SOIL RECONNAISSANCE SURVEY

PROPOSED DEVELOPMENT SCHEME
"MYL 30"

RUNDU/KAVANGO

SWA/NAMIBIA

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1. Introduction

In January 1987 a soil reconnaissance survey was carried out approximately 50 km south-west of Rundu in the Kavango. The two survey areas are situated close to the main tarred road leading from Rundu to Grootfontein (Annexure I). Small settlement areas are located close to the tarred road thus giving some of the local people the opportunity to sell wood-carvings.

A large and increasing number of people living in the area depend on traditional subsistence farming. The environment is only marginally suited for agriculture because of its climate, soils and availability of water, thus limiting agricultural production in terms of certain crops.

Fieldwork (soil mapping, soil profile description and soil sampling) was carried out to obtain information on the existing soil forms, soil series and the main physical soil characteristics. Soil profiles were described to identify the main soil forms. 18 soil samples were collected and analysed in terms of their chemical properties (i.e. phosphorus -Bray I-, potassium, calcium, magnesium, sodium -ammonium acetate-, exchangeable zinc -AMBIC- and pH in KCl).

In addition particle size distribution of all samples was determined and the textural class was identified. In this report a fertilizer was recommended (applying to the survey area) for sorghum (*Sorghum bicolor (L) Moench*) and maize based on the analytical results of all 18 soil samples and general information on irrigation methods and their application to the proposed scheme at "Myl 30" are also discussed in the report.

A detailed geographical location map indicating the different soil forms in the area under investigation was drawn at 1:10 000 scale and is attached to this report as Annexure I. All information (climatic data, soil data etc.) given in this report might also be applicable to other agricultural development projects throughout the Kavango.

2. Survey area

2.1 Description and location

The proposed settlement scheme which was surveyed is located approximately 50 km south-west of Rundu close to the tarred road which links Grootfontein with Rundu. The two survey areas to the west and to the east of the tarred road are located at 18° 12'latitude and 19° 28' longitude (see Annexure I) on the Aeolian/ Inland Sand Plateau at an average altitude of 1160 to 1162m above sea-level.

137 ha have been investigated and mapped. The area is situated between 30 and 40 km south of the Kavango River which is the main drainage system in the area.

A prominent feature throughout the Okavango are extensive areas of large seif dunes which occur on the Inland/ Aeolian Sand Plateau and also close to the survey area. These dunes are now partly stabilised by vegetation and were formed under arid conditions by prevailing easterly winds (LOXTON et.al., 1971), thus allowing water from the Central Highlands to drain towards the west and north-west (possibly during a wetter period and similar climatic conditions as today) causing dissection of these dunes which form the main omuramba valleys in the Okavango (e.g. Omuramba Omatako and Omuramba Fumbe).

There are plans to make water available for irrigation purposes in the survey area from borehole pumping.

3. Physiography

3.1 Topography, landforms and drainage

Geologically the survey area belongs to the Kalahari System (COOKE, 1964). Outside the Okavango River Valley the Inland/Aeolian Sand Plateau consists of sandy plains with dunes. Over vast stretches only minor variations in surface topography are visible.
The sand, which may primarily be of Pliocene age and which was redistributed during the Pleistocene age (Quaternary), covers the area in several meters of reddish-brown to greyish sand of the so called Kalahari type. Only several hundreds of meters below the sand, original rock formations can be found.
A forest of large trees grows in the deep sands, whereas the vegetation of the different omiramba is almost restricted to shrubs and grass.
The Inland/Aeolian Sand Plateau is an erosion surface over which aeolian sands have been deposited. The more or less monotonous sand plain comprises massive seif dune formations with systems of parallel dunes and omiramba (compare 2.1). The uniformity and the depth of the sand cover varies which is due to recent aeolian activities.
The uniformity of the parent materials is the reason why variations in the main soil characteristics are limited so that the normal topographic features (formation of dunes and omiramba (pl.) cannot be linked with soil differences. The sandy soils which were found in the area are low in clay and silt-content (<14%). Major soil differences only occurred in the omuramba valleys and

their tributaries which are not of significant importance to the area under investigation.

Two physiographic regions are of a dominant influence within the Inland/Aeolian Sand Plateau and are closely associated with the survey area these are the seif dune formations (A) and the so called featureless plains (B):

(A): According to LOXTON et.al. (1971) the seif dune formations were classified according to the physiognomy and the degree of development of the dunes, so that four dune types can be recognised:

1) Uneven dunes developed along the margin of the Okavango River terrace and the sides of the major tributaries; red and brown sands occur (not applicable to the survey area).
2) Parallel dune systems which are barely discernible; predominanly grey sands occur (not applicable to the survey area).
3) Dune systems are clearly discernible but normally small and discontinuous; grey sands occur (not applicable to the survey area).
4) Large and prominent dunes where the crests consist of red and brown sands (not applicable to the survey area).

(B): The flat featureless plains comprise three dominant morphological areas of which a combination of 2, 2a and 2b applys to the survey area:

1) Large incipient, poorly defined omiramba within extensive featureless grey sand areas with a very diffuse drainage pattern (not applicable to the survey area).

2) Featureless terrain of grey sands with no omiramba. In small depressions and isolated low mounds red and brown sands were found (applicable to the survey area).

2a) Diffuse pattern of extensive, very flat and slight elevations with no significant drainage pattern. Occasionally incipient omiramba, grey sands and pedocretes (soils which inter alia have been cemented or replaced by carbonates (calcrete)) occur. Partly applicable to the survey area.

2b) Faint hummocky relief with small depressed areas comprising brown and grey sandy soils. No omiramba occur and a drainage pattern is not developed (partly applicable to the survey area).

3) Very flat plain with poorly defined omiramba and numerous large deep waterholes. Red and brown sands are dominant (not applicable to the survey area).

All described geomorphological units and areas on the Inland/Aeolian Sand Plateau comprise a different vegetation pattern, which also might be considered, when classifying the survey area (compare chapter 5).

4. Climate

4.1 Atmospheric circulation and weather sytems

The weather of southern Africa is strongly influenced by air pressure and wind systems of the southern hemisphere, i.e. the subtropical high pressure cells over the Atlantic and Indian Ocean, the Inter Tropical Convergence Zone (ITCZ) and further south the disturbed westerly air stream and finally the thermally induced lows over the interior of the continent (TYSON, 1978a).

In summer the south Atlantic high is centered off the South-West African coast and causes south-westerly on-shore winds that blow over cold ocean currents. The Indian Ocean high is located off the Durban coast from which air moves in a north-easterly direction over warm ocean currents. South of these highs lie the westerlies, in which midlatitudinal frontal lows form and traverse eastwards.

Thermal lows also develop over the interior of the central southern African continent. The change of these highs and lows in absolute and relative positions also determines the weather of the northern and north-eastern parts of South-West Africa.

4.2 Rainfall and temperatures

Climatic data applying to the survey area is available at the meteorological station at Rundu (Longitude: 19° 46' E and Latitude 17° 55' S). Rundu has one of the highest annual rainfalls (600 mm) in SWA most of which occurs during the summer months (Table 1). The first showers occur in September/October and steadily increase reaching a peak in January after which the rainfall declines till April/May and thereafter is a rare occurrence.

Rainfall during the summer months is highly variable with a variation coefficient of >50% and occurs in either isolated high intensity showers associated with thunderstorms or intermittent rainshowers of 2-3 day duration separated by dry spells lasting from a few days to several weeks. During the winter months some drizzle originates from the cold fronts associated with the mid latitudinal lows. Although the northern zone of SWA is characterised by the highest and most reliable rainfall of the country, years of arable droughts are common during which low and poorly distributed rainfall during the growing season causes serious reduction in or complete failure of crop production.

The mean annual rainfall for Rundu which occurs mainly in summer is approximately 625 mm; the mean annual temperature is 22,4°C and the mean annual gross Class A pan evaporation is about 2600 mm. Weinert's N-value is 4,0 and the survey area is classified as semiarid warm, moisture deficient in all seasons according to Thornswaite's classification. A single rain season occurs from October/November to April. The average duration of the rain season (number of months) with more than 50 mm of average precipitation is 5-6 months. The average number of rainy days fluctuate between 40-60. Approximately 90% of the average annual precipitation occurs from October to March. The average long-term monthly rainfall figures for Rundu based on measurements over a period of 38 years are shown in Table 1 which includes rainfall data from Tondoro (34 years observation period), Rupara (17 years of observation) and Shambyu (23 years of observation).

	RUNDU 1937/75	TONDORO 1931/75	RUPARA 1958/75	SHAMBYU 1952/75
JAN	143,7	145,5	140,7	151,1
FEB	140,7	116,0	104,3	142,1
MAR	98,2	95,8	89,7	87,1
APR	39,7	45,2	46,2	35,2
MAY	2,6	1,8	6,2	4,5
JUN	0,0	0,0	0,2	0,0
JUL	0,1	0,0	0,0	0,0
AUG	0,3	0,1	1,6	0,6
SEP	2,2	1,5	3,1	2,4
OCT	17,7	17,6	13,9	15,9
NOV	57,7	59,9	55,6	57,1
DEC	97,7	83,1	69,9	101,4
TOTAL	600,6	566,5	531,4	597,4

Table 1: Longterm average monthly rainfall (mm) for Rundu,Tondoro, Rupara and Shambyu (after PAGE, 1980).

Table 2 shows the amount of rainy days per month, measured at Rundu, Tondoro, Rupara and Shambyu. The maximum rainfall per month within 24 hours for the same stations are shown in Table 3. Temperature data available is based on the period from 1948-1975 (27 years) and is shown in Table 4.

	RUNDU 1937/75	TONDORO 1931/75	RUPARA 1958/75	SHAMBYU 1952/75
JAN	12,4	11,9	12,2	11,8
FEB	12,4	10,5	10,2	10,0
MAR	9,0	9,1	8,2	7,4
APR	4,2	3,2	4,1	2,9
MAY	0,5	0,4	0,4	0,4
JUN	0,0	0,0	0,1	0,1
JUL	0,1	0,0	0,0	0,0
AUG	0,1	0,1	0,2	0,2
SEP	0,5	0,5	0,8	0,4
OCT	3,4	3,0	3,6	3,0
NOV	7,6	6,3	7,5	6,3
DEC	10,0	8,4	7,4	8,3
TOTAL	60,2	53,4	54,7	50,8

Table 2: Rainy days per month (after PAGE, 1980).

	RUNDU	TONDORO	RUPARA	SHAMBYU
JAN	109,0	82,0	104,0	90,0
FEB	106,2	77,0	70,0	75,0
MAR	120,2	65,3	82,0	90,3
APR	76,0	75,0	87,0	80,0
MAY	19,0	18,0	35,0	10,0
JUN	0,8	0,2	1,0	0,1
JUL	1,3	0,4	0,0	0,0
AUG	4,3	1,1	28,3	12,0
SEP	15,5	14,0	15,0	24,4
OCT	47,5	42,0	25,0	60,0
NOV	103,1	63,3	60,0	68,0
DEC	89,1	78,5	53,0	74,7
TOTAL	120,2	82,0	104,0	90,3

Table 3: Maximum rainfall per month (mm) within 24 hours (after PAGE, 1980).

	MAXIMUM	MINIMUM	MAX. + MIN./2
JAN	30,9	18,4	24,8
FEB	30,0	18,3	24,4
MAR	30,3	17,5	23,9
APR	30,3	15,1	22,7
MAY	28,7	10,0	19,0
JUN	26,2	6,5	16,3
JUL	26,7	6,5	16,6
AUG	29,7	8,9	19,3
SEP	33,4	13,3	23,3
OCT	35,1	17,7	26,4
NOV	32,8	18,4	25,6
DEC	33,2	18,4	25,3
YEARLY AVERAGE	30,5	14,1	22,3

Table 4: Average max. and min. monthly temperature for Rundu: 1948- 1975 (C) (after PAGE, 1980).

The summer months are hot with maximum temperatures above 30°C and occasional extremes above 40°C (compare Tables 4 and 5). In winter the days are quite warm with maximum temperatures exceeding 30 °C, the nights, however, are cold with minimum temperatures of usually below 15°C. Light to medium frosts are fairly common from May to August.

The air temperature regime for the Rundu region is defined by seasonal mean, maximum, minimum and extreme air temperatures and rated according to the specific grain crop requirements into four suitability classes which are the same for maize and sorghum but differ to some extent from millet (Table 2a). Optimum temperatures for crop growth range between 25 - 30°C for millet and 20 - 30 °C for maize and sorghum and start affecting the grains negatively above 35 and below 15°C.

The summer temperature regime of Rundu is characterised by a seasonal mean of 25°C (Table 4), a mean maximum at 32°C (Table 4) and a mean minimum of 19°C (Table 6a and 6b). Extreme maximum temperatures may occasionally rise just about 40°C and extreme minimum temperatures may fall below 10°C.

With regard to crop requirements the air temperature regime of Rundu is highly suitable for maize, sorghum and millet. High maximum and low minimum air temperatures do not inhibit crop development significantly during the summer (Table 2b). The winter air temperature regime has a mean of 19°C, a mean maximum of 29°C (Table 6a and 6b) and a mean minimum of 9°C and light to medium frosts are common from May to August. The winter air temperature regime of the Rundu Region is rated unsuitable for selected grain crops, mainly due to their sensitivity to frost.

More detailed information regarding extreme air temperature and precipitation regimes at different times during the day, dry and wet bulb temperatures, relative humidity, cloud cover, as well as data on the occurrence of thunderstorms, hail and fog are given in Table 6a, 6b, 7 and 8a and 8b. All available data takes a reading period of 34 years (1951-1984) into account.

AIR TEMPERATURE REGIME measured properties	DEGREE OF SUITABILITY FOR CROPS high S1	moderate S2	marginal S3	none N
		<u>MILLET</u>		
	25-30	31-33	34-35	>35
Seasonal mean,		24-18	17-16	<15
maximum, minimum		<u>SORGHUM</u>		
air temperature °C,	20-30	31-33	34-35	>35
occurrence of		19-18	16-17	<15
frost		<u>MAIZE</u>		
	20-30	31-33	34-35	>35
		19-18	17-16	<15

<u>Table 2a</u>: Rating of the air temperature regime at Rundu (after BREYER, 1986).

AIR TEMPERATURE REGIME OF RUNDU		DEGREE OF SUITABILITY*			FINAL SUITABILITY*
		SUMMER			
Seasonal mean °C	25	S1	S1	S1	
Seasonal maximum °C	32	S2	S2	S2	
					S1
Seasonal minimum °C	18	S2	S2	S2	
Occurrence of frost	none	–	–	–	
		WINTER			
Seasonal mean °C	19	S2	S2	S2	
Seasonal maximum °C	29	S1	S1	S1	
					N
Seasonal minimum °C	9	N	N	N	
Occurrence of frost	yes	N	N	N	

Table 2b: The air temperature regime of Rundu (after BREYER, 1986);
*=millet, maize and sorghum

AIR TEMPERATURE IN °C

	MEANS								EXTREMES							
A	B	C	D	E	F	G	H	I	HIGHEST		LOWEST		LOWEST		HIGHEST	
1	30,9	18,8	24,9	12,1	35,3	15,7	25,2	21,4	39,0	73/19	9,5	56/26	21,0	65/22	25,6	65/26
2	30,1	18,4	24,2	11,7	34,1	15,4	24,5	20,5	39,5	64/19	11,5	72/14	19,3	77/10	22,2	52/19
3	30,3	17,6	24,0	12,7	33,6	13,8	24,3	20,2	37,5	62/26	9,3	75/24	20,0	72/11	25,0	63/08
4	30,0	15,0	22,5	15,0	32,8	10,2	24,2	18,9	36,5	64/06	7,5	80/20	18,3	51/21	20,3	78/08
5	28,4	10,1	19,3	18,3	31,6	4,5	24,5	15,9	34,2	51/03	-0,7	74/19	18,3	51/21	20,2	56/30
6	26,1	6,0	16,1	20,1	29,0	1,5	22,0	12,5	31,6	68/11	-2,8	78/21	18,5	68/02	15,6	61/30
7	26,4	5,7	16,1	20,6	29,8	0,6	22,2	11,1	35,6	52/30	-4,2	51/27	17,5	82/03	17,3	59/17
8	29,5	8,4	19,0	21,2	33,4	2,7	24,1	15,1	35,6	52/30	-0,5	83/10	18,8	76/12	19,4	75/30
9	33,2	13,4	23,3	19,8	36,3	7,1	26,8	19,8	38,2	72/30	3,4	69/04	20,3	66/20	21,9	66/28
10	34,6	17,8	26,2	16,8	38,2	12,3	26,9	23,1	40,8	68/26	8,5	71/16	21,4	74/24	26,0	57/27
11	32,7	18,4	25,6	14,4	37,4	13,9	25,5	22,2	40,0	53/01	6,5	72/17	17,6	68/13	24,0	53/03
12	32,1	18,5	25,4	13,7	36,3	15,0	25,1	21,7	39,3	68/21	12,0	74/24	20,1	77/27	23,8	74/07
AV	30,4	14,0	22,2	16,4	34,0	9,4	24,6	18,5	40,8	1968	-4,2	1951	17,5	1982	26,0	1957

Table 6a: Air temperature data in °C (period 1951-1984); according to the Weather Bureau, Pretoria (see next page for legend).

A = MONTH
AV = AVERAGE
B = DAILY MAX.
C = DAILY MIN.
D = MAX. & MIN./2
E = RANGE
F = HIGHEST MONTHLY DAILY MAX.
G = LOWEST MONTHLY DAILY MIN.
H = LOWEST MONTHLY DAILY MAX.
I = HIGHEST MONTHLY DAILY MIN.

	AIR TEMPERATURE IN °C										
	Average Temperature			FREQUENCIES Average number of days with values							
	08H00	14H00	20H00	>35	>30	<17,5	<10	>20	<5	< 0	<-2,5
JAN	21,0	29,1	25,0	3,4	17,0	0,0	0,0	3,9	0,0	0,0	0,0
FEB	20,2	28,5	24,1	0,9	13,5	0,0	0,0	2,3	0,0	0,0	0,0
MAR	19,5	28,9	23,9	0,4	15,9	0,0	0,0	1,1	0,0	0,0	0,0
APR	17,2	28,9	22,6	0,0	14,9	0,0	0,0	0,1	0,0	0,0	0,0
MAY	12,3	27,4	19,5	0,0	7,1	0,0	0,0	0,0	1,8	0,1	0,0
JUN	8,1	25,0	16,8	0,0	1,1	0,0	0,0	0,0	10,6	0,4	0,0
JUL	7,5	25,3	16,9	0,0	0,8	0,0	0,0	0,0	11,8	0,6	0,0
AUG	10,9	28,4	20,3	0,0	12,1	0,0	0,0	0,0	3,7	0,1	0,0
SEP	17,1	32,2	24,8	6,1	24,8	0,0	0,0	0,7	0,2	0,0	0,0
OCT	22,0	33,0	27,2	12,8	26,9	0,0	0,0	5,7	0,0	0,0	0,0
NOV	22,3	31,2	26,4	6,8	23,7	0,0	0,0	5,1	0,0	0,0	0,0
DEC	21,8	30,3	26,1	4,7	22,2	0,0	0,0	4,0	0,0	0,0	0,0
AV	16,7	29,0	22,8	35,1	179,9	0,0	0,0	22,8	28,1	1,2	0,1

Table 6b: Air temperature data for Rundu (1951-1984)

	Air Temperature in °C						Relative Humidity %								
	Average Dry-Bulb Temperature at			Average Wet-Bulb Temperature at			08H00			14H00			20H00		
	08H00	14H00	20H00	08H00	14H00	20H00	A	B	C	A	B	C	A	B	C
JAN	21,0	29,1	25,0	19,0	21,4	20,4	82	97	58	49	67	34	61	85	44
FEB	20,2	28,5	24,1	18,9	21,3	19,7	88	99	70	54	74	30	68	76	48
MAR	19,5	28,9	23,9	17,9	21,0	19,3	87	98	67	48	61	29	66	82	44
APR	17,2	28,9	22,6	15,1	19,5	17,8	83	97	57	40	54	30	56	71	46
MAY	12,3	27,4	19,5	9,9	16,8	14,0	76	87	51	32	52	21	46	60	32
JUN	8,1	25,0	16,8	5,9	14,4	11,1	73	88	54	29	42	18	41	54	26
JUL	7,5	25,3	16,9	5,1	14,3	10,4	70	93	50	26	46	18	33	45	24
AUG	10,9	28,4	20,3	6,9	15,4	12,0	55	65	36	21	35	10	25	37	14
SEP	17,2	32,2	24,8	11,0	17,7	14,7	45	57	31	20	29	8	23	32	13
OCT	22,0	33,0	27,2	15,6	19,4	17,5	50	68	35	26	41	15	30	48	17
NOV	22,3	31,2	26,4	18,1	20,6	19,2	67	81	43	36	51	21	44	64	32
DEC	21,8	30,3	26,1	18,9	21,1	20,1	77	89	53	43	72	25	53	73	43
AV	16,7	29,0	22,8	13,5	18,6	16,4	71			35			46		

Table 7: Air temperature data (dry-bulb and wet-bulb temperature and relative humidity in %) for Rundu (1951 - 1984).
A = Average humidity,
B = Average of highest max. (max. humidity),
C = Average of lowest min. (min. humidity).

	PRECIPITATION IN MM						
	A	MAX IN 24 HRS		HIGHEST MONTHLY MAX AND DATE		LOWEST MONTHLY MIN AND DATE	
	SUM	MM	DATE	SUM	DATE	SUM	DATE
JAN	146	109	1971/24	389	1971	26	1973
FEB	148	106	1952/03	387	1978	8	1964
MAR	87	120	1955/30	267	1972	8	1952
APR	38	76	1967/02	180	1967	0	1969
MAY	12	53	1951/15	147	1951	0	1982
JUN	0	4	1981/01	4	1981	0	1984
JUL	0	1	1961/30	1	1961	0	1984
AUG	0	4	1969/11	6	1969	0	1984
SEP	2	12	1974/03	25	1956	0	1984
OCT	20	42	1978/26	81	1951	0	1960
NOV	58	44	1965/16	191	1967	0	1972
DEC	85	78	1951/02	267	1977	7	1968
A	596	120	1955	946	1978	335	1959

Table 8a: Precipitation data in mm for Rundu (observation period: 1951-1984).
A = Average

	PRECIPITATION IN MM - FREQUENCIES												CLOUD COVER		
	NO OF DAYS														
	PRECIPITATION							AVERAGE					0 - 8		
	≥ 0,1 MM			≥ 1,0 MM			≥ 10 MM								
	A	B	C	A	B	C	A	D	E	F	G	H	I	J
JAN	14,2	25	3	11,5	19	2	4,3	8,1	0,0	0,0	0,0	5,3	5,8	5.
FEB	12,8	25	3	11,0	21	2	4,5	8,0	0,0	0,0	0,1	5,2	5,6	5.
MAR	9,6	17	2	7,6	16	1	2,9	5,9	0,1	0,0	0,0	4,4	5,3	4.
APR	4,4	10	0	3,5	10	0	1,3	2,8	0,0	0,0	0,0	2,8	4,1	2.
MAY	2,2	9	0	1,4	8	0	0,4	1,8	0,0	0,0	0,0	1,5	2,0	1.
JUN	1,6	9	0	1,0	5	0	0,3	0,3	0,0	0,0	0,0	0,7	0,7	0.
JUL	1,7	9	0	1,0	5	0	0,3	0,1	0,0	0,0	0,0	0,2	0,3	0.
AUG	1,1	7	0	0,7	4	0	0,1	0,2	0,0	0,0	0,0	1,0	1,1	0.
SEP	1,1	6	0	0,6	4	0	0,1	0,8	0,0	0,0	0,0	1,0	1,1	0,8
OCT	4,1	9	0	2,8	8	0	0,5	4,0	0,0	0,0	0,0	2,7	3,6	2.
NOV	8,3	14	2	6,5	12	2	2,0	7,0	0,0	0,0	0,0	4,1	5,2	4.
DEC	10,3	21	3	8,3	16	2	2,8	6,6	0,0	0,0	0,1	4,5	5,2	4.
AVE	71,4			55,9			19,5	45,6	0,1	0,0	0,2	2,7	3,2	2.

Table 8b: Precipitation data for Rundu (observation period: 1951-1984).

A = Average D = Thunder G = Fog J = 20H00
B = Maximum E = Hail H = 08H00 AVE = Average
C = Minimum F = Snow I = 14H00

Cloud cover is measured in "OKTAS", i.e. 8 = Total Cover
0 = No Cover

4.3 Longterm rainfall variations

With regard to arable drought frequencies and risks the question of long-term rainfall trends is an important issue, i.e. whether arable droughts are likely to occur in clusters over a consecutive number of years or are likely to increase or decrease in future.
There is no doubt that southern Africa has undergone many long-term rainfall changes as, for xample, landforms of wet and dry environments such as dune systems, fossile rivers and the once huge Pleistocene Lake Makgagikgadi in Botswana indicate (COOKE, 1978).
Theories that southern Africa is becoming progressively drier are based on observations of early explorers and missionaries who report on areas in southern Africa with heavy rainfall and large amounts of standing water which are now semi-arid. The problem of disproving this theory lies in the limited length of rainfall records.
Quantitative studies on the cyclic nature of rainfall mainly in the RSA have been published by TYSON (1978) and DYER (1978).

4.4 Potential evaporation, evapotranspiration and the water balance

Annual potential evaporation (gross evaporation - A pan/mm) measured at an open water surface is very high with 2875 mm and shows marked seasonal differences (Table 5). During summer potential evaporation is as high as 1740 mm and in winter drops to 1134 mm. Evaporation is highest in December corresponding to high air temperatures and strong winds. The lowest evaporation month is June. Evapotranspiration is the reverse of precipitation, that is, the return of moisture to the atmosphere by evaporation from land and water surfaces and by transpiration from plants. Potential evapotranspiration is then the maximum of moisture return to the atmosphere that could result in a given temperature regime.

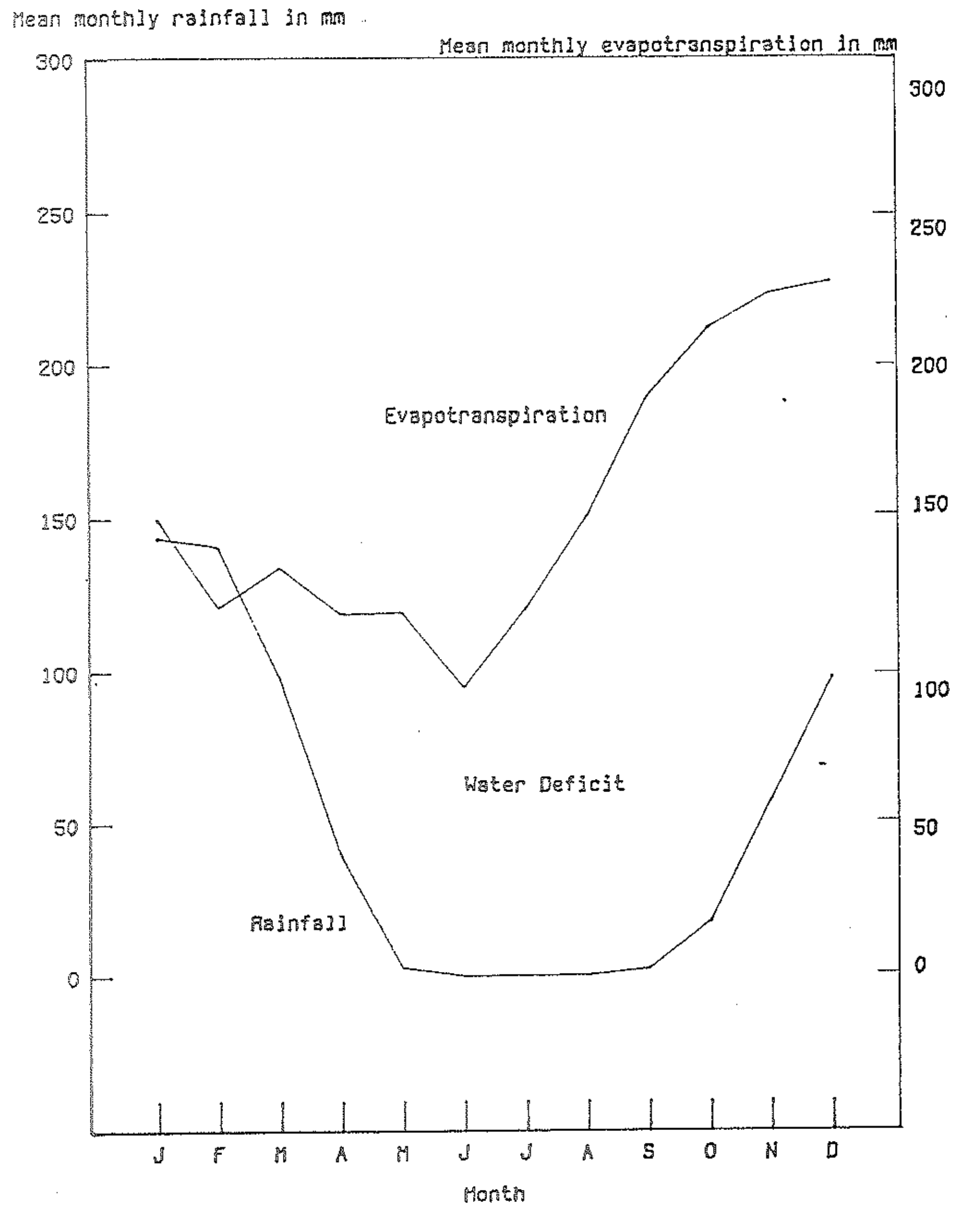
Potential evapotranspiration from a short green grass surface completly covering the ground and not subject to any moisture stress follows similar annual and seasonal characteristics. Annual potential evapotranspiration is 1859 mm with 1185 mm in summer and 674 mm in winter.

Potential evapotranspiration and rainfall combined in a water balance provides a general picture of soil moisture availability to crops (Figure 1). Throughout the year potential evapotranspiration is considerably higher than rainfall, indicating a severe limitation with respect to soil moisture availability to crops. However, crops are able to exist on lower than potential evapotranspiration rates although their development becomes increasingly affected with decreasing evapotranspiration rates due to soil moisture stress.

	Ø monthly rain fall (mm)		Gross evaporation/A pan (mm)	Potential evapotranspiration (mm)	Surplus/ Deficit (mm)
Jan.	S U	143,7	217,0	149,7	- 5,9
Feb.		140,7	179,2	121,1	+ 19,6
March		98,2	198,4	134,0	- 35,8
April		39,7	189,0	118,9	- 79,2
May	W I	2,6	207,7	119,4	- 116,8
June		0,0	177,0	94,7	- 94,7
July		0,1	213,9	120,2	- 120,1
Aug.		0,3	246,0	150,3	- 150,0
Sept.	S U	2,2	288,0	189,5	- 187,3
Oct.		17,7	306,9	211,7	- 194,0
Nov.		57,7	321,0	222,9	- 165,2
Dec.		97,7	328,6	226,6	- 128,9
Total		600,6		1859,0	- 1258,3

Table 5: Potential evapotranspiration (max. moisture return) for Rundu (after PAGE, 1980).

Figure I: The water balance for Rundu (after BREYER, 1986)



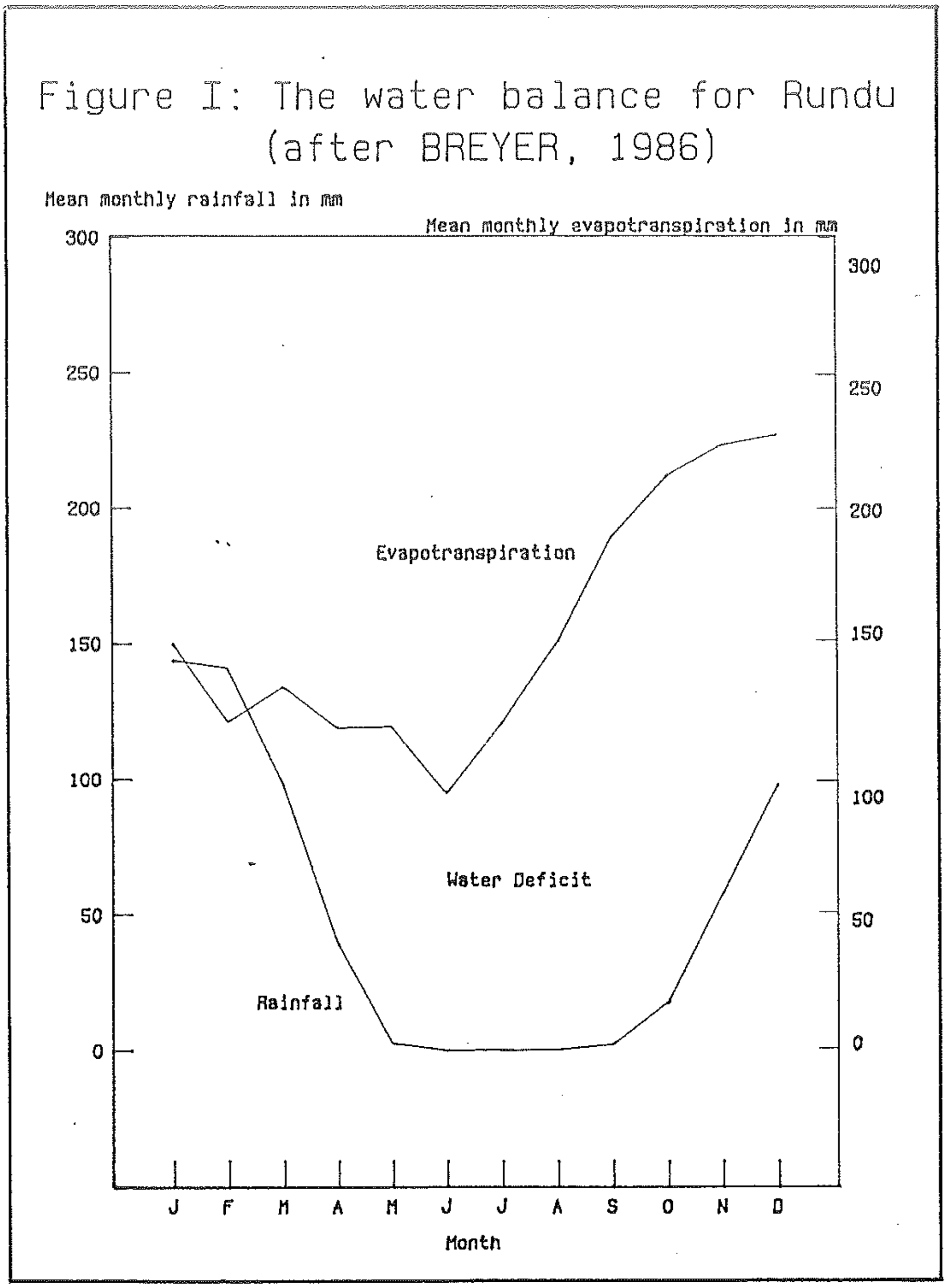
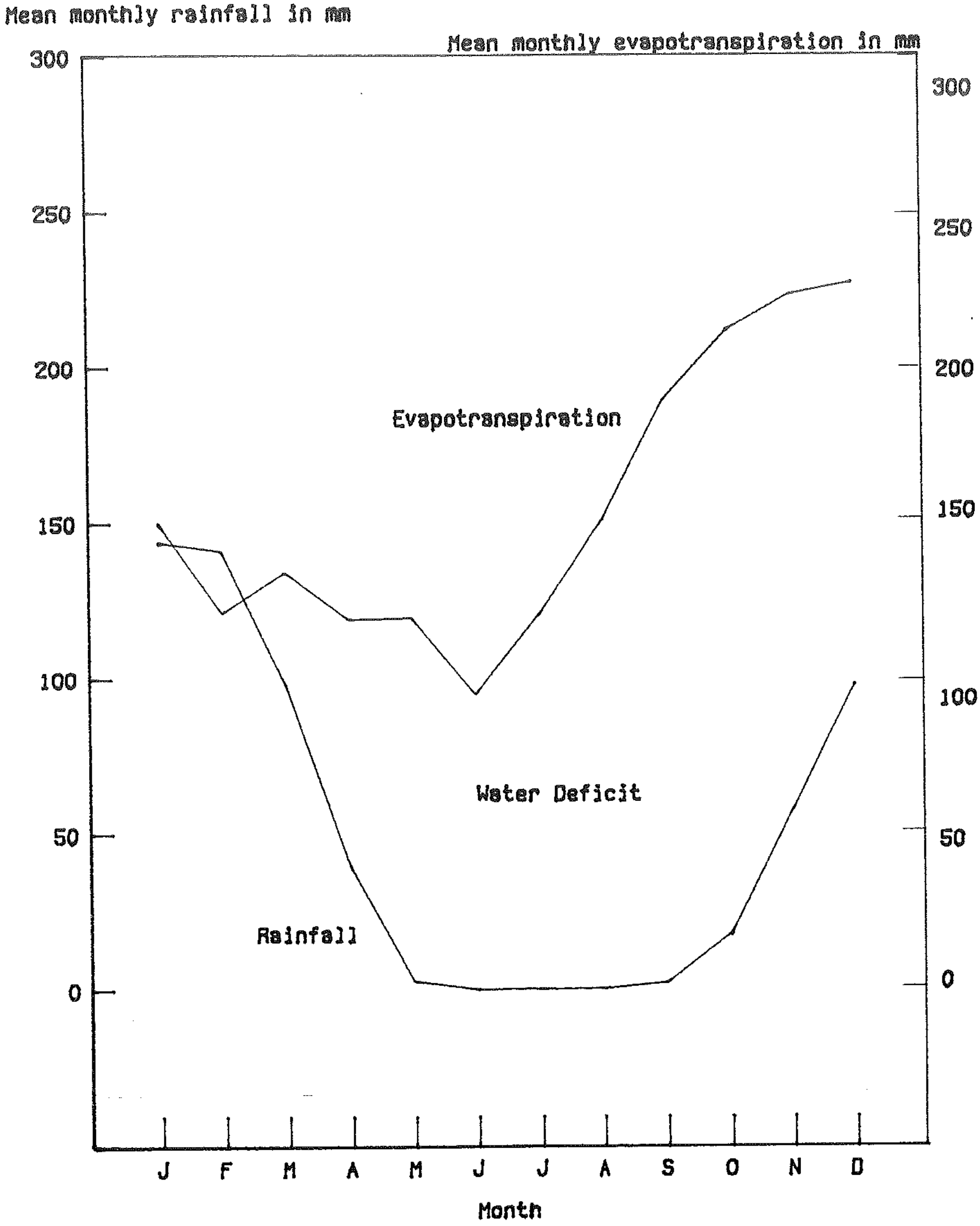


Figure 1: Water balance for Rundu(after BREYER, 1986).

Figure I: The water balance for Rundu (after BREYER, 1986)



4.5 Soil temperature regime

The soil temperature regime refers to the crop soil temperature and it is defined according to the U.S. soil taxonomy, both employing different soil temperature data. The crop soil temperature regime determines the suitability of the Kavango (mainly the Rundu area) with respect to germination and root development of selected grain crops, while the soil temperature regime according to the U.S. soil taxonomy is an important property in the description and classification of soil units.

Soil temperatures are fairly consistent within seasons but show marked differences between summer and winter. Mean soil temperatures at rooting depth are around 29 °C in summer and below 25 °C in winter. Differences between maximum and minimum temperatures are relatively insignificant.

The crop soil temperature regime is defined by daily mean, maximum and minimum soil temperatures at rooting depth between 0-60 cm and classified into four suitability classes according to crop root requirements. Due to lack of data, suitability classes are not differentiated according to the individual crops (Table 9). Optimum soil temperatures for root development range between 25-30 °C and become detrimental above 40 °C and below 15 °C. If the mean, maximum and minimum soil temperatures deviate by more than one suitability class from each other, the suitability class for mean soil temperature is downgraded by one.

In summer a mean soil temperature of 29 °C, a mean maximum of 30 °C and a mean minimum of 27 °C makes the summer

soil temperature regime of the area around Rundu highly suitable for selected grain crops (Table 10).
In winter soil temperatures at rooting depth are considerably lower with a mean at 21 °C, a maximum at 23 °C and a minimum at 20 °C, making the winter soil temperature regime only moderately suitable for millet, maize and sorghum (Table 10). The soil temperature regime after the U.S. soil taxonomy is hyperthermic with a mean temperature for the entire year of 26 °C over a depth of 0-120 cm and a difference between the mean daily summer and winter soil temperatures of 7 °C a depth of 60 cm.

SOIL TEMPERATURE REGIME	DEGREE OF SUITABILITY*			
measured properties	high	moderate	marginal	none
	S1	S2	S3	N
Seasonal mean, maximum,	25 - 30	31 - 35	36 - 40	>40
minimum °C		24 - 20	19 - 15	<15

Table 9: Rating of the soil temperature regime at Rundu (after BREYER, 1986); * = for millet, maize and sorghum.

SOIL TEMPERATURE REGIME		DEGREE OF SUITABILITY*	FINAL SUITABILITY*
		SUMMER	
Seasonal mean °C at 0 - 60 cm depth	29	S1	
Seasonal maximum °C at 0 - 60 cm depth	30	S1	S1
Seasonal minimum °C at 0 - 60 cm depth	27	S1	
		WINTER	
Seasonal mean °C at 0 - 60 cm depth	21	S2	
Seasonal maximum °C at 0 - 60 cm depth	23	S2	S2
Seasonal minimum °C at 0 - 60 cm depth	20	S2	

Table 10: Soil temperature regime of Rundu (after BREYER, 1986); * = for millet, maize and sorghum.

5. Vegetation

The Aeolian Sand Plateau has its typical vegetation; generally the area at Rundu comprises riparian woodland. In the survey area this vegetation type occurs on aeolian sands. Physiognomically this type ranges from medium to high open woodland. Important constituents of economic value are *Pterocarpus angolensis* and *Baikiaea plurijuga* (ohahe, mucusi, Rhodesian teak). The dominant tree is

Burkea africana (mutundungu, wild syringa) with which Terminalia, Combretum and Grewia species are usually associated. Other common species are Lonchocarpus capassa, Guibourtia coleospermum (nusibi, ushivi), Ricinodendron rautanenii and Peltophorum africanum (mupororo) which is used for carving. In the area under investigation the better stands of tall trees usually occur on those sandy soils that have the lowest agricultural potential. It would appear, that because of the poor water-holding capacity and nutrient status of these sands, a less luxuriant grass cover develops, which is not as vulnerable to hot burns as the denser sward on more fertile soil types. The rare areas of grassland and wooded grassland in this specific vegetation region occur only on heavier bottomland soils some of which are saline.

6. Present farming practices

6.1 Traditional arable farming

Sorghum and millet are traditionally important subsistence food crops in the communal areas of the Kavango. Pearl millet has a high nutritive value desirable for human, pig and poultry feeding. The protein content of pearl millet grain is not significantly different from that of maize, sorghum and finger millet (Eleusine). The main crops are sorghum (Sorghum vulgare), maize (Zea mays), millet (Pennisetum typhoides), cow peas (Vigua unguiculata), water melon (Colocynthis citrullus), sweet melon (Cucumis melo) as well as pumpkin (Curucubita pepo), sweet reed (Sorghum dochna) and occasionally groundnuts (Arachis hypogaea) and cabbage (Brassica *oleracea*).

Land preparation for planting under traditional dryland farming is very limited. After the dry season the previously harvested area is usually cleared of weeds and crop remains by means of termite activity and grazing animals and ready for ploughing. Farming operations start when the soil is moist. For dryland farming this is usually after the first heavy rainshowers in November or December. A seed mixture of mainly sorghum and beans, melons, maize or millet is broadcast over parts of the unploughed field which is then worked into the soil by using the mouldboard plough drawn by oxen or donkeys. The planting and ploughing operations are repeated several times between October and January after more rainshowers until a substantial part of the field is planted or when the rainfall has ceased.

The seed input by means of the broadcasting method is high compared to the final low plant population. The use of kraal manure or fertilizer is extremly uncommon because farmers complain that it 'burns' their crop unless there is sufficient rainfall.

Traditional arable farming as specific crop, draft power, implement and conservation requirements with respect to climate, relief, soils, hydrological conditions and vegetation for optimum production. The crop requirements considered concern the most commonly grown grains in the Kavango, i.e. millet, maize and sorghum. Draft power and implement requirements refer to the traditionally used animal-drawn single furrow mouldboard plough and conservation requirements are related to measures taken for sustained production. These requirements of traditional arable farming can e expressed in terms of land qualities (see Table 11).

Relevant land qualities to consider with reference to crop requirements are temperature, wind, day length and flooding regimes, soil moisture and oxygen availability for crops, foothold for roots, chemical soil fertility, soil salinity and alkalinity. Land qualities related to draft power and implements are soil workability and those related to conservation are soil resistance to wind and water erosion (Table 11).

LAND QUALITIES	Considered Land Characteristics
	CLIMATE
Air temperature regime	mean, maximum, minimum air temperature during summer and winter
Soil temperature regime	mean, maximum, minimum soil temperature at rooting depth during summer and winter
Wind regime	mean and maximum wind speeds during summer and winter
	HYDROLOGICAL CONDITIONS
Flooding regime	duration and frequency of flooding during winter & summer
	LANDFORMS/SOILS
Soil moisture regime	rainfall, evapotranspiration, available moisture holding capacity
Oxygen availability	draining class
Seedling establishment	crust, stoniness, structure, consistency
Foothold for roots	depth
Chemical fertility	pH, organic carbon, phosphorus and cation exchange capacity
Salinity	electrical conductivity
Alkalinity	pH
Workability	stoniness, rock outcrops, consistency, coarse fragments
Erosion Resistance	silt contents organic carbon, structure, infiltration rate, slope steepness/length, texture, consistency, cementation.

Table 11: Considered land qualities for traditional arable farming (adopted from BREYER, 1986).

7. Survey methods

7.1 Mapping scale

Topographical maps used for mapping in the field were at a scale of 1:25 000. The final soil map, however, accompanying this report (see Annexure I) is drawn at a scale of 1:10 000, using the 1:50 000 scale topographic series maps as an additional information source. The maps representing the survey area are No.: 1819 AB & 1819 BA.

7.2 Profile description

Various soil profile pits were dug to describe and classify the range of soils occurring in the survey area using the South African Binomial System (MACVICAR et.al., 1977). On the basis of profile descriptions and augering, three main soil forms (Hutton-, Clovelly- and Oakleaf Form Soils) were encountered and the soil map, including the legend, was modified accordingly (see Annexure 1).

8. Soils

8.1 Sandy soils

The aridity of the climate in the Kavango is responsible for the slow chemical weathering and soil formation of the sandy soil body. The sparse vegetation cover coupled with high soil temperature is the cause of the low organic matter content and biological activity in the soil. Carbonates, gypsum and salts may be present at some level depending on the penetration depth and intensity of rainfall. Generally, all sandy soils are weakly developed.

Calcification and gypsification are the main soil forming processes. Under strong winds which promote sand and dust storms, the upper layer is either blown off or buried under aeolian deposits depending on the topography.
Sandy soils are generally poor in plant nutrients and the nutrients applied to these soils are lost because of irrigation water. Fertilization of these soils is therefore a necessary practice. Sandy soils with sand and loamy sand texture deserve special considerations since they have a larger percentage of sand fractions that adversely affect their agricultural potentialities. Sands being noncoherent and structureless are erodible. Although they have a high specific gravity and low total porosity, their pores are large and contribute to good aeration, rapid drainage and low water holding capacity. The low specific surface area of sand is a main factor affecting their low surface activity and explains dissimilarities from clays in their physical behaviour. Sandy soils are often described as droughty. Their low available water range, high infiltration rate and rapid redistribution affect their irrigation practices and agricultural potentialities. The water transmitting properties of sands encourage upward water movement when they are wet and discourage it when they are dry.

8.2 Previous surveys

Very general and broad soil surveys have been carried out in the Kavango (e.g. Loxton, Hunting & Associates; FNDC/ENOK and Page). However, detailed soil surveys for small scale irrigation purposes did not permit the inclusion of results from these reports due to the shortage of detailed analytical data related to the survey area.

8.3 Soil types and main characteristics

During the soil survey three main soil forms were identified and subdivided into different soil series. Owing to the homogenity of the aeolian sand in the survey area, the whole region is pedologically homogeneous and most soil series occur fairly extensively (compare soil map in Annexure I). The series are mostly the sandy series within each form and differ mainly in colour. More than 80% of the analysed soils contain sands in amounts above 90. All of them contain more than 60% coarse fine sand to finer coarse sand mixtures. The humus content determined in the topsoils from the different sites is quite low and the percentages are always less than 3%. The soil reaction of the analysed samples appeared to be between 4,5 and 7,0 (i.e. strong to slight acidity).

The rainfall is sufficient for dry cultivation (under surface watering systems could be organized also for fruit trees), but run off during heavy thunderstorms and the lack of humus makes the shortage of water in high sandy soils worse than the actual shortage of rainfall. Dry periods are very common between the first rains and they can cause difficulties even though the question of drought is reduced. Thus there are opportunities for farmers to organize more reliable water supplies through boreholes for example.

A further characteristic of the surveyed soil series is that nearly all are eutrophic in their degree of leaching. This seems to be the result of the relatively low rainfall and the high evapotranspiration rate which saturates the exchange complex of the soil with basic cations.

The soils developed on the described parent material were identified as those series belonging to the Clovelly-, Hutton- and Oakleaf Soil Forms. They are the dominating group of soils also found in other areas.

8.4 Analytical data

18 soil samples have been collected from the various fields which are proposed to become utilized (i.e. land S1 - S5 and land 1 - 12; see Annexure I). Each sample (A - R) has been collected from a different field and the precise location is indicated on the map as well as the size (in ha) of each field. Analytical data includes results on: Phosphorus (in mg/kg; method: BRAY I), potassium, calcium, magnesium and sodium (in mg/kg; method: Ammonium acetate), exchangeable zinc (in mg/kg; method: AMBIC), pH in KCl and on the textural class (clay, silt and sand in %). The results are as follow (see next page):

Sample:	P	K	Ca	Mg	Na	Zn	pH	Clay	Silt	Sand
			(mg/kg)				(KCl)		(%)	
A	3	13	535	38	2	0,26	6,4	6	0	94
B	4	13	378	39	2	0,07	6,1	8	0	92
C	4	28	776	61	2	0,19	6,1	10	2	88
D	3	20	1517	14	2	0,46	6,4	8	0	92
E	2	72	3987	60	3	0,22	7,0	10	4	86
F	3	16	341	67	3	0,82	6,7	6	2	92
G	3	24	378	64	3	0,25	6,6	8	0	92
H	4	47	695	51	2	0,60	6,6	6	0	94
I	3	33	295	55	2	0,31	5,7	8	0	92
J	3	21	387	154	1	0,56	5,7	8	4	88
K	5	40	284	72	2	0,81	5,3	6	2	92
L	3	10	301	77	2	0,71	4,5	8	2	90
M	3	10	302	50	2	0,34	4,9	6	0	94
N	5	16	241	55	2	0,66	5,1	6	2	92
O	3	14	434	68	2	0,14	5,5	6	0	94
P	3	11	304	67	2	0,13	5,6	6	0	94
Q	4	22	248	59	2	0,06	5,3	8	0	92
R	3	8	248	63	2	0,64	5,7	8	0	92

Table 12: Analytical data

8.5 Soil fertility

Restrictions on agricultural production due to soil nutrient deficiencies are removed simply by applying appropriate fertilizers. The easiest way to increase production in most countries is to increase the general use of fertilizers. The problem that arises is that the cost of using fertilizers is never negligible and may be considerable, or even prohibitive, relative to the economic resources of farmers. In general it is not economical to attempt to eliminate deficiencies and maximise production in the short term by massive applications of fertilizers. Rather, lesser, economic rates of fertilizer application have to be chosen with due allowance for the costs involved, the value of the crops, expected responses, risks, other demands on capital resources, and so on. In other words, fertilizer rates have to be chosen primarily for the economic benefit of farmers, the elimination of deficiencies and the maximisation of production following in the long term from the resulting progressive build-up of soil fertility by fertilizer residues, as has happened with some of the highly developed agricultural lands of Europe and North America.

8.6 Fertilizer requirements

According to the soil analysis (compare 8.4), fertilizer recommendations have been worked out to increase the levels of phosphorus and potassium as well as for the general applications of nitrogen. The crops referred to are sorghum and maize under dryland, as well as under

irrigation farming. According to Outspan Laboratories in Pretoria the phosphorus level for sorghum and maize "should be about 15-20 (dryland) and 20-30 (irrigation) mg P kg. Applications of potassium to increase the levels to about 50 to 75 mg K kg are also required. Under irrigation sorghum and maize require about 120-150 kg N per ha per annum. Dry land cultivation needs about 60-100%."
The following application amounts for phosphorus (under dryland <u>and</u> irrigation farming conditions) are based on a recommended increase of up to 20 mg P kg with the use of superphosphate (10,5%); the potassium applications take into consideration an increase of up to about 75 mg K kg with the use of potassium chloride (KCl; 50% K) - (see next page):

*For example sample A: 3 ppm P=6 kg P, 17 ppm P=34 kg P; i.e. 34 kg P x 100/10,5 = 340 kg superphosphate 10,5%/ha; total amount necessary for land S1: 1700 kg superphosphate 10,5%; 1 ha = 2 million kg soil, being 15cm deep;

**For example sample A:13 ppm K=26 kg K, 62 ppm K=124 kg K; i.e.124 kg K x 100/50 = 248 kg potassium chloride/ha; total amount necessary for land S1: 1240 kg potassium chloride; 1 ha = 2 million kg soil, being 15cm deep.

9. Irrigation

9.1. Irrigation of sandy soils

In irrigation development projects involving sandy soils the irrigation method must be considered very carefully. In general surface irrigation methods are not the most suitable for sandy soils whether by basin, border or furrow. The high permeability and the low water storage capacity make it very difficult to apply the correct amounts of water. Irrigation of sandy soils may lead to water wastage by deep percolation and low irrigation efficiencies of less than 50 per cent. Moreover the yield of crops may also be affected by bad uniform application. The lowest parts of fields often do not receive enough water to meet their requirements whereas the upper parts are generally over-irrigated. Nutrients are carried away and micro-elements are frequently lacking. Usually under normal conditions, surface irrigation methods are not recommended for sandy soils.

Sandy soils have a low pore space and a high infiltration rate. The consequences of these two features on irrigation systems and methods are of great importance. The low pore space is responsible for a low water holding capacity. Consequently the frequency of irrigation and labour requirements are high independent of the irrigation method used. Labour requirements can be reduced but the initial cost of equipment is then considerably increased. The high infiltration rates make surface irrigation very difficult and an important objective is to avoid losses when applying water to the fields. The adaptation of surface irrigation, when possible, requires higher investment costs for increased length and size of canals, canal lining, large number of small plots and eventually special on-farm equipment.

On the other hand high infiltration rates have little influence on sprinkler irrigation. This method can therefore be considered as the best for sandy soils. It will lead to acceptable efficiencies if properly designed and managed. Drip irrigation is a promising method but its cost is still quite high. In any case irrigation of sandy soils requires a good deal of knowledge and skill. Guidance should be provided to farmers by a well organized irrigation education programme.

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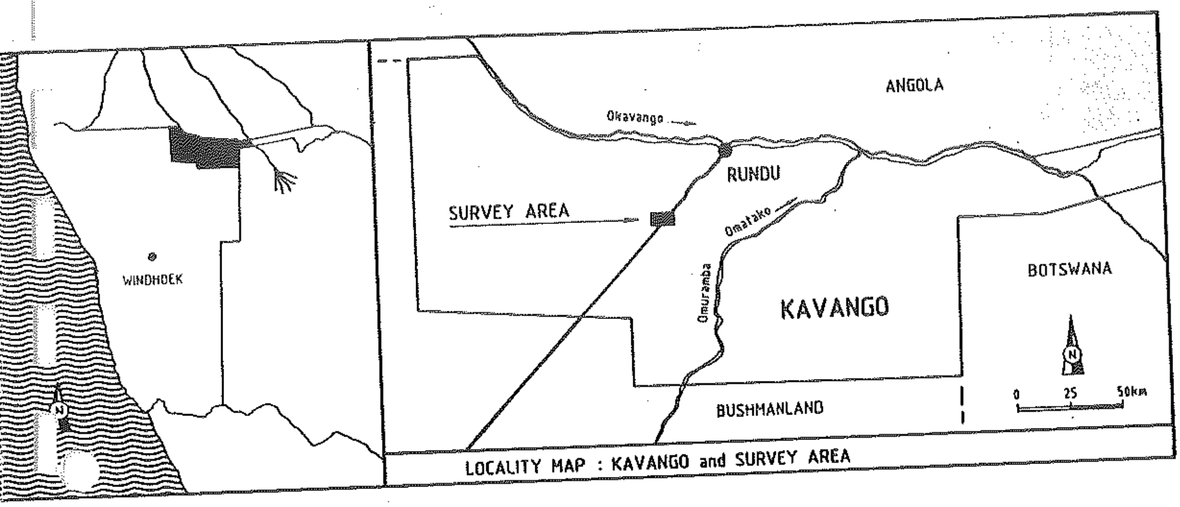
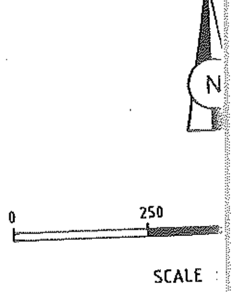


ANGOLA
Okavango
RUNDU
SURVEY AREA
Omatako
Omuramba
KAVANGO
BOTSWANA
BUSHMANLAND
WINDHOEK
N
0 25 50km
LOCALITY MAP : KAVANGO and SURVEY AREA



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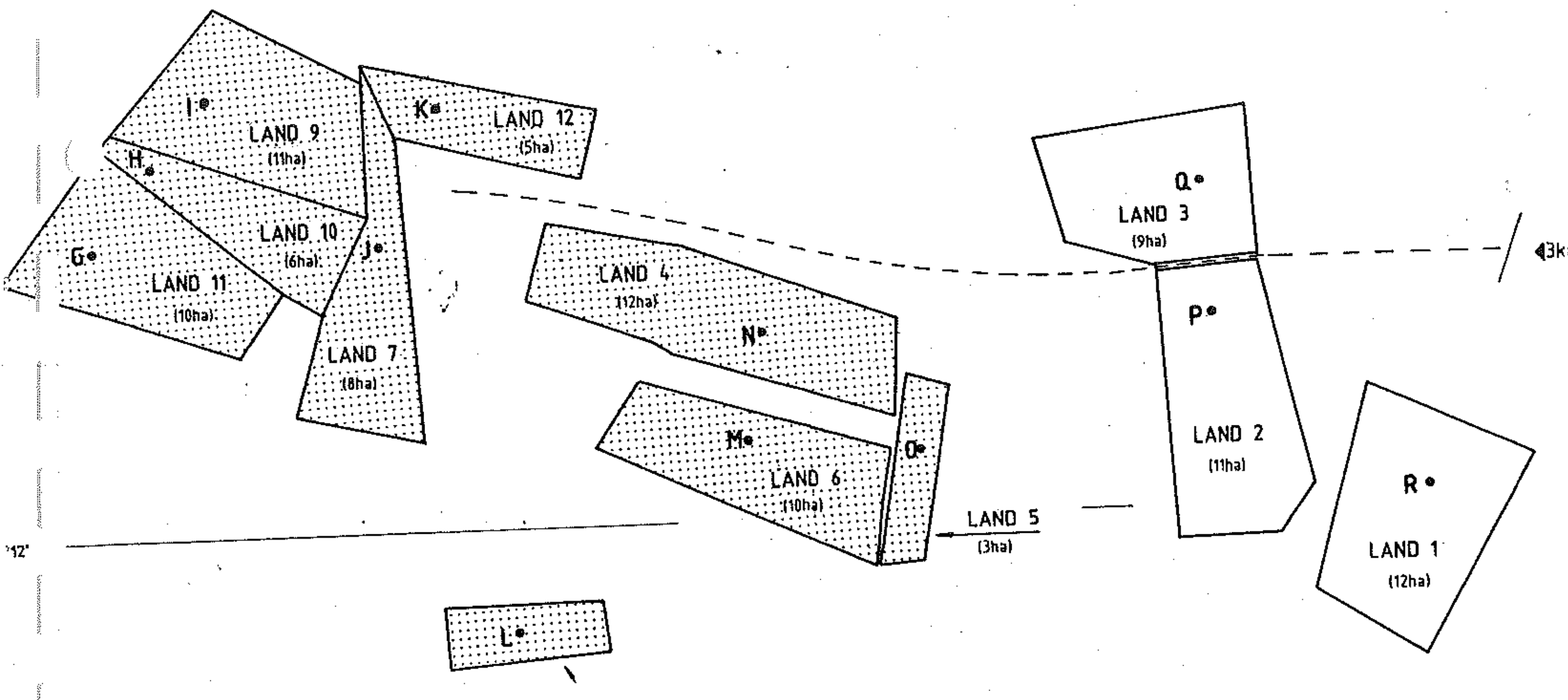

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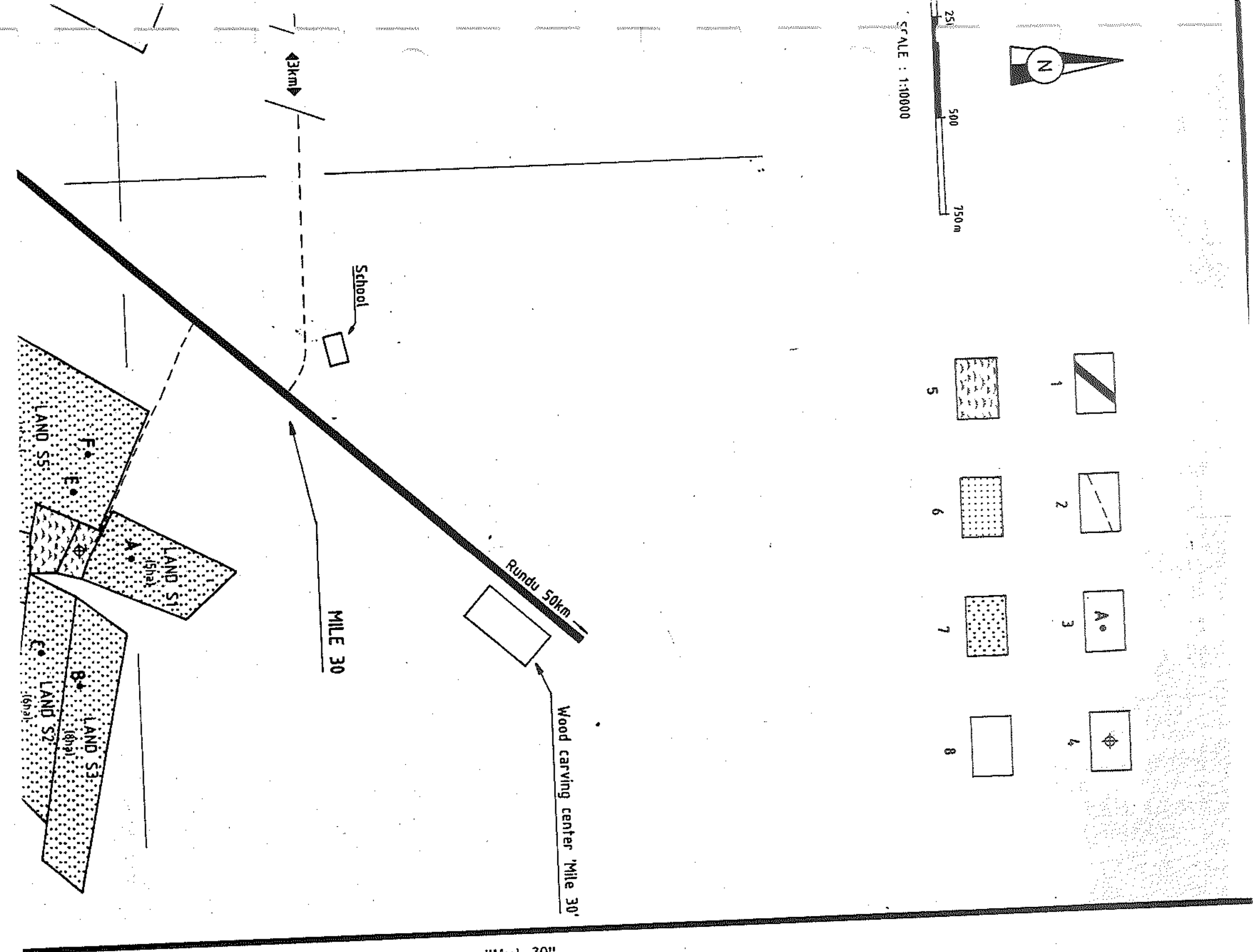
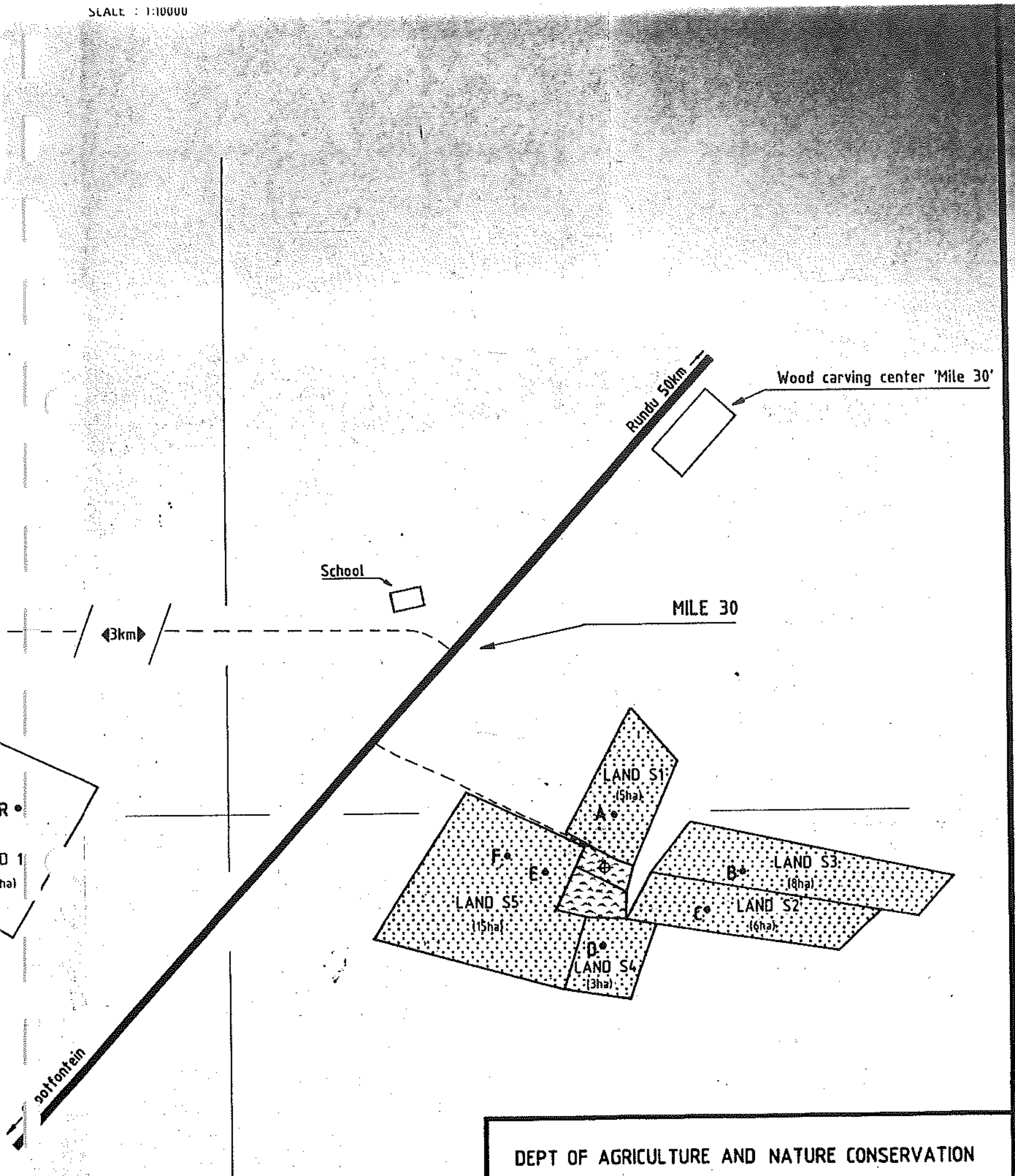


graphical location and soil map of the survey area "Myl 30"

Main road	5 = Cattle camp
Field-path	6 = Predominant Soil Form: Oakleaf & Clovelly
Sample point	7 = Predominant Soil Form: Oakleaf, Clovelly & Hutton
Water supply/borehole	8 = Predominant Soil Form: Oakleaf,

SCALE : 1:10000



DEPT OF AGRICULTURE AND NATURE CONSERVATION

SOIL SCIENCE SECTION

M.B. Schneider (1987)

Annexure 1: Geographical location and soil map of the survey area "Myl 30"

1 = Main road
2 = Field-path
3 = Sample point
4 = Water supply/borehole
5 = Cattle camp
6 = Predominant Soil Form: Oakleaf
7 = Predominant Soil Form: Oakleaf & Clovelly
8 = Predominant Soil Form: Oakleaf, Clovelly & Hutton

AIR TEMPERATURE	DEGREE OF SUITABILITY FOR CROPS			
REGIME	high	moderate	marginal	none
measured properties	S1	S2	S3	N
		MILLET		
	25-30	31-33	34-35	>35
Seasonal mean,		24-18	17-16	<15
maximum, minimum		SORGHUM		
air temperature °C,	20-30	31-33	34-35	>35
occurrence of		19-18	16-17	<15
frost		MAIZE		
	20-30	31-33	34-35	>35
		19-18	17-16	<15

Table 2a: Rating of the air temperature regime at Rundu (after BREYER, 1986).