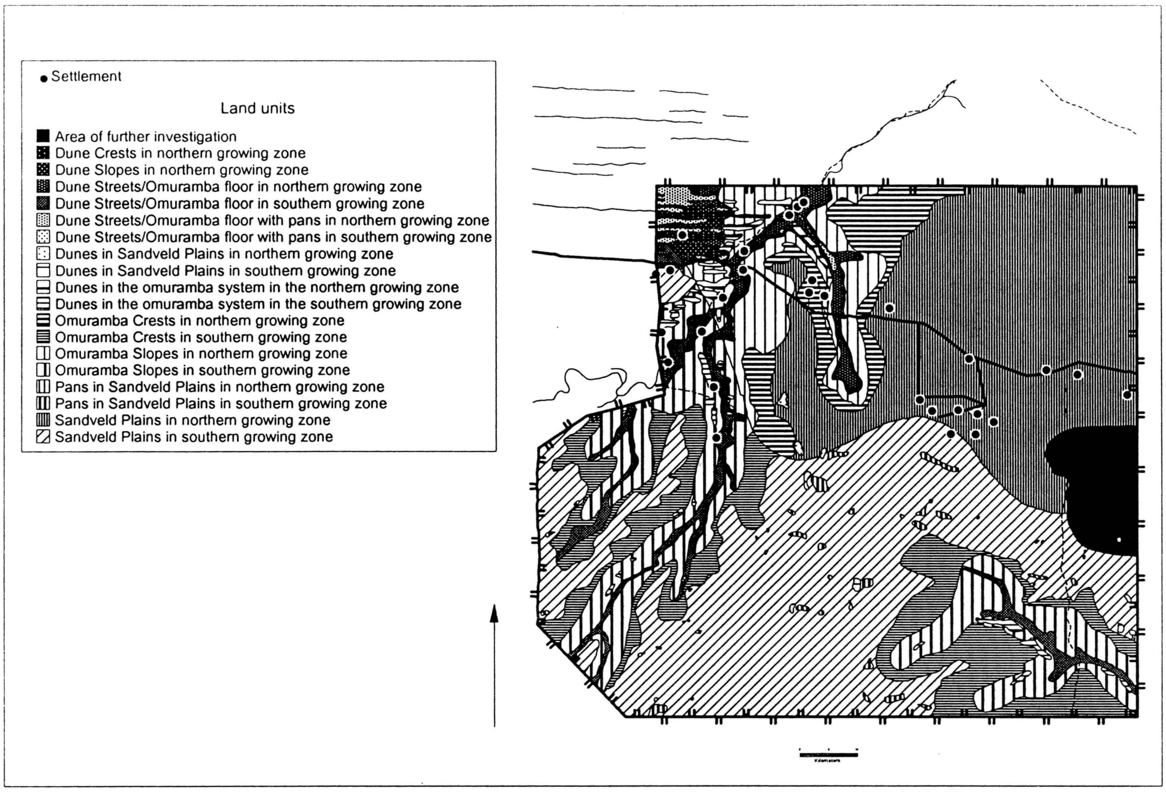
A part of the Complex Dunes and Streets Area was also added. That is because the dune area has, over time, become tilted eastwards and now functions as a drainage area for the Omatako omuramba.

6. Vegetation Map



The vegetation map was difficult to compile. We had more than one source map, all with an incomplete coverage. The satellite image was also an important source. The soils map was also important when classifying the vegetation of the omiramba as the floor turned out to have a different specific type of vegetation. Also the omuramba sides could be defined as a vegetation unit. The sand drift plain was divided into smaller units by the vegetation source map in combination with the satellite image. Otherwise, the plains have the same vegetation as the omuramba crests. We also obtained a digitized vegetation map from the Directorate of Forestry in Windhoek. This map was in digital form and covered the entire study area. The previous vegetation maps were replaced with the new one.

7. Land Units Map



A land unit is a piece of land within which environmental conditions are assumed to be uniform. In our study, land units differ by the means of land use potential. The overall aim of the mapping is to create Land Units, which is a complex task. The idea is to have a base of as much information as possible of the study area and by using this to differentiate the area by attributes significant to land use.

The geology was chosen as the initial base for the land units. It was traced onto the Land Types map. The soils were also assumed to affect the land units, and the soils map was traced over the geology and the land types map. That gave us the base for further development of the land units.

But the importance of geology as a base for the land unit map was questioned because one dominating geology could be found in >95% of the study area. When examining the satellite image, the differences in geology did not show. Therefore geology was rejected as a differentiating factor in the area. The information from the land type map was also too coarse for our purpose, and was thus rejected. The land unit map was put aside for a completely new one: the drainage area map. It was created using a map of surface drainage and a topography map. The topographic lines connected the drainage lines in order to indicate the slope of the area towards the Omatako omuramba. This map became the new base map. From this drainage area map, the soil association map and the physiography map, we derived the *Land Systems* map.

The land systems map was divided into three systems. The drainage area of the omiramba, including the crests, slopes and floors became the first land system. The great plain of Kalahari sand became the second, and the dune system, the third.

The land systems map was used as the base map for the compilation of the Land unit map. Looking at the omiramba land system, it was quite obvious from the soil and vegetation patterns that it could be divided into three land units. The omiramba land system was divided into *floors, slopes* and *crests.*

The land systems map was later updated to include pans and dunes, as they would affect the land enough to define new land units. This also caused changes to the land units of the omiramba and the dune system. At this point the land units were the following:

- Dunes
- Dune Streets
- Dune Streets with pans
- Omuramba Floor
- Omuramba Floor with Pans
- Omuramba Floor with Dunes
- Omuramba Slopes
- Omuramba slopes with dunes
- Omuramba Crest
- Omuramba Crest with Dunes
- Omuramba Crest with Pans
- Sandveld Plains
- Sandveld Plains with Pans
- Sandveld Plains with Dunes.

When looking at unit attributes, several could be merged. The dunes were the same wherever they were found outside the omiramba. The dunes inside the omiramba were of different soil type, and remained a unit. The pans of the omiramba and the pans of the dune streets could also be merged. The same could be done with the omiramba floors and dune streets.
This made eight Land Units.

The Growing Seasons map divides Western Bushmanland into a northern and a southern part. In the northern part 60 days of moist soil for growing can be expected per year and in the southern part, less than 60 days. The rainfall is higher and the evaporation is less in the north.

The vegetation classification divided the area into woodland and shrub/grassland. In the north we found an area with denser woodland, and a southern part with mostly grasses and shrubs. A map of ground water levels indicated shallower ground water in the north and deeper in the south. These three factors were put together to create two zones within Western Bushmanland. This correction doubled the number of land units.

In the east of the Sandveld Plain area we found another area which seemed to be similar to land system one. It had dunes and streets. The satellite image and the aerial photographs also supported our discovery. Because the map showed neither dunes nor streets in the area, we could not classify it as such. Instead we classified it as a land unit of its own that requires more research.

Table 8.1. All the final land units and their codes used on the Land Units Map

Name of Land Unit	**Code**
Dune Crests in northern growing zone	11n
Dune Crests in southern growing zone	11s
Dune Slopes in northern growing zone	12n
Dune Slopes in southern growing zone	12s
Dune Streets/Omuramba floor in northern growing zone	13n
Dune Streets/Omuramba floor in southern growing zone	13s
Dune Streets/Omuramba floor with pans in northern growing zone	13n
Dune Streets/Omuramba floor with pans in southern growing zone	14s
Omuramba Crests in northern growing zone	21n
Omuramba Crests in southern growing zone	21s
Omuramba Slopes in northern growing zone	22n
Omuramba Slopes in southern growing zone	22s
Dunes in the omuramba system in the northern growing zone	23n
Dunes in the omuramba system in the southern growing zone	23s
Dunes in Sandveld Plain Area in northern growing zone	31n
Dunes in Sandveld Plain Area in southern growing zone	31s
Pans in Sandveld Plain Area in northern growing zone	32n
Pans in Sandveld Plain Area in southern growing zone	32s
Sandveld Plain Area in northern growing zone	33n
Sandveld Plain Area in southern growing zone	33s
Area of further investigation	4

CHAPTER 9 – LAND EVALUATION

During the planning phase of this project it was decided to look into the suitability of the following land uses:

- Large livestock grazing
- Small livestock grazing
- Dryland cropping
- Cotton farming
- Irrigated horticulture
- Charcoal production
- Veldfood
- Conservancy

Due to time constraints and lack of information about the requirements of all these land uses it was decided to look only at the suitability of the two dominating land uses: large livestock grazing and dryland cropping of mahangu.

The general procedure of a land evaluation is outlined in chapter 1. For the land evaluation made here the following steps were taken:

- Gathering of information about the land potential in Western Bushmanland. The land potential was given by summarising the information collected by the soil, vegetation and water groups (i.e. chapters 4 - 6). This information formed the basis for the land characteristic descriptions made for each land unit.
- The requirements (i.e. critical values) for the two chosen land uses: dryland mahangu cropping and large livestock grazing, were determined from the literature (Appendix F).
- A reference value was obtained by taking the worst value of the range of values for each land characteristic per land unit (Appendix E).
- The suitability of each land use was obtained by matching the reference value for each land characteristic (per land unit) with the requirements of each land use (Appendix G & H). Four different suitability classes were used:
  S1: very suitable
  S2: suitable
  S3: marginally suitable
  n: not suitable
- Each land unit was given an overall suitability rating for mahangu cropping or large livestock grazing which was determined by taking the lowest suitability rating in that land unit, see Table 9.1, Fig.9.1 & Fig.9.2. Certain land characteristics were upgraded if they were found to be not influential enough.

  The limiting factors for each land unit are mentioned. These are the land characteristics which determined the suitability rating the land unit received. They are also the reasons the land unit would not be suitable for cattle grazing or mahangu cropping (Table 9.1., Fig. 9.3. & Fig. 9.4).

Table 9.1. Summary of suitability ratings of each land unit for extensive grazing with cattle and horticulture with reference to limiting factors **S1**: very suitable, **S2**: suitable, **S3**: marginally suitable, **n**: not suitable

Land Unit	**Extensive Grazing with Cattle**	**Horticulture**
Dune crest in nothern growing zone	N Grazing density	N CEC; Erosion tolerance: wind, ground cover
Dune slopes in nothern growing zone	S3 Erosion tolerance: slope & vegetation cover	N CEC; Erosion tolerance: ground cover, wind
Dune streets/omuramba floor in northern growing zone	S2 Length of growing period, soil depth, shade, erosion tolerance: vegetation cover	S3 Erosion tolerance: wind, ground cover
Dune streets/omuramba floor in southern growing zone	S2 Length of growing period, soil depth, shade, erosion tolerance: vegetation cover	N AEZ growing period
Dune streets/omuramba floor with pans in northern growing zone	S3 Grazing density, erosion tolerance: vegetation cover	N Erosion tolerance: wind, ground cover; soil drainage; bulk density
Dune streets/omuramba floor with pans in southern growing zone	S3 Soil depth, grazing density, erosion tolerance: vegetation cover	N Erosion tolerance: wind, ground cover; soil drainage; bulk density
Omuramba Crests in northern growing zone	S2 Erosion tolerance: vegetation cover	N CEC; Erosion tolerance: ground cover, wind
Omuramba crests in southern growing zone	S2 Erosion tolerance: vegetation cover	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period
Omuramba slopes in northern growing zone	S3 Erosion tolerance: vegetation cover, grazing density	N CEC; Erosion tolerance: ground cover, wind
Omuramba slopes in southern growing zone	S3 Erosion tolerance: vegetation cover; grazing density	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period

Dunes in the omuramba system in the northern growing zone	S3 Erosion tolerance: vegetation cover, slope; grazing density	N CEC; Erosion tolerance: ground cover, wind
Dunes in the omuramba system in the southern growing zone	S3 Erosion tolerance: vegetation cover, grazing density	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period
Dunes in unconsolidated sand drift area, northern growing zone	S3 Erosion tolerance: vegetation cover, CEC	N CEC; Erosion tolerance: ground cover, wind
Dunes in unconsolidated sand drift area in southern growing zone	S2 Erosion tolerance: vegetation cover	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period
Pans in unconsolidated sand drift area in northern growing zone	S3 Erosion tolerance: vegetation cover	N CEC; Erosion tolerance: ground cover, wind
Pans in unconsolidated sand drift area in southern growing zone	S2 Erosion tolerance: vegetation cover	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period
Unconsolidated sand in northern growing zone	S2 CEC	N CEC; Erosion tolerance: ground cover, wind
Unconsolidated sand in southern growing zone	S2 CEC	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period
Area of further study	S3 Erosion tolerance: vegetation cover, CEC	N CEC; Erosion tolerance: ground cover, wind; AEZ growing period

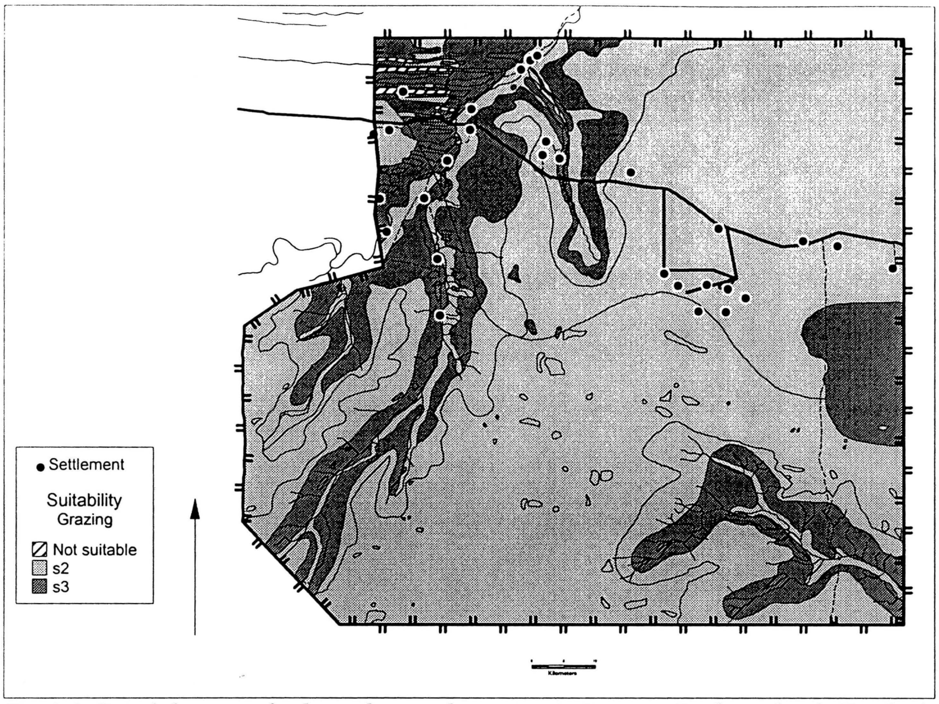


Fig 9.1. Suitability map for large livestock grazing in Western Bushmanland. Hatched regions are not suitable for grazing, light grey units are suitable and dark grey units are marginally suitable.

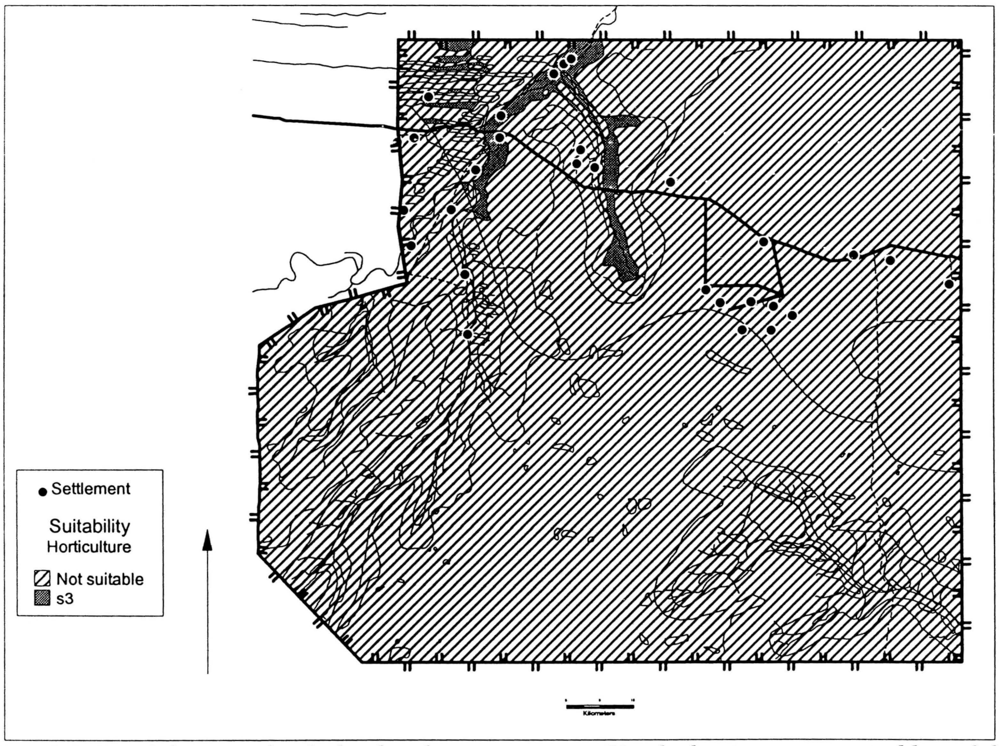


Fig. 9.2. Suitability map for dryland mahangu cropping. Hatched units are not suitable and dark grey units are marginally suitable.

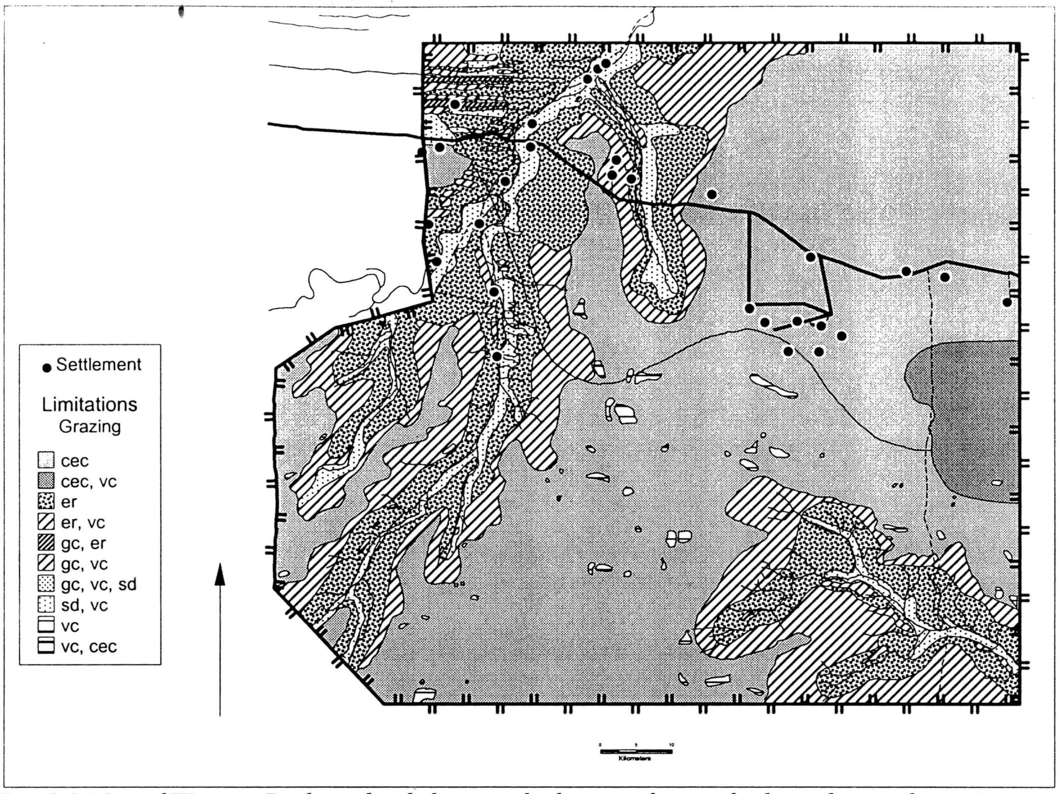


Fig. 9.3 Map of Western Bushmanland showing the limiting factors for large livestock grazing.

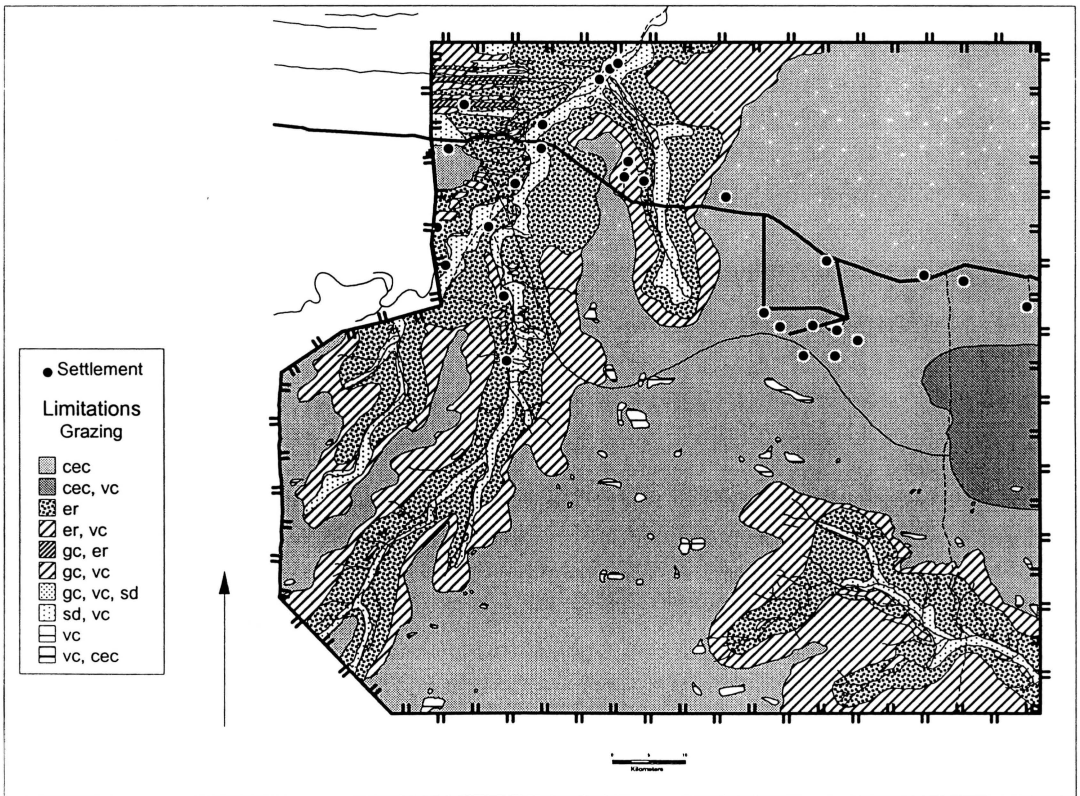


Fig 9.4. Map of Western Bushmanland showing the limited factors for dry land mahangu cropping

INTENSIVE CATTLE GRAZING

Cattle grazing is suitable and marginally suitable in most places of Western Bushmanland (Table 9.1. & Fig.9.1). The dune crests in the north-west are not suitable for grazing because of the low grazing capacity caused by dense tree cover. The main limiting factors for cattle grazing are the threads of erosion caused by low ground cover and that the cation exchange capacity is sometimes too low to support a high biomass of grass (Table 9.1, Fig.9.1 & 9.3).

Availability of water was not included in the suitability rating and would be the major limiting factor for cattle grazing. All the working boreholes occur within a radius of 3km around a village (Chapter 6). Seasonal water sources like the pans can be used during the wet season (Appendix G). To make the grazing areas available for permanent grazing, boreholes would need to be drilled.

Reasons against increasing the number of boreholes:

- The water available at the moment is sufficient to sustain the present population of Western Bushmanland.
- New water availability in good grazing areas would attract owners of large cattle herds from other parts of Namibia.
- These "outside" cattle farmers could create an increased dependency of the San on them which could prevent the communities from reaching a higher living standard.
- Boreholes attract settlements which might have an adverse impact on the environment.
- The region is heavily dependent upon outside support, and additional people will reduce the capacity of the area to be self sustaining
- Cattle destroy the veld food on which the San still depend.
- Cattle destroy the mahangu fields.
- The ground water level in the southern part of Western Bushmanland is very deep.
- It is expensive to drill for water in areas where it is not easily accessible.
- Roads need to be made into the inaccessible grazing areas in the southern parts.

DRYLAND MAHANGU CROPPING

Dryland mahangu cropping is unsuitable in the whole of Western Bushmanland except the northern part in the omuramba floor and dune streets where it is marginally suitable (Table 9.1. & Fig. 9.2). The factors limiting the mahangu growth in Western Bushmanland are the overall low cation exchange capacity (CEC) in the soils (Chapter 5) and the threads of soil erosion through wind and water. Wind and water erosion blows or leaches the organic matter and nutrients from the soil (Chapter 5). The soil in Western Bushmanland is infertile and cannot support mahangu on a long term basis. The yield of mahangu decreases after 3-5 years of growing mahangu on the same field.

Physical inputs required to make the land suitable for dryland mahangu cropping

To make mahangu growing in Western Bushmanland more suitable, the soil fertility has to be increased and soil erosion has to be prevented.

- Fertilizers – organic fertilizer from left over mahangu stumps or livestock manure Chemical fertilizers are presently supplied by the Goverment
- Inter-cropping – If both mahangu and legumes are grown in the fields, the nitrogen input will increase
- *Faidherbia albida* – is a nitrogen fixer and can be planted around the fields for wind break and nutrient input.
- Wind breaks – trees and shrubs should be planted around the field or left standing when fields are cleared.
- Size - fields should be small to prevent wind erosion.

CHAPTER 10 - CONCLUSION AND RECOMMENDATIONS

1. Prior to any development being carried out in the area, necessary feasibility studies should be carried out.

2. No outsider absentee large cattle farmers should be allowed into Western Bushmanland.

3. The local people employed as cattle herders in the area by outsiders should not remain as herders.

4. Conflicts between livestock owners and veld food collectors/mahangu growers need to be resolved.

5. In the vicinity of settlements it should be the obligation of the livestock owner to control his herd or to pay for the damage done.

6. No more boreholes should be drilled.

7. The Ministry of Education should improve the education because only a few of the local people are educated.

8. Communication should be improved through radio and other media. The ministries should make sure that important issues reach all the people.

9. The GRN should make sure that all the services they render render the San self-reliant. The food supply program has been going on for some time but there has been no progress yet.

10. Positive industries and community projects should be recommended for the area to contribute towards the development of the area.

11. The capacity of this environment to support residents by foraging for veld food decreases as the number of cattle and people increases. The people should be made aware of societal costs of population increases and ways to prevent the same.

12. Increase of agricultural extension.

13. Increase soil fertility for mahangu cropping by adding chemical or organic fertilizer.

14. Decrease wind erosion to the mahangu fields by planting wind breaks of bushes and trees.

15. The Omuramba ridges are very prone to wind and water erosion and the present level of vegetation cover should be maintained.

16. Create a local seed bank possibly organized and dispersed by the Agricultural Development Center.

17. The setting up of a demonstration farming center that would provide guidance and extension on conservation orientated field cropping especially the building of wind breaks.

18. The possibility of a conservancy should be considered.

19. Increase the propagation of veld food by supporting the Kanovlei Forestry Station with their cropping and growing of veld food species.

20. A bush burning policy should be adopted and enforced.

Appendix A: Trees and bushes found in Western Bushmanland while doing the Tree Atlas for the National Botanical Institute.

SCIENTIFIC NAMES	ENGLISH NAMES	VASSIKELE NAME
Acacia erioloba	Camelthorn	!Ei
Acacia fleckii	Plate thorn	
Acacia luederitzii	False umbrella thorn	
Acacia mellifera	Black thorn	
Acacia ataxacantha	Flame thorn	
Acacia hebeclada	Candle thorn	
Baphia massaiensis	Sand camwood	
Bauhinia petersiana	Coffee neet's foot	
Boscia albitrunca	Shepherd's tree	
Burkea africana	Wild seringa	\Gru
Catophractes alexandri	Trumpet thorn	
Combretum collinum	Variable bush willow	
Combretum zeyheri	Large-fruited bushwillow	
Combretum hereroensis	Russet bushwillow	
Commiphora africana	Hairy corkwood	
Croton gratissimus	Lavender fever-berry	
Dichrostachys cinerea	Sickle bush	
Diplorynchus condylocarpon	Horn-pod tree	
Ehretia rigida	Puzzle bush	
Grewia flava	Brandy bush	Kanjonjonjo
Grewia flavescens	Sandpaper raisin	
Grewia tenax	Small-leaved cross-berry	
Lonchocarpus nelsii	Apple leaf tree	Mpanda
Mundulea sericea	Cork bush	
Ochna pulchra	Peeling bark ochna	
Ozoroa paniculosa	Common resin tree	
Pterocarpus angolensis	Wild teak	
Rhigozum brevispinosum	Short-thorn pomegranate	
Rhus tenuinervis	Kalahari currant	
Schinziophyton rautanenii	Mangetti tree	Mangongo
Securidaca longipunculata	Violet tree	
Strychnos pungens	Monkey oranges	Da
Terminalia sericea	Silver cluster-leaf	Tchaou
Ximenia caffra	Large sourplum	
Ziziphus mucronata	Buffalo-thorn	

Appendix B: Summary of soil characteristics by sample site and soil pit.

Soil Pit No	Land Unit Map Code	Land Facet Description	Soil Map Code	Soil Series (RSA Classification)	Texture	Surface colour (Munsell)	Texture Class (FAO Legend)	Depth cm	Depth Class (FAO Legend)	Stoniness	Soil Pit No
1	22n	omuramba slope	D16	Gaudam	sand	5YR4/6	C	>100	4	none	1
2	13n	omuramba crest	D16	Sandpruit	sand	7.5YR5/6 strong brown	C	>100	4	none	2
3	13n	omuramba crest	D16	Gaudam	loamy sand	5YR4/5 reddish brown	C	>100	4	none	3
4	22n	omuramba floor	A22	Okavango	silt loam	10YR2/3	C	>100	4	none	4
5	22s	omuramba floor	A22	Okavango	silty sand	7.5YR2/2	C	>100	4	none	5
6		slope base/dune street	D30	Fernwood	loamy sand	7.5YR4/6 strong brown	C	>100	4	none	6
7		slope base/dune street	D30	Fernwood	sandy silt loam	7.5YR4/6 brown	C	>100	4	none	7
8	12n	lower slope dune	D33	Fernwood	loamy sand	7.7YR3/6	C	>100	4	none	8
9	11n	dune crest	D33	Sandspruit	loamy sand	7.5YR4.6 strong brown	C	>100	4	none	9
10	14n	dune street	D33	Okavango	sandy silt loam	2.5YR2/1 black	C	38	2	none	10
11		dune street	D30	Okavango	loamy sand	10YR4/4 brown	C	58	3	none	11
12		omuramba crest calc outcrop	A22	Okavango ?	silty loamy sand	10YR5/3 dull yellowish brown	C	20	2	none	12
13	33n	sandy plain	D19	Fernwood	sand	10YR3/3 dark brown	C	>100	4	none	13
14	21n	sandy plain	D19	Fernwood	sand	7.5YR5/6 strong brown	C	>100	4	none	14
15	13s	omuramba floor	A22	Okavango	sandy loam	10YR4/3 brown	C	>100	4	none	15
16	13s	sandy plain	D19	Sandspruit	loamy sand	7.5YR3/3 dark strong brown	C	>100	4	none	16
Test Pit 1		sandy plain		Sandspruit							Test Pit 1
Test Pit 2		sandy plain		Gaudam							Test Pit 2
Test Pit 3		sandy plain		Fernwood							Test Pit 3
Test Pit 4		omuramba floor		Okavango							Test Pit 4

Appendix B: Summary of soil characteristics by sample site and soil pit.

Soil Series (RSA Classification)	Permeability	Drainage class (FAO Legend)	Bulk Density (Surface)	Total Porosity % (Surface)	Free Carbonates %	Na me/100g	K me/100g	Ca me/100g	Mg me/100g	Pit no
Gaudam	excessively drained	6	1.64	38	zero					1
Sandpruit	excessively drained	6	1.55	42	<0.5%					2
Gaudam	excessively drained	6	1.42	46	zero					3
Okavango	somewhat excessively drained	5	1.64	38	0.5-1.0%					4
Okavango	well drained	4	1.42	46	zero					5
Fernwood	excessively drained	6	1.53	42	zero					6
Fernwood	excessively drained	6	1.52	43	zero					7
Fernwood	somewhat excessively drained	5	1.48	44	zero					8
Sandspruit	somewhat excessively drained	5	1.508	60	zero					9
Okavango	well drained	4	1.37	48	5-10%					10
Okavango	well drained	4	1.34	49	zero					11
Okavango ?	well drained	4	1.49	44	1-5%					12
Fernwood	excessively drained	6	1.3	51	zero					13
Fernwood	excessively drained	6	1.58	40	zero					14
Okavango	well drained	4	1.51	43	zero					15
Sandspruit	somewhat excessively drained	5	?	?	zero					16
Sandspruit						A1: 0.05	A1: 0.15	A1: 0.80	A1: 0.65	Test Pit 1
						B2: 0.05	B2: 0.15	B2: 0.70	B2: 0.45	
Gaudam						No A Hor	No A Hor	No A Hor	No A Hor	Test Pit 2
						B21: 0.00	B21: 0.10	B21: 0.75	B21: 0.45	
Fernwood						A1: 0.05	A1: 0.15	A1: 0.50	A1: 0.40	Test Pit 3
						C1: 0.05	C1: 0.05	C1: 0.25	C1: 0.25	
						C2: 0.05	C2: 0.20	C2: 0.15	C2: 0.20	
Okavango						No A Hor	No A Hor	No A Hor	No A Hor	Test Pit 4
						B2: 0.15	B2: 0.10	B2: 3.00	B2: 2.10	
						Clca: 0.05	Clca: 0.15	Clca: 2.85	Clca: 1.95	

Appendix B: Summary of soil characteristics by sample site and soil pit.

Soil Series (RSA Classification)	CEC Clay me/100g	ESP %	SAR meq/l	Max Slope %	FAO Slope Class	Estimated Erodibility (F)	Estimated Erosion Hazard	Estimated Salinity Hazard
Gaudam				5	U1			
Sandpruit				3	U1			
Gaudam				5	U1			
Okavango				2	L5			
Okavango				0	L1			
Fernwood				0-1	L3			
Fernwood				0	L1			
Fernwood				3	U1			
Sandspruit				5	U1			
Okavango				1	L4			
Okavabgo				1	L4			
Okavango ?				5	U1			
Fernwood				1	L4			
Fernwood				1	L4			
Okavango				0	L1			
Sandspruit				?	?			
Sandspruit	A1: 29	A1: 2.78	A1: 0.19	0		3.5	High	low
	B2: 30	B2: 2.13	B2: 0.21					
Gaudam	No A Hor	No A Hor	No A Hor	2%		3.5	High	high
	B21:38	B21: 0	B21: 0					
Fernwood	A1:65	A1: 3.84	A1: 0.24	0		3	High	low
	C1: 68	C1: 2.44	C1: 0.32					
	C2: 63	C2: 2.63	C2: 0.38					
Okavango	No A Hor	No A Hor	No A Hor	0		3.5	High	moderate
	B2: 44	B2: 2.46	B2: 0.30					
	Clca: 71	Clca: 0.70	Clca: 0.1					

Appendix C: Water data base for Western Bushmanland

Topo	Map ref	Community /farm name	Latitude	Longitude	collar-elev	Well no.	Bh no.	Drilled Depth (m)	Diameter (mm)	Yield(max) (m3/h)	Rest water level (m)	Strike(M))	Tds(mg/l)	Power	Status	Purpose	Resrevoir	Total reservior volume (m3)	Apparent water qual.	Distance nearest BH (km)	OBSERVATIONS
1919AA	62	Grashoek	-19.23792	19.24647	1198	1	WW24754	206.4	150	4	118	129	600	diesel	in use	D,L&G	1 corru	50	good		installed 16-03-1980 supplies a cluster of households with vegetable gardens near by BH62
1919AA	100	Grashoek	-19.23761	19.22602			WR803H						800	diesel	in use	L,D&G	1 plastic	4	good		74 cattle,32 goats(at present) and a few residents (some resettled) are supplied with water.
1919AB	65	unknown	-19.2042	19.2811	1197	4	WW9354	201	150	6	131	140	1564								not found
1919AB	72	Kanovlei (area)	-19.2073	19.3469	1175	1	WW24755	169	150	7	94	100									not found-not accessible
1919AB	73	Kanovlei (area)	-19.234	19.3803	1146	3															not found
1919AB	75	Kanovlei	-19.20853	19.42757	1158	4					86			diesel	in use	D&L	3 corru	48	good		BH 75 linked to BH 76 by pipe line three family units share these boreholes.
1919AB	76	Kanovlei	-19.21017	19.42927	1148	5					85.78			diesel	in use	D&L	3 corru	48	good		as above
1919AB	77	Kanovlei	-19.2059	19.4448	1155	2	WW23456	180	150	5	78	80			not in use						residents at Kanovlei revealed that BH 77 is abandoned - (but was not found)
1919AC	55	Rooidak/vet gate	-19.28366	19.20447	1197	39	WW32652	170	200	3		134	600	electric	in use	L,D&G	3 plastic	12	med.salty		# on door BH 9354,diesl & repair by Namwater,BH supplies water to 3 vet. Officers and families.
1919AC	56	Rooidak/vet gate	-19.28331	19.20426	1199	37	WW32654	180	150	7	135	140		diesel	not in use						abandoned - was in use from 1969-1988,drilling equipment fell in hole
1919AC	57	unknown	-19.2818	19.2045	1199	38	WW32653	170	200	5		136									not found
1919AC	59	Omatako	-19.4367	19.2267	1163	6	WW23369	184	150	3	113	118	519	diesel	in use	L,D&G	2 pla & 1corru.	50	good		BH supplies clinic,prim.school, livestock & many family groups,farmer &comm dispute over water
1919AC	60	Omatako	-19.435	19.2275	1162	40	BH004							diesel	in use	L,D&G	2 pla &1 corru.	12	good		BH 60 app. Owned by local farmer (Deon Louw),BH 60 broken then,new BH besides BH 60.
1919AC	61	Swarthaak	-19.2896	19.22493	1190	5	WW8808	195	200	6	127	130	1165	diesel	in use	D&L	1 plastic	10	good		# on BH WR 664 H newly installed ,controlled by rural water supply.
1919AD	63	Kandu	-19.36561	19.26915	1155	5	WW23340	176	150	4	120	126	577	diesel	in use	L,D&G	1 corru	48	good		controlled by local farmer (Streidwolf),five households with small vegetable gardens.
1919AD	66	Boby se Pos	-19.46672	19.3	1165	6	WW24838	185	50	5	124	125		diesel	in use	L,D&G	2 pla &1 corru.	85	med.salty	8	shared by five family units,water a bit salty,40 m3 filled in half a day.
1919AD	68	Kameelwoud	-19.33575	19.31216	1155	8	WR807H			1.8	>100		500	diesel	in use	L,D&G	1 corru	85	good		situated amid a few cattle posts ,a garden with a variety of vegetables .watered every 3 days
1919AD	69	Kanovlei (opp.rest camp)	-19.28075	19.32436	1153	3	WW6452	505	150	6	35	293	2925		not in use						abandoned -alleged to have become a spring ,was sealed by comm.members (hot water !!).
1919AD	70	Omatako rest camp	-19.28812	19.32741	1153	1	WW24753	152	150	4	98	100	300	solar	in use	T,G&D	2 plastic	50	good		solar run pump donated by an NGO (WIMSA)
1919AD	71	Kanovlei (opp.rest camp)	-19.28075	19.32436	1153	4	WW8809	210	150	6	104	104			not in use						abandoned - dry
1919AD	74	forestry area	-19.30661	19.40316	1207	2	WW8810	215	150						not in use		1 corru	40			site abandoned by San group in 1996-BH dried up.
1919AD	78	forestry area	-19.36684	19.49011	1185	7	WW8811	201	200	9	88	91	225	not instald	not used		none	none		4	BH 78 sealed was temporarily sealed at time of study,formerly used by road works (so it appeared)
1919AD	79	MET forest.research sta	-19.33251	19.48075	1218	9							300	diesel	in use	R,D&G	1 corru & 1 pla	44	good		water used for seedling growth (nursery) & for domestic purposes, there's no back-up borehole.
1919AD	101	Etameko	-19.25977	19.34507										windmill	not in use						abandoned, residents use pan during rainy season but move to omatako comm.camp when dry.
1919BC	80	not known	-19.37057	19.60499	1207	1	WW6453	331	150	8	94	119	620		not in use						Dry and abandoned, concrete dam formerly used as reservoir,calcrete lying around.
1919BC	83	Oruhepo	-19.43679	19.7211	1216	2	WW8812	186	250	4	89	89	356	diesel	in use	D&L	2 corru	8	good		date installed 07-03-1985
1919BC	84	Oruhepo	-19.43327	19.71997	1216	4									not in use						abandoned
1919BC	102	M'kata(agric)	-19.49874	19.60421									300	dsl+elect	in use	L,D&G	1 pla &1 corru	8	good		supplies agric. Centre and local residents.
1919BC	103	Namktakwaare	-19.49874	19.60421											in use	L,D&G	1 corru & 1 fib	84	good		maintained by Tsumkwe Rural Water Supply.
1919BD	90	sawmill	-19.45734	19.84391	1211	2	WW8813	165	150	9	69	68	265	electricity	in use	D&L	1 plastic	4	good		used by tourists and locals
1919BD	91	unknown	-19.4575	19.8431	1211	1	WW8985	180	150	9	73	74									not found (info.based on previous surveys)
1919BD	98	Velskoen	-19.459	19.9717	1211	3	WW8983	186	50	7	67	68									not found(information based on previous surveys)
1919BD	106	unknown	-19.45777	19.9725						5.2			900	diesel	in use	D&G	2 corru	44	med.salty		also used by works department.
1919CA	58	unknown	-19.74	19.2083	1203	1	WW24841	256													not accessible ,road very bad.
1919CB	64	unknown	-19.6707	19.2721	1187	2	WW24840	237		0					not in use						dry when drilled(Z)
1919CB	67	(south of Bubi se Pos)	-19.54616	19.31187	1172	1	WW24839	186		0					not in use						dry when drilled (Z)
1919DA	81	M'kata	-19.50245	19.63414	1211	4	WW24843	163	150	5	128	130	300	diesel	in use	S,D&L	2 plastic	8	good		drilled on 09-03-1983, was used by former SWAD, used by many family groups,supplies distant village.
1919DA	82	M'kata	-19.50431	19.63489	1211	5							300	diesel	in use	S,D&L	2 plastic	8	good		New BH after SWATF,(other as above)
1919DA	85	Mangetti Dune	-19.53485	19.728	1213	2	WW23458	180	150	7	111	120	207	diesel	in use	D&L	3 corru	48	good		supplies hospital, police, school & local people (not used for livestock),BH owned by Namwater.
1919DA	86	Mangetti Dune	-19.5183	19.74473	1241	6							300	diesel	in use	D&L	3 corru	48	good		as above
1919DA	87	Mangetti Dune	-19.5161	19.74473	1219	1	WW23191	197	150	8	97	101	191	diesel	in use	D&L	3 corru	48	good		BH 85,86 & 87 supplies Mangetti community (excluding livestock).
1919DA	88	Danger and Soweto	-19.53578	19.73965	1213	3	WW28794	60	140					diesel	in use	D&L	3 plastic	12	good		appeared to have been drilled through drought relief programme by rural water supply.
1919DA	104	Kukuruse	-19.54954	19.69207			WR 810 H				>100		300	diesel	in use	D&L	2 corru &1 pla	48	good		one 4m3 tank is a distance from the borehole.
1919DA	105	Kukuruse	-19.55174	19.69986			WR 811 H							diesel	in use	D&S	1 corru &1 plas	44	good		
1919DB	92	unknown	-19.7095	19.8723	1211	2															not found (info. based on previous surveys)
1919DB	94	unknown	-19.7308	19.8776	1211	3	WW23368	209		0	147	182									not found(info. based on previous surveys)
1919DB	95	unknown	-19.6198	19.879	1214	1	WW7791	219	150	4	113	137	295								not found (info.based on previous surveys)
1919DD	89	unknown	-19.8462	19.8046	1171	2	WW21385	231	150	2	143	145	635								not found(info. based on previous surveys)
1919DD	93	unknown	-19.9068	19.8728	1160	3	WW23455	251	150	1	128	138									not found (info. based on previous surveys)
1919DD	96	unknown	-19.7885	19.8846	1206	1	WW23193	248		1	158	181	2588								not found (info. based on previous surveys)
1919DD	97	unknown	-19.90375	19.90138	1160	4	WW7840	203	50	0	134	168	860		not in use						BH deep and dry
1919DD	99	unknown	-19.9436	19.987	1149	5	WW23194	75	150	1	117	124	2251								not found (info.based on previous surveys)
1920AA	110	Nhoma	-19.23549	20.22726			WW23467	45	150	7	28		200	diesel	in use	D&L	3 corru	48	good		installed date 18-03-1985
1920AA	112	Nhoma	-19.23549	20.22726											not in use						this is a hand dug well ,3m deep ,no water was used before 1978.
1920AC	107	Aasvoelnes	-19.45104	20.10852			WW23192	176	150	9	60	72	200	diesel	in use	D&S	2 plastic	8	good		installed on 17-03-1985.
1920AC	108	unknown	-19.44769	20.10921						3.6											no information gathered
1920AC	109	Viksrus	-19.35251	20.0975			WW23195	126	150	12	57		100	diesel	in use	D			very good		installed date 03-04-1979.
1920AC	111	Perspetka	-19.51345	20.08212			WW33901						200	diesel	in use	D	2 corru	44	good		pump broke the day before survey

Appendix D: Family histories of individuals interviewed, by village

Village groups	Person (male/female)	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
A.Omatako							
Bubi se Pos	Paul Haudom (m)	M	15 not specified	Otjiwarongo,Tsumeb,G'fontein and some are schooling at Tsumeb.	1980	Outjo	Brought by S.A. army.
	Karowase Kxao (m)	M	11 not specified	3 at Omatako, 1 at Tsumeb and 1 here	born here		Brought by S.A. army
	Ephraim Ubideb (m)	M	3 7		1980	Outjo	Brought by S.A. army
Etameko	Petrus Nakwa (m)	None	1	Rundu	1996	M'kata	Veld food and employment
	Elizebeth Hamupolo (f)	M	1 4	M'kata	1996	M'kata	Establishing her own post.
	Japhet Hamukwaya (m)	M	5 5	9 stay here and 1 is in M'kata	1996	M'kata	Came with the family
	Cecilia Haupindi (f)	M	5 5	3 stay here, 1 in Okavango	1996	M'kata	Came with the family
	Rahia Haushona (f)	M	2 1		1996	M'kata	Came with the family
	Tame Manuel (m)	Not	1 4		1996	M'kata	Brought by S.A. army
	Lucas Masiro (m)	M			1996	M'kata	Brought by S.A. army

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Omatako	John Arnold (m)	M	2 4	Stay with him	1973	Maroela boom district	For farming purpose
	Tjiongora Tjioro (m)	M			1993	Otjituuo	For farming purpose
	Samuel Karangombe (m)	Not	None		1993	Otjituuo	Visited his brother
Omatako Valley Restcamp	Anestus Adrinu (m)	M	3 3	All stay here	1995	Omatako	For employment
B. Mangetti dune							
Danger	Ndala kavango (m)	M	1	Stays with him	1996	Mangetti	Decided himself to come.
	Ndala Solia (f)	Not	1	Stays with sister	1996	Mangetti	Decided himself to come

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Kukurushe	Taimi Haushona (f)	M	5 2	Stay with her	1981	Mpungu	Brought by S.A army
	Rauha Mbango (f)	M	6 3	Some stay with and some in M'kata	1981	Mpungu	Brought by S.A army
	Thimo Mcame (m)	M	10 Not specified	Stay with him	1981	Mpungu	Brought by S.A army
	Daniel Kapanza (m)	M	5 0	stay here	1981	Mpungu	Brought by S.A army
	Hikondo Mbinda (m)	M	None		1981	Mpungu	Brought by S.A army
	Mazonga Kasw (m)	M	None		1981	Mpungu	Brought by S.A army
Mangetti	Costa Swau (m)	M	5 3	Stay with him	1980	Omega	Brought by S.A army

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Meduletu	Junias Haixuxwa (m)	M	3 5	Stay here	1996	Kukurushe	Church mission
	Indileni Haixuxwa (f)	M	0 2	Stay with her	1996	Kukurushe	Came with the pastor
	Vilho Junias (m)	M	0 1	Stays with him	1996	Kukurushe	Came with the pastor
	Sakaria Kamati (m)	Not	None		1996	Kukurushe	Came with the pastor
	Abraham Sakaria (m)	M	None		1996	Kukurushe	Came with the pastor
	Raina Haixuxwa (f)	M	2 1	Stay with her	1996	Kukurushe	Came with the pastor
	Veronica Haikonda (f)	M	4 4	Stay with him	1996	Kukurushe	Came with the pastor

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Mparara	Willem N!ume (m)	M	2 2	Stay with him	1981	Mpungu	Brought by S.A army
	N!ume Kampandja (m)	M	None		1981	Mpungu	Brought by S.A army
	Regina Kaci (f)	M	4 0	Stay with him	1981	Mpungu	Brought by S.A army
	Erina Simon (f)	M	2 2	Stay with him	1981	Mpungu	Brought by S.A army
	Ebby Ephraim (f)	M	3 3	Stay with him	1981	Mpungu	Brought by S.A army

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Luhebo	Chaowandwa John (m)	M	3 3	Stay with him	1983	Nkurenkuru	Because of war in Angola
	Esther Mandjoro (f)	M	3 3	Stay with her	1983	Nkurenkuru	Brought up by the SA govt.
	Maria Kapangera (f)	M	3 2	Stay with her	**check**	Omega	Brought by S.A army
	Makena Ndamba (f)	M	2 4	Stay with her	1978	Omega	Brought by S.A army
	Mtango Tjiwoko (m)	M	Died		1978	Omega	Brought by S.A army
	Sakaria M'taka (m)	M	0 4	Stay with him	1978	Omega	Brought by S.A army
	Veronica Jengu (f)	M	1 2	Stay with him	1978	Omega	Brought by S.A army
	Mate Mushongo (f)	Not	0 3	Stay with him	1978	Omega	Brought by the S.A army
	N!a Mata (f)	Not	None		1978	Omega	Brought by the S.A army

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Soweto	Agusto Joao (m)	M	0 4	Stay with him	1996	Mangetti	Brought by the S.A army
	Mario Munyenga (m)	M	1 2	Stay with him	1996	Mangetti	Brought by the S.A army
C. Outlays							
Aasvoëlnes	Mushongo Andreas (m)	M	3 4	1 Stays with him and the rest at school	1991	Rundu	To teach(principal)
	Knxa Lailae (f)	M	3 3	3 Stay with him and 3 are at Rooidak	1979	Kaudum	Brought by the S.A army
Grashoek	Lekker Boy (m)	M	0 2	Stay with him	Born here		
	Raby N!aci (m)	M	2 1	Stay with him	1990	Tsumkwe	For employment
	Thomas Gaogab (m)	M	3 5	Stay with him	1991	G'fontein	For grazing
	Johannes Sevekua (m)	M	5 2	Stay with him	1998	Tsumkwe	Look for veld food
	Frans Naka (m)	M	3 2	2 at the farm, 2 stay with him		Omatako	Brought by the S.A army
	Kxao !ui (m)	M	3 2	Stay with him		Tsumkwe	Collect veld food
	Lluce N#ance (f)	M	3 2	Stay with her		Tsumkwe	Collect veld food

Appendix D: Family histories by village (continued)

Village groups	Person	Married	# of children (m) (f)	Location of children	When arrived @ village	From where	Why
Nhoma	Gcao Kaeshi (m)	M	4 5	Stay with him	Born here		
	Loece Khau (f)	M	1 2	Stay with her	Born here		
	N!hao Kxa (f)	Not	0 2	Stay with her	Born here		
	Ncaukga Cwi (f)	M	4 5	Stay with her	Born here		
	N#isa lui (f)	M	0 1	Married	Born here		
	Lucas Phillip (m)	M	0 1	Stays with his wife in Okavango	1997	Okavango	Brought by the principal to be the cattle herder
	Maya Donatius (m)	M	1 1	Stay with him	1997	Rundu	Farming purpose
	Joseph Mundunge (m)	Not	Not known		1998	Rundu	Visiting the brother Maya

Appendix E: The following 19 tables give the reference value for each land characteristic in every land unit.

Table 1 – Dune crests in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.35
Soil depth (cms)	>100
Soil stoniness class (FAO)	None
Soil drainage class (FAO)	5
Bulk density (gm/$^{-3}$)	1.5
Soil sodicity (ESP %)	2.78
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	5%
Vegetation cover: trees	0-25%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	
Presence of pans	
Water quality (TDS mg/l)	600-800
Grazing density (ha/head)	15
Elevation (masl)	1189

Table 2. - Dune slopes in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.05
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	5
Bulk density (gm/$^{-3}$)	1.48
Soil sodicity (ESP %)	3.84
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	5
Vegetation cover: trees	0-25%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	1-10%
Surface stoniness (%)	0
Presence of boreholes	
Presence of pans	
Water quality (TDS mg/l)	600-800
Grazing density (ha/head)	4
Elevation (masl)	1189

Appendix E : Reference value for each land characteristic in every land unit

Table 3 - Dune streets / omuramba floor in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g) 0-30cm soil depth	6.10
Soil depth (cms)	75
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	4
Bulk density ($gm/^{-3}$)	1.54
Soil sodicity (ESP %)	2.46
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	0
Vegetation cover: trees	0-25%
Vegetation cover: shrubs	0-25%
Vegetation cover: grasses	10-50%
Surface stoniness (%)	0
Presence of borholes	Y
Presence of pans	Y
Water quality (TDS mg/l)	300-1564
Grazing density (ha/head)	4
Elevation (masl)	1150

Table 4 – Dune streets/omuramba floor in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	6.10
Soil depth (cms)	68
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	4
Bulk density ($gm/^{-3}$)	1.54
Soil sodicity (ESP %)	2.46
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	0
Vegetation cover: trees	0-25%
Vegetation cover: shrubs	0-25%
Vegetation cover: grasses	10-50%
Surface stoniness (%)	0
Presence of boreholes	Y
Presence of pans	Y
Water quality (TDS mg/l)	124-145
Grazing density (ha/head)	4
Elevation (masl)	1218

Appendix E : Reference value for each land characteristic in every land unit

Table 5 - Pans in omuramba system / dune streets in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	>12
Soil depth (cms)	60-80
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	2
Bulk density (gm/$^{-3}$)	1.2
Soil sodicity (ESP %)	8-9
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	0
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	Y
Water quality (TDS mg/l)	
Grazing density (ha/head)	Low
Elevation (masl)	1199

Table 6 – Pans in dune streets/omuramba floor in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	>12
Soil depth (cms)	40-50
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	2
Bulk density (gm/$^{-3}$)	1.2
Soil sodicity (ESP %)	8-9
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	0
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	Y
Water quality (TDS mg/l)	
Grazing density (ha/head)	Low
Elevation (masl)	1517

Appendix E : Reference value for each land characteristic in every land unit

Table 7 - Omuramba crests in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.35
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.42
Soil sodicity (ESP %)	2.78
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	2
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-25%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	300
Grazing density (ha/head)	9
Elevation (masl)	1249

Table 8 – Omuramba crests in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.35
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.42
Soil sodicity (ESP %)	2.78
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	2
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-25%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	
Grazing density (ha/head)	9
Elevation (masl)	1236

Appendix E : Reference value for each land characteristic in every land unit

Table 9 – Omuramba slopes in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.3
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.64
Soil sodicity (ESP %)	0
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	5
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	25-50%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	Y
Presence of pans	N
Water quality (TDS mg/l)	225-2925
Grazing density (ha/head)	10
Elevation (masl)	1216

Table 10 – Omuramba slopes in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.30
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.64
Soil sodicity (ESP %)	0
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	5
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	25-50%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	Y
Presence of pans	N
Water quality (TDS mg/l)	118-126
Grazing density (ha/head)	10
Elevation (masl)	1196

Appendix E : Reference value for each land characteristic in every land unit

Table 11. – Dunes in the omuramba system in the northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.3
Soil depth (cms)	76
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density (gm/$^{-3}$)	1.42
Soil sodicity (ESP %)	0
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	5
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	
Grazing density (ha/head)	10
Elevation (masl)	1210

Table 12 – Dunes in the omuramba system in the southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	2.3
Soil depth (cms)	76
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density (gm/$^{-3}$)	1.42
Soil sodicity (ESP %)	0
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	5
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	
Grazing density (ha/head)	10
Elevation (masl)	1198

Appendix E : Reference value for each land characteristic in every land unit

Table 13 – Dunes on Sandveld plains in northern growing zone

Land Characteristic	**Reference Value**
CEC total (me/100g)	1.8
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.4
Soil sodicity (ESP %)	2.78
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	3
Vegetation cover: trees	0-25%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	
Grazing density (ha/head)	9
Elevation (masl)	1212

Table 14 – Dunes on Sandveld plains in southern growing zone

Land Characteristic	**Reference Value**
CEC total (me/100g)	2.05
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	6
Bulk density ($gm/^{-3}$)	1.4
Soil sodicity (ESP %)	2.78
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	3
Vegetation cover: trees	0-10%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	10-25%
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	N
Water quality (TDS mg/l)	
Grazing density (ha/head)	9
Elevation (masl)	1241

Appendix E : Reference value for each land characteristic in every land unit

Table 15. – Pans on Sandveld plains in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	>12
Soil depth (cms)	35->100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	2
Bulk density (gm/$^{-3}$)	1.2
Soil sodicity (ESP %)	8-9
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	0
Vegetation cover: trees	
Vegetation cover: shrubs	
Vegetation cover: grasses	
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	Y
Water quality (TDS mg/l)	
Grazing density (ha/head)	
Elevation (masl)	1224

Table 16. – Pans on Sandveld plains in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	>12
Soil depth (cms)	35->100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	2
Bulk density (gm/$^{-3}$)	1.2
Soil sodicity (ESP %)	8-9
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	4
Slope (%)	0
Vegetation cover: trees	
Vegetation cover: shrubs	
Vegetation cover: grasses	
Surface stoniness (%)	0
Presence of boreholes	N
Presence of pans	Y
Water quality (TDS mg/l)	
Grazing density (ha/head)	
Elevation (masl)	1209

Appendix E : Reference value for each land characteristic in every land unit

Table 17. – Sandveld plains in northern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	1.7
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	5
Bulk density (gm/$^{-3}$)	1.58
Soil sodicity (ESP %)	3.84
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3
Slope (%)	1
Vegetation cover: trees	25-50%
Vegetation cover: shrubs	10-25%
Vegetation cover: grasses	0-10%
Surface stoniness (%)	0
Presence of boreholes	Y
Presence of pans	Y
Water quality (TDS mg/l)	191-620
Grazing density (ha/head)	9
Elevation (masl)	1219

Table 18 – Sandveld plains in southern growing zone

Land Characteristic	Reference Value
CEC total (me/100g)	1.7
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	5
Bulk density (gm/$^{-3}$)	1.58
Soil sodicity (ESP %)	3.84
Length of growing period	61-90
Wind speed dry season (m/s)	>100
AEZ growing period zone	4
Slope (%)	0
Vegetation cover: trees	10-25
Vegetation cover: shrubs	25-50
Vegetation cover: grasses	0-10
Surface stoniness (%)	0
Distance to water (km)	Y
Distance to water (metres)	Y
Water quality (TDS mg/l)	2588
Grazing density (ha/head)	9
Elevation (masl)	1250

Appendix E : Reference value for each land characteristic in every land unit

Table 19. – Area of further investigation on Sandveld plains

Land Characteristic	Reference Value
CEC total (me/100g)	1.8
Soil depth (cms)	>100
Soil stoniness class (FAO)	0
Soil drainage class (FAO)	5
Bulk density (gm/$^{-3}$)	1.45
Soil sodicity (ESP %)	3.4
Length of growing period	61-90
Wind speed dry season (m/s)	>10
AEZ growing period zone	3+4
Slope (%)	2
Vegetation cover: trees	10-25
Vegetation cover: shrubs	25-50
Vegetation cover: grasses	0-10
Surface stoniness (%)	0
Presence of boreholes	
Presence of pans	
Water quality (TDS mg/l)	
Grazing density (ha/head)	
Elevation (masl)	1250

Appendix F: Critical Factor Values for large livestock grazing and dryland mahangu cropping

Large livestock grazing

Land Use Requirement	Land Characteristic	Factor Rating			
		s1	s2	s3	n
Growth requirements for primary production					
Availability of nutrients	CEC (total) 0-30cm soil depth (me/100g)	> 4	2-4	1-2	< 1
Rooting conditions	Soil depth (cms)	> 100	50-100	25-50	< 25
	Soil stoniness (FAO class)	< 2	3		4
	Bulk density (g/cm^{-3}) (for coarse textured soils)	1.4 - 1.6	1.2 - 1.4 and 1.6 - 1.7	1.7 - 1.8 and < 1.2	> 1.8
	Exchangeable sodium percentage (ESP)	<6	6-15	15-20	>20
Soil moisture availability	Length of growing period (days/annum)	91-120	61-100	41-60	<40
Growth requirements for secondary production					
Accessibility for animals	Slope (%)	0-16	16-30	30-49	> 40
	Surface stoniness (%)	0-50	50-80		> 80
Availability of drinking water	Distance to water (kms)	< 2	2-6	6-10	> 10
	Water quality (TDS mg/l)	< 2000	2000-3000	3000-6000	> 6000
Presence of shade	% tree cover	>50	30-50	10-30	<10
Physical hindrance of vegetation	% shrub cover	<60	60-75	75-90	>90
Presence of sodicity	Exchangeable sodium percentage (ESP)	<6	6-10	10-15	>15
Grazing capacity	Grazing density (ha per adult head)	< 8	8-10	10-15	>15
Conservation requirements					
Tolerance to erosion	Slope (%)	< 1	1-5	5-8	> 8
	Vegetation cover (%)	> 75	50-75	20-50	< 20
	Soil depth (cms)	> 100	50-100	25-50	< 25
Tolerance to compaction by trampling	Bulk Density (g/cm3) coarse textured soils medium & fine textured soils	 <1.4 - 1.6 <1.1	 1.65 - 1.75 1.1 - 1.3	 1.75- 1.85 – 1.4	 > 1.9 > 1.4

Appendix G: Western Bushmanland suitability matrix for large livestock grazing for each land unit (based on physical factors only)

Land Use Requirement	Land Characteristic	1.1n	1.2n	1.3n	1.3s	1.4n	1.4s	2.1n	2.1s	2.2N	2.2S	2.3N	2.3S	3.1N	3.1S	3.2n	3.2s	3.3N	3.3S	?
Growth requirements for primary production																				
Availability of nutrients	CEC (total) 0-30cm soil depth (me/100g)	S2	S2	S1	S1	S1	S1	S2	S2	S2	S2	S2	S2	S3	S2	S1	S1	S3	S3	S3
Rooting conditions	Soil depth (cms)	S1	S1	S2	S2	S2	S3	S1	S1	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S1
	Soil stoniness (FAO class)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
	Bulk density (g/cm^{-3}) (for coarse textured soils)	S1	S1	S1	S1	S2	S2	S2	S1	S2	S2	S1	S1	S1	S1	S2	S2	S1	S1	S1
	Exchangeable sodium percentage (ESP)	S1	S1	S1	S1	S2	S2	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S1	S1	S1
Soil moisture availability	Length of growing period (days/annum)	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
Growth requirements for secondary production																				
Accessibility for animals	Slope (%)	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
	Surface stoniness (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Availability of drinking water	Distance to water (kms)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Presence of permanent water sources	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓	?
	Presence of temporary water sources	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	?
	Water quality (TDS mg/l)	S1	S1	S1	S1	-	-	S2	-	S2	S1	-	-	-	-	-	-	S1	S2	-
Presence of shade	% tree cover	S2	S2	S2	S2	S1	S1	S1	S1	N	N	S1	S1	S2	S1	N	S1	S2	S2	S2
Physical hindrance of vegetation	% shrub cover	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Presence of sodicity	Exchangeable sodium percentage (ESP)	S1	S1	S1	S1	S2	S2	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S1	S1	S1
Grazing capacity	Grazing density (ha per adult head)	N	S1	S1	S1	S3	S3	S2	S2	S3	S3	S3	S3	S2	S2	?	?	S2	S2	?
Conservation requirements																				
Tolerance to erosion	Slope (%)	S2	S3	S1	S1	S1	S1	S2	S2	S3	S3	S3	S3	S2	S2	S1	S1	S1	S1	S2
	Vegetation cover (%)	S3	S3	S2	S2	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	N	S3	S2	S2	S3
	Soil depth (cms)	S1	S1	S2	S2	S2	S3	S1	S1	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S1
Tolerance to compaction by trampling	Bulk Density (g/cm3) coarse textured soils medium & fine textured soils	S1	S1	S1	S1	S2	S2	?	S1	S2	S1	S1	S1	S1	S1	S2	S2	S1	S1	S1

Appendix H: Western Bushmanland land suitability matrix for dryland mahangu cropping for each land unit.

Land Use Requirement	Land Characteristic	1.1n	1.2n	1.3n	1.3s	1.4n	1.4s	2.1n	2.1s	2.2N	2.2S	2.3N	2.3S	3.1N	3.1S	3.2n	3.2s	3.3N	3.3S	?
Growth requirements for primary production																				
Availability of nutrients	CEC (total) 0-30cm soil depth (me/100g)	N	N	S3	S3	S1	S1	N	N	N	N	N	N	N	N	N	N	N	N	?
Oxygen availability to roots	Soil drainage class	S3	S3	S1	S1	N	N	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	?
Rooting conditions	Soil depth (cms)	S1	S1	S2	S2	N	N	S1	S1	S1	S1	S2	S3	S1	S1	S1	S1	S2	S2	?
	Soil stoniness (FAO class)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	?
	Bulk density (g/cm^{-3}) (for coarse textured soils)	S1	S1	S1	S1	N	N	S1	S1	S2	S2	S2	S2	S1	S1	S1	S1	S1	S1	?
Soil moisture availability	Length of growing period (days/annum)	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
	AEZ growing period zone (Namibia)	S3	S3	S3	N	S3	N	S3	N	S3	N	S3	N	S3	N	S3	N	S3	N	S3
Sodicity	ESP (%)	S2	S2	S2	S2	S3	S3	S2	S2	S1	S1	S3	S3	S2	S2	S2	S2	S2	S2	?
Availability of emergency irrigation water	Boreholes present	✓	✓	✓	✓	×	×	✓	×	✓	✓	×	×	×	×	×	×	✓	✓	?
	Water Quality (TDS mg/l)	S3	S3	S3	S1			S1		S1	S1							S1	S2	
Growth requirements for secondary production																				
Tolerance to water erosion	Slope (%)	S2	S2	S1	S1	S1	S1	S2	S2	S2	S2	S1	S1	S1	S1	S1	S1	S2	S2	?
	Soil depth (cm)	S1	S1	S2	S2	S2	S2	S1	S1	S1	S1	S2	S3	S1	S1	S1	S1	S2	S2	?
	Ground water cover (%)	N	N	S3	S3	N	N	N	N	N	N	N	N	N	N	N	N	N	N	?
Tolerance to wind erosion	Wind speed (dry season)	N	N	S3	S3	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	Dry season ground cover (%)	N	N	S3	S3	N	N	N	N	N	N	N	N	N	N	N	N	N	N	?
Management requirements																				
Ease of tilling operations	Soil stoniness (FAO class)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1