National Soil Service
Tanzania

AG: URT/73/006
Technical Report 1

SOIL SURVEY REPORT OF ULYANKULU REFUGEE SETTLEMENT

United Nations Development Programme

Food and Agriculture Organization
of the United Nations

Tanga 1981

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OF
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Report prepared for the
Government of the United Republic of Tanzania
by
The Food and Agriculture Organization of the
United Nations acting as executing agency for the
United Nations Development Programme

based on the work of
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UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

TANGA, 1981

TABLE OF CONTENTS

ABSTRACT

This report describes a medium-intensity soil survey of Ulyankulu Refugee Settlement, Tabora Region. The survey was conducted by the National Soil Service at the request of the Ministry of Home Affairs and the United Nations High Commissioner for Refugees, United Republic of Tanzania.

About 542 sq.km. were surveyed. The survey was based on field observations using aerial photographs and topographic maps for compiling the data. The field work was supported by laboratory analysis of representative soils. The soils map of the area was prepared at a scale of 1: 50,000.

The major soils of the area were identified and described and their suitability for agricultural use, in particular for rainfed crop production, was evaluated.

Nearly 55 percent of the surveyed area is suitable for the production of drough-resistant crops and about 15 percent is suitable for intensive cultivation of a wide range of upland crops. The remaining land can be used in other ways : some areas are suitable for cultivation of paddy rice, other areas are only suitable for grazing, production of firewood, or charcoal.

INTRODUCTION

BACKGROUND AND IMPLEMENTATION

The soil survey and related land use suitability study of Ulyankulu Refugee Settlement, Tabora Region, were undertaken by the National Soil Service Project in order to assist the Ministry of Home Affairs and the United Nations High Commissioner for Refugees (UNHCR) in planning the production of food crops for a population of about 30,000 refugees.

The field work was carried out between the months of November and December, 1977, by J. Magoggo, Agr. Research Officer, L. Daggaa and N.R. Lesika, Agr. Field Assistants, E. Bomans and J. Hof, FAO Associate Experts.

The aerial photographs of the area were interpreted by J. Hof and E. Bomans, FAO Associate Experts. The chemical analysis of the soils was conducted at the Central Soils Laboratory, ARI Mlingano, under the supervision of R. Menon, FAO Soil Chemist.

The report was prepared by J. Hof, FAO Associate Expert, E.J. Espinosa Project Manager and J. Magoggo, Agr. Research Officer, in consultation with Mr. E. De Pauw, Soil Survey Officer.

The report includes 3 main chapters, several technical appendices and a soils map at a scale of 1:50,000. In Chapter 1 the environmental factors of the surveyed area are described, in particular the geology, physiography, climate, vegetation and land use. In Chapter 2 a general account of the soils is followed by a description of the mapping units established during the survey and shown on the accompanying soils map. Chapter 3 discusses the suitability of the area for the production of rainfed upland crops, paddy rice and woodland. The appendices are mainly intended for soil scientists as they include detailed technical descriptions of the soils, soil analytical data, methods of soil survey, methods for evaluating land suitability and soil classification.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. Four main physiographic units were recognized in the surveyed area : Isolated Steep Hills, Footslopes, Upland Plain and Bottomlands. Some of these units were further subdivided on the basis of topographic position, slope gradient and erosion hazards.

2. Most of the Isolated Steep Hills are occupied by shallow, gravelly soils and numerous rocks outcrops. The Footslopes and Upland Plain include mainly well drained, deep, red or yellowish red sandy clay loams and sandy clays on the upper parts; and somewhat excessively to moderately well drained, yellowish brown or pale brown sands and loamy sands on the lower parts. The Bottomlands are covered by imperfectly to poorly drained soils, ranging from sands to sandy clays.

3. A total of about 29,000 Ha. of the surveyed area (55%), included mainly in mapping units 3 and 5, are suitable for the production of millet, sorghum, cassava, and some groundnuts. Nearly 8,000 Ha. (15%) occuring in units 2 and 4 are suitable for a sustained production of a wide range of upland crops, including maize and beans.

4. The remaining land is not suitable for upland crops, but can be used in other ways for the sustenance of refugees. Depending of the amount of available water in the soil, some areas of mapping unit 6 are suitable for the cultivation of paddy rice. The hilly areas (unit 1) may be used for production of firewood and charcoal.

5. The main constraints for a sustained crop production are the inherent low fertility of the soils, the rather low moisture availability for plant growth and the moderate risk of soil erosion on the slo-ping land.

6. Crop rotations having a short period of cultivation followed by a long period of fallow are recommended for the area as a whole, in particular for mapping units 3 and 5 where sandy soils predominate. Where it is necessary, more intensive cropping can also be practised in units 2 and 4, but this would require heavy application of fertilizers and/or manure.

7. Owing to marked differences in soil characteristics the response to fertilizers may vary widely. Most soils of mapping units 2 and 4 are expected to respond well, but not those of units 3 and 5. Particular attention should be given to the utilization of crop residues, cultivation of leguminous crop and application of farm manures where possible. The feasibility of using human wastes in the near future deserves study.

8. Recommended soil conservation practices to control soil erosion, mainly in units 2 and 3, include contour cultivation, tied-ridging, cover crops and mixed cropping, and minimum tillage. The steep hills (unit 1) should be kept under vegetative cover.

9. For the sustenance of a population of nearly 30,000 refugees, it is suggested to cultivate every year about 3,000 Ha. of intercropped maize and beans in mapping units 2 and 4; some 8,000 Ha. of bulrush millet and sorghum in units 3 and 5; and about 1,500 Ha. of units 3 and 5 with groundnuts and sweet potatoes.

10. A more detailed survey of unit 6 is suggested for identifying the most suitable area for rice cultivation.

Chapter 1

GENERAL DESCRIPTION OF THE AREA

1.1 LOCATION, POPULATION AND COMMUNICATIONS

Ulyankuly Refugee Settlement is located on both sides of the Igombe river in Urambo District, Tabora Region, at about latitude $4^{o}40$, South and longitude $32^{o}10'$ East. It lies between 990 and 1,230 m. above sea level. The settlement covers a total area of 1,000 sq.km. approximately out of which 542 sq.km. were surveyed.

The Settlement is inhabited at present by nearly 60,000 refugees from Burundi.

Non-metalled, dry-weather roads link the Settlement with Urambo and Tabora towns, at a distance of 50 and 90 km. respectively. There is a railway connecting Urambo and Tabora with Dar-es-Salaam, Mwanza and Kigoma. Air service is available at Tabora town only.

In the Settlement itself there is a well-developed network of roads linking homestead sites with the administrative quarters, dispensary, school and other facilities.

1.2 GEOLOGY AND PHYSIOGRAPHY

Ulyankulu Refugee Settlement is included in the Central Granite of the East African Basement system. The rocks, which trend NW-SE, are mainly coarse grained granites and gneisses. They form the substratum of the area. A thick regolith of weathered rocks and soil cover the footslopes and upland plain. The bottomlands are overlain by both alluvial and colluvial, sandy and clayey sediments.

The Settlement occupies a gently sloping upland plain between two ranges of steep, isolated hills with granitic rock outcrops and extensive footslopes. The upland plain has been dissected by the Igombe river forming a wide main valley and a network of smaller tributary valleys. The tributary valleys run parallel or at right angles to the main valley, which suggest that joints and faults in the bedrock control the drainage pattern.

Four major physiographic units were recognized: Isolated Steep Hills, Footslopes, Upland Plain and Bottomlands. Some of the units were further subdivided on the basis of position and slope gradient. The units and their subdivisions are shown on the Soils Map.

Isolated Steep Hills

This unit comprises a number of isolated, small hills occuring mainly in the south-eastern part of the surveyed area. The hills are rounded (dome-like shape) and often rise upto 100 m, sometimes more, over surrounding land. Dominant slopes range between 16 and 40 percent. Granitic rock outcrops and boulders are common. Where present the regolith is very thin.

Footslopes

This unit includes gently sloping areas lying at the foot of the isolated hills. Slopes range from 2 to 6 percent throughout most of the unit, except the lower parts which are almost flat. The slopes are slightly concave in shape which indicates that running water is the main slope forming agent. The regolith is several metres thick and appears to be in situ.

Upland plain

This unit comprises a plain of little relief, with broad, slightly convex summits and slightly concave slopes. Dominant slopes generally do not exceed 2 percent. The overall shape of the landform suggests that both splash erosion and running water are the main slope forming agents. As in the case of the footslopes, the regolith is several metres thick and apparently in situ.

Bottomlands

This unit includes a network of almost flat, wide, shallow valleys locally known as 'mbugas'. The main valley has been formed by the Igombe river; the smaller tributary valleys are the drainage ways of the area.

The valleys have been filled by alluvial and colluvial sediments. Clayey, alluvial sediments predominate in valley centres and depressions; rather sandy, colluvial sediments cover most valley edges. Sediments appear to be a few metres thick only, over the basement rocks.

1.3 CLIMATE

The climate of Ulyankulu Refugee Settlement is characterized by a warm rainy season (November-May), during which 90 percent or more of the rainfall occurs; and by a warm, almost rainless dry season (June-October).

There is no meteorological station in Ulyankulu. Instead available climatic data for Urambo are given in Tables 1,2 and 3, which are believed to be fairly representative. Also data for Tabora are included. In Figure 1 the temperature, rainfall and potential evapotranspiration data for Urambo are correlated. Figure 2 shows a rainfall probability curve for Tabora.

Owing to differences in altitude, it is expected that temperatures would be slightly higher (possibly 0.5°C) in Ulyankulu than in Urambo. On the other hand, the annual rainfall is expected to be slightly lower in Ulyankulu.

Temperature at Urambo is rather uniform throughout the year. June and July are the coolest months with a mean temperature of about 21°C. October is the hottest month with a mean of 25.5°C. Daily amplitudes range from 11°C to 17°C.

The mean rainfall in Urambo is 981 mm, out of which 90 percent or more falls between November and mid May. Comparison of the number of days with rain and number of days with thunder suggests that most of the rain falls during thunderstorms. Rain intensity during these storms is expected to be high*.

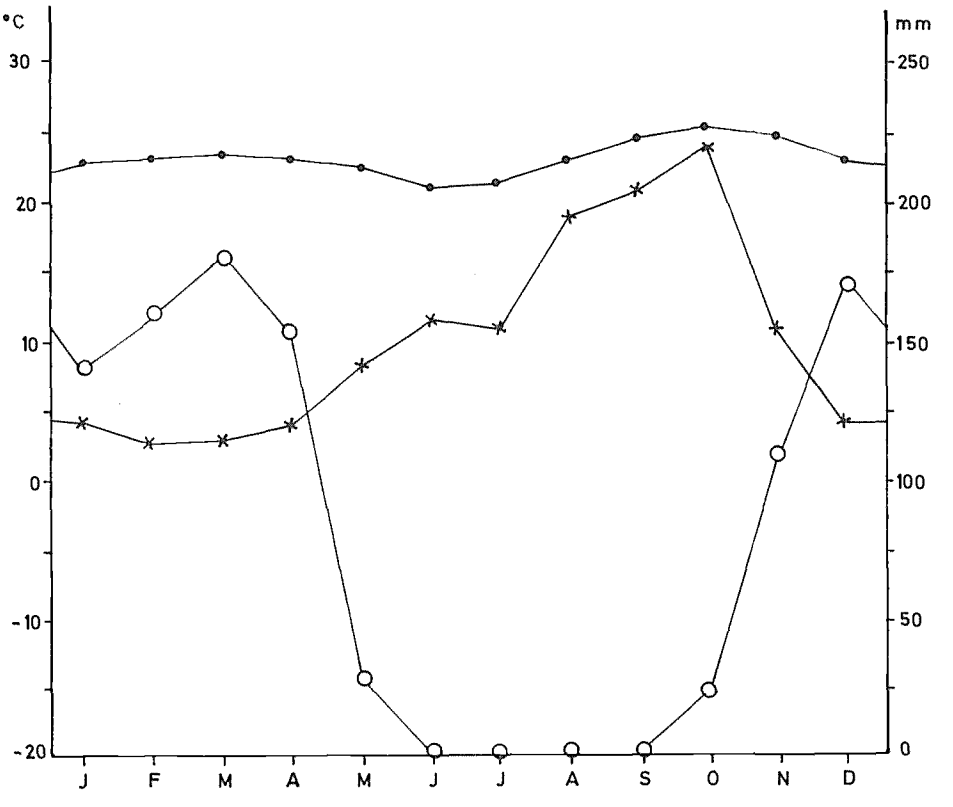
The rainfall probability curve given in Figure 2 for Tabora Observatory shows that annual rainfall exceeds 750 mm in 80 percent of the time (4 out of 5 years). Extremes vary between 354 and 1390 mm. A similar rainfall pattern is expected to occur in Ulyankulu.

From available data for Urambo T.A.C. and Tabora Airport, it is inferred that relative humidity in Ulyankulu is moderate in the dry season and high in the rainy season. Mean minimum values may vary between 50 and 75 percent.

Estimated potential evapotranspiration at Urambo is about 1800 mm a year. During the dry season potential evapotranspiration largely exceeds rainfall (932 mm as against 29 mm), whereas rainfall exceeds potential evapotranspiration in the rainy season.

Note * Of greater hydrological significance than the mean storm intensity are the frequency and duration of high intensity fall. To a good extent these factors determine the erosivity of the rain.

Figure 1: TEMPERATURE, RAINFALL AND POTENTIAL EVAPOTRANSPIRATION URAMBO T.A.C.

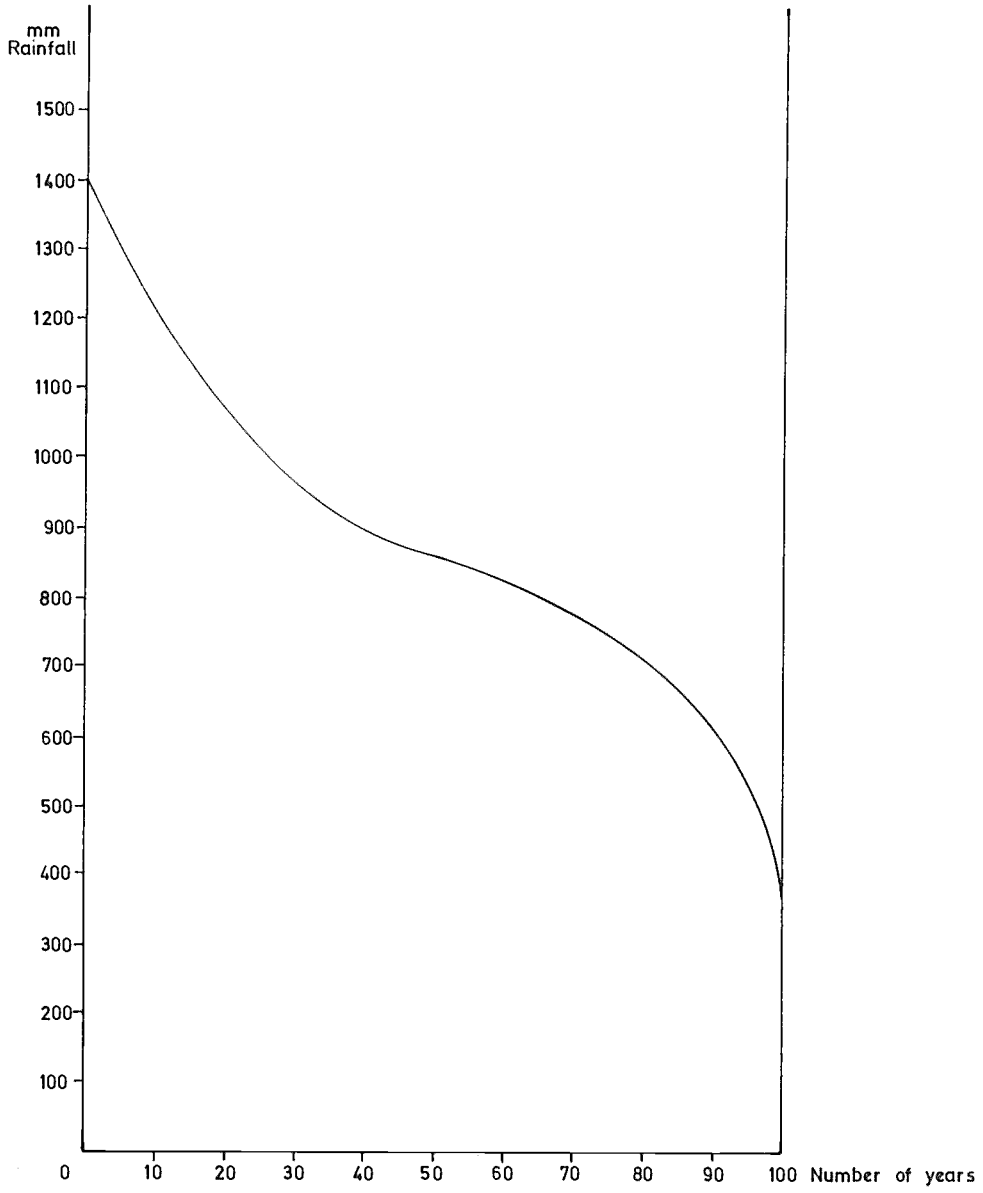


o-o-o Mean Temperature

O-O-O Mean Rainfall

x-x-x Potential evapotranspiration according to Penman (7)

Figure 2: RAINFALL PROBABILITY TABORA TOWN



Source: Data taken from several sources, mainly from East African Meteorological Department and Tanzania in Maps (2, 4, 5, 6, 8, 9, 17, 19.)

Table 1 – Temperature, oC

URAMBO T.A.C.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Absolute Maximum	33.2	34.4	32.8	32.2	33.3	35.0	33.3	33.5	36.7	36.1	36.7	34.7	36.7
Mean Maximum	28.7	29.2	29.1	28.8	29.4	29.5	29.6	30.6	31.9	32.4	31.1	28.8	29.9
Mean	23.0	23.2	23.2	23.0	22.7	21.2	21.3	22.9	24.8	25.5	24.7	23.2	23.2
Mean Minimum	17.4	17.2	17.4	17.3	16.1	12.9	13.1	15.3	17.8	18.6	18.3	17.7	16.6
Absolute Minimum	13.3	11.1	14.4	14.2	10.7	8.7	6.1	10.0	11.1	13.3	12.6	13.9	6.1
TABORA Observatory													
Absolute Maximum	33.9	34.4	32.6	33.4	31.6	31.4	31.7	32.3	34.3	36.0	34.9	34.2	36.0
Mean Maximum	27.7	28.0	28.1	27.8	27.9	28.0	28.2	29.3	31.0	32.1	30.9	28.1	28.9
Mean	22.6	22.7	22.7	22.5	22.1	21.3	21.3	22.5	24.2	29.5	24.9	22.9	22.9
Mean Minimum	17.3	17.4	17.4	17.2	16.3	14.7	14.4	15.7	17.4	18.9	18.9	17.7	17.0
Absolute Minimum	13.9	15.0	14.7	14.9	11.2	10.0	10.0	10.0	13.9	15.0	14.0	15.0	10.0

Mean temperature calculated as (mean maximum temperature + mean minimum temperature) ÷ 2

Temperature data for Tabora Observatory : average from 27 years, 1930-1956

Temperature data for Urambo T.A.C. : average from 16 years, 1953-1968

Source : East African Meteorological Department (10, 11)

Table 2, Rainfall, mm

URAMBO T.A.C.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Highest	281	200	273	318	133	12	15	15	26	110	364	322	1347
Mean	140	160	181	153	38	1	1	1	3	23	108	173	981
Lowest	63	74	60	38	0	0	0	0	0	0	21	60	651
Maximum in 24 hours	75	143	66	59	69	1	15	11	26	38	59	67	143
TABORA Observatory													
Highest	228	323	378	328	145	39	3	11	87	68	432	371	1390
Mean	132	129	166	134	27	2	0	1	7	17	103	174	892
Lowest	57	41	25	28	1	2	0	0	1	0	22	34	354
Maximum in 24 hours	74	79	84	74	71	27	-	6	13	39	71	87	87
TABORA Airport													
Highest	194	292	303	163	115	0	0	0	21	87	305	260	1197
Mean	147	144	162	107	25	0	0	0	8	24	95	170	882
Lowest	73	22	20	13	1	0	0	0	1	1	18	45	672
Maximum in 24 hours	61	62	77	73	29	0	0	1	15	28	81	51	81

Rainfall data for Tabora Observatory : Average from 69 years, 1894-1962

Rainfall data for Tabora Airport : Average from 11 years, 1952-1962

Rainfall data for Urambo T.A.C. : Average from 5 years, 1948-1962; except mean rainfall which is the average from 23 years

Source: East African Meteorological Department (10)

Table 3, Other climatic data

	URAMBO T.A.C.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Records No.of Years	Records Period
*	Potential evapotranspiration	123	114	114	121	140	157	155	195	204	221	155	123	1822	-	-
	Relative humidity: mean minimum, %	51	57	54	36	49	36	40	37	30	28	37	52	44	10	1953-1962
	TABORA Observatory															
	% of years mean rainfall is exceeded	47	43	43	47	27	10	-	13	30	37	37	47	49	30	1931-1960
**	Average number of days with rain	16	14	15	13	4	0	0	0	1	3	13	20	99	69	1894-1962
	Average number of days with thunder	14	13	14	9	2	0	0	0	1	2	9	15	79	69	1894-1962
	Mean cloud cover, in octas 06.00 GMT	5.9	5.8	5.7	5.6	4.3	2.5	1.7	1.9	2.9	4.1	5.1	5.7	4.3	25	1931-1955
	12.00 GMT	5.9	5.8	5.9	6.0	5.5	3.8	2.9	3.4	4.5	5.3	5.9	6.0	5.1	25	1931-1955
	TABORA Airport															
	Mean evaporation from a 15' waterpan	167	129	142	169	202	211	239	271	311	314	209	164	2528	6	1957-1962
	Relative humidity: mean maximum, %	94	94	94	94	89	79	71	66	65	65	79	90	82	11	1952-1962
	Mean windspeed, knots 06.00 GMT	3	3	4	7	8	9	9	11	12	10	6	3	7	11	1952-1962
	12.00 GMT	5	5	5	7	7	7	7	7	7	6	6	5	6	11	1952-1962

Sources : * Calculated with modified Penman method as given in Crop Water Requirements, FAO (7), using climatic data from Urambo and Tabora.

** Atlas of Tanzania (4), calculated with data assumed to be from Tabora Observatory.
All other data: East African Meteorological Department (10,11).

1.4 VEGETATION AND LAND USE

Most of the vegetation which remains in Ulyankulu is miombo woodland with an open canopy, sometimes with shrubs interspersed Grasses, herbs and hedges predominate in the bottomlands, with some scattered trees and shrubs on termite mounds.

The cultivated, well drained land is used for rainfed crops, mainly maize, cassava, beans and sweet potatoes. Tobacco and groundnuts, though grown on a rather small scale, are the main cash crops together with sweet potatoes. Intercropping is a common practice e.g. maize and beans, cassava and sweet potatoes.

Rice is the main crop in bottomlands, especially in the vicinity of the Igombe river. It is grown by preference in poorly drained, waterlogged soils.

Chapter 2

SOILS

A general account of the soils of Ulyankulu Refugee Settlement and a description of the mapping units, as shown on the accompanying Soils Map, are given below.

As far as possible the soils have been described in non-technical terms. Detailed technical descriptions of individual soils together with available analytical data are given in Appendix 4 of this report. An account of their classification in terms of internationally accepted systems is included in Appendix 3.

2.1 GENERAL DESCRIPTION OF THE SOILS

The soils of the area can conveniently be discussed in relation to the physiographic units established during the survey, as given in the Soils Map.

The Isolated Steep Hills are characterized by a complex pattern of generally shallow, rather coarse-textured soils and numerous granitic rock outcrops. Dominant slopes range from 16 to 40 percent, exceeding 100 percent in some places. Main limitations for agricultural development are rockiness, steep slopes and severe drought and erosion hazards.

The Footslopes include gently sloping areas, 0-6 percent slope, at the foot of the isolated hills. The major soils on the upper parts are well drained, deep, friable sandy clay loams and sandy clays, sometimes with abundant ironstone gravels at less than 100 cm from the surface. The surface horizon is usually dark red or dark reddish brown in colour; the subsoil is either red/dark red or yellowish red. Soil reaction is slightly to moderately acid. Low natural fertility and moderate to severe erosion hazards are the main limiting factors for a sustained crop production.

In contrast the lower parts are covered by somewhat excessively drained and moderately well drained, deep, loose sands and loamy sands. The suface horixon is dark greyish brown to dark grey in colour; the subsoil is light yellowish brown and pale brown, often with many strong brown mottles in the upper part. In some areas, especially in those adjoining the Bottomlands, these soils have an ironstone layer within 100 cm. of the surface. Soil reaction is slightly to moderately acid. Crop production in these sandy soils is restricted to a great extent by their low moisture and nutrient retention capacity. Other limiting factors are risk of erosion and limited root penetration.

The Upland Plain is covered by the same kinds of soils as the Footslopes. Dominant slopes are 0-2 percent.

The Bottomlands include a wide range of soils occuring in intricate patterns. Texture varies from sand to sandy clay; and colour from greyish brown to dark grey, sometimes dark brown, usually with prominent strong brown mottles. Some of the soils have a hardpan (hardened layer) at about 50 cm. of the surface.

Drainage is generally poor. A good part of the soils remain waterlogged during the growing season, which precludes most agricultural crops except paddy rice. Many areas receive water mainly as run-off and groundwater seepage from adjoining higher-lying land. In some years areas near the Igombe river are flooded.

2.2 DESCRIPTION OF THE MAPPING UNITS

The soils of Ulyankulu Refugee Settlement were mapped on a physiographic basis. More specifically, for setting up mapping units the soils were correlated with landforms, landform elements and parent materials. In addition due attention was given to drainage, degradation processes and to those soil characteristics relevant to management. The units represent soil associations which include two or more soils occuring together in a regular, geographic pattern.

Six mapping units were set up and are described below in numerical order, as they are shown in the legend of the Soils Map. The descriptions are given in a tabular form. They indicate the kind of landscape within the unit; how the different soils within the unit occur in relation to this landscape; the main identification features of each soil, which usually lie within the subsoil layer; drainage class; and an estimate of the proportion of the unit occupied by each soil. There is also a column of soil symbols, the main purpose being to facilitate identification and correlation of the individual soils recognized during the survey. The same symbols are used throughout the report and on the Soils Map, therefore. At the bottom of each table, a general description of the mapping unit is given together with information on present land use.

MAPPING UNIT 1 Area: 11 sq.km., 2% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Isolated steep hills, 16-40% slope	H	Granitic rock outcrops and undifferentiated, mainly shallow, gravelly soils	Somewhat excessively drained	100

Notes : The unit occupies a number of isolate steep hills occuring mainly in the south-eastern part of Ulyankulu. Dominant slopes range from 16 to 40 percent, exceeding 100 percent in some places. No crops are grown in the area. Open woodland is the main vegetative cover, but rock outcrops are bare of vegetation.

MAPPING UNIT 2 Area: 32 sq.km., 6% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Footslopes, gently sloping upper part, 2-6% slope	U1	Deep, friable, red/dark red and yellowish red sandy clay loams and sandy clays	Well drained	60
Ditto	U2	Ditto, but ironstone gravels within 100 cm of the surface	Ditto	30
Ditto, but lower end	U3	Deep, friable, yellowish red sandy loams	Ditto	5
Ditto	U4	Ditto, but ironstone gravels within 100 cm of the surface	Ditto	5

Notes: This unit includes gently sloping areas lying at the foot of the isolated hills, mainly in the south-eastern part of the area. Many areas have been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. Uncultivated areas are under woodland.

MAPPING UNIT 3 — Area: 48 sq.km., 9% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Footslopes, gently sloping lower part, 2-6% slope	U5	Deep, loose, light yellowish brown and pale brown sands and loamy sands	Somewhat excessively drained	40
Ditto	U6	Ditto, but ironstone layer within 100 cm of the surface	Ditto	15
Ditto	U7	Deep, loose, light yellowish brown and pale brown sands and loamy sands with many strong brown mottles within 100 cm of the surface	Moderately well drained	35
Ditto	U8	Ditto, but ironstone layer within 100 cm of the surface	Ditto	10

Notes: In the vicinity of mapping units 2 and 4, there are some areas occupied by somewhat excessively drained strong brown loamy sands and sandy loams, with or without an ironstone layer within 100 cm of the surface. This unit occupies gently sloping lower parts of the footslopes. A good part of the land has been cleared for cultivation, mainly of maize, beans, cassava and sweet potatoes. Tobacco and groundnuts are also grown in some areas. Uncultivated areas are under woodland.

MAPPING UNIT 4 — Area: 105 sq.km., 19% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Upland plain, almost flat upper part, 0-2% slope	U1	Deep, friable red/dark red and yellowish red sandy clays loams and sandy clays	Well drained	60
Ditto	U2	Ditto, but ironstone gravels within 100 cm of the surface	Ditto	30
Ditto, but lower end	U3	Deep, friable yellowish red sandy loams	Ditto	5
Ditto	U4	Ditto, but ironstone gravels within 100 cm of the surface	Ditto	5

Notes: This unit occupies the almost flat upper parts of the upland plain. Major crops grown in the unit are maize, beans, cassava and sweet potatoes. There are also areas used for cultivation of tobacco and groundnuts. Extensive areas have been left under woodland.

MAPPING UNIT 5 — Area 191 sq.km., 35% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Upland plain and footslopes, almost flat lower part	U5	Deep, loose, light yellowish brown and pale brown sands and loamy sands	Somewhat excessively drained	40
Ditto	U6	Ditto, but ironstone layer within 100 cm of the surface	Ditto	15
Ditto	U7	Deep, loose light yellowish brown and pale brown sands and loamy sands, with many strong brown mottles within 100 cm of the surface	Moderately well drained	35
Ditto	U8	Ditto, but ironstone layer within 100 cm of the surface	Ditto	10

Notes: In the vicinity of mapping units 2 and 4, there are some areas occupied by somewhat excessively drained, strcng brown loamy sands and sandy loams, with or without an ironstone layer within 100 cm of the surface.

This unit covers almost flat lower parts of the footslopes and upland plain. Maize, beans, cassava and sweet potatoes are the main crops. Minor crops include tobacco and groundnuts. Uncultivated areas are under woodland.

MAPPING UNIT 6 Area: 155 sq.km., 29% of surveyed area

Position in landscape, slope	Soil Symbol	Soils	Drainage	Proportion %
Bottomland, almost flat edges and centres, 0-2% slope	L1	Dark greyish brown sandy clay loams and sandy clays, with hardpen (hardened layer) below about 50 cm of the surface	Poorly drained	30
Ditto, and waterways and depressions	L2	Deep, grey and dark brown sandy clay loams and sandy clays	Imperfectly and poorly drained	50
Bottomland, scattered patches throughout the unit, 0-2% slope	L3	Mainly deep, loose, greyish brown sands and loamy sands	Imperfectly drained	20

Notes: Most of the soils have prominent strong brown mottles throughout the profile. Owing to the complexity of the soil patterns the proportion of the individual soils could not well be estimated.

The unit occupies almost flat bottomlands, locally known as "mbugas". A good part of the soils remain waterlogged during the rainy season, especially in waterways and depressions. These soils receive water run-off and/or seepage from adjoining, higher-lying land. Occasionally (not every year) areas near the Igombe river are flooded for short periods at a time.

Rice is the main crop in waterlogged areas. Maize, cassava, beans, and sweet potatoes are grown in the better drained land. Scattered trees occur in many areas, often on termite mounds.

Chapter 3

LAND EVALUATION

In this chapter the practical significance of the soil differences recognized during the survey, together with important evironmental factors, are assessed in respect of crop production. More specifically the soils, climate, physiography, drainage characteristics, soil degradation processes, etc. are evaluated in relation to relevant kinds of land use. This assessment is made taking into account the main socio-economic aspects applying to the surveyed area. It may be noted, however, that detailed quantitative studies correlating social and economic factors with physical land attributes are beyond the scope of this report.

The principles and methods given in A Framework for Land Evaluation, FAO (13), by means of a land suitability classification have been followed (Suitability refers to the fitness of a given type of land for a specified kind of land use). The different land units recognized in the Settlement are evaluated below in terms of land suitability classes in respect of ten land use alternatives. The rating is determined on the basis of five physical land attributes, which are considered as the most relevant ones for the purpose. In terms of land evaluation these attributes are referred to as "land qualities".

3.1 LAND USE ALTERNATIVES

In view of the limited agro-ecological information available at present the land use alternatives, for which suitability ratings are given, include most of the crops which are commonly grown in the area. The crops under consideration are :

i) Rainfed upland crops: maize, sorghum, bulrush millet, sweet potatos, beans, groundnuts and tobacco;

ii) Paddy rice which is grown on land that is waterlogged for most of the growing season;

iii) Woodland, mainly for firewood and charcoal.

It is assumed that the crops are grown in small holdings, with low capital inputs, high labour intensity and no or little mechanization. Other inputs include light or moderate application of fertilizers; and some minor management practices such as contour farming, ridging, mulching, simple flood-protection measures, etc.

Table 4 - Main ecological requirements of relevant crops, Ulyankulu Refugee Settlement

Crop	Water Requirement	Soil Fertility requirements	Susceptibility to water-logging	Remarks
Maize	H	H	H	Very susceptible to dry spells in critical growth stages
Cassava	L	L	M	Tuber development is restricted in shallow/ clayey/stony soils
Bulrush-millet	L	L	M	
Sorghum	L	L	M - L	
Sweet-potatoes	L	M	M	Tuber development is restricted in clayey/ stony soils
Groundnuts	M	M	H	Harvesting and nut development are hampered in hard/clayey soils
Beans	H	M	H	
Tobacco	M	M	H	Flue-cured types are best grown on light and medium textured soils
Paddy rice	H	H	L	Soils should be level and should maintain surface water
Woodland	L	L	M	Root development is restricted in shallow soils

H: high M: medium L: low

Land use alternatives which deserve attention in the future include fruit trees, cowpeas, soya beans, vegetables, sunflower, forages crops, rangeland, etc.

The main ecological requirements of the crops under consideration are given in Table 4. The requirements, as shown in the table, are of general qualitative nature only and may vary with different plant varieties or management practices. Water/soil fertility requirements and susceptibility to waterlogging are expressed in relative terms such as high (H), medium (M) and low (L). In preparing the table most of the data have been taken from a number of publications on tropical crops, notably East African Crops by Acland (1), Guide for Field Crops in the Tropics and the Subtropics by Litzenberger (16), Manual for Land Suitability Classification for Agriculture by Van der Kevie (24), and Crop Water Requirements by Doorembos and Pruitt (7).

3.2 LAND QUALITIES

A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Examples are moisture availability, flooding hazard, nutritive value of pastures, etc. Land qualities are combinations of individual land characteristics which are attributes that can be measured or estimated, such as rainfall, available water capacity, texture, slope angle, etc. As land qualities cannot be measured directly, they are usually rated in relative terms such as good, poor, etc. based on the measured land characteristics which determine them.

The five land qualities that have been selected for assessing the suitability of the land units established in the surveyed area are are moisture availability, soil fertility, drainage conditions in growing season, erosion hazards and capability for maintaining surface water. These land qualities are believed to be relevant to the land use alternatives under consideration.

Moisture availability

The moisture in the soil which is available to plants is determined by two major factors : the water supply by rainfall and/or irrigation, and the available water-holding capacity of the soil.

The water supply under rainfed conditions is dependent on the total amounts of rainfall and potential evapotranspiration as well as on the length of the rainy season. The available water-holding capacity is determined by a number of soil characteristics such as texture, structure, organic matter, depth and amount of gravels and stones in the profile.

Soil fertility

The appraisal of soil fertility is based on chemical data only. It mainly refers to the presence of plant nutrients in the soil and whether these nutrients are readily available to the plants. Main parameters are nitrogen content, available phosphorus, exchangeable potassium, cation exchange capacity, base saturation and soil reaction.

Drainage conditions in growing season

Soil drainage refers to the rapidity and extent of the removal of water from the soil, in relation to additions from rainfall, surface run-off and groundwater seepage. The drainage condition of a soil is estimated by the frequency and duration of the periods when the soil is saturated with water. It is also inferred from soil characteristics such as texture, structure, colour, mottling, quality and quantity of organic matter as well as topographical position and groundwater levels.

Erosion hazards

In the surveyed area, this land quality refers mainly to the susceptibility of the soil to water erosion. The susceptibility of the soil to water erosion. The susceptibility depends on a number of factors such as rainfall (total rainfall, intensity and frequency of showers); slope gradient and slope length; soil erodibility, which is the inherent susceptibility of the soil to detachment and transport by rainfall and run-off; and the vegetative cover. The risk of soil loss by wind erosion appears to be insignificant and it is not considered at present.

Capability for maintaining surface water

This land quality is used only for rating suitability for paddy rice, which is a crop that grows well in waterlogged or shallowly flooded soils. Thus soils on which surface water can be maintained are most favourable. This capability depends on soil drainage, permeability, infiltration rate, texture, slope, etc.

Rating of land qualities

The rating of the land qualities in respect of the different land units established during the survey is shown in Table 5. The methodology and technical specifications used for this rating are given in Appendix 2 of the report.

Each land quality is rated as good, moderate, poor or very poor for agriculture in general. The code numbers given to these ratings are 1, 2, 3 and 4 respectively. The ratings also reflect how severe is a given limitation and to what extent it may restrict the use of the land. For instance the rating poor for erosion hazards indicates the presence of severe erosion hazards, the need for adequate protection measures and/or what kind of land use may be safely selected.

These assessment of the land qualities shows that the inherent low fertility of the soils, the moderate risk of soil erosion of the sloping land and the rather low moisture availability for plant growth are the main constraints for a sustained crop production.

1.- The limitation of soil fertility is severe throughout the Settlement, which implies in general that good crop yields cannot be obtained without the use of fertilizers and/or manures. However, owing to marked differences in soil characteristics, the response may vary widely. The low soil fertility can be corrected with relative ease in mapping units 2 and 4, but not in units 3 and 5 where sandy soils predominate. These soils have a very low capacity for storing plant nutrients, which may lead to substantial losses of fertilizer by deep, downward percolation. Conversely, during dry spells the crops may be adversely affected due to an increased concentration of fertilizer in the upper soil layers. It is preferable, therefore, that chemical fertilizers be introduced gradually in order to gain experience in their use.

On the other hand, the soil fertility may be maintained, or even enhanced, by a combination of management practices, such as crop rotations with a long fallow period, cultivation of leguminous crops and application of farm manures and crop residue. The feasibility of using human wastes deserves study as well.

As discussed above the appraisal of soil fertility is based on available analytical data only, not on controlled field trials. No detailed recommendations can be made at present, therefore. Also data on important micro-nutrients, such as boron, copper, zinc or sulphur are not yet available.

Table 5 – Rating of land qualities per land unit, Ulyankulu Refugee Settlement

Land unit		Land quality				
Mapping unit	Soil	Moisture availability	Soil fertility	Drainage conditions in growing season	Erosion hazards	Capability for maintaining surface water
1*	H	4	–	1	4	4
2	U1	2	3	1	2	4
	U2	3	3	1	2	4
	U3	3	3	1	2	4
	U4	3	3	1	2	4
3	U5	4	3	1	2	4
	U6	4	3	1	2	4
	U7	4	3	2	2	4
	U8	4	3	2	2	4
4	U1	2	3	1	1	4
	U2	3	3	1	1	4
	U3	3	3	1	1	4
	U4	3	3	1	1	4
5	U5	4	3	1	1	4
	U6	4	3	1	1	4
	U7	4	3	2	1	4
	U8	4	3	2	1	4
6	L1	2–3**	3	4	1	1–2
	L2	1–2**	3	3–4	1	1–2
	L3	3–4**	3	3	1	4

* Available information is not adequate enough for rating all land qualities.

** Some areas receive water as run-off and/or seepage from adjoining higher areas. The higher rating is meant for water-receiving areas; the lower one, for areas not exposed to run-off or seepage.

2.- Since the Settlement was until a few years ago under a protective cover of woodland and grasses, the land cleared for cultivation shows little or no evidence of past erosion by water, such as rills and gullies, or truncated soils in the case of sheet erosion. In the absence of severe damage, the susceptibility of the soils to water erosion is the main factor taken into account for the rating of the land quality 'erosion hazards'. It is noted, however, that accelerated erosion is already taking place in some areas, e.g. incipient gullies near roadsides occuring mainly in mapping unit 3, deposition of fine soil material at the foot of lengthy slopes etc.

Owing to the intensity of the rainstorms prevailing in the area, the sloping soils of mapping units 2 and 3 may be damaged by water erosion, specially under intensive farming. The risk of erosion in units 4, 5 and 6 is slight, whereas the steep hills (unit 1) need to be kept under vegetative cover in order to avoid severe land degradation.

3.- The climatic moisture regime of the Settlement is characterized in having a water surplus in the rainy season, whereas potential evapotranspiration largely exceeds rainfall in the dry season. The growing season is about 6 months long, but there is the risk of dry spells. Hence the moisture availability for crop production is dependent, to a good extent, on the capacity of the soils for storing water in the root zone. Soils U1 and L2 (mapping units 2, 4 and 6) appear to have a moderate storing capacity; the moisture holding capacity of the remaining soils is regarded as low or very low.

Some areas of mapping unit 6 receive additional water, chiefly as run-off and/or seepage from adjoining higher land. This makes it difficult to assess the soil moisture regime of the unit as a whole. Instead two tentative ratings have been given for each soil. The higher rating is meant for water receiving areas; the lower one, for areas not exposed to run-off or seepage. Further studies are required for a more accurate evaluation of the moisture availability of these bottomlands.

4.- It may be noted that the ratings for drainage conditions in the growing season do not imply any important restriction for agricultural production in the surveyed area, except in mapping unit 6. In many areas of this unit poor drainage precludes the cultivation of most agricultural crops, except paddy rice.

The assessment of the capability for maintaining surface water of the different soils recognized in the Settlement, indicates that only soils L1 and L2 (mapping unit 6) can maintain surface water satisfactorily for rice cultivation.

3.3 LAND SUITABILITY CLASSIFICATION

The process of land suitability classification is the appraisal and grouping areas of land in terms of their suitability for defined uses. According to the terminology given in A Framework for Land Evaluation, FAO (13), the classification adopted for the Settlement is a "qualitative classification", in which the relative suitability of the different land units recognized and mapped during the survey are expressed in qualitative terms only, without precise calculation of costs and returns. It is also classed as "current suitability", which refers to the suitability for a defined use of land in its present condition, or with minor improved management practices only. Major investments on irrigation, land levelling, flood control, etc. appear to be unpractical within the prevailing socioeconomic context of the area.

Four land suitability classes have been recognized. They are described below in sequence of decreasing degree of suitability.

Class S1: Highly suitable land

Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2: Moderately suitable land

Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that on Class S1 land.

Class S3: Marginally suitable land

Land having limitations which in aggregate are severe for sustained application of a given use and will reduce productivity or benefits or increase required inputs, that this expenditure will be only marginally.

Class N: Not suitable land

Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner; or the limitations may be surmountable in time but cannot be corrected with existing knowledge at currently acceptable cost.

3.4 LAND SUITABILITY CLASSIFICATION OF ULYANKULU REFUGEE SETTLEMENT

The different land units recognized during the survey of the area and shown on the Soils Map are rated in terms of land suitability classes, in respect of relevant land use alternatives. More specifically the rating involves the confrontation of the physical crop requirements (Table 4) with the land qualities (Table 5), in order to give a prediction of crop performance.

In correlating these factors, it may be noted that a severe or very severe limitation for agriculture in general, as indicated by rating poor or very poor of a specific land quality, will yet not cause a limitation for every one of the land use alternatives under consideration. Examples are poor drainage and severe risk of soil erosion. Poor drainage is a severe limitation in the case of rainfed upland crops, but not for rice cultivation. Strongly sloping land may be largely destroyed by gully erosion if cultivated with maize, yet this condition is not severely limiting for tree crops which give good protection to the land. Thus in assessing the suitability for the different land use alternatives, different weight is given to the rating of these land qualities.

The land suitability classification of the land units and the area of each land suitability class per crop are given in Tables 6 and 7, as well as in the legend of the Soils Map. From these tables it follows that :

1. Mapping Unit 1 (11 sq.km) is considered as moderately to marginally suitable for woodland; and not suitable for agricultural crops.

2. Mapping Units 2 and 4 (137 sq.km) are highly suitable for woodland and drought-resistant crops such as sorghum, bulrush millet and cassava; moderately suitable for groundnuts as well as for maize and beans but over about 60 percent of the area only.

3. Mapping Units 3 and 5 (239 sq.km) are considered as moderately suitable for sorghum and sweet potatoes; for tobacco and cassava on about 40 percent of the area; for bulrush millet on more than 50 percent of the land; and for groundnuts over 15 percent approximately of the area.

Table 6 - Land suitability classification per land unit, Ulyankulu Refugee Settlement

Land Unit				Rainfed upland crops									
Mapping unit	Area sq.km.	Soil	Area sq.km.	Maize	Cassava	Bulrush millet	Sorghum	Sweet Potatoes	Groundnuts	Beans	Tobacco	Paddy Rice	Woodland
1	11	H	11	N	N	N	N	N	N	N	N	N	S2-S3(b)
2	32	U1	19	S2	S1	S1	S1	S2	S2	S2	S3	N	S1
		U2	10	S3	S1	S1	S1	S1	S2	S3	S3	N	S1
		U3	1.5	S3	S1	S1	S1	S1	S2	S3	S2	N	S1
		U4	1.5	S3	S1	S1	S1	S2	S2	S3	S2	N	S1
3	48	U5	19	S3	S2	S2	S2	S2	S3-S2(c)	S3	S2	N	S1
		U6	7	S3	S3	S2	S2	S2	S3	S3	S3	N	S3
		U7	17	S3	S3	S3	S2	S2	S3-S2(c)	S3	S3	N	S2
		U8	5	S3	S3	S3	S2	S2	S3	S3	S3	N	S3
4	105	U1	63	S2	S1	S1	S1	S2	S2	S2	S3	N	S1
		U2	32	S3	S1	S1	S1	S2	S2	S3	S3	N	S1
		U3	5	S3	S1	S1	S1	S1	S3	S2	S2	N	S1
		U4	5	S3	S1	S1	S1	S2	S2	S3	S2	N	S1
5	191	U5	76	S3	S2	S2	S2	S2	S3-S2(c)	S3	S2	N	S1
		U6	29	S3	S3	S2	S2	S2	S3	S3	S3	N	S3
		U7	67	S3	S3	S3	S2	S2	S3-S2(c)	S3	S3	N	S2
		U8	19	S3	S3	S3	S2	S2	S3	S3	S3	N	S3
6	155	L1	45	N	N	N	N	N	N	N	N	S2-S3(a)	N
		L2	78	N	N	N	S3	S3	N	N	N	S2-S3(a)	N
		L3	32	N	N	N	N	S3	N	N	N	S3-N (a)	N

Total area 542 sq.km.

Notes: Areas given in fourth column are field estimates only, not the result of direct measurements.

(a) Depending on availability of water

(b) Depending on soil depth.

(c) Depending on soil texture: loamy sand soils are better rated.

Table 7 - Land suitability classes : areas and crops

Mapping Unit	Area sq.km.	Land suitability class	Area per crop, sq.km.									
			Maize	Cassava	Bulrush millet	sorghum	Sweet Potatoes	Ground-nuts	Beans	Tobacco	Paddy rice	Woodland
1	11	Highly suitable	-	-	-	-	-	-	-	-	-	-
		Moderately suitable	-	-	-	-	-	-	-	-	-	3
		Marginally suitable	-	-	-	-	-	-	-	-	-	3
		Not suitable	11	11	11	11	11	11	11	11	11	5
2	32	Highly suitable	-	32	32	32	11.5	-	-	-	-	32
		Moderately suitable	19	-	-	-	20.5	32	19	3	-	-
		Marginally suitable	13	-	-	-	-	-	13	29	-	-
		Not suitable	-	-	-	-	-	-	-	-	32	-
3	48	Highly suitable	-	-	-	-	-	-	-	-	-	19
		Moderately suitable	-	19	26	48	48	7	-	19	-	17
		Marginally suitable	48	29	22	-	-	41	48	29	-	12
		Not suitable	-	-	-	-	-	-	-	-	48	-
4	105	Highly suitable	-	105	105	105	5	-	-	-	-	105
		Moderately suitable	63	-	-	-	100	100	68	10	-	-
		Marginally suitable	42	-	-	-	-	5	37	95	-	-
		Not suitable	-	-	-	-	-	-	-	-	105	-
5	191	Highly suitable	-	-	-	-	-	-	-	-	-	76
		Moderately suitable	-	76	105	191	191	28	-	76	-	67
		Marginally suitable	191	115	86	-	-	163	191	115	-	48
		Not suitable	-	-	-	-	-	-	-	-	191	-
6	155	Highly suitable	-	-	-	-	-	-	-	-	-	-
		Moderately suitable	-	-	-	-	-	-	-	-	39	-
		Marginally suitable	-	-	-	78	110	-	-	-	39	-
		Not suitable	155	155	155	77	45	155	155	155	77	155

Note: The areas given are field estimates only, not the result of direct measurements.

4. Mapping Unit 6 (155 sq.km) is not suitable for rainfed upland crops; and moderately suitable to not suitable for paddy rice, availability of water being the main critical factor.

3.5 RECOMMENDATIONS

The main constraints for a sustained crop production in the Settlement are the low natural fertility of the soils, the risk of soil erosion of the sloping land and the rather low moisture availability. Unless improved management practices are adopted, these hazards may lead to poor crop yields as well as to severe degradation of the land resources. In this context the following recommendations are made:

1.- Crop rotations

Crop rotations having a short period of cultivation followed by a long period of fallow are recommended for the area as a whole, in particular for mapping units 3 and 5 where sandy soils predominate. These soils are best suited for drought-resistant crops, such as bulrush millet, sorghum, cassava and sweet potatoes.

Owing to the increasing population pressure, it might be necessary in the near future to shorten the fallow period of the crop rotations. In this case, it is noted that the relatively more fertile soils of mapping units 2 and 4 are better suited for this purpose than those of mapping units 3 and 5. It is also suggested that leguminous crops be introduced in the rotations with a reduced fallow period. Continuous cropping could also be practised in units 2 and 4, but this would certainly require improved management practices, including heavy applications of fertilizers and/or manures.

Continuous farming or crop rotations with a short fallow period are not recommended for mapping units 3 and 5.

2.- Controlled fertilizer use

The limitation of soil fertility is severe throughout the area, which implies that chemical fertilizers and/or manures are required in order to obtain good crop yields. However the response may vary widely. Most of the soils of mapping unit 2 and 4, in particular soil U1, are expected to respond well. In contrast, substantial losses of fertilizers by deep percolation may occur in mapping units 3 and 5. It is recommended, therefore, that chemical fertilizers be introduced gradually so as to gain experience in their use. As far as possible, this should be supported by controlled field trials.

For the immediate future, it is suggested that preference be given to "natural" methods of restoring soil fertility, such as crop rotations with a long fallow period, cultivation of leguminuous crops, and utilization of crop residues and farm manure. The feasibility of using human wastes deserves study as well.

3.- Control of soil erosion

The sloping soils of mapping units 2 and 3 can be moderately damaged by erosion, whereas in units 4, 5 and 6 the risk of erosion is slight. Suggested soil conservation measures include contour cultivation, tied ridging, cover crops and mixed cropping, mulching and minimum tillage. They can be used singly or in varying combinations according to the severity of the problem. It may be noted that, at one time or another, most of these practices have been successfully used in Tanzania, e.g. the results of trials carried out between 1939 and 1947 in the then Lake Province, showed that tied-ridge plots of cotton, sorghum and maize outyielded flat cultivated plots in most years, providing at the same time a good protection against erosion (3). Some of these practices also help to conserve soil moisture.

The steep hills included in mapping unit 1 should be kept under vegetative cover. Cutting of woody species for firewood or charcoal is to be controlled.

4.- Sustenance of refugees

In accordance with a recent viability study carried out by the United Nations High Commissioner for Refugees, the main target is to produce 5,650,000 kg. of maize, 1,050,000 kg. of beans and 550,000 kg. each of groundnuts and sweet potatoes annually, so as to provide a cheap, basic diet to a population of about 30,000 refugees (20).

Assuming a crop rotation consisting of 3 years of cultivation followed by 5 years of fallow, the corresponding land requirements are as follows :-

Crop	Attainable Yield	Land to be cultivated every year	Total land required
Maize	1,500 kg/ha	3,750 ha	9,000 ha
Beans	160 "	6,600 "	15,800 "
Groundnuts	450 "	1,250 "	3,000 "
Sweet potatoes	2,000 "	280 "	670 "

Taking into account the availability of suitable land for these crops as well as its geographical distribution (Table 7), it follows that :

i) In the surveyed area there are about 8,000 ha only of land suitable for both maize and beans, as compared to the total requirement of 24,800 ha. On the other hand, there is enough land suitable for groundnuts and sweet potatoes;

ii) Nearly 3,000 ha of intercropped maize and beans could be grown every year in mapping units 2 and 4. Assuming average yields of 1,200 and 100 kg/ha of maize and beans respectively, a total of 3,600,000 kg. of maize and 300,000 kg. of beans per annum could thus be produced. To meet the envisaged annual target some 2,050,000 kgs. of maize and 750,000 kgs. of beans are still required;

iii) A total of 8,000 ha approximately of mapping units 3 and 5 can be cultivated every year with sorghum. Assuming an attainable yield of 2,000 kg/ha, some 16 million kg. of grain could be produced annually. The proceeds of the sale of the grain could be used for the purchase of the required maize and beans. Instead of sorghum, bulrush millet can be grown over 50 percent or more of this land, if so desired;

iv) Mapping units 3 and 5 should be preferred for growing the required groundnuts and sweet potatoes;

v) Most of mapping unit 6 is not suited for upland crops, and only paddy rice can be grown in some areas. Unit 1 is not suited for agricultural crops, but can be used for the production of firewood, charcoal etc.

5.- Further studies

Additional survey studies are suggested for identifying and mapping in further detail the best suited areas for rice cultivation in mapping unit. This mainly involves a more accurate assessment of the soil resources, flood hazards and availability of water.

In view of the increasing population pressure, it appears desirable that studies be undertaken to determine the water requirement of individual crops, including risk of crop failure due to drought. According to available climatic data (given in Chapter 1), severe drought periods may occur in 20 percent of the years.

Appendix 1

SOIL SURVEY METHODS

The soil survey of Ulyankulu Refugee Settlement was carried out on the basis of field observations together with interpretation of aerial photographs and topographic maps. The field work was supported by laboratory analysis of representative soils. The survey methods comprised a sequence of main operations which can be grouped as Pre-Survey; Field Work; Soil Correlation and Map Compilation; and Soil Analysis.

A1.1 PRE-SURVEY

Following a preliminary visit to the area, all relevant information on geology, climate, natural vegetation, land use etc, as well as available base maps were compiled. The base maps included a topographic map at a scale of 1: 25,000 and aerial photographs taken in 1976 at a scale of 1:60,000.

Both the aerial photographs and topographic maps were studied and interpreted. A preliminary physiographic map at a scale of 1: 100,000 and maps showing slope gradients and elevations, at a scale of 1:50,000 were then prepared. These maps were used mainly as an aid for planning the field work.

A1.2 FIELD WORK

A preliminary field reconnaissance of the soils and landforms was made along traverses selected to cross the physiographic units previously established. Preliminary physiographic and soil legends were thus prepared. Also a traverse layout was plotted on the topographic map at a scale of 1: 25,000 on the basic of which the systematic soil surveying of the area was undertaken.

The traverses were covered on foot and the soil observations were made by spade and anger. Major soils were described in detail from special pits and samples were taken for laboratory analysis and soil correlation. Notes on land use, natural vegetation, relief, erosion and drainage characteristics were also taken. As field work progressed, the physiographic and soil legends as well as the traverse layout were amended from time to time as required. Soil mapping was progressively updated too.

A total of 424 soil observations were made and 54 soil profiles were sampled. The soils were described using the standard method of the USDA Soil Survey Manual together with the FAO Guidelines for Soil Description (14). Special boxes made of galvanized iron sheeting were used for soil correlation.

A1.3 SOIL CORRELATION AND MAP COMPILATION

After completion of the field work, a final correlation of the soils recognized in the area was carried out. Available field and analytical data were used for the purpose. The soils were classified in terms of both the FAO/UNESCO Legend of the Soil Map of the World (15) and USDA Soil Taxonomy (22). Final physiographic and soil legends were then prepared.

Following a detailed review of the mapping units established in the field, the mapping unit boundaries were plotted on a topographic map at a scale of 1: 25,000. Reduction to publication scale (1: 50,000) was made by pantograph.

Because of the scale of mapping and complexity of the soil patterns, it was not possible to differentiate individual soils on the soils map. Instead soil-associations were delineated, which include one or two main soils as the most dominant within a specific mapping unit. The proportion of the individual soil components was estimated in the field.

A1.4 SOIL ANALYSIS

The soil samples were analysed in the Central Soils laboratory of the Agricultural Researoh Institute, Mlingano, using internationally accepted methods.

Particle size distribution was estimated by the Bouyoucos hydrometer method using calgon as the dispersing agent.

Soil pH was measured in water and 0.01 M calcium chloride suspensions using a pH meter with glass and reference electrodes. A soil: solution ration of 1: 2.5 was used.

Walkley and Black's chromic acid oxidation method was used in determining organic carbon. Nitrogen was estimated by the semi-micro Kjeldahl method.

Available phosphorus was extracted with 0.03 M ammonium fluoride in 0.025 hydrochloric acid (Bray and Kurtz No.1 solution) and estimated colorimetrically.

Electrical conductivity was measured in 1:5 soil water extracts with an Electronic Switchgear conductivity bridge.

Exchangeable cations were extracted with neutral, 1 molar ammonium acetate solution. Sodium and potassium were determined flame photo-metrically. Calcium and magnesium were estimated complexo-metrically by the titration chloride-triethanolamine buffer method.

Cation exchange capacity was estimated by the summation of the exchangeable cations except in profile P 1C (soil U1) where exchange capacity was determined directly by the ammonium acetate method.

Appendix 2

METHODS FOR THE RATING OF LAND QUALITIES

The basic concepts and practical aspects of the land suitability classification for agriculture as applied to Ulyankulu Refugee Settlement are discussed in Chapter 3 (Land Evaluation) of this report. In this Appendix, the emphasis is on the technical criteria for the rating of those land qualities selected for assessing the land suitability classification of the area.

A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Examples are moisture availability, flooding hazard, nutritive value of pastures, etc. Land qualities are combinations of individual land characteristics which are attributes that can be measured or estimated, such as rainfall, available water capacity, texture, slope angle, etc. As land qualities cannot be measured directly, they are usually rated in relative terms such as good, poor, etc. based on the measured land characteristics which determine them.

The suitability of a tract of land is determined by a number of land qualities. Five of them have been selected for assessing the suitability of the land units recognized in the Settlement, namely moisture availability, soil fertility, drainage conditions in growing season, erosion hazards, and capability for maintaining surface water.

Each land quality is rated as good, moderate, poor or very poor for agriculture in general. The code number given to these ratings are 1, 2, 3 and 4 respectively.

For each land unit ratings are given to the land qualities, based on different ranges of the individual land characteristics, which in combination determine the land quality.

In rating the land qualities, the methodology recently developed in Sudan by Van der Kevie, W. (Manual for Land Suitability Classification for Agriculture) has been followed (24). The basic data for Tables 8, 9, 11, 13, 15 and 18 have been taken from this publication.

Owing to the limited information available for the surveyed area, some of the ratings are defined in a general qualitative way only, not in quantitative terms. Also a number of assumptions are made.

A2.1 MOISTURE AVAILABILITY

The moisture in the soil which is available to plants is determined by two major factors: the water supply by rainfall and/or irrigation, and the quantity of water the soil can store. In the surveyed area there is no supply of water by irrigation at present.

Table 8 - Estimation of AWC in cm if no soil moisture data are available

AWC in cm		Texture	Max. Vol.% coarse fragments allowed if soil is deep (weighted average)	Minimum soil depth allowed if there are no coarse fragments (for AWC of subsoil)	
Topsoil 0-30 cm	Subsoil 30-120 cm			hard	soft
4	> 12	sandy clay		1	
		loam and loam	5	120	100
		clay loam and sandy clay	15	105	85
		Clay	30	90	70
3-4	9-12	sandy loam	5	120	100
		sandy clay loam and loam	20	105	85
		clay loam and sandy clay	35	90	70
		clay	50	75	55
2-3	6-9	loam sand	5	120	100
		sandy loam	20	105	85
		sandy clay loam and loam	40	90	70
		olay loam and sandy clay	50	75	55
		olay	65	60	40
1-2	3-6	fine sand	5	120	100
		loamy sand	20	105	85
		Sandy loam	40	90	70
		sandy clay loam and loam	50	75	55
		clay loam and sandy clay	65	60	45
		clay	75	50	40

Table 9 – Rating of moisture availability

Rating	Climate moisture regime	AWC in cm	
		Topsoil 0–30 cm	Subsoil 30–120cm
1	M2	> 4 and	> 12
2	M2	> 3 and	> 9
3	M2	> 2 and	> 6
4	M2	> 1 and	> 3

Table 10 – Rating of moisture availability per land unit, Ulyankulu Refugee Settlement

Land Unit		Land characteristic			Rating of land quality
Mapping unit	Soil	Climate moisture regime	AWC in cm		
			Topsoil 0–30 cm	Subsoil 30–120 cm	
1	H	M2	0–3	Insignificant	4
2,4	U1	M2	3–4	9–12	2
	U2	M2	2–3	6–9	3
	U3	M2	2–3	6–9	3
	U4	M2	2–3	6–9	3
3,5	U5	M2	1–2	3–6	4
	U6	M2	1–2	3–6	4
	U7	M2	1–2	3–6	4
	U8	M2	1–2	3–6	4
6	L1	M2	2–3	6–9	2–3*
	L2	M2	3–4	9–12	1–2*
	L3	M2	1–2	3–6	3–4*

* Some areas receive water as run-off and/or seepage from adjoining higher land. The higher rating is meant for water receiving areas; the lower one, for areas not exposed to run-off or seepage.

The water supply under rainfed conditions is dependent on the total amounts of rainfall, potential evapotranspiration and length of the rainy season. On the basis of this data and using a water balance model, a number of climatic zones were recognized in Sudan by Van der Kevie, that are supposed to be significant for the production of agricultural crops (24).

The climate regime of Ulyankulu Refugee Settlement resembles that of Climatic Zone M2 in Sudan: Dry Monsoon Climate with Medium Dry Season. This regime is characterized mainly by a water surplus in the rainy season that is lower than 10% of the annual potential evapotranspiration (penman). The growing season is 6 to 8 months long, but there is the risk of dry spells. Because of the higher elevation the temperatures are somewhat lower in the surveyed area than in zone M2, notably the mean minimum temperature which differs by about $5^{\circ}C$.

The influence of the soil on the water supply to plants is expressed as the 'available water holding capacity' (AWC). It is the maximum amount of readily available water for plant growth that can be stored in the soil. It can be estimated by determining the moisture content of samples taken at different depths, at field capacity (1/3 bar suction) and permanent wilting point (15 bar suction). If soil moisture measurements are not available, the available water holding capacity can be inferred from a number of soil characteristics, such as texture, structure, organic matter content, depth, and amount of gravels and stones in the profile (Table 8).

The rating of moisture availability in fuction of climatic moisture regime and AWC is given in Table 9. The assessment of this land quality in respect of the land units recognized in the Settlement is shown in Table 10. As mentioned above, the climate moisture regime M2 of Sudan is assumed for the area.

A2.2 SOIL FERTILITY

This land quality refers mainly to the presence of plant nutrients in the soil and whether these nutrients are readily available to the plants. At present the appraisal of soil fertility is based on chemical data only, major parameters being nitrogen content, available phosphrus, exchangeable potassium, cation exchange capacity, base saturation and soil reaction. Although the presence of micro-elements such as boron, copper, zinc or sulphur are important for plant growth, no information is available for the soils of the surveyed area. They are not considered in the rating, therefore.

The rating of this land quality is given in Table 11. The soil fertility status of the soils of the area is assessed in Table 12. It may be noted that available information for the rating of phosphorus is scanty. For further details on analytical data, Appendix 4 of the report should be referred to.

Table 11 - Rating of soil fertility

Rating	pH (water)	Land characteristic					Base saturation
		%C	%N	P	me/100g soil		
					CEC	K	
1	6.0-8.0	> 2.25	> 0.15	high	> 20	> 0.4	> 70
2	5.0-6.0	0.75-2.25	0.05-0.15	moderate	10-20	0.2-0.4	40-70
3	4.5-5.0	0.15-0.75	0.01-0.05	low	3-10	0.1-0.2	10-40
4	< 4.5	< 0.15	< 0.01	very low	< 3	< 0.1	< 10

Table 12 – Rating of soil fertility per land unit, Ulyankulu Refugee Settlement

Land Unit Mapping Unit	Soil	Land characteristic					Rating of land quality
		pH (water)	%C	%N	Exch K me/100 g	Sum bases me/100 g	
1	H	–	–	–	–	–	–
2,4	U1	5.0–8.0	0.75–2.25	0.01–0.05	0.1–0.2	3–10	3
	U2	5.0–8.0	0.75–2.25	0.01–0.05	0.1–0.2	3–10	3
	U3	5.0–8.0	0.75–2.25	0.01–0.05	0.1–0.2	3–10	3
	U4	5.0–8.0	0,15–2.25	0.01–0.05	0.1–0.2	3–10	3
3,5	U5	5.0–8.0	0.15–2.25	0.01–0.05	< 0.1	3–10	3
	U6	5.0–8.0	0.15–2.25	0.01–0.05	< 0.1	3–10	3
	U7	5.0–8.0	0.15–2.25	0.01–0.05	< 0.1	3–10	3
	U8	5.0–8.0	0.15–2.25	0.01–0.05	< 0.1	3–10	3
6	L1	5.0–6.0	0.15–0.75	0.01–0.05	< 0.1	3–10	3
	L2	5.0–6.0	0.15–0.75	0.01–0.05	< 0.1	3–10	3
	L3	5–0–6.0	0.15–0.75	0.01–0.05	< 0.1	3–10	3

Notes: To be rated at the final rating level atleast 4 out of the 5 listed land characteristics should satisfy that level or higher.

– Analytical data not available for the rating of soil H.

– Inadequate information for the rating of phosphorus

CEC data not available, instead Sum of Bases have been used.

A2.3 DRAINAGE CONDITIONS IN GROWING SEASON

The drainage condition of a soil estimated by the frequency and duration of the periods when the soil is saturated with water. These conditions are seldom accurately measured but can be inferred from soil characteristics such as texture, colour, mottling, quantity and kind of organic matter, and groundwater levels. Length and frequency of periods with standing water above the soil surface need also to be estimated. The rating of this land quality is given in Table 13. The ratings for the land units recognized in the area are shown in Table 14.

Table 13 - Rating of drainage conditions in growing season

Rating	Soil drainage	Land characteristic		
		Ponding hazard, frequency		
		every 1-2 years	every 3-5 years	every 6-10 years
1	good to excessive	none	none	< 2 weeks
2	moderately good	none	< 2 weeks	2-6 weeks
3	imperfect	< 2 weeks	2-6 weeks	6-10 weeks
4	poor to very poor	2-6 weeks	6-10 weeks	> 10 weeks

Table 14 - Rating of drainage conditions in growing season per land unit, Ulyankulu Refugee Settlement

____ unit			Land characteristic			Rating
Mapping unit	Soil	Soil drainage	Ponding hazard, frequency*			
			every 1-2 years	every 2-5 years	every 6-10 years	
1	H	good to excessive	none	none	none	1
2,4	U1	good to excessive	none	none	< 2 weeks	1
	U2	good to excessive	none	none	< 2 weeks	1
	U3	good to excessive	none	none	< 2 weeks	1
	U4	good to excessive	none	none	< 2 weeks	1
3,5	U5	good to excessive	none	none	< 2 weeks	1
	U6	good to excessive	none	none	< 2 weeks	1
	U7	moderately good	none	< 2 weeks	2-6 weeks	2
	U8	moderately good	none	< 2 weeks	2-6 weeks	2
6	L1	poor to very poor	2-6 weeks	6-10 weeks	> 10 weeks	4
	L2	imperfect and poor	2-6 weeks	2-10 weeks	> 10 weeks	3-4
	L3	imperfect	< 2 weeks	2-6 weeks	6-10 weeks	3

* The rating of "ponding hazard, frequency" is based on a limited number of field observations. Further study is required.

A2.4 EROSION HAZARDS

As used here, this land quality refers to the susceptibility of the soils of the Settlement to water erosion only. The risk of soil loss by the action of wind appears to be insignificant and has not been considered.

Since the area was until a few years ago under a protective cover of woodland and grasses, the land cleared for cultivation shows no or little evidence of past water erosion such as rills and gullies, or truncated soils in the case of sheet erosion. There are, however, some indications that accelerated erosion is already taking place, eg.g. incipient gullies near roadsides occuring mainly in mapping unit 3, deposition of fine soil material at the foot of lengthy slopes, etc.

In the absence of severe damage by erosion, the susceptibility of the soils to water erosion is the main factor taken into account for the assessment of erosion hazards in Ulyankulu Refugee Settlement. The susceptibility depends on the rainfall (total rainfall, intensity and frequency of showers); slope gradient and slope length; soil erodibility, which is the inherent susceptibility of the soil to detachment and transport by rainfall and run-off; and the vegetative cover.

Owing to the limited information available for the surveyed area, the potential soil losses due to sheet and rill erosion cannot be predicted by the Universal Soil-Loss Equation. Instead the susceptibility to water erosion is estimated by correlating climatic data, slope characteristics and soil erodibility as applied in Sudan by Van der Kevie (24). Table 15 refers. It should be noted, however, that the original ratings have been slightly modified to fit local conditions. Soil erodibility has been estimated according to the methodology devised by Erickson (12,23). (See Table 16 and Figures 3 and 4.) The final rating of both susceptibility to erosion and erosion hazards of the land units recognized in the Settlement is given in Table 17.

Table 15 - Rating of susoeptibility to soil erosion of an unproteoted soil

Climatio zone	slope peroent	Soil erodibility		
		low erodibility factor (K)	moderate erodibility factor (K)	high erodibility factor (K)
M2 *	0-1	insignifioant	slight	moderate
M2	1-2	insignifioant	slight	moderate
M2	2-8	slight	moderate	severe
M2	8-16	moderate	severe	severe
M2	> 16	severe	severe	severe

* As in the oase of the land quality 'Moisture Availability', the climatio oonditions of zone M2 of Sudan have been assumed for the surveyed area (23)

Table 16 - Erodibility faotor (K) of the soils of Ulyankulu Refugee Settlement

Soil	Average % sand	silt	clay	Average % organio matter	K faotor
H *	-	-	-	-	-
U1,U2	76	12	12	0.9	0.19
U3,U4	76	10	14	1.4	0.18
U5,U6,U7,U8	83	9	8	0.9	0.16
L1,L2,L3 **	-	-	-	-	-

* Analytioal data are not available for estimating the K factor of soil H.

** As soils L1, L2 and L3 are subjeot to deposition rather than erosion, the K faotor has not been estimated.

Table 17 - Rating of susceptibility to soil erosion and erosion hazards per land unit, Ulyankulu Refugee Settlement

Land Unit		Slope percent*	Erodibility factor (K)	Susceptibility to erosion	Rating of erosion hazards
Mapping unit	Soil				
1	H	16-40	-	severe	4
2	U1	2-6	low	slight	2
	U2	"	"	"	2
	U3	"	"	"	2
	U4	"	"	"	2
3	U5	2-6	"	"	2
	U6	"	"	"	2
	U7	"	"	"	2
	U8	"	"	"	2
4	U1	0-2	"	insignificant	1
	U2	"	"	"	1
	U3	"	"	"	1
	U4	"	"	"	1
5	U5	0-2	low	insignificant	1
	U6	"	"	"	1
	U7	"	"	"	1
	U8	"	"	"	1
6	L1	0-2	-	insignificant	1
	L2	"	-	"	1
	L3	"	-	"	1

* Field studies are required for a better assessment of soil erosion in relation to slope characteristics, such as gradient, length and shape (concave, convex or linear).

Soil erodibility is rather difficult to measure quantitatively because of the many variables involved, not only when the soil is in its natural state, but particularly after it has been subjected to the influence of man. There are however soil properties which in combination affect erodibility, such as the physical quality of texture and structure, the chemical composition, the extent of weathering and the content of organic matter.

The soil erodibility factor (K) reflects the influence of a number of soil characteristics, namely texture of the surface soil (particularly percentage silt and very fine sand, fraction 0.002–0.10 mm), organic matter content, soil permeability and content of coarse fragments. The K factor is estimated by using the Textural Triangle Nomograph for Soil Erodibility (Figure 3) which is designed for soils that do not contain coarse fragments and have a normal range of 5 to 15 percent very fine sand (0.05–0.10 mm), a permeability which is normal for the texture class, and an organic matter content of 2 percent. If soil characteristics deviate from this, adjustments should be made as outlined in the Nomograph. A soil may be considered compact if its bulk density is 1.5, in loamy or finer textured soils; and if bulk density 1.7 in soils more sandy than loam. The same correction of the K value (+ 0.3) should be made if soils are shallow (rock or hard pan within 50 cm from the surface).

The content of very fine sand (0.05–0.0.10 mm), which is usually not determined in the laboratory, can be estimated as follows :–

i) Estimate percentage of fine fraction (<2mm) passing through a # 200 sieve (0.74 mm), by using the diagram given in Figure 4; and

ii) Estimate percentage of very fine sand by using the formula % very fine sand = f(% 0,74 mm – % clay – % silt in which clay is fraction < 0.002 mm and silt fraction 0.002–0.005 mm, and f is a factor which varies with the textural class as follows :–

f = 1.0 for clay (C), silty clay (SIC) and silty clay loam (SICL)
1.1 for clay loam (CL), loam (L) and silt loam (SIL)
1.2 for fine sandy loam (FSL) and sandy loam (SL)
1.35 for sandy clay loam (SCL)
1.5 for loamy sand (LS)
1.75 for sand clay (SC), sand (S) and fine sand (FS)

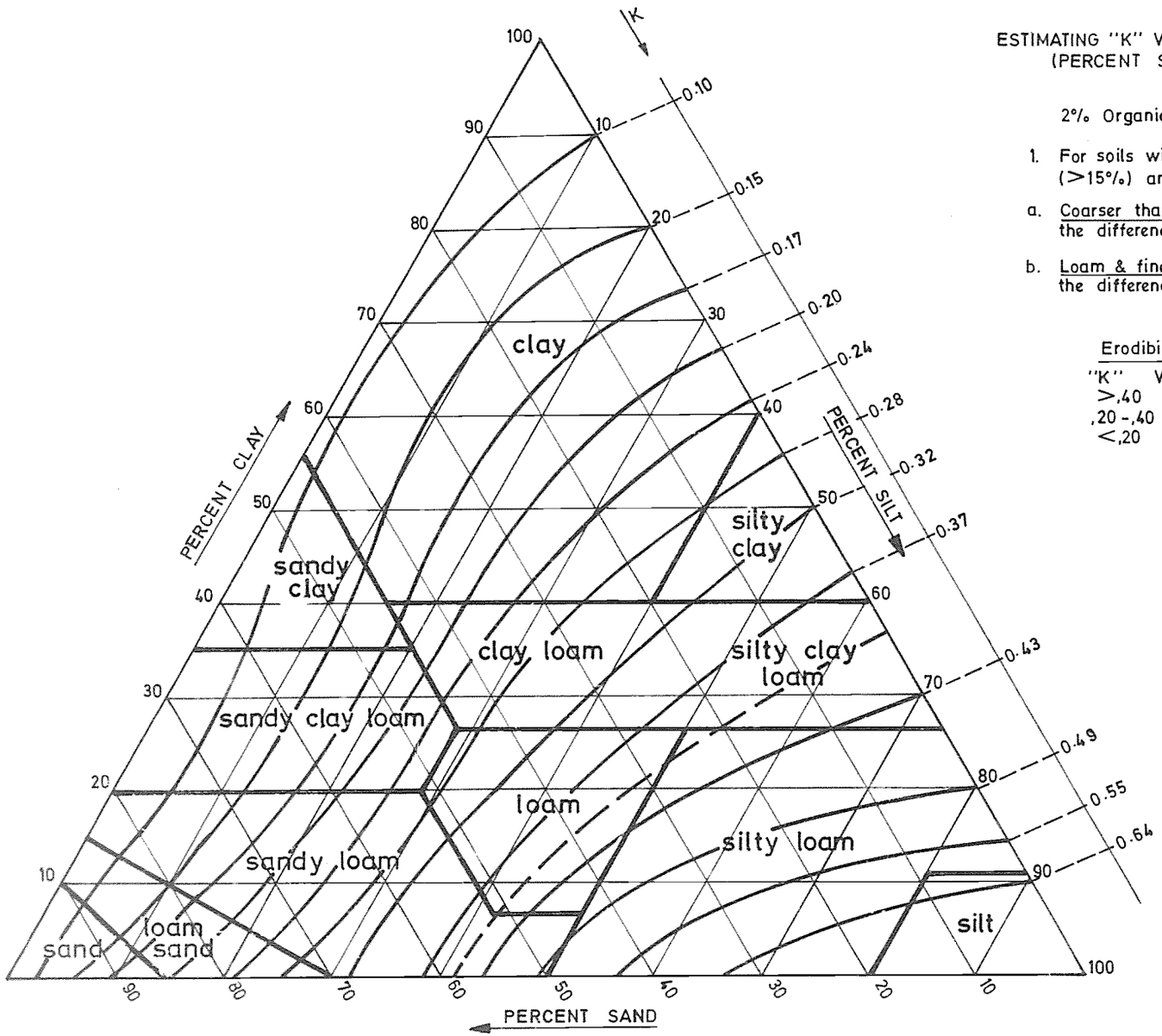


Figure 3 TEXTURAL TRIANGLE NOMOGRAPH FOR SOIL ERODIBILITY

Source:- Taken from Erickson

ESTIMATING "K" VALUE CLASS FROM TEXTURE (PERCENT SILT, CLAY & SAND)

2% Organic matter & structure other than granular.

1. For soils with high content of very fine sand (>15%) and texture

a. Coarser than loam: Subtract 5% from the % vfs and add the difference to the silt content.

b. Loam & finer: Subtract 10% from the% vfs and add the difference to the silt content.

Erodibility Group

"K" Value	
>.40	- High
.20 - .40	- Moderate
<.20	- Low

2. Corrections

a. Structure:

very fine granular	- .09
fine granular	- .06
moderate or coarse granular	- .03

b. Organic Matter:

"K" Value	Percent O.M. 0	1	2	3	4
> .40	+.14	+.07	0.	-.07	-.14
.20 - .40	+.10	+.05	0.	-.05	-.10
< .20	+.06	+.03	0.	-.03	-.06

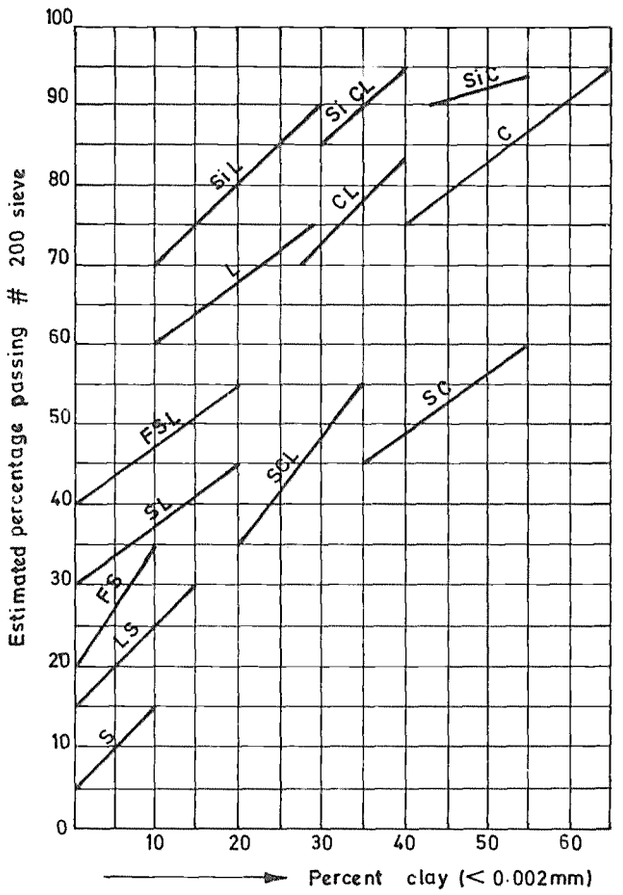
c. Rock Fragments (by Volume)

Rock Fragment Content - (Percent) 0 - 20	20 - 35	35 - 50	50 - 70
.10	.10	.10	.10
.15	.15	.10	.10
.17	.15	.10	.10
.20	.17	.15	.10
.24	.20	.17	.15
.28	.24	.20	.17
.32	.28	.24	.20
.37	.32	.28	.24
.43	.37	.32	.28
.49	.43	.37	.32
.55	.49	.43	.37
.64	.55	.49	.43

d. Permeability

Compact soil or PH > 9.0	+.03
Many medium or coarse pores	- .03

Figure 4. DIAGRAM FOR ESTIMATING PERCENT OF FINE FRACTION PASSING # 200 SIEVE (0·74mm)



Procedure:

Go vertical from % clay on abscissa to appropriate texture class line; then go horizontal to ordinate to find estimate of percent of fine fraction passing # 200 sieve.

Source:

Taken from Erickson

A2.5 CAPABILITY FOR MAINTAINING SURFACE WATER

This land quality is rated only in case of suitability classification for paddy rice, which is a crop that needs to be grown in waterlogged or shallowly flooded soils. Thus soils on which surface water can be maintained are most favourable. Soils, therefore, should have imperfect to poor drainage or have slow permeability and infiltration rate. The latter can be accomplished by puddling if soil textures are favourable. Fields should be level, with no strong microrelief which may cause surface run-off or uneven distribution of surface water.

The rating of this land quality and that of the land units recognized in the Settlement are given in Tables 18 and 19, respectively.

Table 18 - Rating of capability for maintaining surface water

Rating	Slope %	Land characteristic		
		Microrelief cm *	Drainage class	Texture of surface & subsurface horizon
1	< 0.5	0-5	imperfectly to poorly drained	clay, silty clay, sandy clay, clay loam, silty clay loam
2	< 2	5-10	imperfectly to poorly drained	same as above plus sandy clay loam
3	< 3	10-20	moderately well drained	same as above plus loam and sandy loam
4	< 3	> 20	excessively to well drained	clay to sand

* Microrelief is expressed as the average difference in height between low and high spots within 50 m distance. No major improvement by levelling is considered.

Table 19 -- Rating of capability for maintaining surface water per land unit, Ulyankulu Refugee Settlement

Land Unit		Land characteristic				Rating of land quality
Mapping Unit	Soil	Slope %	Microrelief cm	Drainage class	Texture of surface & subsurface horizon	
1	H	16-40	none	somewhat excessively drained	--	4
2	U1	2-6	none	well drained	sandy clay loam and sandy clay	4
	U2	"	"	"	"	4
	U3	"	"	"	sand loam	4
	U4	"	"	"	"	4
3	U5	2-6	"	somewhat excessively drained	sand and loamy sand	4
	U6	"	"	"	"	4
	U7	"	"	"	"	4
	U8	"	"	"	"	4
4	U1	0-2	none	well drained	sandy clay loam &	4
		"	"	"	sandy clay	4
	U2	"	"	"	"	4
	U3	"	"	"	sandy loam	4
	U4	"	"	"	"	4
5	U5	0-2	"	somewhat excessively drained	sandy and sandy loam	4
	U6	"	"	"	"	4
	U7	"	"	"	"	4
	U8	"	"	"	"	4
6	L1	0-2	*none to 20	poorly drained	sandy clay loam and sandy clay	1-2
	L2	"	"	imperfectly and poorly drained	"	1-2
	L3	"	"	imperfectly drained	sand and loamy sand	4

* The microrelief is due to the presence of termite mounds. However, as rice is usually grown in small fields, they do not cause uneven distribution of surface water. The mounds are not considered for the rating of the land quality, therefore.

Appendix 3

SOIL CLASSIFICATION

The soils of Ulyankulu Refugee Settlement have been classified in terms of the FAO/UNESCO Legend of the Soil Map of the World (15), as well as in terms of the USDA Soil Taxonomy (22). The classification is tentative and subject to change as it is not yet supported, in some cases, by the required analytical data. The correlation of the soils of the area within these systems of classification is given in Table 20.

Mapping unit 1: Soils of the isolated steep hills

The soil depth to continuous hard rock, the presence or absence of a cambic horizon, and an ustic soil moisture regime are the main diagnostic properties for the classification of these soils.

Because of the high rainfall and favourable soil characteristics for the leaching of bases, a base saturation of less than 50 percent has been assumed. On the other hand, owing to the presence of numerous rock fragments with weatherable primary minerals, CEC values for the clay fraction of more than 24 me% may be expected.

The shallow soils with continuous hard rock at less than 10 cm of the surface are classified as Lithosols in the FAO/UNESCO Legend and Lithic Ustorthents in the USDA Soil Taxonomy. In contrast, the deep soils having a cambic horizon and rock fragments in the soil mass are Dystric Cambisols stony phase, and Ustic Dystropepts, respectively.

It should be mentioned, however, that a much wider range of soils does occur on these granitic rocks. Since the area was not surveyed in detail, they have not been discussed here.

Mapping units 2, 4: Soils of the footslopes and upland plains, upper parts

The classification of these soils is still a matter of conjecture. In many physical aspects they resemble the Ferralsols of the FAO/UNESCO Legend and the Oxisols of the USDA Soil Taxonomy. They occur on a relatively old, stable geomorphic surface, are dominantly red in colour and have stable aggregates, high porosity, gradual horizon boundaries and no evidence of clay movement and/or illuviation. However, inferred values of CEC and Sum of Bases + Al indicate that these soils fall within the Cambisols and Inceptisols, respectively.

According to available data the clay fraction of some soils, notably U1, has CEC values of 16-24 me % in some subsurface horizons. Also the Sum of Bases + Al is about 10 me %. On the other hand, the clay fraction of soil U4 appears to have much higher values in both cases. However, these significant chemical properties cannot be correlated in the field with soil characteristics such as colour, texture, content or ironstone nedules, etc.

Mapping units 3, 5: Soils of the footslopes and upland plains, lower parts

The main diagnostic property for classifying these soils is their dominantly coarse texture of loamy sand or coarser, the sand fraction of which apparently contains more than 95 percent of quartz and other normally insoluble minerals that do not weather to liberate iron or aluminium.

Other important differentiating properties applying to these soils are their ustic soil moisture regime and the presence or absence of a continuous ironstone layer at less than 100 cm. of the surface. It is also assumed that they have a CEC of more than 24 me 100 g clay.

The deep soils have been classified as Cambic Arenosols in the FAO/UNESCO Legend and Ustic? Quartzipsamments in the USDA Taxonomy; and those overlying an ironstone layer as Cambic Arenosols petroferric phase, and Petroferric? Quartzipsamments, respectively. It is noted that the Subgroups "Ustic" and "Petroferric" are not recognized at present as subdivisions of the Quartzipsamments Great Group.

Mapping unit 6: Soils of the bottomlands

The soils included in this mapping unit have been classified as Dystric Gleysols in the FAO/UNESCO Legend and Tropaquents in the USDA Soil Taxonomy. In brief these soils are considered to be permanently warm and to have a reducing moisture regime free of dissolved oxygen due to saturation with water. However, this may well be an overestimation, especially in respect of the moisture regime. The soils that have slowly permeable layers and/or receive water as run-off or seepage from adjoining higher-lying land, usually remain waterlogged throughout most of the rainy season. Soil L1 is an example in this regard. On the other hand there are soils, such as the coarse-textured L3, that are little exposed to run-off or seepage. These soils are believed to remain saturated with water during periods of heavy rainfall only.

Owing to the complexity of the soil patterns and to the limitations imposed by the surveying scale, these important differences in drainage could not be studied in detail, nor their effects on soil morphological characteristics. Accordingly, the classification of these soils is of provisional nature only.

Appendix 4

DESCRIPTION OF THE SOILS AND ANALYTICAL DATA

Technical description and available analytical data for the soils recognized in each mapping unit are given below. The soils are described in the same order in which they are shown on the Soils Map and Chapter 2 of the report. Each soil is classified in terms of both the Legend of the FAO/UNESCO Soil Map of the World (15) and USDA Soil Taxonomy (22). In describing the soils the nomenclature of the USDA Soil Survey Manual (21) and FAO Guidelines for Soil Profile Description (14) have been followed. Colour notation is according to the Munsell Colour Charts (18).

A4.1 MAPPING UNIT 1: SOILS OF THE ISOLATED STEEP HILLS (H)

This unit includes a wide range of somewhat excessively drained, mainly shallow, moderately coarse-textured soils occuring in a complex pattern, together with numerous granitic rock outcrops. In terms of the FAO/UNESCO Legend these soils may be Lithosols, Dystric Cambisols stony or lithic phase, etc; and Lithic Ustorthents, Ustic Dystropepts, etc, in the USDA Soil Taxonomy.

They occupy a number of isolated, small hills at 1,000-1,200 m. above sea level. Dominant slopes range from 16 to 40 percent, exceeding 100 percent in some places. Open miombo woodland is the main vegetative cover, but rock outcrops are bare of vegetation. No agricultural crops are grown in the area.

These soils were not studied in detail. The profiles described below are examples only of the wide range of soils that may be encountered in the area.

Profile D 24

Location : road 16, at 3,050 m. north of main road
Date of examination : 23/11/1977. Authors : Hof, Daggaa
Landform : summit of isolated steep hill
Site : gently sloping, 4% slope
Microrelief : rock outcrops
Elevation : 1,055 m. above sea level
Vegetation : miombo woodland
Moisture condition : moist throughout
Groundwater : none
Rock outcrops/surface stones : fairly rocky, exceedingly stony
Erosion/deposition: none detected

0	0–1 cm	Litter of partly decomposed leaves and twigs
Ah1	1–5 cm	Very dark grey (7.5YR3/0) moist; stony sandy loam; moderate medium crumb; friable moist, slightly sticky and slightly plastic wet; many fine tubular pores; many fine and medium roots; 40–50% of irregular rock fragments, mainly granite and quartz; clear smooth boundary.
Ah2	5–10 cm	Dark brown (7.5YR3/2) moist; very stony sandy loam; moderate medium crumb; friable moist, slightly sticky and slightly plastic wet; many fine tubular pores; many fine and medium roots; more than 50% of irregular rock fragments, mainly granite and quartz; abrupt smooth boundary.
R	10 cm+	Slightly weathered granitic rock

Profile D5

Location : road 4, at 450 m north of main road

Date of examination : 24/11/1977. Authors: Bomans, Magoggo, Daggaa

Landform : summit of isolated steep hill

Site : sloping, 10% slope

Microrelief : rock outcrops

Elevation : 1,050 m above sea level

Parent material : granitic rock

Land use : fallow, abandoned field

Moisture condition : moist to 90 cm, dry below

Groundwater : none

Rock outcrops/surface stones : fairly rocky, exceedingly stony

Erosion/deposition : none detected

Ap	0–15 cm	Brown (7.5YR4/4) moist; very stony loamy sand; weak medium crumb; very friable moist, nonsticky and nonplastic wet; common fine tubular pores; more than 50% of irregular rock fragments, mainly granite and quartz; many fine and few medium roots; clear smooth boundary
AB	15–65 cm	Dark reddish brown (5YR3/4) moist; very stony sandy loam; weak medium crumb; friable moist, slightly sticky and slightly plastic wet; oommon fine tubular pores; more than 50% of irregular rock fragments, mainly granite and quartz; few fine roots; clear smooth boundary.

Bw	65–100+ cm	Yellowish red (5YR4/6) moist, very stony sandy clay loam; weak medium crumb; friable moist, sticky and plastic wet; common fine tubular pores; more than 50% of irregular rock fragments, mainly granite and quartz; few fine roots.

A 4.2 MAPPING UNITS 2,4: SOILS OF THE FOOTSLOPES AND UPLAND PLAINS, UPPER PARTS

Soil U1

The U1 soils are classified as Ferralic Cambisols in the FAO/UNESCO Legend and Ustoxic Dystropepts in the USDA Soil Taxonomy. These soils include well drained, deep, friable sandy clay loams and sandy clays with weak structural development. They are red, dark red or yellowish red in colour.

Typical profile (P1)

Location : 40 m. east of road 16, 300 m. north of road 24
Date of examination: 20/12/1977. Authors: Lesika, Magoggo, Bomans
Landform: upper part of upland plain
Site: almost flat, 1–2% slope
Microrelief: scattered termite mounds
Elevation: 1,040 m. above sea level
Parent material: weathered granitic rock
Vegetation: miombo woodland
Moisture condition: moist throughout
Groundwater: unknown
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ah	0–7 cm	Dark reddish brown (5YR3/4) moist, brown (7.5YR4/4) dry loamy sand; moderate fine and medium crumb; very friable moist, slightly sticky and slightly plastic wet; many fine tubular pores; many fine roots; abrupt smooth boundary.
AB	7–21 cm	Dark red (2.5YR3/6) moist, red (2.5YR4/6) dry, sandy loam; moderate fine and medium crumb; very friable moist, slightly sticky and slightly plastic wet, many fine tubular pores; many fine roots; gradual smooth boundary.
Bw	21–164 cm	Red (2.5YR4/6–4/8) moist and dry; sandy clay loams; weak fine crumb; friable moist, sticky and plastic wet: many fine tubular pores; few fine roots; abrupt smooth boundary.
Bcs	164–180+ cm	Soil mass as Bw, but more than 80% occupied by small (0.5–1.0 cm diameter), hard, spherical red and dark red ironstone nodules of concentric structure.

Typical profile (P 10)

Location : 20 m west of Health Centre
Date of examination : 27/12/1977. Author : Bomans
Landform : footslope of isolated steep hill, upper part
Site : gently sloping, 3% slope
Microrelief : scattered termite mounds
Elevation : 1,040 m. above sea level
Parent material: weathered granitic rock
Vegetation : miombo woodland
Moisture condition : moist to 170 cm, dry below
Groundwater : unknown
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ah1	0-7 cm	Dark reddish brown (5YR3/3) moist, reddish brown (5YR4/4) dry; sandy loam; moderate fine crumb; very friable moist; slightly sticky and slightly plastic wet; many fine and very fine tubular pores; many fine roots; abrupt smooth boundary
Ah2	7-19 cm	Dark reddish brown (2.5YR3/5) moist, yellowish red (5YR5/6) dry; sandy loam; moderate fine crumb; very friable moist, slightly sticky and slightly plastic wet, many fine and very fine tubular pores; common fine, medium and coarse roots; gradual smooth boundary.
AB	19-46 cm	Dark red (2.5YR3/8) moist, red (2.5YR4/7) dry; sandy clay loam; weak fine crumb; friable moist, slightly sticky and plastic wet; common fine and very fine tubular pores; common fine medium and coarse roots; gradual smooth boundary.
Bw1	46-120 cm	Dark red (2.5YR3/8) moist, red (2.5YR5/8) dry; sandy clay loam; weak fine crumb; friable moist, slightly sticky and plastic wet; common fine tubular pores; common fine, medium and coarse roots; gradual smooth boundary.
Bw2	120-150 cm	Ditto, but sandy clay in texture

Range of profile characteristics

The A horizon ranges from very dark brown to dark reddish brown in colour, and from loamy sand to sandy clay loam in texture; the B horizon, from red or dark red to yellowish red and from sandy clay loam to sandy clay. Ironstone nodules often occur below 100 cm. Soil reaction is slightly to moderately acid, sometimes strongly acid.

Environment characteristics

These well drained soils occupy the upper parts of gently sloping footslopes and almost flat upland plains. Slope gradient ranges from 0 to 6 percent. Miombo woodland is the main vegetative cover. Termite mounds are scattered throughout the area.

Land use

A part of the area has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U2, U3 and U4. They differ from U2, which they otherwise resemble, in not having ironstone nodules at a shallow depth; from U3 in their finer texture; and from U4, which are coarser in texture and have frequent ironstone nodules below about 50 cm of the surface.

Analytical data soil profile P1

Sample No.	Depth cm	Particle size distribution % Sand 2-.05	% Silt .05-.02	.02-.002	% Clay .002	Silt/clay	Text class
11.5458	0-7	77	8	4	9	1.3	LS
59	7-21	82	6	2	11	0.7	SL
60	21-60	66	8	2	25	0.4	SCL
61	60-100	60	6	2	33	0.2	SCL
62	100-164	58	8	2	33	0.3	SCL

O.C. %	N %	C/N	Exchangeable cations me % Na	K	Ca	Mg	H	Sum of bases me%	Sum of cations me %
0.82	0.07	11	0.05	0.19	2.80	2.00	9.5	5.04	14.54
0.26	0.02	17	0.04	0.13	2.00	2.00	3.3	4.17	7.47
0.18	0.02	9	0.04	0.16	1.60	2.40	12.7	4.20	16.90
0.11	0.02	5	0.05	0.13	1.66	1.20	10.5	3.04	13.54
0.07	0.01	13	0.05	0.10	2.80	0.80	22.5	3.75	26.25

H_2O	$CaCl_2$	Sum of bases clay me %	Sum of cations clay me %	ESP	BS%	P ppm
6.0	5.2	57.3	165.2	0.4	34.7	8
5.4	5.0	38.5	69.1	0.5	55.8	12
5.5	4.9	16.9	51.5	0.3	24.9	7
5.6	5.1	9.5	41.1	0.4	22.1	8
5.2	4.8	11.4	80.0	0.2	14.3	6

Analytical data soil profile P10

Sample No.	Depth cm	Particle size distribution % sand 2-.05	% silt .05-.03	% silt .02-.002	% clay .002	silt/clay	Text class
11.5490	0-7	75	5	6	14	0.8	SL
91	7-19	72	7	5	16	0.7	SL
92	19-46	68	6	2	24	0.3	SCL
93	46-120	56	8	2	34	0.3	SCL
94	120-150+	51	8	3	38	0.3	SC

O.C. %	N %	C/N	Exchangeable cations me% Na	K	Ca	Mg	H	Sum of bases me%	Sum of cations me%	CEC me%
1.73	0.06	31	0.07	0.17	3.60	1.60	15.5	5.44	20.94	4.8
1.21	0.04	30	0.08	0.13	2.00	0.80	5.5	3.01	8.51	4.4
0.87	0.03	28	0.07	0.17	2.00	2.00	1.0	4.24	5.24	5.1
0.69	0.02	34	0.07	0.14	4.00	1.20	13.0	5.41	18.41	6.3
0.52	0.02	34	0.07	0.18	2.40	0.80	13.0	3.45	16.45	4.5

pH H2O	pH CaCl2	Sum of bases clay me %	Sum of Cations clay me %	CED	ESP	BS %	P ppm
6.4	6.0	38.7	149.4	34.3	0.3	25.9	7
5.9	5.4	18.3	51.8	26.8	0.9	35.3	3
5.3	4.7	17.7	21.8	21.3	1.3	80.9	2
5.8	5.1	15.9	54.2	18.5	0.4	29.4	0
6.4	6.0	9.1	43.3	11.8	0.4	20.9	0

Soil U2

The U2 soils are classified as Dystric Cambisols, petric phase in the FAO/UNESCO Legend and Ustic Dystropepts in the USDA Soil Taxonomy. They consist of well drained, friable sandy clay clams and sandy clays, with frequent ironstone nodules at a shallow depth. Soil colour is red, dark red or yellowish red. Structural development is weak.

Typical profile (P2)

Location : 300 m east of road 16, 300 m north of road 24

Date of examination : 27/12/1977. Authors: Lesika, Daggaa, Hof

Landform : upper part of upland plain

Site : almost flat, 1-2% slope

Microrelief: scattered termite mounds

Elevation: 1,035 m. above soa level

Parent material: weathered granitic rock

Vegetation: miombo woodland

Moisture condition: moist throughout

Groundwater: unknown

Rock outcrops/surface stones: none

Erosion/deposition: none detected

Ah1	0-4 cm	Black (7.5YR2/0) moist, very dark greyish brown (10YR3/2) dry; sandy loam; moderate fine crumb; very friable moist, slightly sticky and slightly plastic wet; many fine tubular pores; many fine roots; abrupt smooth boundary.
Ah2	4-10 cm	Dark brown (7.5YR3/2) moist, very dark greyish brown (10YR3/2) dry; slightly gravelly sandy loam; moderate fine crumb; friable moist, slightly sticky and slightly plastic wet; many very fine tubular pores; less than 3% of ironstone nodules; many fine roots; clear smooth boundary.
AB	10-23 cm	Dark reddish brown (5YR3/4) moist, yellowish red (5YR5/6) dry; slightly gravelly sandy clay loam; friable moist, sticky and plastic wet; many very fine tubular pores, 5% of ironstone nodules; many fine and few medium roots; gradual smooth boundary.
Bw	23-83 cm	Yellowish red (5YR4/6-5/8) moist and dry; very gravelly sandy clay; weak fine subangular blocky; friable moist, sticky and plastic wet; many fine tubular pores; 50-60% of ironstone nodules; common fine and few medium roots; clear smooth boundary.
Bcs	83-88+ cm	Massive, consolidated horizon of dark red (2.5YR3/6 moist) sand, clay and ironstone nodules.

Note: Ironstone nodules are (dark) red hard, sphorical (0.5-1.0 cm in diameter) and have concentric structure.

Range of profile characteristics

The A horizon ranges from very dark brown to dark reddish brown in colour, and from sand to sandy clay loam in texture; the B horizon, from red or dark red to yellowish red and from sandy clay loam to sandy clay. Ironstone nodules usually occupy more than 50 percent of the soil mass below about 50 cm of the surface. Soil reaction is slightly to moderately acid, sometimes strongly acid.

Environmental characteristics

These well drained soils are on the upper parts of gently sloping footslopes and almost flat upland plains. Slope gradient ranges from 0 to 6 percent. Miombo woodland is the main vegetative cover. Termite mounds are scattered throughout the area.

Land use

A part of the area has been cleared for cultivation mainly of maize, cassava, beans and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U1, U3 and U4. They differ from U1, which they otherwise resemble, in having ironstone nodules at a shallow depth; from U3 in their finer texture and in having ironstone nodules; and from U4 in their finer texture.

Analytical data Soil Profile P2

Sample no.	Depth cm	Particle size distribution % sand 2-.05	% silt .05-.02	% silt .02-002	% clay .002	silt/clay	Text class
11.5463	0-4	75	6	3	16	0.6	SL
64	4-10	71	8	4	17	0.7	SL
65	10-23	59	7	4	30	0.4	SCL
66	23-60	53	6	4	37	0.3	SC
67	60-83	51	6	6	37	0.3	SC

			Exchangeable cations me %						
O.C. %	N %	C/N	Na	K	Ca	Mg	H	Sum of bases me %	Sum of cations me %
2.25	0.08	28.1	0.10	0.36	2.80	4.00	4.5	7.26	11.76
1.90	0.06	31.7	0.86	0.21	2.80	2.00	14.0	5.87	19.87
1.21	0.04	30	0.12	0.29	2.40	1.20	16.0	4.01	20.01
1.38	0.03	46	0.09	0.29	2.40	1.60	13.0	4.38	17.38
0.69	0.03	27	0.11	0.27	2.40	2.40	10.5	5.18	15.68

pH		Sum of bases clay me %	Sum of cations clay me %	ESP	BS %	ppm
H20	CaCl2					
6.4	6.0	46.0	112.4	0.5	61.7	7
6.3	5.6	30.3	113.6	0.5	26.7	5
6.4	5.5	13.4	67.1	0.6	20.0	4
6.0	5.4	14.6	48.2	0.5	26.7	5
6.1	5.6	14.1	42.6	0.7	33.1	5

Soil U3

The U3 soils are classified as Ferralic Cambisols in the FAO/UNESCO Legend and Ustoxic Dystropepts in the USIA Soil Taxonomy. These soils include well drained, very friable yellowish red sandy loams. Structural development is weak.

Typical profile

No adequate description of a typical profile was recorded. These soils are similar to U4, but they do not have frequent ironstone nodules at a shallow depth.

Range of profile characteristics

The colour of the A horizon varies from very dark brown to dark reddish brown, that of the B horizon from yellowish red to red. The texture of the A horizon may be loamy sand or sandy loam. Ironstone nodules may occur below about 100 cm of the surface.

Environmental characteristics

These well drained soils occupy the upper parts of gently sloping footslopes and almost flat upland plains. Slope gradient ranges from 0 to 6 percent. Miombo woodland is the main vegetative cover. Termite mounds are scattered throughout the area.

Land use

A part of the area has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U1, U2 and U4. They differ from U1 in their coarser texture and in occupying a somewhat lower position; from U2, which are finer in texture, have frequent ironstone nodules at a shallow depth and occupy a higher position; and from U4 in not having frequent ironstone nodules.

Soils U4

The U4 soils are classified as Dystric Cambisols, petric phase in the FAO/UNESCO Legend and Ustic Dystropepts in the USDA Soil Taxonomy. They consist of well drained, very friable, yellowish red sandy loams, with frequent ironstone nodules within 100 cm of the surface. Structural development is weak.

Typical profile (P22)

Location: main road between roads 54 and 55
Date of examination: 28/12/1977. Authors: Hof, Bomans
Landform: upper part of upland plain
Site: almost flat, 1-2% slope
Microrelief: scattered termite mounds
Elevation: 1,015 m. above sea level
Parent material: weathered granitic rock
Vegetation: miombo woodland
Moisture condition: moist throughout
Groundwater: unknown
Rock outcrops/surface stoniness: none
Erosion/deposition: none detected

A	0-5 cm	Dark reddish brown (5YR2.5/2) moist, (5YR3/4) dry; sandy loam; moderate medium crumb; very friable moist, non sticky and nonplastic wet; few fine tubular pores; many very fine roots; abrupt smooth boundary.
Ah	5-20 cm	Dark reddish brown (5YR3/4) moist, yellowish red (5YR4/8) dry; loamy sand; moderate medium crumb; very friable moist, slightly sticky and slightly plastic wet; very few fine tubular and many very fine interstitial pores; common fine and medium roots, clear smooth boundary.

Bw1	20-50 cm	Red (2.5 YR4/6-5/8) moist and dry; loamy sand; moderate medium crumb; very friable moist, slightly sticky and slightly plastic wet; common very fine tubular and many very fine interstitial pores; common fine medium and coarse roots; clear smooth boundary.
Bw2	50-79 cm	Ditto, but sandy loam in texture
Bcs	79-120+ cm	Red (2.5YR4/6-5/8) moist and dry; very gravelly sandy loam; moderate medium crumb; friable moist, slightly sticky and plastic wet; common very fine tubular and many fine interstitial pores; more than 50% of small (0.5-1.0 cm diameter), hard, spherical, red or dark red ironstone nodules of concentric structure; common fine roots.

Note: This profile is redder in colour than is usual in U4 soils. The B horizon is yellowish red in most profiles.

Range of profile characteristics

The A horizon ranges from dark reddish brown to red in colour, and from loamy sand to sandy loam in texture. The B horizon is usually yellowish brown, sometimes red or dark red. Soil reaction varies from slightly to moderately acid. Ironstone nodules are frequent or very frequent below about 50 cm. from the surface.

Environmental characteristics

These well drained soils are on the upper parts of gently sloping footslopes and almost flat upland plains. Slope gradient is 0-6 percent. Miombo woodland is the dominant vegetation. Termite mounds are scattered throughout the area.

Land use

A part of the land has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U1, U2 and U3. They differ from U1 in their coarser texture and in having ironstone nodules at a shallow depth; from U2, which are finer in texture; and from U3, which they otherwise resemble, in having frequent ironstone nodules.

Analytical data

Sample no.	Depth cm	Particle size distribution % sand 2–.05	.05–.02	.02–.002	% clay	Silt/clay	Text class
11.5505	0–5	75	13	1	11	1.4	SL
06	5–20	81	9	3	8	1.6	LS
07	20–50	77	5	1	8	0.7	LS
08	50–79	72	9	1	18	0.5	SL
09	79–120	72	7	5	16	0.7	SL

O.C. %	N %	C/N	Exchangeable cations me % Na	K	Ca	Mg	H	Sum of bases me %	Sum of cations me %
0.56	0.02	28	0.42	0.13	4.40	1.60	6.5	6.55	13.05
2.53	0.04	63	0.07	0.13	5.20	2.80	5.5	8.20	13.70
0.38	0.12	3	0.06	0.16	5.60	4.40	7.0	10.22	17.22
0.28	0.04	7	0.06	0.07	2.00	2.80	11.0	4.93	15.93
0.19	0.02	9	0.06	0.07	3.60	1.20	8.0	4.93	12.93

pH H2O	pH CaCl2	Sum of bases clay me %	Sum of cations clay me %	ESP	BS %	P ppm
6.4	5.8	58.2	119.5	3.4	48.7	2
6.6	6.2	107.8	180.1	0.5	59.8	4
6.3	5.6	134.3	226.5	0.3	59.3	1
5.4	5.0	27.1	87.5	0.4	31.0	0
5.5	4.6	30.0	78.8	0.4	38.1	0

A 4.3 MAPPING UNITS 3, 5: SOILS OF THE FOOTSLOPES AND UPLAND PLAINS, LOWER PARTS

Soil U5

These soils are classified as Cambic Arenosols in the FAO/UNESCO Legend and Ustic? Quartzipsamments in the USDA Soil Taxonomy. They include somewhat excessively drained, loose, yellowish brown and pale brown sands and loamy sands. Structural development is weak.

Typical profile (D15)

Location: 50 m south of main road, 1,000 m east of junction with road to administration quarters.

Date of examination: 28/11/1977. Authors: Bomans, Magoggo, Lesika

Landform: footslope of isolated steep hill, lower part

Site: almost flat, 2% slope

Microrelief: scattered termite mounds

Elevation: 1,020 m. above sea level

Parent material: quartz sand derived from granitic rocks

Vegetation: miombo woodland, thicket in places

Moisture condition: moist to 115 cm, dry below

Groundwater: unknown

Rock outcrops/surface stones: none

Erosion/deposition: none detected

Ah1	0-8 cm	Very dark greyish brown (10YR3/2) moist; sand; weak fine and medium crumb; very friable moist, nonsticky and nonplastic wet; many fine interstitial pores; many fine roots; clear smooth boundary.
Ah2	8-23 cm	Brown (10YR4/3) moist; sand; weak fine to medium crumb; very friable moist, nonsticky and nonplastic wet; many fine interstitial pores; many fine and medium roots; diffuse smooth boundary.
Cu1	23-44 cm	Pale brown (10YR6/3) moist, sand; single grain; loose moist, nonsticky and nonplastic wet; many fine interstitial pores, few coarse roots; diffuse smooth boundary.
Cu2	44-115+ cm	Ditto, but very pale brown (10YR7/3) moist, in colour

Range of profile characteristics

The soils range from sand to loamy sand in texture. The colour of the A horizon may be very dark greyish brown, dark brown or brown; that of the C horizon varies from light to dark yellowish brown, or very pale brown to brownish yellow. Soil reaction varies from slightly to moderately acid. Some profiles have common mottles and/or a continuous ironstone layer at more than 100 cm of the surface.

Environmental characteristics

These soils are somewhat excessively drained. They occupy the lower parts of gently sloping footslopes and almost flat upland plains. Slope gradient is 0-6 percent. Miombo woodland is the dominant vegetation. Termite mounds are scattered throughout the area.

Land use

A part of the land has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U6, U7 and U8. They differ from U6 in not having an ironstone layer; from U7 in being better drained; and from U8, which overlie an ironstone layer at a shallow depth and is poorer in drainage.

Soil U6

The U6 soils are classified as Cambic Arenosols, petroferric phase in the FAO/UNESCO Legend and Petroferric? Quartzipsamments in the USDA Soil Taxonomy. They consist of somewhat excessively drained, loose, yellowish brown and pale brown sands and loamy sands, overlying a continuous ironstone layer within 100 cm of the surface. Structural development is weak.

Typical profile (D21)

Location: road 16, at 350 m from junction with road 15
Date of examination: 21/11/1977. Authors: Hof, Daggaa
Landform: low part of upland plain
Site: almost flat, 2% slope
Microrelief: scattered termite mounds
Elevation: 995 m. above sea level
Parent material: quartz sand derived from granitic rocks
Land use: fallow
Moisture condition: moist throughout
Groundwater: unknown
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ap	0-18 cm	Very dark grey (10YR3/1) moist; sand; weak medium crumb; loose moist, nonsticky and nonplastic wet; many fine interstitial pores; common very fine roots; clear smooth boundary
Cu	18-48 cm	Light yellowish brown (10YR6/4) moist; sand; weak medium crumb; loose moist, nonsticky and nonplastic wet; many fine interstitial pores; common very fine roots; irregular boundary.
Cms	48+ cm	Petroferric horizon: continuous ironstone layer composed of cemented nodules, mainly quartz, with some fissures

Range of profile characteristics

These soils vary from 40 to 100 cm in thickness, from sand to loamy sand in structure. Colour of the A horizon may be very dark brown or very dark greyish brown; that of the C horizon ranges from yellowish brown to pale brown, sometimes brownish yellowish brown. Soil reaction varies from slightly to moderately acid, sometimes strongly acid.

Environmental characteristics

These somewhat excessively drained soils are on gently sloping to almost flat lower parts of footslopes and upland plains. Slope gradient varies from 0 to 6 percent. Miombo woodland is the main vegetative cover. Termite mounds are scattered throughout the area.

Land use

A part of the land has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are some areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U5, U7 and U8. They differ from U5 and U7 in overlying an ironstone layer at a shallow depth; and from U6, which are poorer in drainage and have prominent mottling.

Soil U7

The U7 soils are classified as Cambic Arenosols in the FAO/UNESCO Legend and Ustic? Quartzipsamments is the USDA Soil Taxonomy. They include moderately well drained, loose, yellowish brown and pale brown sands and loamy sands, with strong brown mottles. Structural development is weak.

Typical profile (P4)

Location: 800 m. east of road 16,300 m. north of road 24
Date of examination: 27/12/1977 -- Authors: Lesika, Daggaa
Landform: lower part of upland plain
Site: almost flat, 2-3 percent slope
Microrelief: scattered termite mounds
Elevation: 1,035 m. above sea level
Parent material: quartz sand derived from granitic rocks
Vegetation: miombo woodland
Moisture condition: moist throughout
Rock outcrops/surface stones: none
Erosion/deposition: none

Ah1	0-8 cm	Very dark greyish brown (10YR3/2) moist, dark greyish brown (10YR4/2) dry; sand; single grain; loose moist, nonsticky and nonplastic wet; many fine interstitial pores; many fine roots; clear smooth boundary.
Ah2	8-41 cm	Brown (10YR4/3-5/3) moist and dry; sand; single grain; loose moist, nonsticky and nonplastic wet; many fine interstitial pores; many fine roots; clear smooth boundary.
Cu	41-150 cm	Light yellowish brown (10YR6/4) moist, very pale brown (10YR7/4) dry; many medium, clear, distinct strong brown and few yellowish red mottles; sand; single grain; loose, nonsticky and nonplastic wet; many fine interstitial pores; few fine and medium and many coarse roots; clear smooth boundary.
Cg	150-180	Very pale brown (10YR7/3-8/3) moist and dry; many fine and medium, diffuse, distinct dark greyish brown and yellowish brown mottles; sand; single grain; loose moist, non-sticky and nonplastic wet; many fine interstitial pores few fine and coarse roots.

Range in profile characterestics

These soils vary from sand to loamy sand in texture, but sometimes have sandy loam layers at variable depths. The colour of A horizon ranges from very dark greyish brown to dark brown; that of the C horizon from light to dark yellowish brown, brownish yellow or pale brown. Some profiles have a continuous ironstone layer below 100 cm of the surface.

Environmental characteristics

These moderately well drained soils are on the gently sloping to almost flat lower parts of footslopes and upland plains. Slope gradient is 0-6 percent. Miombo woodland is the dominant vegetation. Termite mounds are scattered throughout the area.

Land use

A part of the land has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. Some areas are under tobacco and groundnuts.

Associated soils

These soils are associated with soils U5, U6 and U8. They differ from U5 in being poorer in drainage and in having prominent mottles; and from U6 and U8, which overlie an ironstone layer at a shallow depth.

Analytical data soil profile P4

Sample no	Depth cm	Particle size distribution % sand	% silt .05-.02	% silt .02-.002	% clay .002	silt/clay	Text class
11.5473	0-8	92	0	0	8	-	S
74	8-41	92	0	0	8	-	S
75	41-150	92	0	0	8	-	S
76	150-180	92	0	0	8	-	S

O.C. %	N %	C/N	Exchangeable cations me% Na	K	Ca	Mg	H	Sum of bases me %	Sum of cations me %
0.44	0.04	10	0.04	0.19	2.40	1.60	12.9	4.23	17.13
0.26	0.02	12	0.03	0.07	2.40	1.60	20.1	4.10	24.20
0.09	0.01	18	0.04	0.04	2.40	2.40	11.5	4.88	16.38
0.07	0.02	4	0.03	0.07	2.40	2.80	3.5	5.30	8.80

pH H2O	pH CaCl2	Sum of bases clay me%	Sum of cations clay me %	ESP	BS %	P ppm
6.2	5.4	50.9	203.8	0.2	24.7	9
5.1	4.7	48.8	288.0	0.1	16.9	6
5.2	5.0	58.0	194.9	0.2	29.8	5
5.2	4.7	63.2	104.9	0.4	60.3	4

Soil U8

The U8 soils are classified as Gambic Arenosols, petroferric phase in the FAO/UNESCO Legend and Petroferric? Quartzipsamments in the USDA Soil Taxonomy. These soils include moderately well drained, loose light yellowish brown and pale brown sands and loamy sands with strong brown mottles. They have a continuous ironstone layer within 100 cm of the surface.

Typical profile (P32)

Location: road 16, at end of motorable part

Date of examination: 29/12/1977. Authors: Hof, Bomans

Landform: lower end of upland plain

Site: almost flat, 1-2% slope

Microrelief: scattered termite mounds

Elevation: 995 m. above sea level

Parent material: quartz sand derived from granitic rocks

Vegetation: miombo woodland

Moisture condition: moist throughout

Groundwater: unknown

Rock outcrops/surface stones: none

Erosion/deposition: very weak signs of stratification in Ap which may indicate deposition

Ap1	0-12 cm	Very dark greyish brown (10YR3/2) moist, greyish brown (10YR5/2) dry; loamy sand; moderate medium crumb; very friable moist, nonsticky and nonplastic wet; many fine tubular and interstitial pores; many fine and very fine roots; clear smooth boundary.
Ap2	12-38 cm	Dark greyish brown (10YR4/2) moist, greyish brown (10YR5/2) dry; loamy sand; moderate medium crumb; very friable moist, nonsticky and nonplastic wet; few fine tubular pores; common fine and few coarse roots; gradual smooth boundary
C1	38-64 cm	Light yellowish brown (10YR6/4) moist, very pale brown (10YR7/3) dry; loamy sand; weak medium crumb; very friable moist, nonsticky and nonplastic wet; many very fine interstitial pores; few medium and coarse roots; gradual smooth boundary.
Cg	64-85 cm	Very pale brown (10YR7/4) moist, white (10YR8/4) dry; many fine and medium prominent strong brown mottles; loamy sand; weak medium crumb; very friable moist, nonsticky and nonplastic wet; many very fine interstitial pores; very few medium roots; clear wavy boundary.
Cms	85-122+ cm	Petroferric horizon: continuous ironstone layer composed of cemented nodules, mainly quartz, with some fissures.

Range of profile characteristics

These soils are usually moderately well drained, ranging to imperfectly drained where the ironstone layer is either massive and/or occurs at a shallow depth. This layer is largely constructed of cemented nodules, but sometimes is massive with no recognizable structure. They vary from 50 to 100 cm in thickness, from sand to loamy sand in texture and from single grain to weak fine crumb in structure. Colour of the A horizon may be very dark brown or very dark greyish brown; and that of the C horizon ranges from yellowish brown to pale brown, sometimes brownish yellow or dark yellowish brown. Soil reaction varies from slightly to moderately acid.

Environmental characteristics

These soils occupy the gently sloping to almost flat lower parts of footslopes and upland plains. Dominant vegetation is miombo woodland. Scattered termite mounds cover less than 10 percent of the area.

Land use

Part of the land has been cleared for cultivation of mainly maize, beans, cassava and sweet potatoes. There are also areas under tobacco and groundnuts.

Associated soils

These soils are associated with soils U5, U6 and U7. They differ from U5 and U7 in having an ironstone layer, and from U6 in their poorer drainage and presence of mottles.

Analytical data soil profile p32

Sample no	Depth cm	Particle size distribution % sand	% silt .05–02	% silt 002–.002	% clay .002	silt/clay	Text class
11.5510	0–12	87	6	0	7	0.9	LS
11	12–64	83	8	2	7	1.5	LS
12	64–122	85	6	3	6	1.5	LS
13	122+	86	6	1	6	1.2	LS

O.C. %	N	C/N	Exchangeable cations me % Na	K	Ca	Mg	H	Sum of bases me %	Sum of cations me %
0.69	0.03	23.	0.04	0.10	3.60	4.40	4.0	8.14	12.14
0.52	0.02	25	0.04	0.07	4.80	0.80	2.0	5.71	7.71
0.86	0.00	173	0.03	0.03	4.80	1.60	2.0	6.46	8.46
0.69	0.01	69.	0.03	0.04	2.80	0.80	3.0	3.67	6.67

pH H2O	pH CaCl2	Sum of bases clay me%	Sum of cations clay me%	ESP	BS %	P ppm
6.1	5.4	119.7	178.5	0.3	67.1	8
6.1	5.6	81.6	110.1	0.5	74.1	6
6.0	5.4	107.8	141.2	0.4	76.4	6
6.2	5.5	59.2	107.6	0.5	55.0	4

A4.4 MAPPING UNIT 6: SOILS OF THE BOTTOMLAND

Soil L1

The L1 soils are classified as Dystric Cleysols in the FAO/UNESCO Legend and Tropaquents in the USDA Soil Taxonomy. They consist of poorly drained, dark to dark greyish brown sandy clay loams and sandy clays, overlying a hardpan at a shallow depth.

Typical profile (D 16)

Location: 25 m. north of main road, 750 m east of headquarters
Date of examination: 28/11/1977. Authors: Bomans, Magoggo, Lesika
Landform: bottomland
Site: almost flat, 0-1% slope
Microrelief: scattered termite mounds
Elevation: 1,012 m. above sea level
Parent material: alluvial and colluvial sediments
Vegetation: grassland with scattered trees
Moisture condition: moist to 40 cm, wet below
Groundwater: unknown
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ah	0-14 cm	Black (10YR2/1) moist, common medium distinct dark yellowish brown (10YR4/4) mottles; sandy clay; moderate medium crumb; friable moist, sticky and plastic wet; common fine and medium tubular pores; many fine roots; diffuse wavy boundary
Ac	14-37 cm	Very dark greyish brown (10YR3/2) moist, many medium distinct dark yellowish brown (10YR4/4) mottles; sandy clay; weak medium subangular blocky; friable moist, sticky and plastic wet; many fine tubular pores; diffuse wavy boundary.
Cu	37-60 cm	Dark greyish brown (10YR4/2) moist, many medium distinct dark yellowish brown (10YR4/4) mottles; sandy clay; massive; friable moist; sticky and plastic wet; many fine tubular pores; few fine roots; clear smooth boundary.
Cm	60+ cm	Hardened, massive, fine-textured horizon with no recognizable structure.

Range of profile characteristics

These soils usually range from sandy clay loam to clay in texture, but the A1 horizon may be coarser in some profiles. The colour of the soil matrix varies from dark grey or black to dark greyish brown, that of the mottles from dark yellowish brown or strong brown to yellowish red. Soil structure is weak to moderate crumb or subangular blocky in the upper horizons, grading into massive below about 40 cm.

Environmental characteristics

These poorly drained soils occupy edges and centres of almost flat bottomlands, which receive water as run-off and/or seepage from adjoining higher-lying areas. During most of the rainy season the soils remain waterlogged, especially in depressions. Occasionally, areas near the Igombe river are flooded for short periods at a time.

A number of termite mounds are scattered throughout the area. Dominant vegetation is grassland, with some trees and thickets on termite mounds.

Land use

Only a small part of the land has been cleared for cultivation. Rice is the main crop.

Associated soils

These soils are associated with soils L2 and L3, from which they differ in having a hardpan at a shallow depth and in being poorer in drainage.

Soil L2

The L2 soils are classified as Dystric Gleysols in the FAO/UNESCO Legend and Tropaquents in the USDA Soil Taxonomy. They include imperfectly to poorly drained, grey to dark brown sandy clay loams and sandy clays, with prominent mottles throughout the profile. Structural development is weak.

Typical profile (P7)

Location: 300 m north of road 24, 100 m. east of road 16
Date of examination: 27/10/1977. Authors: Lesika, Bomans
Landform: bottomland
Site: almost flat, 0-1% slope
Microrelief: scattered termite mounds
Elevation: 1,027 m. above sea level
Parent material: alluvial and colluvial sediments
Vegetation: grassland with some trees
Moisture condition: moist to 17 cm, saturated below
Groundwater: 140 cm
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ah	0-5 cm	Very dark brown (10YR2/2) moist, very dark greyish brown (10YR3.5/2) dry; loamy sand; moderate fine crumb; very friable moist, slightly sticky and nonplastic wet; common fine tubular and interstitial pores; many fine roots; abrupt smooth boundary
Ahg	5-17 cm	Dark greyish brown (10YR4/2) moist, brown (10YR5/3) dry; many medium distinct clear strong brown (7.5YR5/6) mottles; sandy loam; moderate medium crumb; very friable moist, sticky and slightly plastic wet; common fine tubular and interstitial pores; many fine and few medium roots; clear smooth boundary
Aog	17-43 cm	Greyish brown (10YR5/2) wet, light yellowish brown (10YR 6/4) dry; many coarse prominent clear strong brown (7.5YR5/6) mottles; sandy clay loam; moderate medium crumb; sticky and plastic wet; many fine tubular pores; fine roots; clear smooth boundary
Cg1	43-81 cm	Pale brown (10YR6/3) wet, light yellowish brown (10YR6/4) dry; many coarse prominent clear strong brown (7.5YR5/6) and few dark red (2.5YR3/6) mottles; sandy clay loam; massive; sticky and plastic wet; many fine tubular pores; few fine medium and coarse roots; clear smooth boundary.
Cg2	81-141 cm	Light brownish grey (10YR6/2) wet; light yellowish brown (10YR6/4) dry; many medium and coarse prominent clear strong brown (7.5YR5/6) and dark brown (2.5YR3/6) mottles; sandy clay; massive; sticky and plastic wet; many fine tubular pores; few medium and coarse roots; clear smooth boundary
Cg3	141+ cm	Ditto, but many coarse, prominent, sharp yellowish r[illegible] (5YR5/8) mottles

Range of profile characteristics

These soils have chromas of 2 or less, varying in colour from gr dark brown. Mottles may be strong brown, yellowish brown, yellowish red or dark red. Dominant textures are sandy clay loam and sandy clay, occasionally being coarser in the topsoil. Soil reaction is moderately to strongly acid.

Environmental characteristics

These soils are imperfectly or poorly drained. They occupy almost flat bottomlands, which receive water as run-off and/or seepage from adjoining, higher-lying areas. A good part of these soils remain water-logged during most of the rainy season, especially in waterways and depressions. Occasionally areas near the Igombe river are flooded for short periods at a time.

Termite mounds are scattered throughout the area. The dominant vegetation is grassland, with some trees and thicket on termite mounds.

Land use

Only a part of the land has been cleared for cultivation. Rice is the main crop in waterlogged areas; and cassava, sweet potatoes and some maize in the best drained soils.

Associated soils

These soils are associated with soils L1 and L3. They differ from L1 in not having a hardpan; and from L3 in their finer texture and in being poorer in drainage.

Analytical data soil profile p7

Sample no	Depth cm	Particle size distribution % sand 2–.05	% silt .05–.05	% silt .02–.002	% clay .002	silt/clay	Text class
11.5484	0–5	82	6	4	9	1.1	LS
85	5–17	80	4	2	15	0.4	SL
86	17–43	62	4	6	28	0.3	SCL
87	43–81	58	4	3	35	0.2	SCL
88	81–141	58	2	4	36	0.2	SC
89	141+	52	6	4	38	0.3	SC

O.C.	N	C/N	Exchangeable cations me% Na	K	Ca	Mg	H	Sum of bases me%	Sum of cations me %
0.87	0.04	21	0.04	0.24	3.20	0.80	19.9	4.28	24.18
0.55	0.05	12	0.05	0.07	4.80	0.80	7.1	5.72	12.82
0.47	0.03	17	0.08	0.06	3.20	3.20	17.1	6.54	23.64
0.22	0.03	8	0.13	0.06	3.20	1.20	8.4	4.59	12.99
0.11	0.02	5	0.20	0.05	3.20	1.60	14.8	5.05	19.85
0.07	0.02	3	0.26	0.04	3.20	2.40	19.5	5.90	25.40

pH H20	pH CaCl2	Sum of bases clay me %	Sum of cations clay me %	ESP	BS %	P ppm
5.4	5.0	48.6	274.8	0.2	17.7	8
5.2	4.6	38.7	86.6	0.4	44.6	6
5.0	4.5	23.3	84.4	0.3	27.6	3
5.4	4.8	13.0	37.6	1.0	35.3	7
5.6	5.1	14.0	55.1	1.0	25.4	9
5.4	4.9	15.5	66.8	1.0	23.2	8

Soil L3

The L3 soils are classified as Dystric Gleysols in the FAO/UNESCO Legend and Tropaquents in the USDA Soil Taxonomy. They consist of imperfectly drained, loose, greyish brown sands and loamy sands with common mottles at a shallow depth. Structural development is weak.

Typical profile (D42)

Location: southern end of road 10; 150 m. beyond motorable part
Date of examination: 28/11/1977. Authors: Hof, Daggaa
Landform: Bottomland
Site: almost flat, 1% slope
Microrelief: scattered termite mounds
Elevation: 1,024 m. above sea level
Parent material: alluvial and colluvial sediments
Land use: fallow
Groundwater: unknown
Rock outcrops/surface stones: none
Erosion/deposition: none detected

Ap	0-20 cm	Very dark greyish brown (10YR3/2) moist; sand; single grain loose moist, nonsticky and nonplastic wet; many fine interstitial pores; common fine roots; clear smooth boundary.
C	20-110 cm	Pinkish grey (7.5YR6/2) moist; common medium and fine prominent strong brown (7.5YR5/6) mottles; sand; single grain; loose moist, nonsticky and non plastic wet; many fine interstitial pores.

Range of profile characteristics

These soils have chromas of 2 or less, varying in colour from grey to light brownish grey or pinkish grey. Mottles may be few or common, yellowish brown, brown or strong brown, sometimes yellowish red below 100cm. Soil texture is sand or loamy sand, but some profiles have sandy loam layers at variable depths. Soil reaction is moderately to strongly acid.

Environmental characteristics

These imperfectly drained soils occur in scattered, almost flat areas in the bottomlands. During the rainy season they may receive water as run-off and/or seepage from adjoining, higher-lying land. These soils appear to remain waterlogged for rather short periods at a time, probably owing to their rapid internal drainage.

Termite mounds are scattered throughout the area. Dominant vegetation is grassland, with some trees and thicket.

Land use

Only a part of the area has been cleared for cultivation of mainly cassava and sweet potatoes. Maize and beans are grown in the best drained land.

Associated soils

These soils are associated with soils L1 and L3, from which they differ in their coarse texture and in being better drained.

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