SOIL RECONNAISSANCE SURVEY
PROPOSED IRRIGATION SCHEME
KATIMA MULILO

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WINDHOEK

CONTENT:

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I. Introduction

This study aims to supply some basic details on the soils west of Katima Mulilo. For soil texture and soil fertility determination samples were collected at various sites.

The following report is the result of a soil reconnaissance survey which was undertaken by the Department of Agriculture, Nature Conservation and Veterinary Services. Included are the analytical laboratry results as well as the soil profile descriptions (see Appendix A). and a soil map at 1 : 7500 scale (see Appendix B).

18 soil profiles were described according to the Binomial System (MACVICAR et al., 1977). 44 soil samples were taken, of which 20 were analysed in terms of chemical and physical soil characterization. The samples represent the surface, subsurface and subsoil and are examples of different soil forms.

II. Survey Area

II.1. Description and location

The area surveyed is located 2,5km west of Katima Mulilo between 24°15'/24°16' latitude and 17°29'/17°30' longitude (see Appendix B), lying on an average height of 940m above sea-level.

50-60 ha which are situated approximately 1000-2000m from the Zambezi river as the main drainage system in the area, have been investigated and mapped. The flood level of the Zambezi during peak periods (February - April) is not of significant disturbance to the survey area.

III. Geology

The survey area is situated in the Zambezi Region which belongs to the Great African Plateau, with an altitude of more than 900m above sea-level. The Zambezian Region is drained by the Zambezi river which is diverted by faults, dirived from large-scale graben structures (BAILLIEUL, 1975). Within the Zambezian Region the Great African Plateau with its peripheral uplands is surrounding the northern part of the Kalahari basin. The basin is filled with sediments, known as the Kalahari Sands.

Geologically the soils of the survey area belong to the Kalahari Group. They are mainly of extreme sandy nature. They may primarily be of Pliocene age, but are redistributed during Quaternary (Pleistocene) by aeolian and fluviatile activities (COOK, 1964). The sands originate from quartizite outcrops within the Kalahari basin (KING, 1963).
Various authors (SÖHNGE & VISSER, 1937; VAN ZINDEREN BAKKER, 1957 and KING, 1963) mentioned climatic changes, which took place during Tertiary and Pleistocene times. Shifting of sands by aeolian activity therefore took place during interpluvial periods, being responsible for the development of various systems of dunes in the Caprivi (VAN DER MERWE, 1954 and DU TOIT, 1966). Dune formations are observable in the landscape, especially visible on aerial photographs at 1 : 64000 scale. The aerial photos show no visible higher relief in the area surveyed, but water tends to run on plain relief along the direction of possible transverse dunes, which can be seen surrounded by cultivated fields 5-6km west of Katima Mulilo.
During pluvial periods stabilization of aeolian sand by vegetation occured. The sedimentary characteristics of the sandy deposits west of Katima Mulilo indicate that they are relatively stable at present. The sands of the Kalahari Group (e.g. those west of Katima Mulilo) are of a pure, loose and coarse-grained type. Grain surfaces are rounded and frosted by aeolian activity. The sand layers are attaining great thickness but they seldom have clear profile characters. The country rocks can only be found several ten meters deep. Colours vary from whitish to greyish. Surface horizons may be stained by organic matter or ash. Reddish colours dominate where iron oxide is present.

IV. Climate

Katima Mulilo is situated within the tropical summer-rainfall zone. A single raining season occurs from October/November to April. The average variability of precipitation is about 30%, being somewhat lower than in the western Caprivi. The average duration of the rainy season (number of months) with more than 50mm of average precipitation is 5-6 month. The average annual number of rainy days vary from 40-60. Approximately 90% of the average annual precipitation occurs from October to March.

IV.1. Rainfall

The average longterm monthly rainfall figures for Katima Mulilo, based on measurements over a period of 41 years are shown in Table 1, which includes rainfall data from Mahanene (5 years observation period), Ondangwa (74 years of observation) and Rundu (28 years of observation). Table 2 shows the amount of rainy days in Katima Mulilo per month, also measured over 41 years. The maximum rainfall amounts within 24 hour periods for each month in Katima Mulilo, Rundu and Andara are shown in Table 3.

	Katima Mulilo 1933-75	Rundu 1937-75	Mahanene 1970-75	Ondangwa 1902-75
Jan.	176,9	143,7	104,9	107,6
Feb.	160,8	140,7	130,8	115,4
March	97,7	98,2	143,3	90,1
April	22,8	39,7	42,1	35,0
May	4,2	2,6	0,4	3,3
June	0,6	0,0	1,1	0,4
July	0,0	0,1	0,0	0,2
Aug.	0,4	0,3	0,0	0,1
Sept.	1,6	2,2	0,1	2,1
Oct.	20,4	17,7	17,2	13,6
Nov.	74,9	57,7	25,0	46,1
Dec.	146,2	97,7	48,4	77,9
Total	706,5	600,6	513,3	491,8

Tab.1: Longterm average monthly rainfall (mm) for Katima Mulilo, Rundu, Mahanene and Ondangwa (after PAGE, 1980).

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	Katima Mulilo 1933-75	Rundu 1937-75
January	14,6	12,4
February	12,4	12,4
March	8,1	9,0
April	2,4	4,2
May	0,5	0,5
June	0,2	0,0
July	0,0	0,1
August	0,1	0,1
September	0,5	0,5
October	3,0	3,4
November	8,2	7,6
December	12,6	10,0
Total	62,6	60,2

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

	Katima Mulilo	Rundu
January	84,8	109,0
February	338,0	106,2
March	86,1	120,2
April	52,3	76,0
May	71,1	19,0
June	4,5	0,8
July	0,0	1,3
August	7,9	4,3
September	9,7	15,5
October	75,5	47,5
November	83,3	103,1
December	83,3	89,1
Total	338,0	120,2

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

IV.2. Temperatures

Temperature data available is based on the period from 1976 to 1979 as shown in Table 4:

	Maximum	Minimum	Max. + Min. / 2
January	31,4	19,6	25,5
February	30,2	19,0	24,6
March	28,9	18,7	23,8
April	28,6	15,2	21,9
May	26,7	10,3	18,5
June	24,6	9,3	16,9
July	25,1	5,1	15,1
August	28,8	7,6	18,2
September	32,5	14,5	23,5
October	32,8	18,4	25,6
November	30,8	19,2	25,0
December	29,8	18,8	24,3

Tab.4: Average max. and min. monthly temperature for Katima Mulilo: 1976-1979 (°C)(after LOXTON et al., 1971)

IV.3. Evaporation

The potential evapotranspiration for Katima Mulilo is shown in Table 5. A total water defficit of about 1000 mm/year occurs due to water shortage between March and December. Figure 1 shows the evaporation for Katima Mulilo, Windhoek, Outjo and Tsumeb in relation to the monthly rainfall.

	ø monthly rain-fall (mm)	Gross evapora-tion (mm)	Potential eva-potranspiration (mm)	Surplus/ Deficit (mm)
January	159,0	201,6	139,0	+ 20,0
February	120,6	172,7	116,7	+ 3,9
March	81,0	212,6	143,6	- 62,6
April	15,5	190,2	119,6	- 104,1
May	1,5	179,6	103,2	- 101,7
June	1,8	155,9	83,4	- 81,6
July	0,0	164,6	92,5	- 92,5
August	0,8	214,6	130,1	- 129,3
September	1,0	262,6	172,8	- 171,8
October	13,5	322,3	222,3	- 208,8
November	72,6	248,4	172,5	- 99,9
December	135,0	205,9	142,0	- 7,0
Total	602,3		1637,7	- 1035,7

Tab.5: Potential evapotranspiration (max. moisture return) for Katima Mulilo (after PAGE, 1980)

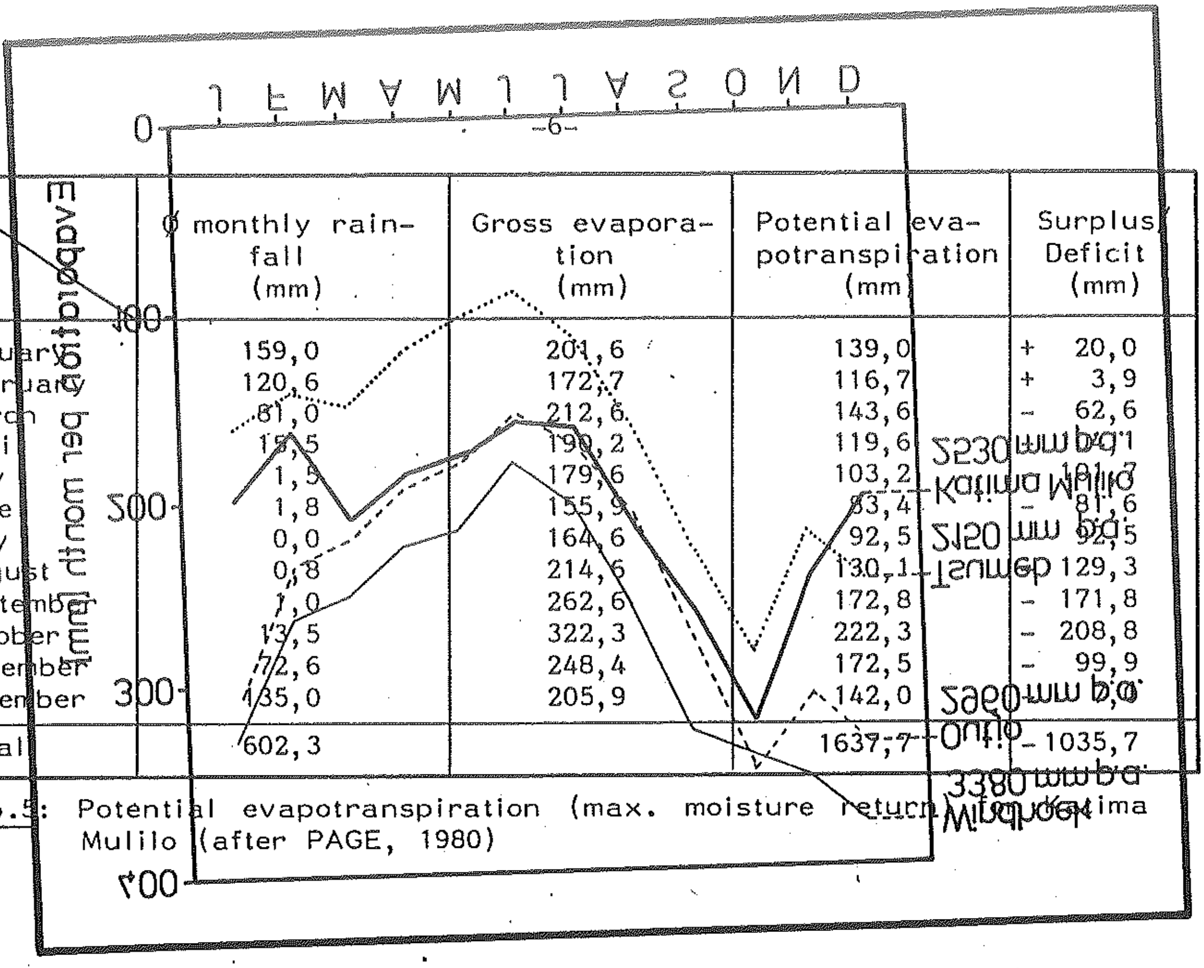

Fig.1: Mean monthly gross evaporation (A-pan (mm)) for Katima Mulilo, Windhoek, Outjo and Tsumeb (observation period for all 4 locations: 1960-1968) (after LOXTON et al., 1971)

V. Vegetation

The natural type of vegetation in the survey area is a forest savanna with Baikiaea plurijuga (Rhodesian Kiaat, "omupapa"), Guibourtia Coleosperma (Rhodesian mahogony, "uusiri"), Sclerocarya birrea (murula, "ongongo") and various others, mainly deciduous trees.
According to WHITE (1983) the survey area belongs to the Zambezian dry deciduous forest, scrub forest and secondary grassland vegetation type. This major vegetation type occurs on deep developed sandy soils which usually absorbs all the rainfall, being between 600 and 900mm per year in the survey area (see Tab. 1 & 5).
Baikiaea forests were identified as a typical deciduous forest on Kalahari Sand west and south west of Katima Mulilo. Baikiaea forest is the habitat of the so called Miombo woodland and savanna, which is the driest type of broadleaved woodland and derived savanna formation. Acacia erioloba (giraffae) and Combretum collinum were found as well as Ricinodendron rautanenii locally, which form a pure canopy in the Baikiaea forest. Comberfaceae-Acacia thickets and Mopane (Colophospermum mopane) appear towards the southwest of the survey area. The shrub layer consists i.a. of the following identified species:

- Acacia ataxacantha,
- Combretum celastroides.

The flora of the area is quite rich in herbs and grasses, which vary from sparse to dense and include:

- Dactyloctenium giganteum,
- Eragrostis rigidior and
- Schmidtia pappophoroides.

It was recognized that the area surveyed, contains dwarf species of Baikiaea less than 2m tall, such as Brachystegia bakerana. Dwarfing conditions of various individuals may be related to "unfavourable soil conditions" (WHITE, 1983).

VI. Present irrigation

Riverside-irrigation using water from the nearby Zambezi river

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is practised north and northwest of the survey area by FNDC/ ENOK (FIRST NATIONAL DEVELOPMENT COOPERATION). The operation is situated very close to the Zambezi river and includes centre-pivot-irrigation systems, as well as sprinklers. The water is pumped from the Zambezi river via pipes to the area being irrigated. The main crop is "omahangu" millet (Pennisetum typhoides), while others are "ii yalyaka" (Sorghum sp.), beans, pumpkins, watermelons, legumes as well as various groundnuts. Several native plants are also irrigated as for example vegetables: onions, leaves and tuberous roots.

VII. Survey methods

VII.1. Mapping scale

The aerial photographs used for mapping in the field were at 1 : 64000 scale, but the final soil map accompanying this report (see Appendix B) is at 1 : 7500 scale, using the 1 : 50000 scale orthophoto series maps as an additional information source. Maps of this series, showing part of the survey area are 1724 AD & CB and 1724 AC & CA. The northern and eastern boundaries of the survey area were first marked on the 1 : 50000 scale sheet and then transfered onto the aerial photos for fieldwork.

VII.2. Profile description and mapping scale

18 soil profile pits were dug in total, to describe and classify the range of soils occuring in the area, using the BINOMIAL SYSTEM (MACVICAR et al., 1977). On the basis of profile descriptions and augering, 3 diffrent soil forms and 4 diffrent soil series were encountered and the soil map, including the legend, was modified accordingly (see Appendix B).

VIII. Soils

VIII.1. Previous surveys

Previous analysis of soils close to the survey area have been carried out. The obtained data served as means of checking main nutrient elements, texture and soil acidity. The investigated soil samples were taken by "Katima Boerdery", which is developed and managed by FNDC/ENOK and is situated north to northwest of the survey area (see Appendix B). Additional work on soils was carried out by OPPERMAN (1982).

VIII.2. Soil types and main characteristics

Generally, soils developed from Kalahari ands under tropical conditions as being observed at Katima Mulilo, show the following main characteristics (partly after VAN DER MERWE, 1954):

- Sand as the parent material is uniform and of aeolian origin, laid down during an arid period;
- soils are very sandy, with grain size not exceeding 1mm;
- water-taking capacity is good, water-retaining capacity is poor;
- soils respond well to phosphate, nitrogen and manure;
- physiographycally the areas covered by Kalahari Sands are fairly level plateaux, interrupted by fossilized sand dunes in drier regions.

The soils developed on the described aeolian sandy parent material were identified as those series, belonging to the Clovelly-, Vilafontes- and Constantia soil forms. They are the most dominating group of soils, not only within the survey area. The occuring soil forms, together with additional relevant details are set out in Table 6 and Appendix A. Their destribution is shown on the soil map (see Appendix B).

Soil type	Map symbol	Occuring Soil form & series	Effective depth (mm)*	General characteristic of map symbol	Limiting factors	Irrigation suitability	Main texture
Young alluvial & aeolian soils	Ct 10	Constantia-Strombolis (5 %)	300 +	Reddish brown to yellowish brown sands; apedal; loose; non-calcareous	Low water holding capacity; very rapid infiltration rate & permeability	Irrigateble under good management; limiting factors partly occur	Coarse sand to very fine sand
	Cv 20	Clovelly-Tweefontein (67 %)	900-1200				
	Vf 10	Vilafontes-Moreland (22 %)	900-1200				
	Vf 30	Vilafontes-Sedgefield (5 %)	900-1200				

Tab.6: Additional soil characteristics

* = Effective depth refers to the depth of soil occuring before a layer is reached that is markedly restricting to water and/or root penetration

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SOIL SURVEY - KATIMA FARMING PROJECT (18 - 21 MAY 1987)

At the time of the Survey being conducted, part of the unit was under cultivation (approximately six-week old maize plants), on another, maize was being harvested, a third consisted of fields on which corn had been cultivated the previous season, and the rest lay fallow. Prior to the visit it had been arranged that profile holes, 150 m apart, would be dug on the approximately 300 ha area. The holes were to be at least 1 m deep, but, probably owing to the firmness of the soil, few were more than 70 cm in depth. (It is, however, doubtful whether any depth limitation exists, since the profile examination revealed no signs of restricted drainage.) No soil erosion was noticed, although it is believed that torrential rains occur in summer.

A striking phenomenon which constantly came to the fore, however, was that root development was limited to the topsoil (approximately 30 - 35 cm). At that level, the soil is dark-grey throughout owing to the damp conditions, in contrast with the much lighter hue of the subsoil. This contrast held true for the adjacent veld as well, according to profile holes dug there, confirming that the roots of grass, in particular, were confined to the topsoil layer.

Soil texture consists mostly of fine sand - probably blown there by the wind, although some of it may be alluvium from the adjacent Zambesi River. Initially, the intention was to distinguish between soil-types in terms of differences in colour and texture. Laboratory tests, however, proved such differences to be of secondary importance. In respect of the moisture-retention capacity of the soil, smaller variations in value occur. These are roughly indicated on the attached sketch-map, although they are certainly not crucial to the planning of irrigation. Details of test hole No. 3 may be used as a general profile description of the area (see sketch-map):

Topsoil (0 - 35 cm): grey-brown (5YR-4/2) fine sand, moderately soft (in dry conditions), structureless, good root distribution, changing sharply to -

Subsoil (35 - 70+ cm) pale yellow-brown (10YR-5/4) fine sand, soft (in damp conditions), structureless, hardly any roots, isolated old, larger root channels, a few pieces of charcoal (probably old, burnt-out roots of trees or shrubs), no signs of drainage having been disturbed (eg reduction stains).

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(Colour differences usually occur as a grey-black topsoil in the vicinity of test hole No. 1 and a dull reddish-brown soil profile in the area surrounding test holes No.'s 6 and 7.)

1. Texture, soil density and moisture-retention capacity

Since the retarded root development mentioned above occurs throughout the area, potential physical problems were investigated. Values for particle size distribution, as well as those for matrix density and usable moisture-retention capacity, are reflected in tables 1 and 2. These clearly show the correlation between the dominant fine texture of the soil and the exceptionally high proportion of fine sand (often exceeding 50 %), in contrast with the low clay content (often less than 4 %) over almost the entire area. Also, the matrix density is consistently high (more than 1,6 g/cc), except for that of test hole No. 7. Under these conditions it is self-evident that the exchange of gases in the soil is inadequate, which explains the restricted root development observed.

Furthermore, the high fine sand content accounts for the high moisture capacity values, which by far exceed the norm for sandy soil. (These values were obtained by using soil columns to simulate field conditions.) The high soil moisture values, in turn, point to slow internal drainage, retarded exchange of gases and the resulting retardation of root growth, although soil moisture does not collect at lower subterranean levels.

N.B. Despite the potentially high moisture capacity available, it is recommended that the usable moisture capacity of the area be calculated to a depth of 30 cm, i.e. only the topsoil values. In practice, thus, it is recommended that irrigation scheduling for the area be calculated and provided for according to the above proposal.

2. Chemical properties

These analysed values are reflected in table 3. It is obvious that the sandy soil with low clay content is also consistently poorly buffered (low CEC values) and has a poor cationic status as well. Calcium (Ca), magnesium (Mg) and potassium (K) are low, and the supply of Mg and K, in particular, requires special attention for successful crop farming.

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Phosphorus (P) appears adequate in the fields under cultivation and need only be supplemented to maintain present levels. The neutral pH and high R values indicate no build-up of salt in the subsoil, as well as low Na levels. Overirrigation is thus not necessary.

The higher carbon (C) values in the topsoil provide further confirmation of restricted root growth, a situation which occurs under field conditions as well (compare the values for test holes 8 - 11). In contrast, the C values of the subsoil are consistently lower.

The low CEC values explain the total lack of soil structure development. The benefits of deep tillage to root development would, therefore, be of temporary value only.

Furthermore, the low CEC values indicate the danger of a loss of nutritive elements (except for P) through leaching, particularly if excessively acidifying sources of nitrogen (e.g. urea and ammonium compounds) are administered unseasonably. The obvious remedy would be organic matter and N, administered at intervals throughout the growth season, via the irrigation water. The administration of K and Mg by means of the irrigation water is another acceptable alternative. In respect of Mg, dolomite lime (approximately 0,5 t/ha) may be applied annually. This would also supply the Ca requirements. To provide P, an SRA mixture could be used for annual planting. The mixture contains Langfos as its base ingredient, supplemented by soluble P and a small quantity of N. It is an excellent source of Ca and may serve to delay problems relating to nutritive micro-elements. Shortages of the latter are, naturally, quite possible in such poor sandy soil. These micro-elements should preferably also be administered via the irrigation water.

3. General recommendations

The above recommendations and background details reveal that sound management, in respect of crop nutrition and irrigation, is of particular importance. To this end, a centre pivot irrigation system is decidedly an efficient means of achieving success. The possibility of planting on ridges, as an alternative to deep tillage as a means of promoting root development, is well worth investigating.

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With regard to the citrus orchard, its disappointing yield could also be attributed to the soil deficiencies mentioned above. In this case micro-irrigation ought to be used.

4. Supplementary notes

(1) The rice project

A soil profile analysis conducted in loco revealed no obvious deficiencies. However, certain management problems are, apparently, still being experienced. Substantial extensions to this project probably ought to be postponed until reliable results are obtained from experiments with smallholdings.

(2) The dry-farming maize project

Climatological problems, both wet and dry, could doubtlessly play a major role in any failures experienced with the project. The cultivation of maize on ridges to promote root development and to improve crop growth and yield, could definitely be considered in this regard.

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22 August 1987