National Soil Service
Tanzania

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Technical Report 2

SOIL SURVEY REPORT OF MISHAMO REFUGEE SETTLEMENT

United Nations Development Programme

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SOIL SURVEY REPORT OF MISHAMO REFUGEE SETTLEMENT

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
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based on the work of

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ABSTRACT

This report describes a soil survey of the proposed refugee settlement area at Mishamo, Mpanda District, Rukwa Region. The survey was conducted at the request of the Ministry of Home Affairs and the United Nations High Commissioner for Refugees, United Republic of Tanzania.

About 1,000 sq.km. were surveyed. The survey was based on field observations using topographic maps for compiling the data. 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.

Six physiographic units were recognized. Further sub-divisions of these units were made taking into account the kinds of soils and their inherent soil fertility, slope, erosion hazards and other factors which are likely to restrict agricultural production in the future.

About 54 percent of the surveyed area is suitable for the production of a wide range of upland crops and can be recommended for the settlement of refugees. The remaining land, though not suitable for intensive cultivation of upland crops, can be used in other ways according to the characteristics of the site. Some areas are suitable for cultivation of paddy rice; other areas are only suitable for production of firewood, charcoal etc.

INTRODUCTION

BACKGROUND AND IMPLEMENTATION

The soil survey and related land use suitability study of Mishamo Area, Mpanda District, Rukwa Region, were undertaken by the National Soil Service Project in order to assist the Ministry of Home Affairs and the United Nation's High Commissioner for Refugees (UNHCR) in the establishment of a settlement for 30,000 refugees, the immediate objective being to reduce the excess of population of the Ulyankuly Refugee Settlement, Tabora. This survey follows a recent viability study of 3 potential sites, in which Mishamo Area was identified as the most suitable one for settling refugees (19).

The field work was carried out between the months of May and August, 1978 by J. Magoggo, Agr. Research Officer; A. Kiwelu and L. Dagga, Agr. Field Assistants; E. Mosha, Recorder; E. Bomans and J. Hof, FAO Associate Experts; and E. De Pauw, FAO Soil Survey Officer.

The aerial photographs of the area were interpreted by J. Hof and E. Bomans, FAO Associate Experts. The chemical analysis of the soils were conducted at the Central Soils Laboratory, ARI Mlingano, under the supervision of R. Menon, FAO Soil Chemist. The report was prepared by E. Bomans, FAO Associate Expert and J. Magoggo, Arg. Research Officer; it was reviewed and edited by E. De Pauw, FAO Soil Survey Officer, and E.J. Espinosa, Project Manager.

The report includes 3 main chapters, several technical appendixes 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, vegetation, land use and climate. 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 accompaning soils map. Chapter 3 discusses the suitability of the area for crop production and settlement of refugees. The Appendixes 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, etc.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. A total of 609 sq.km. approximately (54%) of the surveyed area, included mainly in mapping units Pw, Cuw, Clw and Fr, are suitable for a sustained production of a wide range of rainfed, upland crops. They should be preferred for the settlement of refugees.

2. The remaining land is not suitable for intensive cultivation of upland crops, but can be used in other ways for the sustenance of refugees. A total of about 60 sq.km., occuring mainly in mapping units Cup, Clp, Fo and Fa are moderately to highly suitable for paddy rice cultivation. Other areas can be used for the production of firewood, charcoal, fruit trees in places, etc.

3. About 6,000 families (30,000 persons) can be settled in the surveyed area. Not less than 10 ha. of agricultural land need to be allocated to each family, as per a recent UNHCR viability study.

4. The main constraints for a sustained crop production are the low natural fertility of the major soils and the severe risk of soil erosion on the steep and sloping land.

5. Crop rotations having a short period of cultivation followed by a long period of fallow are recommended for the area as a whole. Here it necessary continuous cropping can also be practised in units Pw, Cuw, Clw and Fr, but this would require heavy application of fertilizer and/or manure.

6. As the response of soils to chemical fertilizers is unknown, they should be introduced gradually. Particular attention should be given to the utilization of crop residues, cultivation of leguminous crops and application of farm manures where possible. The feasibility of using human wastes in the near future deserves study.

7. Recommended soil conservation practices to control soil erosion, mainly in mapping units Pw and Cuw, include contour cultivation, tied-ridging, cover crops and mixed cropping, and minimum tillage. Drainage ways and mapping unit E should be kept under vegetative cover.

Chapter 1

GENERAL DESCRIPTION OF THE AREA

1.1 LOCATION, POPULATION AND COMMUNICATIONS

The Mishamo Area is located in the northern part of Mpanda district, Rukwa Region, between latitudes 5°30'S and 5°45'S and longitudes 30°15'E and 30°45'E. It is situated along the road Mpanda-Uvinza, mainly west of it. Uvinza is about 70 km to the north-west, Mpanda at nearly 120 km to the south-east and Lake Tanganyika at about 70 km to the west. Elevation above sea level ranges between 1,000 and 1,600 m. About 1,000 sq.km. were surveyed.

There are scattered inhabitants in the area. They mainly include road workers living in temporary quarters along the Mpanda-Uvinza road. However there is evidence of abandoned, older settlements in some places.

The only means of surface communication is the all-weather, non-metalled road linking Mpanda with Uvinza. The western and central parts of the surveyed area are virtually inaccessible and can only be reached on foot or by car along bushtracks.

From Uvinza there are rail links with Kigoma, Tabora and Dar-es-Salaam through the Central Line. A railway connects Mpanda with Tabora. Telegraph facilities exist in both towns, telephone only in Uvinza.

1.2 GEOLOGY AND PHYSIOGRAPHY

The Mishamo Area is included in the Bukoban geological system. The geological substratum consists mainly of layers of hard, medium to coarse grained quartz sandstones alternating with shales. Conglomerates and siltstones occur as well. In most cases the layers are slightly inclined, rarely horizontal. As a result of the alternation and inclination of these layers having different resistance to weathering, a cuesta relief has developed. This cuesta is characterized by steep front (scarp) slopes and slightly tilted back (dip) slopes. The slopes of the plateaux are determined by the dip of the underlying sandstone and shale layers.

Five main physiographic units were recognized during the survey. A schematic cross-section showing these units as well as their relationships with the dominant geology and soil mapping units is given in the accompanying Soil Map.

Plateaux In the surveyed area the plateaux occur at two main levels of elevation. In the northern and north-eastern areas they lie between 1,500 and 1,700 m. above sea level, whereas in the western and southern areas elevations range from 1,000 to 1,400 m. only. Topography is undulating with dominant slopes of 2 to 8 percent. There are also some nearly flat depressions.

Weathering of the shales has given rise to a thick, loamy regolith with scattered rock outcrops. On the other hand, weathering of the sandstone has developed a thick sandy regolith, with abundant rock outcrops and boulders.

Escarpments They are usually nearly vertical cliffs of sandstone and shale, with associated bouldery slopes and coarse debris at the foot.

Colluvial footslopes The areas lying between the escarpments and either the valley floor basement or the floodplain are occupied by colluvial footslopes, which mainly consist of unconsolidated colluvial materials from the escarpments. Coarse and fine textured materials are intermixed, sometimes stratified. They are derived from sandstones, shales and siltstones.

In cross-section, the colluvial footslopes are slightly concave and have slopes varying from 1 to 8 percent. On the basis of topographic position and slope gradient, two sub-units were recognized:

Upper parts, 2 - 8% slope
Lower parts, 1 - 2% slope

Valley floor basement This unit consists of a broad, flat depression occupying the major part of the Rugufu valley, south of Magunga Hill. Slopes do not exceed 1 percent. The area is characterized by the presence of a contineous ironstone layer near or at the surface. This layer was probably formed of soft, iron-rich materials in a period of more impeded drainage than at present. When lowering of the base level caused incision of the river system, drainage improved, and the ferruginous materials hardened to ironstone. The loose soil material covering the ironstone was probably removed by erosion. The weathering-resistant ironstone formed a valley, which is being covered at present by colluvia from the footslopes. It is also possible that the ironstone was formed by accumulation of iron at the foot of the scarp and expansion as a result of scarp retreat.

Floodplain This unit includes almost flat, relatively narrow areas along the main channels of the Rugufu river system. Most of the unit is occupied by an active floodplain, subject to flooding and yearly deposits of mainly clay and silt. Some areas consists of a system of narrow levels and slightly lower backswamps, which are occasionally flooded during the rainy season. There are also a number of older floodplain ridges occupying a higher topographical position. These ridges are not subject to flooding.

1.3 HYDROLOGY

The porosity of the sandstones and the relative impermeability of the shales provide a good water catchment system. Large amounts of water, stored during the rainy season, appear to be released slowly throughout the year. Water infiltrating the colluvial materials of the footslopes drains towards the rivers. This could explain the perennial nature of the rivers and the presence of seasonal groundwater at a shallow depth in the soils of the footslopes.

The principal river draining the area is the Rugufu, flowing into Lake Tanganyika. This river has formed a narrow flood plain, with a system of levees and backswamps. The Musihasi river and a number of its tributaries have intermittent courses. In some rocky areas the water flows either over or underneath the river bed.

The river pattern is largely determined by geological features such as dip of strata and fractures in the substratum. This is inferred from the dominant direction (SE-NW and NE-SW) and some abrupt, right-angle changes in river courses.

1.4 VEGETATION AND LAND USE

The Mishamo Area is covered by little-disturbed woodland and grassland. Brachystegia, Pterocarpus (Mninga) and Terminalia sp. are the dominant trees. Distribution of the species and density of the vegetation cover appear to be closely related to some soil characteristics such as drainage, soil depth and texture.

The well drained soils of the plateaux are covered by open woodland with short and medium grasses as undercover. Terminalia trees are rare. On the drier, sandy parts of the plateaux open spots with tall grass are common. The woodland on the rocky parts of the plateaux is less dense or even scanty.

The escarpments and bouldery areas carry a scanty tree cover and patches of grasses.

Woodland also covers the footslopes, but it is generally denser and taller than on the plateaux. Terminalia species are abundant, especially where soils are moderately well or imperfectly drained. Tall grass is common on the steepest parts of the upper footslopes.

The valley floor basement, with its ironstone layer near or at the surface, is covered by open woodland with rather small, contorted trees.

River courses are commonly fringed with dense forest. Most swamps are covered by grasses.

1.5 CLIMATE

The climate of Mishamo Area is characterized by a long rainy season (November to April) during which more than 90 percent of the rainfall occurs; and by an almost rainless dry season (May to October).

There is one meteorogical station in the surveyed area, but no data are yet available as the station became operational two years ago only. Instead data for Mpanda and Uvinza are given in Table 1. Although Mishamo Area is nearer to Uvinza than to Mpanda, the data from the latter seem more relevant, as elevations above sea level are similar.

Temperature records (six years observations) for Mpanda (12, 13), show that the coolest month is June with a mean maximum temperature of 29.8°C and a mean minimum temperature of 10.1°C. October appears to be the hottest month with a mean maximum temperature of 34°C and a mean minimum temperature of 16.9°C.

Temperatures in Mishamo Area are expected to be 1 to 2°C lower due to the higher elevation.

The mean annual rainfall for Mpanda, calculated over the period 1959-1977, is 1266 mm with a standard deviation of 193 mm. This indicates that in four years out of five the annual rainfall can be expected to exceed 1100 mm and in nine years out of ten to exceed 1020 mm. Most of the precipitation falls in the rainy season from November to April, without prolonged dry spells. Peaks of rainfall occur in December and March. No rainfall was recorded in July-August.

Potential evaporation is high. However, according to Niewolt (11) there is a balance between evaporation and rainfall, and even an small water surplus can be expected in the rainy season from November through April. Water deficits in this period for general agriculture are rather unlikely to occur.

Table 1 - Rainfall

MPANDA	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean monthly rainfall (mm)	188	194	277	182	36	11	0	0	5	35	161	228	1266
Standard deviation (mm)	62	81	140	77	72	46	0	0	9	40	116	70	193
UVINZA													
Mean monthly rainfall (mm)	123	135	148	157	36	2	1	1	25	98	149	173	950
Standard deviation (mm)	45	47	54	58	41	4	3	3	21	63	60	63	

Source: Meteorological Department, Dar es Salaam (3,4)

Rainfall for Mpanda: Average from 18 years, 1959-1977

Rainfall for Uvinza: Average from 28 years, 1946-1974

Chapter 2

SOILS

A general description of the soils of the surveyed area is given below. Detailed technical descriptions of individual soils together with available analytical data for them are given in Appendix 3 & 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 generally occur in complex patterns and may vary considerably over short distances, especially in texture and drainage. During the survey a number of individual soils were recognized, but could not be shown separately on the accompanying Soils Map at a scale of 1:50,000. Instead the soils were described and mapped in relation to the physiographic units in which they occur. More specifically, a correlation was made of landforms, landform elements, parent materials and soil patterns. The cross-section given in the Soils Map illustrates this correlation.

Soils of the Plateaux

The plateaux are mainly covered by deep, well drained, loamy soils having dark brown to very dark greyish brown topsoils and strong brown or yellowish brown subsoils. The subsoil layers are usually finer in texture than the topsoil. These soils are developed in a thick regolith of weathered shale.

Important areas are occupied by a complex pattern of shallow, sandy and loamy soils and numerous sandstone outcrops and boulders. The soils are developed in both weathered sandstone and colluvium from shale. There are also areas covered by somewhat excessively drained, deep, yellowish brown sands which are developed in weathered sandstone. Sometimes these deep sandy soils occur associated in intricate patterns with the shallow, sandy and loamy soils. They could not be shown separately on the Soil Map.

The depressions on the plateaux are occupied by poorly drained, deep, dark-coloured sands. They occupy a very limited area.

Soil of the Escarpments

The escarpments and associated bouldery slopes are characterized by a complex pattern of shallow, often gravelly soils and numerous rock outcrops and boulders.

Soils of the Colluvial Footslopes

The soils of the colluvial footslopes are developed in colluvial material derived from sandstone, shale and siltstone. These materials are usually intermixed, sometimes stratified, and soil textures often vary considerably in a very irregular pattern.

The upper parts are mostly covered by well drained, deep, coarse to medium textured soils having brown to very dark greyish brown topsoils and strong brown or yellowish red subsoils. Subsoil layers are generally finer in texture than the topsoil. In some areas adjoining the escarpments, the medium textured soils appear to be developed in weathered siltstone. Where small rivers from the escarpments spread out on the footslopes, soil drainage is imperfect or poor.

The lower parts mainly include well drained, deep, coarse to medium textured soils having dark brown to very dark greyish brown topsoils and yellowish brown, strong brown or brown subsoils. Some areas are occupied by moderately well and imperfectly drained, coarse to medium textured soils, often with common ironstone gravel below about 1 m of the surface. Topsoil colours are brown to very dark greyish brown; depending on drainage conditions the subsoil may be strong brown, yellowish brown or pinkish grey, with prominent red or strong brown mottles.

There also occur imperfectly and drained soils at the lower end of the colluvial footslopes, where seepage water is at/or near the surface owing to the presence of compact ironstone or clay layers at a shallow depth. These soils vary widely in texture from loamy sand to clay. Dominant topsoil colours are very dark brown, very dark grey or black; those of the subsoil are grey or brown, often with prominent red mottles.

Soils of the Valley Floor Basement

This unit includes shallow, gravelly soils overlying an ironstone layer at less than 50 cm of the surface. Where well drained, brown to strong brown sandy loams to sandy clay loams predominate. On the other hand, the poorly drained sites are covered by dark-coloured sands to sandy loams. Boulders and ironstone outcrops are common.

Soils of the Floodplain

The active floodplain is occupied by poorly drained, deep clay loam and clay soils, with a dark greyish brown, sometimes black topsoil and a massive or stratified, grey to dark grey substratum. These soils are subject to shallow flooding by river water and remain waterlogged throughout most of the year.

The levees include moderately well drained, pale brown sands, loamy sands or sandy loams, which are usually stratified at less than 50 cm of the surface. In contrast the backswamps are covered by poorly drained clay loams and clays, which are similar in characteristics to those of the active floodplain. They are seasonally flooded by river water up to a shallow depth.

The older floodplain ridges consist of well drained, generally deep, coarse to medium textured soils having brown to very dark greyish brown topsoils and strong brown to yellowish brown subsoils. These soils are not subject to flooding.

2.2 DESCRIPTION OF THE MAPPING UNITS

Seventeen mapping units were set up during the survey and they are described below in the same order as they are shown in the legend of the Soil Map. The descriptions are given in a tabular form, in relation to the physiographic units in which they occur.

The descriptions indicate the kind of landscape within the unit; where relevant how the different soils within the unit occur in relation to the landscape; the main identification features of the soils, which usually lie within the subsoil layer; drainage characteristicks; vegetation and an estimate of the area.

SOILS OF THE PLATEAUX

Area: 613 sq.km 54% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	sq.km	% of surveyed Area
Pw	Plateau on weathered shale, moderately dissected, 2-8% slope	Complex of deep, well drained soils: (i) Dark brown to very dark greyish sands and loamy sands overlying strong brown to yellowish brown sandy loams and sandy clay loams (ii) As above, but sandy loams over sandy clay loams (iii) Less than 15% of unit. Soils as (i), but yellowish red subsoils	Brachystegia woodland with ground cover of medium and short grasses	354	31.2
Ps	As Pw, but on weathered sandstone	Well or somewhat excessively drained, deep sands with very dark greyish brown topsoil and yellowish brown sub-soil	Brachystegia woodland and spot of grassland	8	0.7
Pr	As Pw, but mainly sandstone outcrops	Sandstone out crops: boulders or continuous outcrops; shallow soils in places	Bare rock with some trees and grasses	225	19.8
Pr/Ps	Complex of Pr and Ps	Complex of Pr and Ps	Part as Pr, part as Ps	19	1.7
Pm	Almost flat, shallow depressions on plateau, 0-2% slops	Poorly drained, deep, black to dark greyish brown sands	Grassland, mainly medium grasses	7	0.6

SOILS OF THE ESCARPMENTS

Area: 101 sq.km. 8.9% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	Area sq.km	Area % of surveyed area
E	Nearly vertical sandstone and shale escarpments (100% or more slope) with associated bouldery slopes (8-50% slope)	Mainly rock outcrops and boulders with patches of shallow, often gravelly soils	Bare rock with some trees and grasses	101	8.9

SOILS OF THE COLLUVIAL FOOTSLOPES, UPPER PARTS

Area: 95 sq.km. 8.4% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	Area sq.km.	Area % of surveyed area
Cuw	Moderately dissected upper parts of colluvial footslopes, 2-8% slope	Complex of deep, well drained soils: (i) Brown to very dark greyish brown sandy loams overlying strong brown or yellowish red sandy clay loamy sands (ii) As above, but sands or loamy sands over sandy loams to sandy clay loams	Brachystegia woodland with ground cover of medium and short grasses	90	7.9
Cuw(e)	As Cuw, gullied phase	As Cuw	Scrub	2	0.2
Cup	Gently sloping upper parts of colluvial footslopes, 2-3 slope	Complex of: (i) Imperfectly and poorly drained, brown and grey soils. Topsoils are usually sandy clay loam, sometimes sand or loamy sand, Subsoils range from sandy loam to sandy clay (ii) Less than 10% of unit. Moderately well drained yellowish brown to pale brown sandy loams and sandy clay loams	Grassland and wooded (Terminalia sp.) grassland	3	0.3

Note: In unit Cuw some soils have sand or loamy sand texture throughout the profile.

SOILS OF THE COLLUVIAL SLOPES, LOWER PARTS — Area: 180 sq.km; 159% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	Area sq.km.	Area % of surveyed area
Clw	Slightly dissected lower parts of colluvial footslopes, 1-2% slope	Complex of: (i) Well drained, deep sands or loamy sands overlying sandy loams to sandy clay loams. Topsoils are dark brown to very dark greyish brown; subsoils are yellowsih brown, brown or strong brown (ii) as above, but moderately well or imperfectly drained soils, often with red or strong brown mottles and ironstone gravels below 1 m	Brachystegia-Terminalia woodland with ground cover of short and medium grasses	155	13.7
Clw (e)	As Clw, gullied phase	As Clw	Scrub	1	0.1
Clp	Mainly lower end of colluvial footslopes, with slowly permeable substratum (ironstone) or compact clay layers), 1-2% slope	Complex of deep, imperfectly and poorly drained soils of variable textures: mainly sandy loams and sandy clay loams with ironstone or compact clay layers below 50 cm. Topsoils are very dark greyish brown to black, subsoils are brown or grey, often with prominent red mottles	Medium grasses and wooded grassland	24	2.1

Notes At the time of the survey, the moderately well and imperfectly drained soils of unit Clw usually had groundwater between 50 cm and 200 cm of the surface. In unit Clp the groundwater was usually at less that 50 cm of the surface.

SOILS OF THE VALLEY FLOOR BASEMENT

Area 97 sq.km. 8.6% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	Area sq.km.	Area % of surveyed Area
Vw	Almost flat valley-floor basement, 0-1% slope	Shallow, well drained, often gravelly, brown to strong brown sandy loams to sandy clay loams, overlying an ironstone layer at less than 50 cm of the surface. Common ironstone outcrops and boulders	Woodland with stunted, contorted trees	75	6.6
Vp	Almost flat depressions and drainage ways, 0-1% slope	As Vw, but poorly drained, dark-coloured sands to sandy clay loams. Few ironstone outcrops and boulders	Grassland or wooded grassland with stunted, contorted trees	22	2.0

SOILS OF THE FLOODPLAIN

Area: 46 sq.km, 4.1% of surveyed area

Mapping Unit	Physiography	Soils	Vegetation	Area sq.km.	Area % of surveyed area
Fo	Active floodplain, 0-1% slope	Poorly drained, deep clay loams and clays having a dark grey to black topsoil over grey or dark grey, massive or stratified substratum	Grassland	28	2.5
Fa	Young meander floodplain, 0-1% slope	Association of: -Moderately well drained, deep, pale brown, stratified sands to sandy loams on levees -Poorly drained, seasonally flooded, deep clay loams and clays in back-swamps; topsoils are dark greyish brown to black, subsoils are grey or dark grey	Grasses, scrub, small trees	8	0.7
Fr	Older floodplain ridges, 0-1% slope	Well drained, deep loamy sands overlying sandy clay loams to sandy clays. Top-soils are dark brown to very dark greyish brown; subsoils are strong brown or yellowish brown	Woodland	10	0.9

Notes: Unit Fo and the backswamp areas of unit Fa are seasonally flooded by river water and remain waterlogged throughout most of the growing season.

Chapter 3

LAND EVALUATION

In this chapter the practical significance of the soil differences recognized during the survey, together with important environmental 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,(6), 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 area are evaluated below in terms of land suitability classes in respect of nine 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

The land use alternatives, for which suitability ratings are given, include most of the crops which are expected to be grown in Mishamo Area in the near future. The crops under consideration are:

(i) Rainfed upland crops: Maize, Cassava, Sorghum, Sweet potatoes, Beans, Groundnuts and Tobacco;

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

(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 fertilizer; and some minor management practices such as contour farming, ridging, mulching, simple flood protection measures, etc.

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

The main ecological requirements of the crops under consideration are given in Table 2. The requirements, as shown in this table, are of a 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).

Table 2 - Main ecological requirements of relevant crops - Mishamo Area

Crop	Water requirements	Soil fertility requirements	Susceptibility to waterlogging	Remarks
Maize	H	H	H	Very susceptible to dry spell in critical growth stages
Beans	H	M	H	-
Cassava	L	L	M	Tuber development is restricted in shallow/clayey/stoney soils
Sorghum	L	L	M	-
Groundnuts	M	M	H	Harvesting and nut development are hampered in hard/clayey soils
Sweet - potatoes	L	M	M	Tuber development is restricted in stony/clayey soils
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

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 (9), Manual for Land Suitability Classification for Agriculture by Van der Kevie (17), and Crop Water Requirements by Doorenbos and Pruit (2).

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 holding 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 moisture availability, soil fertility, drainage conditions in the 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 amount 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, soil depth and the amount of gravel 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 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 by rainfall and transport by run-off; and the vegetative cover. The risk of soil loss by wind erosion appears to be insignificant and 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 the land qualities

The rating of the land qualities in respect of the different land units established during the survey is shown in Table 3. 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 a given limitation is and to what extent it may restrict the use of the land. For instance 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.

The assessment of the land qualities demonstrates that the inherent low fertility of the soils and the severe risk of soil erosion of the sloping land are the main constraints for a sustained crop production. In some land units moisture availability is an important limiting factor as well.

1.- The limitation of soil fertility is severe throughout the area, which implies in general that good crop yields cannot be sustained without the use of fertilizer and/or manures. The low soil fertility can be corrected with relative ease in most of the area.

Table 3 - Rating of land qualities per land unit - Mishamo Area

Land unit	Land quality				
Mapping unit	Moisture availability	Soil fertility	Drainage conditions in growing season	Erosion hazards	Capability for maintaining surface water
Pw	2-3	3	1	3-4	4
Ps	3	3	1	2-3	4
Pr	4	4	1	3	4
Pr/Ps	3-4	3-4	1	3	4
Pm	2	3	4	1	4
E	4	3-4	1	4	4
Cuw	1-2*	3	1	3-4	4
Cuw (e)	1-2*	4	1	4	4
Cup	1	3	3-4	1	2
Clw	1-2*	3	1-2	2	4
Clw (e)	1-2*	4	1	3	4
Clp	1	3	3-4	2	2
Vw	4	2	1	1	4
Vp	2	2	4	1	2-4*
Fo	1	3	4	1	1
Fa					
Levees	2	3	2	1	4
backswamps	1	3	2	1	1
Fr	2	3	1	1	4

Note: * Depending on soil texture (coarse textured soils get lower ratings) and/or depth to groundwater table.

However, in unit Ps, owing to the low capacity of the soil for retaining both water and nutrients and its high permeability, substantial losses of fertilizer by leaching are to be expected. Dry spells, in some years, may adversely affect the crops due to an increased concentration of salts 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 (if available) and crop residues. The feasibility of using human wastes deserve study in the near future.

As discussed above the appraisal of soil fertility is based on available analytical data only, not on controlled field trials. Therefore no detailed recommendations can be made at present. Also no information is available on important micro-nutrients such as boron, copper, zinc or sulphur. A detailed interpretation of available analytical data in relation to soil fertility is given in Appendix 4.

2.- Since nearly all of the surveyed area is under a protective vegetative cover, little or no evidence of damage by erosion, such as rills, gullies or truncated soils were observed during the survey, except in Units Cuw(e) and Clw(e). In the absence of severe damage, the susceptibility of the soils to water erosion is the main factor which is taken into account for the rating of the land quality "erosion hazards".

Owing to the high amount of rainfall, the intensity of the rainstorms prevailing in the area and the susceptibility of the soils to erosion, land units E, Pw and Cuw, and to a lesser extent unit Ps, may be damaged by water erosion, especially if they are brought under intensive cultivation. To avoid severe degradation, the steep escarpments of Unit E should be left under vegetative cover. On the other hand, soil conservation measures such as strip farming, contour ridging, etc. would need to be adopted in units Pw, Cuw and Ps. In this respect it should be noted that units Cuw(e) and Clw(e) show severe damage by gully erosion, which appears to be the result of inadequate farming practices in the past.

3.- The moisture regime of the surveyed area is characterized by a water balance or even a small surplus in the rainy season, whereas potential evapotranspiration largely exceeds rainfall in the dry season. The growing season is seven to eight months long, but owing to the pronounced rainfall variability there is the risk of dry spells in some years. Hence the moisture availability for crop production depends to a certain extent on the capacity of the soils for storing water in the root zone. This capacity is good to moderate throughout most of the area, but it is poor in unit Ps and very poor in units Pr, E and Vw.

4.- Poor drainage conditions is the growing season preclude the cultivation of upland crops in units Pm, Cup, Clp, Vp, Fo and backswamps of unit Fa. They imply no restriction in other areas.

5.- The soils of units Fo, Clp, Cup, the backswamps of units Fa and a part of unit Vp are considered to have good to moderate capability for maintaining surface water for rice cultivation. The remaining soils are rated as very poor in this respect.

3.3 LAND SUITABILITY CLASSIFICATION

The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined used. According to the terminology given in a Framework for Land Evaluation, FAO (6), the classification adopted for the surveyed area is a "qualitative classification", in which the relative suitability of different land units recognized and mapped during the survey are expressed in qualitative terms only, without precise calculations 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 some minor improved management practices only. Major investments on irrigation, land levelling, flood control, etc. appear to be unpractical within the prevailing socio-economic 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 justified.

Class N: Not suitable land

Land having limitations which appear so severe as to preclude any possibility 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 MISHAMO AREA

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 2.) with the land qualities (Table 3.), 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 a 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 recognized in the surveyed area are given in Table 4. From this rating it follows that:

1. Units Pw, Cuw, Clw and Fr are considered as highly suitable for sorghum, sweet potatoes and woodland; moderately suitable for maize, beans, cassava, groundnuts and tobacco; and not suitable for paddy rice;

2. Unit Ps is moderately suitable for woodland and drought-resistant crops such as cassava, sorghum, groundnuts and sweet potatoes; marginally suitable for maize, beans and tobacco; and not suitable for paddy rice;

3. Depending on the soil depth to hard rock, unit Pr/Ps is moderately or marginally suitable for woodland; moderately or not suitable for cassava, sorghum, groundnuts and sweet potatoes; and not suitable for paddy rice;

4. Units Cup, Clp, Fo and the backswamp soils of unit Fa are rated as highly or moderately suitable for paddy rice; and not suitable for most upland crops and woodland. Simple flood control measures, such as embankments, are required in units Fo and Fa. Depending on soil texture and/or depth, some areas of unit Vp may be also considered as moderately suitable for rice cultivation. However, these areas need yet to be identified and mapped.

Table 4 - Land suitability classification per land unit, Mishamo Area

Land unit			Rainfed upland crops								
Mapping unit	Area sq.km.		Maize	Beans	Cassava	Sorghum	Groundnuts	Sweet Potato	Tobacco	Paddy rice	Woodland
Pw	354		S2	S2	S2	S1	S2	S1	S2	N	S1
Ps	8		S3	S3	S2	S2	S2	S2	S3	N	S2
Pr	225		N	N	N	N	N	N	N	N	S3
Pr/Ps	19		N-S3*	N-S3*	N-S2*	N-S2*	N-S2*	N-S2*	N-S3*	N	S3-S2*
Pm	7		N	N	N	N	N	N	N	N	N
E	101		N	N	N	N	N	N	N	N	N-S3*
Cuw	90		S2	S2	S2	S1	S2	S1	S2	N	S1
Cuw(e)	2		N	N	S3	N	N	S3	N	N	S2
Cup	3		N	N	N	S3	N	S3	N	S2	N
Clw	155		S2	S2	S2	S1	S2	S1	S2	N	S1
Clw(e)	1		N	N	S3	N	N	S3	N	N	S2
Clp	24		N	N	N	S3	N	S3	N	S2	N
Vw	75		N	N	N	N	N	N	N	N	S3
Vp	22		N	N	N	N	N	N	N	N-S2*	N
Fo	22		N	N	N	N	N	N	N	S1+	N
Fa	8	(levee)	N	N	S3	S3	S3	S3	N	N	S3
		(backswamps)	N	N	N	N	N	S3	N	S1+	N
Fr	10		S2	S2	S2	S1	S2	S1	S2	N	S1

Total area: 1,000 Sq.km.

* Depending on soil depth and/or texture

\+ Assuming simple flood control measures

5. Units Pr, Vw, E, Pm and the levee soils of unit Fa are not suitable for most upland crops and paddy rice; and either marginally or not suitable for woodland.

6. Units Cuw(e) and Clw(e) are considered as moderately suitable for woodland; and not suitable for most upland crops and paddy rice.

3.5 RECOMMENDATIONS

The main constraints for a sustained crop production in the surveyed area are the low natural fertility of the soils and the severe risk of soil erosion on the steep and sloping areas. Unless improved management practices are adopted, these hazards may lead to poor 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 unit Ps where sandy soils predominate.

Owing to population pressure, it might be necessary to shorten the fallow period in the near future. In this respect it should be noted that the soils of mapping unit Ps are not very suitable for this purpose in view of their low capacity to retain plant nutrients. It is also suggested that leguminous crops be introduced in the rotations, especially when fallow periods are kept short. Continuous cropping could also be practised on units Pw, Cuw, Clw and Fr, but this would certainly require improved management practices, including heavy application of fertilizer and/or manure.

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. In the units that are recommended for upland crops and rice cultivation, namely Fw, Cuw, Fr, Cup, Clp, Fo and the backswamp soils of unit Fa, the soils are expected to respond well. In contrast substantial losses of fertilizer by deep percolation may occur in unit Ps. It is preferable, therefore, that chemical fertilizers be gradually introduced 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 an adequate fallow period, cultivation of leguminous crops, utilization of crop residues, and application of farm manures where possible. The feasibility of using human wastes deserves study as well.

3. Control of soil erosion

Waterways and sloping soils of mapping units Pw and Cuw can be severely damaged by erosion, whereas in the other units the risk is light or insignificant. Suggested soil conservation measures for the endangered areas 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. Unit E should be kept under vegetative cover mainly because of the steep slopes. This implies that cutting of woody species for firewood or charcoal is to be controlled. Waterways should be protected by grass or bush cover.

4. Settlement and sustenance of refugees

Mapping units Pw, Cuw, Clw and Fr are suitable for a sustained production of a wide range of upland crops and should be preferred for the settlement and sustenance of refugees. These units cover a total area of 609 sq.km. which represent 54 percent of the surveyed atea.

The remaining land is not recommended for settling refugees, but it may be utilized for their sustenance or for other purposes. Units Cup, Clp, Fo and the backswamps of unit Fa, covering about 60 sq.km. are moderately to highly suitable for paddy rice. It may be noted that simple flood control measure are needed in the case of units Fo and Fa. Some areas of unit Vp, which covers 22 sq.km. are also moderately suited for rice cultivation, but they need yet to be identified and mapped in detail. Although unit Ps is not suited for intensive farming, it may be used for growing crops such as sorghum, cassava, groundnuts and tobacco, preferably in rotation with long fallow periods. Alternatively this unit could be used for controlled production of firewood and charcoal, or for deep-rooted fruit trees, such as mangoes. Units Pr and Vw can provide construction materials and, to some extent, firewood and charcoal.

According to a UNHCR viability report (13), about 6,000 families (30,000 persons) are to be moved to the proposed refugee settlement in the surveyed area. Not less than 10 ha of agricultural land are to be allocated to each family. As per [illegible] survey findings, the total area of land suitable for agricultural crops would be large enough for the purpose. However, since the said report also calls for an expansion of about 30 percent in the near future, additional land needs to be identified outside the surveyed area.

Appendix 1

SOIL SURVEY METHODS

The soil survey of Mishamo Area was carried out on the basis of field observations together with interpretation of topographic maps and serial photographs. 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.

Following a visit to the area, arrangements were made for the construction of a preliminary network of bushtracks and bridges. Also, relevant information on geology, climate, natural vegetation, as well as available base maps were compiled. The base maps included topographic maps at a scale of 1:50,000 and aerial photographs taken in or about 1960 at a scale of 1:50,000.

Both the topographic maps and aerial photographs were studied and interpreted. A preliminary physiographic map and maps showing slope gradients and elevations were then prepared at a scale of 1:50,000.

A1.1 FIELD WORK

A preliminary field reconnaissance of the soils and landforms was made along bushtracks selected to cross the physiographic units previously established. Preliminary physiographic and soil legends were thus prepared. Also the layout of the bushtracks was amended and improved as required. On this basis the systematic soil surveying of the area was undertaken. The field work was carried between mid-May and August 1978.

The traverses, along and from the bushtracks, were covered on foot and the soil observations were by spade and auger. Major soils were described in detail from special pits and samples were taken for laboratory analysis and soil correlation. Notes on 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 progresively updated too.

More than 200 soil observations were made and 25 soil profiles were sampled. The soils were described using the standard method of the USDA Soil Survey Manual (14), together with the FAO Guidelines for Soil Description (7). Special boxes made of galvanised iron sheeting were used for soil correlation.

A1.2 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 (8) and USDA Soil Taxonomy (15). 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 transferred from the aerial photographs to the base maps by means of a sketchmaster.

A1.3 SOIL ANALYSIS

The soil samples were analysed in the Central Soils Laboratory of the Agricultural Research Institute, Miligano, using internationally accepted methods.

Partical size distribution was estimated by the Bouyouoos 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 ratio 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 chloride in 0.025 M hydrochloric acid (Bray and Kurtz No.1 solution) and estimated colorimetrically.

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

Exchangeable cations were extracted with neutral, 1 molar ammonium acetate solution. Sodium and Potassium were determined flame-photometrically. Calcium and Magnesium were estimated complexo-metrically by titration with EDTA. Exchange acidity was determined by the barium chloride triethanolamine buffer method. Cation exchange capacity was estimated by the summation of the exchangeable cations.

Appendix 2

METHODS FOR THE RATING OF LAND QUALITIES

A2.1 GENERAL

The basic concepts and practical aspects of the land suitability classification for agriculture as applied to Mishamo Area are discussed in Chapter 3 of this report (Land Evaluation). In this Appendix the emphasis is on the technical criteria for the rating of these 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 holding 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 the 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 numbers 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, (Manual for Land Suitability Classification for Agriculture) has been followed (17). The basic data for Tables 5, 6, 8, 10, 12 and 14 have been taken from this Manual.

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.

A2.2 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 case of the surveyed area, water supply by irrigation is not considered at present.

The water supply under rainfed conditions is dependent on the total amount of rainfall, the potential evapotranspiration and length of the rainy season. By correlating these data with crop growth, a number of climate zones were recognized in Sudan by Van der Kevie (17). These zones are supposed to be significant for the production of agricultural crops. They are based primarily on the water balance, using monthly rainfall and potential evapotranspiration data.

The climate regime of Mishamo Area resembles that of climate zone M3 in Sudan: Wet Monsoon Climate with Medium Wet Season. This regime is characterised in having a water surplus in the rainy season of more than 20 percent of the annual potential evapotranspiration. The growing season is 7 to 9 months, and the average annual rainfall is between 950 mm and 1400. The mean maximum temperature of the hotests month ranges from 34°C to 39°C, and the mean minimum temperature of the coldest month from 12°C to 20°C. The climatic data for Mishamo Area fall within these limits, but temperatures [illegible] are somewhat lower than in zone M3 of Sudan.

The quantity of water available for plant growth that the soil can retain for a significant period is expressed as available water holding capacity (AWC). It can be estimated by determining the moisture content of samples taken at different depths, at field capacity (1/3 bar section) and permanent wilting point (15 bar section). If these measurements are not available, the AWC can estimated from a number of soil characteristics, such as texture, structure, organic matter content, depth and amount of gravells and stones in the profile.

The estimation of AWC as well as the rating and assessment of moisture availability are given in Tables 5, 6 and 7. In these tables, due consideration is given to the marked differences in texture between the topsoil and subsoil as well as to the wide range in depth of the soils of Mishamo Area. It may be also noted that the climate regime M3 of Sudan is assumed for the area.

A2.3 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 and organic matter content, available phosphorus, exchangeable potassium, cation exchange capacity, base saturation and soil reaction. Although the presence of micronutrients such as boron, copper, zinc or sulphur are important for plant growth, no information is available for surveyed area. They are not considered in the rating, therefore.

The rating of this land quality is given in Table 8. The soil fertility status of the soils of the area is assessed in Table 9. It may be noted that available information for an accurate assessment of the phosphorus is not adequate enough. However, the phosphorus content of the soils of the surveyed area, as determined in the laboratory by the method of Bray and Kurtz, may be considered as low or very low. Contents range from 1 to 5 pm.

For further details on analytical data, Appendix 4 of the report should be referred to.

A2.4 DRAINAGE CONDITIONS IN THE GROWING SEASON

The drainage condition of a soil is estimated by the frequency and duration of the period 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.

Since no information is available on ponding hazards, the assessment of this land characteristic for the surveyed area is based on assumptions only. The rating of drainage conditions in the growing season is given in Table 10. The ratings for the land units recognized in the area are shown in Table 11.

A2.5 EROSION HAZARDS

As used here, this land quality refers to the suceptibility of the soils of Mishamo Area to water erosion only. The risk of soil loss by the action of wind is not considered at present.

Since the area is under a protective cover of woodland and grasses, the land shows little or no signs of past water erosion, such as rills and gullies or truncated soils. Accelerated erosion has taken place in some small areas of the colluvial footslopes only, where farmer settlers cleared the woodland for cultivation. Hence the susceptibility of the soils to water erosion is the main factor taken into account for the assessment of erosion hazards in the surveyed area. This susceptibility is inferred from rainfall data, slope gradient and slope length, and soil erodibility which is the inherent susceptibility of the soil to detachment and transport of soil particles by rainfall and run-off. Owing to the limited information available at present, the potential soil losses due to sheet and rill erosion cannot be predicted by the Universal Soil-Loss Equation. Instead the susceptibility to soil erosion is estimated by correlating climatic data, slope characteristics and soil erodibility as applied by Van der Kevie in Sudan (17). Table 12 refers. Soil erodibility has been estimated according to the methodology devised by Erickson (5,16). See Figures 1 and 2. The final rating of both susceptibility to erosion and erosion hazards of the land units recognized in Mishamo area are given in Table 13.

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 Eredibility (Figure 1) 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).

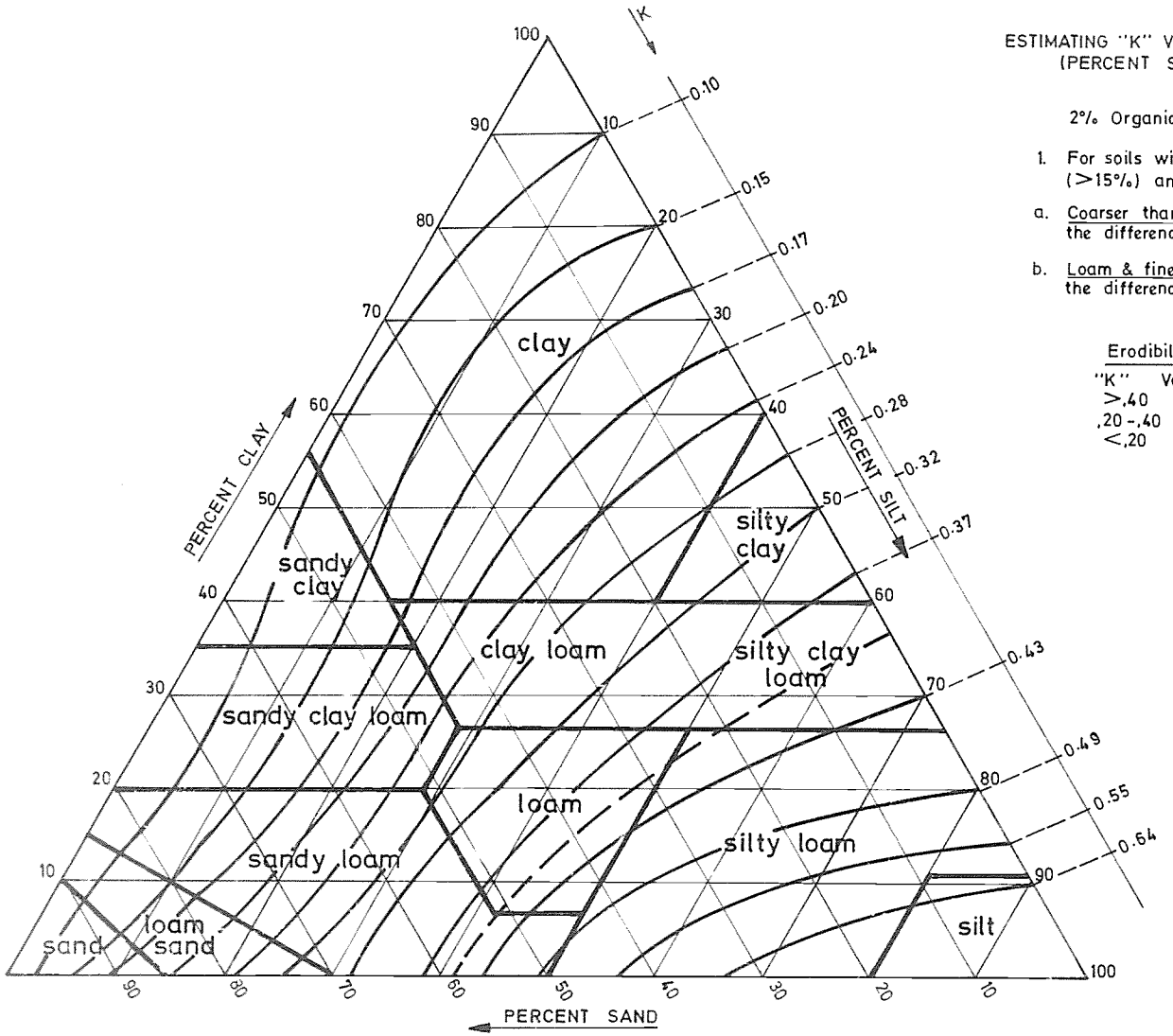


Figure 1 TEXTURAL TRIANGLE NOMOGRAPH FOR SOIL ERODIBILITY

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

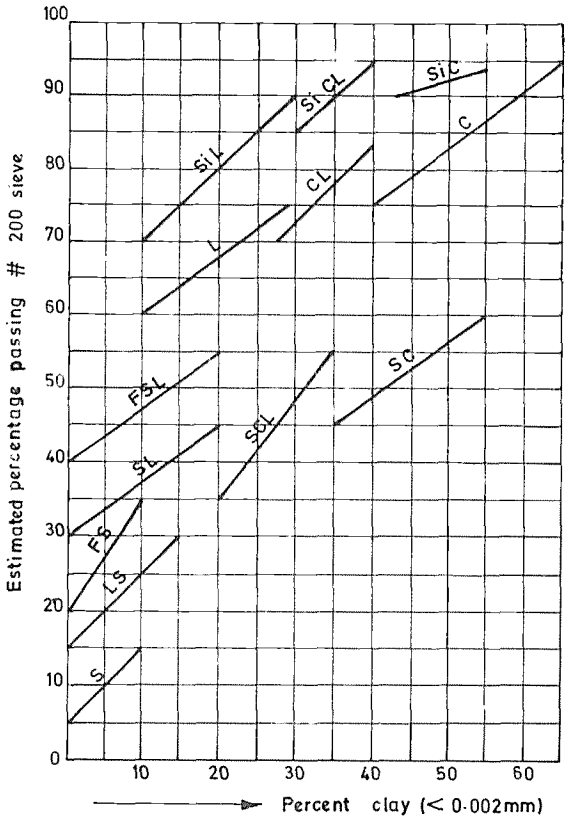
c. Rock Fragments (by Volume)

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 2 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 Ericksor.

The content of very fine sand (0.05-0.10 mm), which is usually not determined in the laboratory, can be estimated as follows :-

i) Estimate percentage of fine fraction ($\leq$ 0.74 mm), by using the diagram given in figure 2, and

ii) Estimate percentage of very fine sand by using the formula % very fine sand = f x (% 0.74 mm - fraction - % 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.

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 sandy clay (SC), sand (S) and fine sand (FS)

A2.6 CAPABILITY FOR MAINTAINING SURFACE WATER

This land quality is rated only in the 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.

If soil textures are favourable, a low permeability can be accomplished by puddling. Fields should be level, with little microrelief which may cause surface run-off or uneven distribution of surface water.

The ratings for this land quality are given in Tables 14 and 15.

Table 5 - Estimation of AWC in cm

Texture of the subsoil 30-120 cm	Texture of the topsoil, 0-30 cm			loam, sandy clay loam and finer
	sand	loamy sand	sandy loam	
Sand	4- 8	n.a.	n.a.	n.a.
loamy sand	7-11	8-12	n.a.	n.a.
sandy loam	10-14	11-15	12-16	n.a.
loam, sandy clay loam & finer	13-14	14-15	15-16	> 16

n.a. - not available in surveyed area

Table 6 - Rating of moisture availability

Estimated AWC in upper 120	Climate regime	Rating		
		Soil depth > 120 cm	Soil depth 50-120 cm.	Soil depth < 50 cm
7 16 cm	M 3	1	2	3
12-16 cm	M 3	2	3	4
8-12 cm	M 3	3	4	4
4- 8 cm	M 3	3	4	4

Table 7 - Rating of moisture availability per land unit - Mishamo Area

Land Unit	Climatic regime	Estimated AWC in upper 120 cm	Soil depth	Rating of land quality
Pw	M 3	8-16 cm	>120 cm	2-3
Ps	M 3	4- 8 cm	>120 cm	3
Pr	M 3	8-16 cm	< 50 cm	4
Pr/Ps	M 3	-	-	3-4
Pm*	M 3	4- 8 cm	>120 cm	2
E	M 3	8-16 cm	≤ 50 cm	4
Cuw	M 3	10-16 cm	>120 cm	1-2
Cuw(e)	M 3	10-16 cm	>120 cm	1-2
Cup*	M 3	10-16 cm	≥120 cm	1
Clw	M 3	10-16 cm	>120 cm	1-2
Clw(e)	M 3	10-16 cm	>120 cm	1-2
Clp*	M 3	10-16 cm	>120 cm	1
Vw	M 3	11-16 cm	< 50 cm	4
Vp*	M 3	4-16 cm	≤ 50 cm	3
Fo*	M 3	≥ 16 cm	>120 cm	1
Fa(Levee)	M 3	4-12 cm	≥120 cm	2
Fa (backswamp)*	M 3	≥ 16 cm	>120 cm	1
Fr	M 3	12_16 cm	>120 cm	2

* These units occur in water-receiving areas

Table 8 - Rating of soil fertility

Rating	Land characteristic						
	pH H2O	% C	% N	P	meq/100 g soil		Base Saturation
					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 9 - Rating of soil fertility per land unit - Mishamo Area

Land unit	Land characteristic							Rating
	pH H2O	%C	%N	P	CEC me/100g	Exch. K me/100g	Base Saturation	
Pw	5.0–6.0	.75–2.25	.05–.15	low	> 20	< .1	10–40	3
Ps	5.0–6.0	.15– .75	.01–.05	low	3–10	< .1	10–40	3
Pr	5.0–6.0	.15–.75	.01–.05	low	3–10	< .1	10–40	3
Pr/Ps	5.0–6.0	.75–2.25	.05–.15	low	3–10	< .1	10–40	3
Pm*	5.0–6.0	.75–2.25	.05–.15	low	10–20	.1–.2	10–40	3
E	5.0–6.0	.75–2.25	.05–.15	low	3–10	.1–.2	40–70	3
Cuw	5.0–6.0	.75–2.25	.05–.15	low	3–10	.1–.2	40–70	3
Cuw(e)*	5.0–6.0	.15– .75	.05–.15	low	3–10	.1–.2	10–40	4
Cup	4.5–5.0	> 2.25	> .15	low	> 20	.2–.4	10–40	3
Clw	5.0–6.0	.75–2.25	.05–.15	low	10–20	.1–.2	40–70	3
Clw(e)*	5.0–6.0	.15– .75	.05–.15	low	3–10	.1–.2	40–70	4
Clp	5.0–6.0	.75–2.25	.05–.15	low	10–20	.1–.2	40–70	3
Vw	5.0–6.0	.75–2.25	> .15	low	10–20	.2–.4	40–70	2
Vp*	5.0–6.0	.75–2.25	> .15	low	10–20	.2–.4	40–70	2
Fo*	4.5–5.0	> 2.25	> .15	low	> 20	.2–.4	10–40	3
Fa(levee)	5.0–6.0	.75–2.25	.05–.15	low	3–10	.1–.2	40–70	3
Fa (backswamp)	4.5–6.0	> 2.25	> .15	low	> 20	.2–.4	10–40	3
Fr	5.0–6.0	.75–2.25	.05–.15	low	3–10	.1–.2	40–70	3

Notes: Values are weighted averages for the upper 0–30 cm of soil

* Assumed values. Analytical data are not available.

Table 10 – Rating of drainage conditions in growing season

Rating	Land characteristic			
	Soil drainage	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 11 – Rating of drainage conditions in growing season per land unit, Mishamo Area

Land Unit	Land Characteristic				Rating
	Soil drainage	Ponding hazard, frequency			
		Every 1–2 years	Every 2–6 years	Every 6–10 years	
Pw	Good	none	none	none	1
Ps	Excessive	none	none	none	1
Pr	Good	none	none	none	1
Pr/Ps	Good to excessive	none	none	none	1
Pm	Poor	2–6 weeks	6–10 weeks	>10 weeks	4
E	Excessive	none	none	none	1
Cuw	Good	none	none	none	1
Cuw(e)	Good	none	none	none	1
Cup	Imperfect to poor	2–6 weeks	6–10 weeks	>10 weeks	3–4
Clw	Good to imperfect	none	<2 weeks	2–6 weeks	1–2
Clw(e)	Good	none	none	none	1
Clp	Imperfect to poor	2–6 weeks	6–10 weeks	10 weeks	3–4
Vw	Good	none	none	none	1
Fo	Poor	2–6 weeks	6–10 weeks	>10 weeks	4
Fa levee	Moderately good	none	<2 weeks	2–6 weeks	2
Fa swamp	Poor	2–6 weeks	6–10 weeks	>10 weeks	4
Fr	Good	none	none	none	1

Table 12 - Rating of susceptibility to soil erosion of an unprotected soil

Climate zone*	Slope percent	Susceptibility to soil erosion		
		Low erodibility factors (K<.20)	Moderate erodibility factor (K .20-.40)	High erodibility factor (K>.40)
M 3	0-1	insignificant	slight	moderate
M 3	1-3	slight	moderate	severe
M 3	3-8	moderate	severe	severe
M 3	>8	severe	severe	severe

* As in the case of the land quality Moisture Availability the climatic conditions of Zone M 3 of Sudan have been assumed for the surveyed area.

Table 13 - Rating of susceptibility to soil erosion and erosion hazards per land unit - Mishamo Area

Land Unit	Slope percent	Erodibility factor (K)	Susceptibility to erosion	Rating of erosion hazards
Pw	2-8	moderate	moderate to severe	3-4
Ps	2-8	low	slight to moderate	2-3
Pr	2-8	low	slight to moderate	2-3
Pr/Pm	2-8	low	slight to moderate	2-3
Pm	0-2	low	insignificant to slight	1-2
E	>8	moderate	severe	4
Cuw	2-8	moderate	moderate to severe	3-4
Cuw(e)	2-8	moderate	moderate to severe	4
Cup	2-3	moderate	moderate	3
Clw	1-2	moderate	slight	2
Clw(e)	1-2	moderate	slight	3-4
Clp	1-2	moderate	slight	2
Vw	0-1	low	insignificant	1
Vp	0-1	low	insignificant	1
Fo	0-1	low	insignificant	1
Fa(levee)	0-1	low	insignificant	1
Fa(backswamp)	0-1	low	insignificant	1
Fr	0-1	moderate	slight	2

* As units Fo and Fa are subject to deposition rather than erosion, the K factor has not been estimated.

Table 14 - Rating of capability for maintaining surface water

Rating	Land Characteristic			
	Slope %	Microrelief cm*	Drainage class	Texture of surface and subsurface horizon
1	< 0.5	0-5	imperfectly to poorly drained	clay, silty clay, sand 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
3	< 3	> 20	excessively to well drained	clay to sand

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

Table 15 - Rating of capability for maintaining surface water per land unit Mishamo Area

Land Unit	Land Characteristic				Rating
	Slope %	Microrelief cm	Drainage class	Texture of surface and subsurface	
Pw	2-8	> 20	well drained	sand to sandy loam	4
Ps	2-8	> 20	somewhat excessively drained	sand	4
Pr	2-8	> 20	well drained	sand to sandy loam	4
Pr/Ps	2-8	> 20	well drained	sand to sandy loam	4
E	8	> 20	somewhat excessively drained	sand to sandy loam	4
Cuw	2-8	> 20	well drained	sand to loam	4
Cuw(e)	2-8	> 20	well drained	sand to loam	4
Cup	2	5-10	imperfectly and poorly drained	sand loam to sandy clay loam	2
Clw	1-2	> 20	imperfectly to well drained	sand to loamy sand	4
Clw(e)	1-2	> 20	well drained	sand to loamy sand	4
Clp	1-2	5-10	imperfectly to poorly drained	sandy loam to sandy clay loam	2
Vw	0-1	10-20	well drained	gravelly sand loam to sandy clay loam	4
Vp	0-1	5-10	poorly drained	sand to sandy clay	2-4
Fo	0-1	0-5	poorly drained	clay loam and clay	1
Fa levee	0-1	> 20	moderately well	sand to sandy loam	4
Fa swamp	0-1	0-5	poorly drained	clay loam and clay	1
Fr	0-1	> 20	well drained	loamy sand to sandy loam	

APPENDIX 3

DESCRIPTION OF THE SOILS AND ANALYTICAL DATA

Technical descriptions 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 in the legend of the soils map and in Chapter 1 (Soils) of the report. Each soil is classified in terms of both the Legend of the FAO/UNESCO Soil Map of the World (8) and the USDA Soil Taxonomy (15). In describing the soils the nomenclature of the USDA Soil Survey Manual (14) and the FAO Guidelines for Soil Profile Description (7) have been followed. Colour notation is according to the Munsell Colour Charts (10).

A3.1 SOILS OF THE PLATEAUX

MAPPING UNIT Pw

This unit includes a number of well drained, deep, predominantly brownish soils of variable textures, occuring in a complex pattern. They are classified as Dystric Cambisols in the FAO Legend and Ustic Dystropepts in the USDA Soil Taxonomy. Major soils are as follows:-

(i) Dark brown to very dark greyish brown sand to loamy sand A horizon overlying a strong brown to yellowish brown sandy loam or sandy clay loam, rarely sandy clay, B horizon.

(ii) As above, but sandy loam A horizon over a sandy clay loam B horizon.

(iii) As (i), but yellowish red upper B horizon. It occupies less than 15% of the area.

(i) Typical profile 132/2/192

Location: grid TJ 130 796

Date of examination: 26/7/1978. Authors: E. Bomans, J. Hof

Landform: undulating plateau

Site: almost flat, 2%slope

Microrelief: scattered termite mounds

Elevation: 1,470 m

Parent material: weathered shale

Moisture condition: moist below 80 cm

Groundwater: none. Drainage class: well drained

Rock outcrops/surface stones: none. Erosion/deposition: none

A	0-15 cm	Very dark brown (10YR2/2) moist and very dark greyish brown (10YR3/2) dry; loamy sand; moderate weak crumb; very friable moist, nonsticky, nonplastic wet; many fine interstitial pores; many fine roots; clear smooth boundary.
Bw1	15-75 cm	Yellowish brown (10YR5/4) moist and light yellowish brown (10YR6/4) dry; sandy clay loam, moderate fine and medium subangular blocky, friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; many fine roots; gradual smooth boundary.

Bw2 75-185 cm Yellowish brown (10YR5/4) moist and pale brown (10YR6/3) dry; sandy clay loam; weak medium subangular blocky; friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; common fine roots.

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text class	Silt/clay
II.6523	0-15	85	2	2	11	LS	0/37
24	15-75	65	5	4	26	SCL	0.35
25	75-185	64	4	3	27	SCL	0.23

O.C %	N %	C/N	pH H_2O	pH $CaCl_2$
2.51	0.09	23	5.3	4.2
0.39	0.02	19	5.2	4.0
0.29	0.13	2	5.8	5.1

(ii) Typical profile 133/1/161

Location : grid TJ 280 814, 300m from Magunga CW camp, 150 m west of road to Uvinza.

Date of examination: 14 July 1978 - Authors: E. Mosha, A. Kiwelu, L. Dagaa

Landform: undulating plateau

Site: gently sloping, 2% slope

Microrelief: scattered termite mounds

Elevation: 1,470 m

Parent material: weathered shale

Moisture condition: moist below 39 cm

Groundwater: none. Drainage class: Well drained

Rock outcrops/surface stones: none. Erosion/deposition: none

Au 1 0-3/5 cm Very dark greyish brown (10YR3/2) moist end dark greyish brown (10YR4/2) dry; sandy loam; weak fine and medium subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; many fine and medium tubular pores; many very fine and fine roots; few charcoal fragments; clear wavy boundary.

Au2	3/5-11/15 cm	Dark brown (10YR3/3) moist and brown to dark brown (10YR4/3) dry; sandy loam; moderate fine and medium subangular blocky; slightly hard dry, friable moist, nonsticky, nonplastic wet; many fine and medium tubular and interstitial pores; clear wavy boundary.
BA	11/15-30 cm	Brown to dark brown (7.5YR4/4) moist; sandy clay loam; strong medium and coarse subangular blocky; friable moist, slightly plastic wet; many fine and medium tubular pores; gradual smooth boundary.
Bw1	39-70 cm	Brown (7.YR5/4) moist; sandy clay loam; moderate medium and coarse subangular blocky; friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; few fine and common coarse roots; gradual smooth boundary.
Bw2	70-230 cm	Strong brown (7.5YR5/6) moist; sandy clay loam; fine and medium subangular blocky; friable moist, sticky, slightly plastic wet; pores not recorded; few fine, few medium and coarse roots.

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/clay
11.6918	0-3/9	81	3	2	14	SL	0.3
19	3/19-11/5	80	3	2	19	SL	0.3
20	11/5-39	69	9	2	24	SCL	0.3
21	39-70	69	2	3	26	SCL	0.2
22	70-230	67	2	4	27	SCL	0.2

O.C %	N %	C/N	Exchangeable cations (meq/100 g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
2.98	0.17	18	0.04	0.10	3.20	1.60	3.00	4.94	7.94
1.12	0.10	11	0.04	0.10	3.20	1.60	7.00	4.95	11.95
0.84	0.06	13	0.04	0.04	2.40	2.00	5.00	4.48	9.48
0.37	0.09	7	0.04	0.03	2.80	1.20	4.00	4.08	8.08
0.37	0.04	9	0.04	0.04	3.20	1.20	4.00	4.48	8.48

H_2O pH	$CaCl_2$	Sum bases clay meq/100 g	CEC clay meq/100 g	ESP	base saturation %	P ppm	E.C. (mmho/cm)
5.5	4.6	35	56	0.98	62	3.0	0.26
5.4	4.4	32	78	0.36	41	0.6	0.24
5.6	5.0	19	41	0.45	47	0.0	0.10
5.5	4.3	16	31	0.93	50	0.0	0.11
5.2	4.5	16	31	0.46	53	13-7	0.12

(iii) Typical profile 132/2/191

Location: grid TJ 150 781

Date of examination: 26/7/78. Authors: L. Dagaa, A. Kiwelu

Landform: undulating plateau

Site: almost flat, 2% slope

Microrelief: scattered termite mounds, 1.5 m high

Elevation: 1,400 m

Parent material: weathered shale

Moisture condition: slightly moist between 20-80 cm, moist below

Groundwater: none. Drainage class: well drained

Rock outcrops/surface stones; none. Erosion/deposition: none

A	0-7 cm	Dark brown (7.5YR3/2) moist and brown to dark brown (7.5YR4/2) dry; loamy sand; weak fine and medium subangular blocky; soft dry, very friable moist, nonsticky, nonplastic wet; fine and medium tubular pores; many fine and very fine roots; gradual smooth boundary.
Bw1	7-48 cm	Reddish brown (5YR4/4) moist and brown (7.5YR5/4) dry; sandy loam; moderate medium subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; common fine and medium tubular pores; few fine, common medium and coarse roots; gradual smooth boundary.
Bw2	48-80 cm	Yellowish red (5YR4/6) moist and (5YR5/6) dry; sandy loam; moderate medium subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; common fine and medium tubular pores; few fine, common medium and coarse roots; gradual smooth boundary.
Bw3	80-312 cm	Strong brown (5YR5/6) moist; sandy clay loam; moderate subangular blocky; friable moist; slightly sticky; slightly plastic wet; few fine tubular pores; few medium and coarse roots.

Environmental characteristics

These soils are developed in a thick regolith of weathered shale, under vegetation of miombo woodland with a ground cover of medium and short grasses. They occupy undulating, moderately dissected plateaux having scattered termite mounds upto 2 m high. Dominant slopes are 2-8 percent.

Land use

None, except for some honey from wild bees.

Soil analytical data

Sample	Depth	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text class	Silt/clay
11.6482	0- 7	85	5	1	9	LS	0.7
83	7- 48	79	4	0	17	SL	0-3
84	48- 80	79	2	1	18	SL	0-2
85	80-202	80	1	0	20	SCL	0.1
86	202-312	75	4	1	20	SCL	0.2

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum	CEC soil (sum)
1.51	0.11	14	0.06	0.02	2.80	2.00	1.00	4.88	5.88
0.81	0.07	12	0.06	0.02	2.00	1.60	21.00	3.68	24.68
0.46	0.06	7	0.06	0.02	2.00	1.60	4.00	3.68	7.68
0.46	0.04	10	0.06	0.02	2.40	0.80	2.00	3.27	5.27
0.41	0.03	14	0.06	0.01	2.00	2.00	2.00	4.01	6.01

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100 g	CEC clay meq/ 100g	ESP	base saturation %	P ppm	E.C. (mmho/cm)
5.4	4.6	51	61	1.0	83	3.9	0.14
5.2	4.4	22	147	0.2	15	1.2	0.15
5.3	4.7	20	41	0.8	48	1.4	0.10
5.4	5.0	17	27	1.1	62	3.4	0.13
5.2	4.6	20	30	1.0	67	1.1	0.06

MAPPING UNIT Ps

This unit include deep, well to somewhat excessively drained, yellowish brown sands having weak structural development. They are Cambic Arenosols in the FAO Legend and Ustic? Quartzipsamments in the USDA Soil Taxomony.

Typical profile 132/2/167

Location: grid TJ 119 794
Date of examination: 17/7/78. Authors: L. Daggaa, E. Bomans, E. Mosha.
Landform: gently sloping, 2% slope
Microrelief: none
Parent material: weathered sandstone
Moisture condition: dry to 30 cm, slightly moist to 120 cm, moist below
Ground water: unknown. Drainage class: somewhat excessively drained
Rock outcrops/surface stones: none. Erosion/deposition: none

A 0-3 cm Very dark grey (10YR3/1) moist and dark grey (10YR4/1) dry; sand; very weak crumb; soft dry, very friable moist, nonsticky, nonplastic wet; common fine and very fine roots; clear smooth boundary.

Cu1 3-170 cm Dark yellowish brown (10YR4/4) moist and light yellowish brown (10YR6/4) dry; sand; single grain; loose dry, very friable moist, nonsticky, nonplastic wet; very few fine roots; clear smooth boundary.

Cu2 170 cm + Light yellowish brown (10YR6/4) moist, few fine distinct clear strong brown (7.5YR5/6) mottles; sand; single grain; very friable moist, nonsticky, nonplastic wet; very few fine roots

Range of profile characteristics

Texture of the profile is usually sand, sometimes loamy sand. The A horizon ranges from 3 to 15cm in thickness, colour of the C layers from light yellowish brown to brown. Drainage varies from good to somewhat excessive.

Environmental characteristics

These soils are developed in a thick regolith of weathered sandstone, under a vegetation of Brachystegia woodland with some open patches of grasses. They occupy undulating, moderately dissected plateaux, with scattered termite mounds up to 2 m high. Dominant slopes are 2-8 percent.

Land use

None, except for some honey from wild bees.

MAPPING UNIT Pr

This unit mainly includes sandstone outcrops and boulders. Shallow, often gravelly soils occur in small patches only. Vegetation is scarce and consists of scattered trees and grasses. The soils of this unit were not studied in detail during the survey.

MAPPING UNIT Pr/Ps

This unit occupies undulating, moderately dissected plateau areas and consists of sandstone outcrops, boulders and deep sandy soils occuring in a complex pattern. The soils are developed in weathered sandstone and are similar in characteristics to those of mapping unit Ps.

MAPPING UNIT Pm

This unit includes poorly drained, deep, dark-coloured sands occupying shallow depressions on the plateaux. These soils are Humic Gleysols in the FAO Legend and Tropaquents in the USDA Soil Taxonomy.

Typical profile 132/2/170

Location: grid TJ 128 745
Date of examination: 18/7/78. Authors: E. Mosha, E. Bomans
Landform: shallow depression in plateau
Site: flat, less than 1% slope
Microrelief: none
Elevation: 1,380 m
Parent material: weathered sandstone
Moisture condition: moist to 15 cm, wet below
Groundwater: 55cm. Drainage class: poorly drained
Rock outcrops/surface stones: none. Erosion/deposition: none

A	0-50 cm	Black (10YR2/1) moist; sand; very weak medium crumb; very friable moist, nonsticky; nonplastic wet; many fine and medium roots
Cu1	50-100 cm	Very dark brown (10YR2/2) moist; sand; single grain; nonsticky, nonplastic wet; very few fine and medium roots
Cu2	100-120 cm	Dark greyish brown (10YR4/2) moist; sand; single grain; nonsticky, nonplastic wet; very few fine and medium roots

Range of profile characteristics

The A horizon usually ranges from 25 to 50 in thickness, but in some profiles it is as thin as 15 cm. Depth to the groundwater varied from 40 to 100 cm at the time of the survey.

Environmental characteristics

These poorly drained soils are developed in weathered sandstone, under a vegetation of short and medium grasses. They occupy flat, shallow depressions on the plateau. Dominant slopes do not exceed 1 percent.

Land use

none.

A3.2 SOILS OF THE ESCARPMENTS

MAPPING UNIT E

This unit occupies nearly vertical sandstone and shale escarpments with associated bouldery slopes. Dominant slope gradients are 8-50 percent on the bouldery slopes and generally more than 100 percent on the rocky scarps. The soils usually overlie weathered shale, occur in scattered patches and mainly consist of shallow, gravelly loamy sands to sandy clay loams. The natural vegetation ranges from isolated trees to open woodland.

The soils of this unit were not studied in detail. The profile description which follows below is an example only of the range of soils that may be encountered. It is classified as Dystrict Regosol lithic phase in the FAO Legend and Lithic Ust0rthents in the USDA Soil Taxonomy. Some of the soils overlie hard, slightly weathered sandstone at less than 10 cm of the surface. These soils are Lithosols in the FAO Legend and Lithic Ustorthents in the USDA Soil Taxonomy.

Profile 132/2/190

Location: grid TJ 177 791
Date of examination: 26/7/78. Authors: J. Magoggo, A. Kiwelu, L. Daggaa
Landform: escarpment
Site: sloping, 7% slope
Microrelief: common termite pillars less than 20 cm high
Elevation: 1,360 m
Parent material: weathered shale
Moisture condition: dry to 17 cm, slightly moist below
Groundwater: none. Drainage class: well drained
Rock outcrops/surface stones: many rock outcrops and boulders
Erosion/deposition: none

Au1	0-4 cm	Dark greyish brown (10YR4/2) moist and greyish brown (10YR5/2) dry; gravelly loamy sand; weak fine and medium subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; common medium tubular pores; many fine and fine roots; abrupt smooth boundary

Au2	4-28 cm	Brown to dark brown (10YR4/2) moist and pale brown (10YR5/3) dry; very gravelly sandy loam; weak fine and medium subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; common medium tubular pores; many fine and very fine, few coarse roots.
R	32cm+	Slightly weathered shale

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/ Clay
11.6487	0-4	87	4	2	7	LS	0.8
88	4-28	80	4	3	13	SL	0.5

O.C %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
1.80	0.15	12	0.06	0.19	2.40	2.80	8.00	5.46	13.46
1.04	0.09	9	0.06	0.15	2.00	2.80	4.00	5.01	9.01

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100g	CEC clay meq/ 100g	ESP	base saturation %	P ppm	E.C. (mmho/cm)
5.4	5.0	72	177	0.48	41	6.4	0.25
5.5	4.6	37	66	0.62	56	2.0	0.13

A3.3 SOILS OF THE COLLUVIAL FOOTSLOPES, UPPER PARTS

MAPPING UNITS Cuw and Cuw(e)

This unit includes well drained, deep, strong brown or yellowish red soils of variable textures, occuring in a complex pattern. They are Dystric Combisols in the FAO Legend and Ustic Dystropepts in the USDA Soil Taxonomy. Major soils are as follows:-

(i) Brown to very dark greyish brown sandy loam A horizon overlying strong brown or yellowish red sandy clay loam to sandy clay B horizon.

(ii) As above, but sand or loamy sand A horizon over a sandy loam to sandy clay loam B horizon.

(i) Typical profile, 133/1/2

Location: grid TJ 895 798

Date of examination: 25/5/78. Authors: E. De Pauw, J. Magoggo

Landform: colluvial footslope, upper part

Site: sloping, 6 % slope

Microrelief: none

Elevation: 1,430 m

Parent material: mixed colluvium of sandstone and shale

Moisture condition: dry to 40 cm, moist below

Groundwater: unknown. Drainage class: well drained

Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-4/8 cm	Very dark greyish brown (10YR3/2) moist and dark greyish brown (10YR4/2) dry; loamy sand; moderate fine and medium subangular blocky; slightly hard dry, friable moist, nonsticky, nonplastic wet; many fine and very fine, common medium and coarse roots; many fine and few medium pores; clear wavy boundary.
Au2	4/8-12/20 cm	Dark brown (10YR3/3) moist and brown to dark brown (10YR4/3) dry; loamy sand; moderate fine and medium subangular blocky; slightly hard dry, friable moist, nonsticky, nonplastic wet; common medium and coarse many fine tubular pores; clear wavy boundary.
Bw1	12/20-90 cm	Brown (7.5YR4/3) moist; sandy loam; weak medium and fine subangular blocky; friable moist, nonsticky, nonplastic wet; common medium and coarse roots; many fine tubular pores; gradual smooth boundary.
Bw2	90-120 cm	Brown to dark brown (7.5YR4/4) moist, sandy loam; weak subangular blocky; friable moist, nonsticky, nonplastic wet; few fine, common coarse and medium roots; many fine tubular pores; gradual smooth boundary.
Bw3	120-160 cm	Strong brown (7.5YR5/6) moist; sandy loam; weak subangular blocky; friable moist, nonsticky, nonplastic wet; few fine, common coarse and medium roots; many fine tubular pores; clear smooth boundary.
2Bw4	160-200 cm	As Bw3, but sandy clay loam in texture.

Soil analytical data

Sample	Depth cm	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/ Clay
11.6506	0-4/8	84	4	1	11	LS	0.40
07	4/8-12/20	87	1	1	11	LS	0.14
08	12/20-90	80	3	2	15	SL	0.32
09	12/20-90	79	2	3	16	SL	0.32
10	90-120	79	4	2	15	SL	0.37
11	120-160	77	4	3	16	SL	0.45
12	160-200	67	2	2	29	SCL	0.12

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
3.35	0.30	11	0.05	0.17	5.20	0.80	9.00	6.23	15.23
0.93	0.11	9	0.04	0.12	2.80	1.20	5.00	4.16	9.16
0.56	0.08	7	0.05	0.12	2.40	0.80	1.00	5.37	4.37
0.28	0.07	4	0.05	0.10	1.60	1.20	1.60	2.96	3.96
0.28	0.04	6	0.05	0.09	2.40	0.80	3.00	3.34	6.34
0.27	0.04	6	0.04	0.09	2.00	0.80	1.00	2.93	3.93
0.28	0.08	4	0.05	0.12	2.40	1.60	2.00	4.17	6.17

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100 g	CEC clay meq/ 100g	ESP	base saturation %	P ppm	E.C. (mmho/cm)
5.2	4.4	59	144	0.34	41	1.1	0.28
5.3	4.3	37	82	0.47	45	0.0	0.21
5.6	4.8	36	29	1.10	77	0.0	0.16
5.3	4.1	19	25	1.31	75	0.0	0.21
5.4	4.2	22	42	0.76	53	0.0	0.25
5.2	4.3	18	25	1.09	75	0.0	0.47
5.3	4.0	14	21	0.84	68	12.1	0.21

(ii) Typical profile 132/2/85

Location: grid TJ 224 739
Date of examination: 20/6/1978. Authors: E. Mosha, L. Daggaa, J. Magogo
Landform: colluvial footslope, upper part
Site: sloping, 5% slope
Microrelief: scattered termite mounds
Elevation: 1,360 m
Parent material: mixed colluvium from shale and sandstone
Moisture condition: dry to 30, slightly moist to 60 cm, moist below
Groundwater: none. Drainage class: well drained.
Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-5/7 cm	Very dark greyish brown (10YR3/2) moist and dark greyish brown (10YR4/2) dry; sandy loam; moderate fine crumb; moist friable, nonsticky nonplastic wet; many fine pores; many fine roots; abrupt wavy boundary
Au2	5/7-12/20 cm	Brown to dark brown (10YR4/3) moist and brown (10YR5/3) dry; sandy loam; moderate fine subangular blocky; friable moist, slightly sticky slightly plastic wet; many fine pores; common fine and coarse roots; very few shale fragments; clear wavy boundary.
Bw1	12/20-50 cm	Yellowish red (5YR4/6) moist and strong brown (7.5YR5/6) dry; sandy clay loam; moderate fine subangular blocky; friable moist, slightly sticky slightly plastic wet; many fine pores; common fine and coarse roots; very few diffuse smooth boundary.
Bw2	50-140 cm	Yellowish red (5YR4/6) moist; sandy clay; moderate medium subangular blocky; moist friable, sticky and plastic wet; few fine and common medium roots; very few shale fragments.

Environmental characteristics

These well drained soils are developed in unconsolidated colluvial materials derived from shale and sandstone, under a vegetation of Brachystegia woodland with a ground cover of short and medium grasses. They occupy the sloping upper parts of the colluvial footslopes which lie between the escarpments and the valley floor basement or floodplain. Unit Cuw(e) is closely dissected by deep gullies. Slope gradient ranges from 2 to 8 percent.

Land use

None, except for some honey from wild bees. In the past, dry-land farming was practised in unit Cuw(e).

Soil analytical data

Sample	Depth cm	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/ clay
11.6513	0-5/7	69	12	5	14	SL	1.3
14	5/7-12/20	68	9	5	18	SL	0.8
15	12/20-50	51	13	6	30	SCL	0.6
16	50-140	48	5	4	43	SC	0.3

O.C %	N %	C/N	Exchangeable cations(meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
2.32	0.20	12	0.06	0.37	5.60	2.40	2.00	8.44	10.44
0.74	0.11	7	0.05	0.18	4.00	1.60	3.00	5.83	8.83
0.74	0.10	7	0.06	0.36	4.40	1.60	7.00	6.42	13.42
0.37	0.08	5	0.16	0.88	2.80	2.80	3.00	6.64	9.64

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100 g	CEC clay meq/ 100g	ESP	base Saturation %	P ppm	EC (mmho/cm)
5.3	4.5	62	77	0.62	80	1.1	0.49
5.0	3.9	33	50	0.54	66	0.0	0.15
5.5	4.5	21	44	0.42	48	0.0	0.66
5.3	4.8	15	22	1.61	69	0.0	0.09

MAPPING UNIT Cup

This unit is occupied by a number of imperfectly and poorly drained, sometimes moderately well drained, soils occuring in a complex pattern.

Major soils are as follows:-

(i) Imperfectly and poorly drained, dark brown and grey soils of variable textures the A horizon is usually sandy clay loam, sometimes and or loam sand; the B horizon ranges from sandy loam to sandy clay. They are classified as Gleyic Cambisols in the FAO Legend and Aeric Tropaquepts in the USDA Soil Taxonomy.

(ii) Moderately well drained, yellowish brown to pale brown sandy loams and sandy clay loams with prominent mottles, covering less than 10 percent of the area. They are Dystric Cambisols in the FAO Legend and Ustic Dystropepts in the USDA Soil Taxonomy.

(i) Typical profile, 131/1/134

Location: grid TJ 270 794
Date of examination: 3/7/1978. Authors: L. Dagaa, J. Hof.
Landform: colluvial footslope, upper part
Site: almost flat, 2% slope
Microrelief: none
Elevation: 1,290 m
Parent material: mixed colluvial materials derived from sandstone and shale
Moisture condition: moist throughout
Groundwater: 100 cm. Drainage class: imperfectly drained.
Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-10 cm	Dark greyish brown (10YR4/2) moist; loamy sand; weak fine and medium subangular blocky structure; very friable moist, nonsticky, nonplastic wet; common fine tubular pores; clear smooth boundary.
Au2	10-25	As Au1, but brown to dark brown (10YR4/3) moist
BW	25-80 cm	Brown to dark brown (10YR4/3) moist, common medium distinct clear yellowish brown (10YR5/8) mottles; sandy loam; weak fine and medium subangular blocky; friable moist, slightly sticky, slightly plastic wet; pores and roots not recorded; clear smooth boundary.
Cg1	80-150 cm	Light grey (10YR6/1) and yellowish brown (10YR5/4) moist, many medium distinct clear yellowish brown (10YR5/8) mottles; sandy loam; massive; friable moist, slightly sticky, slightly plastic wet; pores and roots not recorded; few (less than 3%) small, irregular ironstone fragments; clear smooth boundary.
Cg2	150-200 cm	Pinkish grey (7.5YR4/8) moist, many coarse prominent clear red (2.5YR4/8) mottles; coarse sandy loam; massive; friable moist, slightly sticky, slightly plastic wet; pores and roots not recorded; few (less than 3%) small, irregular ironstone fragments

(ii) Typical profile 133/1/19

Location: grid TJ 359 818

Date of examination: 27/5/1978. Author/s: E. De Pauw

Landform: colluvial footslope, upper part

Site: gently sloping, 4% slope

Microrelief: scattered termite mounds

Elevation: 1,340 m

Parent material: colluvium probably derived from sandstone

Moisture condition: moist throughout

Groundwater: unknown. Drainage class: moderately well drained

Rock outcrops/surface stones: none. Erosion/deposition: none

Ag	0-4/6 cm	Very dark greyish brown (10YR3/2) moist and greyish brown (10YR5/2) dry, many fine distinct clear dark yellowish brown (10YR3/4) mottles; sandy loam; weak fine and medium subangular blocky; moist friable, nonsticky, nonplastic wet; many fine and few medium tubular pores; abrupt wavy boundary.
Bwg1	4/6-20 cm	Yellowish brown (10YR5/4) moist, many fine faint clear strong brown (7.5 YR5/8) mottles; sandy loam; weak fine and medium subangular blocky; friable moist, nonsticky, nonplastic wet; many fine and few medium tubular pores; common fine and medium, few coarse roots; gradual smooth boundary.
Bwg2	20-50 cm	Yellowish brown (10YR5/4) moist; many medium and coarse, faint clear strong brown (7.5YR5/6) mottles; sandy loam; weak fine and medium angular blocky, friable moist, slightly sticky, slightly plastic wet; many fine and common medium tubular pores; common fine and medium few coarse roots; gradual smooth boundary
Bwg3	50-82/92 cm	Pale brown (10YR6/3) moist, many medium and coarse faint diffuse brownish yellow (10YR6/6) mottles; sandy loam; weak fine angular blocky; friable moist, slightly sticky, slightly plastic wet; many fine and medium tubular pores; common medium, few coarse roots; gradual smooth boundary.
Bwg4	82/92-140	Pale brown (10YR6/3) moist, many medium and coarse faint diffuse brownish yellow (10YR6/6) mottles; sand loam; weak fine angular blocky; friable moist, slightly sticky, slightly plastic wet; many fine and medium tubular pores; few fine and medium roots; frequent (about 25%) small, soft, irregular red nodules.

Environmental characteristics

These soils occupy the gently sloping upper parts of the colluvial foot-slopes and are developed in colluvial materials derived from sandstone and shale. Dominant slope gradient is 2-3 percent. The vegetation mainly consist of short and medium grasses, with some Terminalia trees on the better drained sites.

Land use

None

Soil analytical data

Sample	Depth cm	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/ clay
11.6651	0-4/6	66	4	14	16	SL	1.12
52	4/6-20	65	5	14	16	SL	1.09
53	20-50	64	6	12	18	SL	0.96
54	50-82/92	67	3	14	16	SL	1.00
55	82/92-140	66	7	8	19	SL	0.82

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
2.23	0.17	13	0.13	0.15	2.00	2.00	1.00	4.27	5.27
0.16	0.03	8	0.09	0.09	1.20	1.60	2.00	2.98	4.98
0.19	0.04	5	0.09	0.08	2.40	2.40	2.00	4.98	6.98
0.19	0.02	9	0.09	0.08	2.80	2.40	6.00	5.37	11.37
0.28	0.01	28	0.10	0.09	2.40	3.20	7.00	5.75	12.75

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
4.7	4.0	27	33	2.37	81	0.0	0.46
5.0	4.5	18	30	1.81	60	0.0	0.23
5.5	4.8	27	38	1.36	71	0.0	0.23
5.8	5.0	33	69	0.79	47	0.0	0.20
6.1	5.3	31	69	0.78	45	0.0	0.24

43.4 SOILS OF THE COLLUVIAL FOOTSLOPES, LOWER PARTS

MAPPING UNIT Clw and Clw(e)

The soils of these units are classified as Dystric Cambisols in the Legend and Ustic Dystropepts in the USDA Soil Taxonomy. Major soils are as follows:

(i) Deep, well drained soils having a very dark greyish brown to dark brown, sometimes black, sand or loamy sand A horizon overlying a yellowish brown, brown or strong brown sandy loam to sandy clay loam horizon.

(ii) As above, but moderately well or imperfectly drained soils, often with ironstone gravels below 1 m.

(i) Typical profile, 133/1/121

Location: grid TJ 352 822
Date of examination: 29/5/78. Authors: J. Magogo, E. Bomans
Landform: colluvial footslope, lower part
Site: almost flat, 1.5% slope
Microrelief: scattered termite mounds
Elevation: 1,340 m
Parent material: colluvium from sandstone and shale
Groundwater: 220 cm. Drainage class: well drained
Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0–5 cm	Black (10YR2/1) moist and very dark grey (10YR3/1) dry; loamy sand; weak fine crumb; loose dry; very friable moist, nonsticky, nonplastic wet; many fine tubular pores; many fine roots; clear smooth boundary.
Au2	5–13 cm	Dark greyish brown to brown (10YR4/2.5) moist and brown (10YR5/3) dry; loamy sand; moderate fine crumb; soft dry, very friable moist, nonsticky, nonplastic wet; many fine tubular pores; many fine and common medium roots; clear smooth boundary.
BA	13–31/33 cm	Dark greyish brown to brown (10YR4/2.5) moist and brown (10YR5/3) dry; sandy loam; moderate medium and coarse subangular blocky; soft dry, friable moist, nonsticky, nonplastic wet; many fine tubular pores; common fine few medium and coarse roots; gradual smooth boundary.
Bw1	31/33–84 cm	Brown (10YR5/3) moist; sandy loam; moderate coarse subangular blocky; slightly hard dry; friable moist, nonsticky, nonplastic wet; many fine tubular pores; few fine and coarse, common medium roots; clear, smooth boundary.

Bw2 84-115 cm — Brown (10YR5/3) moist, sandy clay loam; moderate coarse subangular blocky; friable moist, slightly sticky, slightly plastic wet; many fine, few medium tubular pores; few fine and medium roots; clear smooth boundary

Bw3 115-160 cm — As Bw2, but few medium prominent clear red (10YR4/6) mottles.

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/clay
11.6561	0-5	82	4	3	11	LS	0.64
62	5-13	84	3	3	10	LS	0.58
63	13-31/33	80	2	2	16	SL	0.28
64	31/33-84	75	4	3	18	SL	0.38
66	84-160	65	4	4	27	CL	0.28

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
3.10	0.30	10	0.05	0.20	5.20	6.00	8.00	11.45	19.45
1.22	0.15	8	0.05	0.11	2.00	2.80	2.00	4.96	6.96
0.37	0.08	5	0.06	0.13	2.40	1.60	4.00	4.18	8.18
0.47	0.07	7	0.06	0.14	4.00	1.60	7.00	5.80	12.80
0.27	0.07	4	0.06	0.16	2.00	2.80	6.00	5.03	11.03

pH H_2O	pH $CaCl_2$	Sum bases clay meq/100g	CEC clay meq/	ESP	base Saturation %	P ppm	EC (mmho/cm)
5.3	4.2	102	174	0.25	59	3.6	0.26
5.5	4.6	50	70	0.69	71	2.9	0.17
5.8	5.2	26	52	0.68	51	0.4	0.19
5.8	5.0	32	70	0.47	45	0.0	0.11
5.2	4.3	19	40	0.59	46	0.0	0.11

Clay

(ii) Typical profile , 133/1/22

Location: grid TJ 348 822

Date of examination: 29/5/78. Authors: E. Bomans, L. Baggaa, E. Mosha

Landform: colluvial footslope, lower part

Site: almost flat, 1% slope

Elevation: 1,320 m

Parent material: colluvium from sandstone and shale

Moisture condition: moist below 30 cm

Groundwater: 260cm Drainage class: imperfectly drained

Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-4/5 cm	Very dark greyish brown (10YR3/2) moist and brown (10YR5/3) dry; loamy sand; moderate medium and fine crumb; soft dry, friable moist, nonsticky, nonplastic wet; many fine tubular pores; many fine and common medium roots; clear wavy boundary.
Au2	4/5-10/12 cm	Dark yellowish brown (10YR4/4) moist and light yellowish brown (10YR6/4) dry; loamy sand; moderate medium subangular blocky; slightly hard dry, friable moist, nonsticky, nonplastic wet; many fine tubular pores; common fine and medium, few coarse roots; clear wavy boundary.
BA	12-22/27 cm	Dark yellowish brown (10YR4/4) moist and very pale brown (10YR7/4) dry; sandy loam; moderate medium subangular blocky; slightly hard dry, friable moist, nonsticky, nonplastic wet; many fine tubular pores; few fine and coarse, common medium roots; gradual wavy boundary.
Bw1	22/27-37/40 cm	Strong brown (7.5YR5/6) moist; sandy loam; moderate medium coarse subangular blocky; slightly hard dry; friable moist, slightly sticky, slightly plastic wet; many fine and common medium pores; few fine to coarse roots; gradual wavy boundary.
2Bw2	37/40-115 cm	Strong brown (7.5YR5/6) moist, many medium prominent clear red (10YR4/8) mottles; sandy clay loam; moderate coarse subangular blocky; friable moist, sticky, slightly plastic wet; many fine and common medium tubular pores; common fine, few medium and coarse roots; gradual wavy boundary.
2Bwg3	115-215	As 2Bwg1, but sandy clay in texture.

Environmental characteristics

These soils are developed in unconsolidated colluvial materials derived from sandstone and shale, under a vegetation of Brachystegia/Terminalia woodland with a ground cover of short and medium grasses. They occupy the almost flat lower parts of the colluvial footslopes. Slope gradients are 1–2 percent. Unit Cuw(e) is closely dissected by gullies. Termite mounds occur in many areas.

Land use

None.

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50–20 m	Silt 20–2 m	Clay	Text Class	Silt/clay
11.6467	0–4/5	71	8	9	12	SL	1.38
68	4/5–10/12	78	6	6	10	LS	1.22
69	10/12–22/27	75	2	11	12	SL	1.12
70	22/27–37/40	69	4	11	16	SL	0.89
71	37/40–115	53	6	8	33	SCL	0.41
72	115–215	45	6	10	39	SC	0.41

O.C %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	E	Sum bases	CEC soil (sum)
1.86	0.15	12	0.06	0.30	2.80	1.60	5.00	4.76	9.76
0.87	0.08	11	0.05	0.13	2.40	1.60	3.00	4.18	7.18
0.52	0.05	10	0.06	0.14	2.40	1.60	3.00	4.78	7.78
0.53	0.04	11	0.05	0.16	2.00	2.40	4.00	4.61	8.61
0.46	0.06	8	0.06	0.52	4.80	1.20	6.00	6.59	12.59
0.46	0.06	8	0.09	0.40	2.50	1.60	10.00	14.90	24.40

pH H_2O	pH $CaCl_2$	Sum bases clay meq/100g	CEC clay meq/100g	ESP	base saturation %	P ppm	EC (mmho/cm)
5.2	4.4	39	80	0.57	49	7.1	0.19
5.4	4.6	43	73	0.72	58	4.8	0.12
5.0	4.2	41	65	0.84	61	3.0	0.10
5.0	4.3	28	53	0.55	54	4.2	0.15
5.2	4.3	20	38	0.52	52	1.9	0.10
5.4	5.0	38	64	0.38	60	3.9	

MAPPING UNIT Clp

This unit include a number of deep, imperfectly and poorly drained soils of variable textures. Major soils are as follows:

(i) Soils having a very dark greyish brown, dark brown or black sandy loam to sandy clay loam A horizon and a brown to grey, clay loam to sandy clay, mottled B horizon overlying a contineous ironstone layer below 50 cm. They are classified as Dystric or Gleyic Cambisols, petroferric phase in the FAO Legend and Petroferric? Dystropepts or Aeric Tropaquepts in the USDA Soil Taxonomy.

(ii) As above but compact, slowly permeable , clay B horizon. They are Gleyic Cambisols in the FAO Legend and Aeric Tropaquepts in the USDA Soil Taxanomy.

(i) Typical profile, 133/1/47

Location: grid TJ 299 746

Date of examination: 3/6/1978. Author/s: J. Magogo

Classification: Dystric Cambisol, petroferric phase (FAO), Petroferric? Dystropepts (USDA)

Landform: colluvial footslope, lower part

Parent material: colluvium from sandstone and shale

Site: almost flat, 1% slope

Elevation: 1,300 m

Moisture condition: moist below 30 cm

Groundwater: 85 cm. Drainage class: imperfectly drained

Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-3/4 cm	Dark greyish brown (10YR4/2) moist and greyish brown (10YR5/2) dry; loam; weak fine crumb; soft dry, very friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; common fine; many medium, few coarse roots; clear smooth boundary.
Au2	3/4-16/18 cm	Brown to dark brown (10YR4/3) moist and brown (10YR5/3) dry; sandy clay loam; moderate medium crumb; dry soft, friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; common fine; many medium, few coarse roots; abrupt smooth boundary.
Bw1	16/18-28/32 cm	Dark yellowish brown (10YR4/4) moist and yellowish brown (10YR5/4) dry; loam; moderate medium subangular blocky; slightly hard dry, friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; few coarse roots; clear wavy boundary.

2Bwg2	28/32–60 cm	Yellowish brown (10YR5/6) moist, many medium prominent clear red (2.5YR5/6) mottles; clay loam; moderate fine and medium subangular blocky, friable moist, slightly sticky, slightly plastic wet; common fine and medium tubular pores; common fine and medium roots, abrupt smooth boundary.
2Bwg3	60–90 cm	As 2Bwg2, but sandy clay texture
ms	90 cm+	Petroferric horizon continuous ironstone layer largely constructed of cemented nodules of irregular shape.

Soil analytical data

Sample	Depth (cm)	Particle size distribution				Text class	Silt/ clay
		Sand	Silt 50–20 m	Silt 20–2 m	Clay		
11.6497	0–3/4	51	4	18	17	L	1.87
98	3/4–16/18	53	8	18	21	SCL	1.25
99	16/18–28/32	47	11	16	26	L	1.01
11.6500	28/32–60	38	8	15	39	SC	0.60
01	60–90	34	7	15	44	SC	0.51

O.C %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum	CEC soil (sum)
1.31	0.19	7	0.08	0.20	2.40	2.40	3.00	5.08	8.08
0.94	0.13	7	0.06	0.14	2.80	1.30	1.00	4.69	5.69
0.38	0.11	3	0.07	0.20	2.40	0.80	5.00	3.47	8.47
0.28	0.09	3	0.16	0.30	2.40	2.00	5.00	4.86	6.89
0.28	0.08	4	0.15	0.23	1.60	2.40	7.00	4.38	11.38

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
5.8	4.6	30	48	0.95	63	2.4	
5.6	4.1	23	27	0.98	82	0.6	
5.4	4.4	13	32	0.81	41	0.0	
5.5	4.6	12	25	1.65	49	0.0	
5.6	4.5	11	26	1.33	38	0.0	

(ii) Typical profile, 133/1/16

Location: grid TJ 351 780
Date of examination: 27/5/78. Author: E. De Pauw
Classification: Gleyic Cambisols (FAO), Aeric Tropaquepts (USDA)
Landform: colluvial footslope, lower part
Site: flat, slope less than 1%
Microrelief: scattered termite mounds
Elevation: 1,300 m
Parent material: colluvium from shale?
Moisture condition: moist below 10 cm
Groundwater: 100 cm. Drainage class: poorly drained
Rock outcrops/surface stones: none. Erosion/deposition: none

A	0-6/8 cm	Dark greyish brown (10YR4/2) moist and greyish brown dry; many medium distinct clear brownish yellow (10YR6/6) mottles; sandy loam; weak medium and coarse crumb; slightly hard friable moist, nonsticky, nonplastic wet; many fine and few medium tubular pores; common fine, few medium tubular pores; common fine, few coarse roots; clear wavy boundary.
BA	6/8-24/26 cm	Brown (10YR5/3) moist, many medium distinct clear brownish yellow (10YR5/3) moist, many medium distinct clear brownish yellow (10YR6/6) mottles; sandy clay; weak fine and medium subangular blocky; fine moist, sticky, slightly plastic wet; common fine and very fine pores; common fine and few coarse roots; gradual wavy boundary.
Bwg1	24/26-46/52 cm	Dark brown to brown (10YR4/3) moist, many medium and coarse distinct clear yellowish red (5YR5/8) mottles; clay; moderate fine and medium angular blocky, firm moist, sticky, plastic wet; common fine and very fine tubular pores; few fine, common medium roots; gradual wavy boundary.
Bwg2	46/52-110 cm	Grey (10YR5/1) moist, many coarse prominent sharp red (2.5YR4/8) mottles on ped faces and some cracks; clay; massive breaking to weak medium subangular blocky; firm moist, sticky, plastic wet; very few very fine tubular pores; very few coarse roots.

Environmental characteristics

These soils occupy the lower end of the colluvial footslopes and appear to be developed in unconsolidated colluvial materials derived from shale and sandstone. Dominant vegetation is wooded (Terminalia sp) grassland with common open areas of medium and tall grasses. Slope gradient does not exceed 2 percent.

Land use

None

Soil analytical data

Sample	Depth (cm)	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text Class	Silt/clay
11.6556	0-6/8	73	4	4	19	SL	0.38
57	6/8-24/28	50	5	2	43	SC	0.16
58	24/26-46/52	31	5	3	61	C	0.13
59	46/52-110	35	4	4	57	C	0.15

O.C %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
1.10	0.13	9	0.07	0.16	2.80	2.80	4.00	5.95	9.95
0.86	0.10	9	0.15	0.17	3.20	0.80	8.00	4.32	12.32
0.37	0.11	3	0.21	0.18	4.80	1.60	6.00	6.79	12.79
0.38	0.11	3	0.18	0.16	2.80	2.00	2.00	5.14	7.14

pH H_2O	pH $CaCl_2$	Sum bases clay meq/100 g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
5.0	4.0	31	51	0.73	59.8	0.0	0.12
5.1	4.3	10	29	1.18	35.1	0.0	0.19
5.7	5.0	1	21	1.68	53.1	0.0	0.18
5.1	4.6	9	13	2.53	72.0	0.0	0.17

A3.5 SOILS OF THE VALLEY FLOOR BASEMENT

MAPPING UNIT Vw

This unit include well drained, shallow, often gravelly, brown to strong brown sandy loams, clay loams or sandy clay loams overlying an ironstone layer at less than 50 cm of the surface. They are Dystric Regosols petroferric phase in the FAO Legend and Petroferric? Ustorthents in the USDA Soil Taxonomy.

Typical profile, 133/1/81

Location: grid TJ 263 740

Date of examination: 15/6/78. Authors: J. Magogo, E. Bomans

Landform: valley floor basement

Site: flat, less than 1% slope

Microrelief: none

Elevation: 1,285 m

Parent material: colluvium from shale and sandstone, (weathered ironstone)

Moisture condition: dry throughout

Groundwater: none Drainage class: well drained

Rock outcrops/surface stones: common ironstone outcrops and boulders

Erosion/deposition: none

Au1	0-8/12 cm	Dark greyish brown (10YR4/2) moist and greyish brown (10YR5/2) dry; sandy clay loam; moderate fine subangular blocky; soft dry, friable moist, slightly sticky, slightly plastic wet; common fine tubular pores; common fine, many medium roots; gradual wavy boundary.
Au2	8/12-18/20	Dark yellowish brown (10YR4/4) moist and dry; gravelly clay loam; moderate fine subangular blocky; soft dry, friable moist, slightly sticky, slightly plastic wet; common fine tubular pores; common fine roots; about 20% angular ironstone fragments, 5-10 mm diameter; abrupt smooth boundary
ms	18/20cm+	Petroferric horizon: ironstone layer with fissures, largely constructed of cemented modules of irregular shape.

Range of profile characteristics

These soils range from a few cm to 50 cm in thickness, and may be brown, dark yellowish brown, yellowish brown or strong brown in colour. They usually overly an ironstone layer with fissures, except in some areas where loose ironstone nodules predominate.

Environmental characteristics

These soils occupy the well drained areas of the valley floor basement and are under open woodland of stunted, contorted trees, with a ground cover of short and medium grasses. They appear to be developed in colluvium from shale and sandstone. Slope gradient does not exceed 1 percent.

Land use

None.

Soil analytical data

Sample	Depth	Particle size distribution				Text class	silt/ clay
		Sand	Silt 50-20 m	Silt 20-2 m	Clay		
11.6490	0-8/12	50	11	18	21	SCL	1.34
91	8/12-18/20	40	7	12	34	CL	0.75

O.C %	N %	C/N	Exchangeable cations (meq/100g soil)					Sum bases	CEC soil (sum)
			Na	K	Ca	Mg	H(*)		
2.32	0.21	11	0.07	0.34	3.20	2.40	8.00	6.01	14.01
1.28	0.14	9	0.06	0.45	2.80	2.80	10.00	6.10	16.10

pH		Sum bases clay meq/ 100 g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
H_2O	$CaCl_2$						
5.7	5.1	28	64	0.493	43	3.4	0.24
5.6	5.0	18	47	0.348	38	1.2	0.22

H(*) : $BaCl_2$ - triethanolamine extraction

MAPPING UNIT Vp

Unit Vp includes a number of poorly drained, dark-coloured, often gravelly soils overlying a continuous ironstone layer at less than 50 cm of the surface. Soil texture usually varies from coarse sand to sandy clay loam, but it may be sandy clay or clay in some profiles.

These soils occupy flat, shallow depressions and drainage ways in the valley floor basement. Slopes usually do not exceed 1 percent. They are probably developed in colluvium from shale and sandstone, under a vegetation of wooden grassland with small, contorted trees.

The profile which follows below is an example only of the wide range of soils which may be encountered in the unit. It is classified as Dystric Gleysols petroferric phase in the FAO Legend and Petroferric? Tropaquents in the USDA Soil Taxonomy.

Profile 133/1/198

Location: grid TJ 290 765

Date of examination: 25/7/78. Authors: L. Daggaa, A. Kiwelu

Site: flat, less than 1% slope

Microrelief: few termite mounds upto 1m high, about 100m apart

Elevation: 1,300 m

Parent material: colluvium from shale and sandstone (weathered ironstone?)

Moisture condition: moist to 20 cm, wet below

Groundwater: unknown. Drainage class: poorly drained.

Rock outcrops/surface stones: few ironstone outcrops and boulders in surrounding area

Erosion/deposition: None

Ag1	0-5 cm	Very dark greyish brown (10YR3/2) moist; sandy clay loam; massive; friable moist, sticky, slightly plastic wet; pores and roots not recorded; clear smooth boundary.
Ag2	5-30 cm	Very dark brown (10YR2/2) moist, common medium prominent clear yellowish brown mottles; gravelly sandy clay loam; massive; friable moist, sticky, slightly plastic wet; pores and roots not recorded; about 20% irregular ironstone fragments, 4-8 cm diameter; abrupt smooth boundary.
ms	30cm+	Petroferric horizon: contineous ironstone layer largely constructed of cemented nodules of irregular shape.

A3.6 SOILS OF THE FLOODPLAIN

MAPPING UNIT Fo

This unit occupy flat active floodplain area along the Rugufu river and its main tributaries. Slope gradient usually does not exceed 1 percent. Major soils are poorly to very poorly drained, grey and dark grey, stratified clay loams and clay loams and clays. They are seasonally flooded by river water and remain waterlogged throughout most of the year. They may be Dystric Fluvisols in the FAO Legend and Typic Fluvaquents in the USDA Soil Taxonomy.

The area was flooded at the time of the survey and the soils could neither be studied nor described in detail.

MAPPING UNIT Fa

This unit occupies the younger meander floodplain of the Rugufu river and its main tributaries. It consists of a number of narrow abandoned levees and slightly lower backswamps.

Major soils are as follows:-

(i) Levees: deep, moderately well drained, pale or yellowish brown, stratified sands to sandy loams. They are Dystric Fluvisols in the FAO Legend and Aquic Ustifluvents in the USDA Soil Taxonomy.

(ii) Backswamps: deep, poorly drained, usually dark grey or black clay loams and clays with prominent mottles. They are Gleyic Cambisols in the FAO Legend and Aeric Tropaquepts in the USDA Soil Taxonomy.

(i) Typical profile, 133/1/50

Location: grid TJ 286 744
Date of examination: 5/6/78. Authors: J. Magogo, E. Bomans
Landform: abandoned levee
Site: flat upper part, 1% slope
Microrelief: none
Elevation: 1,280 m
Parent material: alluvial deposits
Moisture condition: moist throughout
Groundwater: 190 cm. Drainage class: moderately well drained
Rock outcrops/surface stones: none Erosion/deposition: none

Au1	0-3/9 cm	Dark greyish brown (10YR4/2) moist and greyish brown (10YR5/2) dry; sand loam; moderate fine crumb soft dry, friable moist, nonsticky; nonplastic wet; few fine tubular pores; many fine roots; clear wavy boundary.
Au2	3/9-10/15 cm	Dark greyish brown (10YR4/2) moist; sandy loam; weak fine crumb; friable moist, nonsticky, nonplastic wet; few fine tubular pores; common fine and few coarse roots; clear smooth boundary.
C	10/15-35/48 cm	Pale brown (10YR6/3) moist; massive; sandy loam; friable moist, nonsticky, nonplastic wet; few fine tubular pores; few fine roots; abrupt wavy boundary.
2C	35/48-76/100 cm	Pale brown (10YR6/3) moist; common medium and coarse, distinct, clear, strong brown (10YR5/8) mottles; loamy sand; friable moist, nonsticky, nonplastic wet; common fine tubular pores; few fine and coarse roots; abrupt wavy boundary.
3C	76/100-170 cm	Brown (10YR5/3) moist; sandy loam; massive; friable moist, slightly sticky, slightly plastic wet; common fine and few coarse tubular pores; few fine and coarse roots; abrupt wavy boundary.

4C 170 cm + Light yellowish brown (10YR6/4) moist; sand; single grain, loose moist and dry, nonsticky, nonplastic wet; pores and roots not recorded.

Range of profile characteristics

The thickness of the different layers (alluvial strata) may vary widely over short distances. Dominant textures are sand, loamy sand or sandy loam, sometimes sandy clay loam. Drainage class ranges moderately well to imperfectly drained.

Environmental characteristics

These soils occupy abandoned, usually 10-15 m wide levees formed by the Rugufu river and its main tributaries. The dominant vegetation is grassland, with dense groundwater forest in some areas.

Land use

None.

Soil analytical data

Sample	Depth cm	Particle size distribution Sand	Silt 50-20 m	Silt 20-2 m	Clay	Text class	silt/ clay
11.6527	0-3/9	61	18	8	13	SL	2.03
28	3/9-10/15	58	15	11	16	SL	1.54
29	10/15-35/48	59	18	8	15	SL	1.72
30	35/48-76/100	84	5	3	8	LS	0.95
31	76/100-170	81	4	2	13	SL	0.49

O.C %	N %	C/N	Exchangeable cations(meq/100g soil) Na	K	Ca	Mg	H)	Sum bases	CEC soil (sum)
1.47	0.16	9	0.08	0.16	2.40	0.80	3.00	3.45	6.45
1.16	0.07	17	0.09	0.12	4.00	2.00	2.00	6.22	8.22
0.29	0.04	8	0.08	0.06	2.40	1.60	8.00	4.13	12.13
0.19	0.03	6	0.06	0.03	2.80	2.00	8.00	4.10	12.10
0.29	0.05	6	0.11	0.03	2.00	2.00	4.00	4.14	8.14

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100 g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
5.8	5.0	27	60	1.27	53	0.0	0.21
5.4	4.0	38	50	1.15	76	0.0	0.18
5.5	5.0	28	81	0.63	34	0.0	0.11
5.3	4.6	49	144	0.53	34	0.0	0.10
5.2	4.2	33	65	1.32	51	7.0	0.13

(ii) Typical profile 133/1/49

Location: grid TJ 288 745
Date of examination: 5/5/78. Authors: J. Magogo, E. Bomans
Landform: backswamp
Site: flat, less than 1% slope
Microrelief: pillar-shaped termite mounds upto 150cm high
Elevation: 1,280 m
Parent material: alluvium
Moisture condition: slightly moist to 60 cm, moist below
Groundwater: 80 cm. Drainage class: poorly drained
Rock outcrops/surface stones: none. Erosion/deposition: none

Au1	0-5/7 cm	Black (10YR2/1) moist and very dark grey (10YR3/1) dry; clay loam; weak fine crumb; soft dry, very friable moist, slightly sticky, nonplastic wet; common fine tubular pores; clear wavy boundary.
Au2	5/7-20/23 cm	Very dark greyish brown (10YR3/2) moist and dark greyish brown (10YR4/2) dry, few fine faint clear brown (10YR5/3) mottles; clay loam; moderate fine and medium subangular blocky; friable moist slightly sticky, nonplastic wet; common fine tubular pores; common fine and few medium roots; clear smooth boundary.
Bw	20/23-55/60 cm	Very dark greyish brown (10YR3/2) moist, common fine distinct clear strong brown (7.5YR5/6) mottles; clay loam; moderate medium subangular blocky; friable moist, sticky, slightly plastic wet; many fine pores; few fine roots; clear and smooth boundary.
Agb	55/60 cm +	Greyish brown (10YR5/2) moist, many medium distinct clear strong brown (7.5YR5/6) mottles; clay; moderate medium subangular blocky; friable moist, sticky, plastic wet; many fine and few medium tubular pores; very few fine roots.

Range of profile characteristics

The colour of the A horizon ranges from very dark greyish brown to black, and that of the B horizon from dark greyish brown to dark grey. Soil texture usually varies from clay loam to clay.

Environmental characteristics

These soils occupy flat backswamps formed by the Rugufu river and its main tributaries. They remain waterlogged throughout most of the rainy season, but are somewhat protected from river floods by the slightly raised, abandoned levees of the floodplain. Most of the area is covered by short and medium grasses.

Land use

None

Soil analytical data

Sample	Depth cm	Particle size distribution Sand	Silt 50-20m	Silt 20-2m	Clay	Text Class	Silt/ clay
11.6478	0-5/7	34	16	20	30	CL	1.21
79	5/7-20/33	33	12	22	33	CL	1.04
80	20/33-55/60	34	16	18	32	CL	1.08
81	55/60+	21	12	21	46	C	0.74

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
2.26	0.36	6	0.17	0.40	4.80	1.60	20.00	6.98	26.98
3.48	0.22	16	0.14	0.14	3.20	2.40	18.00	5.93	23.93
0.58	0.06	10	0.10	0.06	3.60	1.60	8.00	5.36	13.36
1.10	0.12	9	0.11	0.09	4.40	4.40	16.00	6.60	22.62

pH H_2O	pH $CaCl_2$	Sum bases clay meq/ 100g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
5.0	4.2	23	91	0.65	26	3.4	0.22
4.8	4.1	18	73	0.59	25	1.2	0.17
5.0	4.1	17	42	0.74	22	1.7	0.13
4.8	4.2	14	50	0.48	29	3.4	0.11

MAPPING UNIT Fr

This unit mainly consists of deep, well drained soils having a dark brown to very dark greyish brown loamy sand a horizon, overlying a strong brown or yellowish brown sandy clay loam to sandy clay B horizon. They are classified as Dystric Cambisols in the FAO Legend and Ustic Dystropepts in the USDA Soil Taxonomy.

Typical profile, 133/1/79

Location: grid TJ 282 741
Date of examination: 15/6/78. Authors: J. Magogo, E. Bomans
Landform: old floodplain ridge
Site: flat, 1% slope
Microrelief: none
Elevation: 1,280 m
Parent material: probably old alluvial deposits
Moisture condition: Dry to 30 cm, slightly moist to 80 cm, moist below
Groundwater: none. Drainage class: well drained.
Rock outcrops/surface stones: none. Erosion/deposition: none

A	0–5 cm	Brown to dark brown (10YR3/4) moist and brown (10YR5/3) dry; sandy loam; moderate fine subangular blocky; soft dry, friable moist, nonsticky, slightly plastic wet; many fine and common medium tubular pores; many fine and medium roots; abrupt smooth boundary.
AB	5–20 cm	Yellowish brown (10YR5/4) moist and light yellowish brown (10YR6/4) dry; sandy clay loam; weak medium subangular blocky; slightly hard dry, friable moist, slightly sticky, slightly plastic wet; many fine tubular pores; few fine and common medium roots; gradual smooth boundary.
Bw1	20–125 cm	Strong brown (7.5YR5/6) moist and light yellowish brown to brownish yellow (10YR7/6) dry; sandy clay; weak, medium subangular blocky; friable moist, sticky, slightly plastic wet; many fine tubular pores; few fine and medium, common coarse roots; clear smooth boundary.
Bw2	125–150 cm	Pale brown (10YR6/3) moist, few fine distinct clear red (2.5YR4/8) mottles; sandy clay; weak medium subangular blocky; friable moist, sticky and slightly plastic wet, pores and roots not recorded.

Note: This profile is fairly representative of the soils of the unit, except for the texture of the A horizon which is sandy loam instead of loamy sand.

Range of profile characteristics

The A horizon is usually loamy sand in texture, but ranges to sandy loam in some profiles. The B horizon varies from sandy clay loam to sandy clay in texture, and from brown or yellowish brown to strong brown in colour.

Environmental characteristics

These soils appear to be developed in relatively old alluvial sediments under a vegetation of woodland with a ground cover of short and medium grasses. They are on almost flat ridges occupying a higher topographical position than both the active floodplain areas and levee-backswamp system.

Land use

None.

Soil analytical data

Sample	Depth (cm)	Particle size distribution				Text class	Silt/clay
		Sand	Silt 50-20m	Silt 20-2m	Clay		
11.6492	0-5	74	8	5	13	SL	1.08
93	5-20	68	6	6	20	SCL	0.61
94	20-125	53	6	5	36	SC	0.30
95	20-125	47	5	11	37	SC	0.45
96	125-150	46	8	8	38	SC	0.43

O.C. %	N %	C/N	Exchangeable cations (meq/100g soil) Na	K	Ca	Mg	H	Sum bases	CEC soil (sum)
1.10	0.13	9	0.06	0.18	2.80	1.20	4.00	4.23	8.23
0.81	0.10	8	0.05	0.16	1.60	2.40	2.00	4.21	6.21
0.46	0.08	6	0.06	0.18	1.60	2.00	6.00	3.84	9.84
0.41	0.07	6	0.06	0.14	2.00	1.60	10.00	3.80	13.80
0.35	0.05	7	0.06	0.07	2.40	1.60	14.00	4.70	18.17

pH H_2O	pH $CaCl_2$	Sum bases clay meq/100g	CEC clay meq/	ESP	base saturation %	P ppm	EC (mmho/cm)
5.1	4.3	34	65	0.68	51	5.8	0.16
5.0	4.2	21	32	0.76	68	2.5	0.10
5.0	4.4	11	27	0.66	39	0.1	0.07
5.2	4.5	10	38	0.43	28	0.2	0.05
5.6	5.0	13	49	0.33	23	0.3	0.07

Appendix 4

INTERPRETATION OF SOIL ANALYTICAL DATA

The chemical characteristics of the soils of Mishamo Area and their possible influence on soil fertility are discussed in this Appendix. Table 16 gives the average and standard deviations of the available analytical data in relation to the soil mapping units recognized during the survey. A total of 15 individual soil profiles were analyzed, the results of which are given in Appendix 3 together with the detailed technical descriptions of the profiles.

Owing to the limited number of soil profiles for which analytical data are available, there often occur significant differences in the chemical characteristics within the soils of individual mapping units. These variations, as expressed by standard deviation values in Table 16, are very wide in some cases. On the other hand, the average data of a given soil mapping unit are not significantly different from that of other units.

Reaction

The soils of the area are strongly to very strongly acid (pH-H20), sometimes extremely acid (pH-$CaCl_2$). pH-H20 values range from 4.9 to 5.8, pH-$CaCl_2$ values from 4.2 to 5.0. No significant differences occur between topsoil and subsoil values. The low pH values suggest high exchangeable acidity, probably Al in the exchange complex.

Organic matter

The average content of organic carbon ranges from about 1.5% in the topsoil to 0.4 in the subsoil, which correspond to an organic matter content of 2.6% and 0.7% respectively. The deviations from these values are not high. The organic matter is usually concentrated in the upper 10-15 cm, decreasing abruptly with depth.

The total nitrogen varies from an average of 0.13% in the topsoil to 0.06 in the subsoil. C/N ratios range between 4 and 16.

Exchangeable bases

The total exchangeable bases is invariably low and there are little differences between mapping units. Values range from 7.3 to 3.6 meg/100g soil. No significant variations occur between topsoil and subsoil.

Table 16 - Analytical data, averages and standard deviations

Mapping Units		pH(H_2O)			pH($CaCl_2$)			O.C			N			C/N			P			K			Sum of bases			C.E.C		
		X	S	N	X	S	N	X	S	N	X	S	N	X	S	N	X	S	N	X	S	N	X	S	N	X	S	N
Pw	ts	5.4	0.1	4	4.5	0.2	4	2.03	0.86	4	0.12	0.04	4	16	-	4	2.5	1.7	3	0.07	0.05	3	4.9	0	3	8.6	3.1	3
	ss	5.4	0.2	8	4.7	0.4	8	0.46	0.17	8	0.05	0.03	8	10	-	8	3.3	5.3	6	0.03	0.01	6	4	0.5	6	10.	6.7	7
E	ts	5.5	-	2	4.8	-	2	1.50	-	2	0.12	-	2	10	-	2	4.5	-	2	0.17	-	2	5.2	-	2	11	-	2
Cuw+ Cuw(e)	ts	5.2	0.1	4	4.3	0.3	4	1.84	1.23	4	0.18	0.09	4	10	-	4	3.1	5.3	4	0.21	0.10	4	6.2	1.8	4	10.9	3.0	4
	ss	5.4	0.1	7	4.4	0.3	7	0.40	0.18	7	0.07	0.02	7	6	-	7	1.7	4.8	7	0.25	0.29	7	4.6	1.6	7	8.2	-	7
Cup	ts	4.9	0.2	2	4.3	0.4	2	1.19	1.50	2	0.10	0.09	2	11	-	2	t	0	2	0.12	0.04	2	3.6	0.9	2	5.1	0.2	2
	ss	5.8	0.3	3	5.0	0.3	3	0.22	0.05	3	0.02	0.01	3	14	-	3	t	0	3	0.07	0.02	3	5.4	0.4	3	10.4	3.0	3
Clw+ Clw(e)	ts	5.4	0.3	6	4.6	0.4	6	1.32	1.02	6	0.14	0.09	6	9	-	6	3.6	2.2	6	0.17	0.07	6	5.7	2.8	6	9.9	4.8	6
	ss	5.3	0.3	5	4.6	0.4	5	0.44	0.09	5	0.06	0.01	5	8	-	5	2.0	2.0	5	0.28	0.17	5	7.3	4.3	5	14.8	6.3	5
Clp	ts	5.4	0.3	5	4.3	0.2	5	1.05	0.20	5	0.13	0.03	5	6	-	5	0.6	1.0	5	0.17	0.03	5	4.7	0.9	5	8.9	2.4	5
	ss	5.5	0.3	4	4.7	0.2	4	0.34	0.05	4	0.10	0.01	4	4	-	4	0.0	0.0	4	0.22	0.06	4	6.3	2.5	4	9.6	3.0	4
Vw	ts	5.7	-	2	5.1	-	2	1.8	-	2	0.17	-	2	10	-	2	2.3	-	2	0.40	-	2	6.0	-	2	15.0	-	2
Fa	ts	5.3	0.4	4	4.3	0.5	4	2.09	1.03	4	0.13	0.08	4	12	-	4	1.2	1.6	4	0.20	0.13	4	5.6	1.5	4	16.0	11.0	4
	ss	5.2	0.3	5	4.4	0.4	5	0.49	0.37	5	0.06	0.04	5	8	-	5	2.4	2.9	5	0.05	0.03	5	4.9	1.1	5	14.0	5.0	5
Fr	ts	5.0	-	2	4.2	-	2	0.95	-	2	0.12	-	2	8	-	2	4.2	-	2	0.17	-	2	4.2	-	2	7.2	-	2
	ss	5.3	0.3	3	4.6	0.3	3	0.40	0.05	3	0.07	-	3	6			0.2	-	3	0.13	0.06	3	4.1	0.5	3	14.0	4.2	3
All soils	ts	5.3	0.2	9	4.5	0.3	9	1.53	-	9	0.13	0.03	9	10		9	2.4	1.6	9	0.19	0.09	9	5.1	0.9	9	10	3.5	9
	ss	5.4	0.2	7	4.6	0.2	7	0.40	-	7	0.06	-	7	8		7	1.4	1.3	7	0.15	0.10	7	5.2	1.2	7	11	2.5	7

Notes

ts: topsoil
ss: subsoil
t : trace
X : average
S : standard deviation
N : number of samples

The Cation Exchange Capacity (CEC) is low to moderate, with an average of 10 meq/100g soil which is about twice as much as the average of the total exchangeable bases. This indicates a high exchangeable acidity (H and Al). Base saturation values are also low, often below 50%.

Dominant cations are H, Ca and Mg; the Na values are always low and ESP values are usually less than 1%. The exchangeable K is generally low.

Salinity

All the soil samples analyzed are non-saline. E.C. values usually do not exceed 0.25 mmho/cm.

Phosphorus

Available phosphorus is very low. Average values range from about 3.0 ppm in the topsoil to 1.5 ppm in the subsoil.

The main limitations regarding the fertility of the soils of the surveyed area are high acidity, low exchange capacity, low base saturation and low phosphorus content. Fertilizers and liming are thus required to obtain good crop yields. However as the response to fertilizer application is unknown, they should be introduced gradually. The use of acidifying fertilizers such as sulphate of ammonia is not recommended.

The organic matter levels under the present conditions (miombo woodland) appear to be adequate. However, unless suitable management practices such as crop rotations with a long fallow period, growing of leguminous crops, recyling of organic residues, etc, are adopted the soils will be depleted of organic matter in a short period of time.

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GLOSSARY OF TERMS

Alluvium

The material, such as clay, sand, silt and gravel, transported and deposited by a river.

Association (Soil)

A mapping unit in which two or more defined taxonomic units occuring together in a characteristic pattern are combined because the scale of map or the purpose for which it is being made does not require delineation of the individual soils.

Colluvium

A deposit of loose, unconsolidated mixed material, found at the foot of a slope. Colluvium includes materials which have reached the foot of the slope by soil creep, humid surface wash or mass movement.

Complex (Soil)

A mapping unit where two or more defined taxonomic units are so intimately intermixed that it is undesirable or impractical, because of the scale being used, to separate them. A more intimate mixing of smaller areas of individual taxonomic units than that described under 'soil association'.

Cuesta

An asymmetrical ridge with a steep scarp slope and a gently backslope or dip slope, following the direction of the dip of the adjacent rock beds. Cuestas result from the uneven erosion of inclined, alternating weak and resistant rock strata.

Dip

The angle at which a rock stratum is inclined to the horizontal.

Drainage

A general appreciation of the moisture conditions of a soil, based on runoff, soil permeability and internal discharge of excess water. Seven classes are distinguished:-

- Very poorly drained: water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time

- Poorly drained: water is removed so slowly that the soil remains wet for a large part of the time. The watertable is commonly at or near the surface during a considerable part of the year.

- Imperfectly drained: water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time.

- Moderately well drained: water is removed from the soil somewhat slowly so that the profile is wet for a small but significant part of the time.

- Well drained: water is removed from the soil readily but not rapidly. Well drained soils commonly retain optimum amounts of moisture for plant growth after rains or irrigation.

- Somewhat excessively drained: water is removed from the soil rapidly.

- Excessively drained: water is removed from the soil very rapidly.

Groundwater table

The upper surface of groundwater or that level below which the soil is saturated.

Ironstone

Highly weathered iron-rich clayey material that is irreversibly hardened to concretions, hardpans or crusts, more or less mixed with quartz of other materials.

Mottles

Spots in the soil profile with a different colour than the soil matrix. Their presence is usually indication for impeded drainage conditions in the soil.

Permeability

The ease with which a soil or soil layer permits circulation of air or water. Permeability is closely related to the texture and the structure of the soil.

Porosity

The proportion of void spaces to the total soil or rock volume.

Regolith

The loose incoherent mantle of rock fragments, soils andweathered material which rest upon solid rock. Regolith is not a synonym for soil. It is the unconsolidated material from which soils can develop.

Soil conservation practices

Those soil management practices primarily meant for protecting the soil against erosion. Many of these practices also have beneficial effects on soil fertility and water conservation.

The most important soil conservation practices are:-

- Crop residues: residues of the crops are plowed under, left on the soil surface (mulch) or partially mixed in the soil surface. Runoff and erosion caused by wind and water are reduced. When plant materials are used as a mulch they provide maximum protection to the land; when incorporated they provide less protection against erosion but have stronger effect in conserving soil fertility.
- Minimum tillage: the least tillage needed to produce crops. The purpose of this practice is to avoid the rapid breakdown of soil structure, decomposition of organic matter and moisture losses that would accompany intensive tillage.
- Cover crops: any crops that are planted or allowed to grow for the purpose of keeping the soil covered. Besides protecting the soil from erosion by wind and water, they can be incorporated as green manure and smother weeds.
- Mixed cropping: The concurrent cultivation of two or more crops on the same field. This method provides a better and longer soil cover, especially when harvest does not take place at the same moment. In some cases the method allows a more efficient use of soil moisture and nutrients.
- Tied ridging: system of alternating furrows and ridges across the slope with small dams in the furrows at regular distances in order to prevent the water from flowing over large distances. Runoff is retarded, thus reducing soil erosion and improving water infiltration.
- Strip farming: a system of alternating strips of closegrowing erosion resistant crops (e.g. grass) or natural vegetation and strips of wider spaced crops (e.g. maize) Perpendicularly aligned to wind direction or slope this practice cuts down erosion by wind or runoff.