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# EXPLORATORY SOIL SURVEY OF SOLWEZI, MWINILUNGA AND KASEMPA DISTRICTS, NORTH WESTERN PROVINCE

BY WEN TING-TIANG, R.N. MAGAI AND S.N. KALYANGO

SOIL SURVEY UNIT, DEPARTMENT OF AGRICULTURE
IN COOPERATION WITH
REGIONAL CENTRE FOR SERVICES IN SURVEYING, MAPPING
AND REMOTE SENSING

1984

SOIL SURVEY REPORT 120

The cover illustration is part of a satellite view of the area around Kawana, north of Kasempa District Headquarters in the North Western Province of Zambia. Soil associations were mapped onto this image and are shown as a white line overprint. Corresponding patterns in the satellite image can be easily identified. The satellite image was gathered on 12 September 1981 by the Landsat-2 satellite (scene number 22425—07334)

Scale: 1:500,000

Produced by the
Regional Remote Sensing Facility, Nairobi, Kenya

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## L I S T  O F  T A B L E S



## L I S T  O F  F I G U R E S

# S U M M A R Y

The soils of Kasempa, Mwinilunga and Solwezi district, altogether encompassing 82,100 $km^2$, were surveyed at exploratory level (1:500.000) during the second half of 1982. It was found that contrary to what was shown on earlier maps deep, well drained clay soils with often a high silt content dominate the area. These soils have mostly been derived from meta-sediments and carbonates of the Kundelungu series. The so-called sandveld soils, characterised by a light textured surface horizon, occur only on domes underlain by Basement Complex. All these soils were classified as ferralsols (oxisols) on account of their highly leached character.

The orthic ferralsols (reddish brown) are the most widely distributed, occupying large parts of Kasempa and Solwezi, as well as being common in Mwinilunga. The sandveld soils are represented by xanthic (brownish yellow) ferralsols, while rhodic ferralsols (red) occur scattered throughout the three districts. Other red soils were classified as acric ferralsol, these are the most leached of all the ferralsols. While red ferralsols are normally several metres deep, the xanthic and orthic ferralsols are usually underlain by laterite within 2 m depth. Very shallow soils over laterite are prevalent in the southern part of Kasempa (petroferric dystric regosol). Ironstone sheets do also occur under most of the acrisols, yellowish brown soils with an increase in clay with depth. These soils constitute a minor component of several soil associations derived from Kundelunga, but they can also be found in larger homogeneous units in western Kasempa.

The soils formed in Kalahari sand, labelled as arenosols, are widespread in northern and western Mwinilunga, as well around the Busanga swamps. Transitional soils between the Kalahari sand soils and residual soils are very common, they mostly belong to the lighter textured ferralsols.

All these upland soils are very leached, with pH ($CaCl_2$) values between 4.0 and 4.5. The base status of these predominantly kaolinitic soils is very low, and the aluminium saturation consequently high, reaching levels toxic to most plants in all ferralsols, acrisols and arenosols. One upland soils that stands out is the ferric luvisol of southwestern Mwinilunga. This soil also displays a clay increase down the profile, but is much richer in nutrients, with a base saturation of over 50%. Despite a good fertility status this soil is not free of problems, being very erosive and consequently rather shallow.

Wetland soils occupy large areas in the region, in particular in the Busanga and Jivundu swamps, but also as extensive dambo systems and floodplains along the major rivers. Large dambos are characteristic in the limestone basins and in the Kalahari zone in northern Mwinilunga. These soils belong to the eutric and dystric gleysols, depending on their base status. Mollic gleysols are the soils of the perennially wet swamps. Intermediate wetland soils are the gleyic cambisols (mainly over acid parent material) and the gleyic ferralsols along the Kabompo river near Ntambu. The distribution of the soils per district is given in table I.

The agricultural potential of the ferralsols and acrisols is rather low, due to their inherent low fertility, weak retention of bases applied as fertilizer and high phosphate fixing capacity. Manganese toxicity occurs in the red soils, and boron and zinc deficiencies are generally common. Physically the soils are better, owing to their strong microaggregation. They are mostly well drained, have a good aeration and in particular the clayey soils have a reasonable available water holding capacity.

All the soils were assigned to a suitability class for low input sustained dryland farming under rainfed conditions, based upon a rating which was calculated with the aid of a number of (semi-)quantative parameters. Five land capability classes were defined according to the composition of the soil associations in terms of suitability classes. So is land capability class 3 made up of 65% or more low potential (suitability class 3) or better soils, but has less than 35% moderately high potential soils (which would put it in class 2)

Class 1 consists mostly of ferric luvisols, or acric ferralsols derived from limestone, which have a relatively high pH. The clayey ferralsols (orthic and rhodic) make up most of class 2 land, while the (mainly xanthic) ferralsols with a coarse topsoil or a loamy subsoil form the backbone of class 3 land. Arenosols occupy most of class 4, with land classified as non-suitable (class 5) consisting largely of shallow and/or wet soils. A separation has been made in non-suitable land dominated by freely drained soils (class 5d) and land with hydromorphic properties (class 5w), which is potentially suited for paddy rice.

Soils have also been separated with respect to their crop suitability. Apart from the ferric luvisol, which can support a wide range of crops without having to add lime, all other soils are basically only suited for more or less acid tolerant crops. Under the farming systems considered only the ferralsol derived from limestone might be able to grow maize economically, even though liming will be required. The remaining soils are not suited for maize on account of their acidity. They should be cultivated with crops like millet, sorghum, cassava, upland rice, tea and pineapple.

It is concluded that the project area offers good prospects for agricultural development as it contains sufficient land classified as class 1, class 2 or class 3 which, given the correct choice of crops, careful management and due regard for conservation practices, can be made very reasonable productive.

table I Distribution of soil types in the project area (in $km^2$)

| soil type | Kasempa | Mwinilunga | Solwezi | sub-total |
|---|---|---|---|---|
| rhodic ferralsol | 1200 | 950 | 1100 | 3250 |
| orthic ferralsol | 9050 | 5300 | 12800 | 27150 |
| xanthic ferralsol | - | 3200 | 1800 | 5000 |
| acric ferralsol | 150 | 700 | 3750 | 4600 |
| gleyic ferralsol | - | 750 | 100 | 850 |
| ferric acrisol | 3150 | 450 | 3850 | 7450 |
| ferric luvisol | - | 1200 | - | 1200 |
| gleyic cambisol | 600 | 550 | 650 | 1800 |
| ferralic arenosol | 2150 | 2950 | 50 | 5150 |
| dystric regosol | 9300 | 700 | 2500 | 12500 |
| mollic gleysol | 100 | 50 | - | 150 |
| eutric gleysol | - | 200 | 1550 | 1750 |
| dystric gleysol | 500 | 3900 | 1100 | 5500 |
| undifferentiated | 5200 | - | 450 | 5750 |
| total | 31500 | 20900 | 29700 | 82100 |

ACKNOWLEDGEMENTS

The exploratory soil survey of Solwezi, Kasempa and Mwinilunga districts was the first survey of this kind the Soil Survey Unit carried out. Landsat imagery was brought in to assist in the mapping of the area, many parts of which could not be reached due to inaccessibility and the short time available for the fieldwork. Having no previous experience in the application of satellite imagery, the Soil Survey Unit sought and very cooperatively received support from the Regional Centre for Services in Surveying, Mapping and Remote Sensing in Nairobi.

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# CHAPTER 1 INTRODUCTION

## 1.1 PREFACE

As a precursor to the North Western Province Area Development Project initiated by the Government of Zambia and funded by the Internationa Fund for Agricultural Development, the Soil Survey Unit was requested to carry out an exploratory survey of the project area in order to take stock of the soil resources available. It was furthermore suggested that a land capability map be d rived from the soil map to indentify areas with a (relatively) high agricultural potential.

An agreement was signed in April 1982 between IFAD and the Government of Zambia for a technical Assistance Grant that would enable the Soil Survey Unit to execute the survey. In July 1982 the Ministry of Agriculture and Water Development and the Regional Centre for Services in Surveying, Mapping and Remote Sensing concluded a further agreement that would provide assistence to the Soil Survey Unit in the use and interpretation of Landsat imagery, a medium in which the Unit had not been involved earlier.

Fieldwork started in August 1982, with the arrival of Professor Liang as the first consultant, and lasted until the end of that year. Three more visits with consultants were made to the project area during the first half of 1983. Map compilation and the preparation of the land capability map took up the greater part of tha year, while the report was drafted during the closing months of 1983, and was finely published in April 1984.

## 1.2 LOCATION AND COMMUNICATIONS

The project area encompasses three districts of North-Western Province: Solwezi, Kasempa and Mwinilunga. Chizera district had recently been separated from Kasempa district, but no definite boundary between the new district and the remainder of Kasemá district had been established at the time of the survey. At the advise of the Land Use Planning Section in Solwezi the boundary between these two districts, and thus the southwestern boundary of the project area, was assumed to follow the line from where the Mushingashi river crosses the Solwezi-Kasempa district boundary to the source of the South Musonweji river, and from there along the South Musondweji, the Lower Musondweji and the Dongwe rivers up till the confluence of the latter river with the Lalafuta river, where Western Province boundary lies.

The total area of the three districts is as follows:

| | | | |
|---|---|---|---|
| Solwezi | 2,969,300 ha | 1,213,200 ha | (41%) |
| Kasempa | 3,149,400 ha | 1,310,700 ha | (42%) |
| Mwinilunga | 2,090,400 ha | 719,600 ha | (34%) |
| total | 8,209,100 ha | 3,243,500 ha | (40%) |

the second set of figures indicating the area occupied by national parks, protected forests and game management areas. Meanwhile the boundary between Chizera and Kasempa has been fixed. It is situated far more to the east than the assumed boundary, hence the surveyed area includes about one third of Chizera district.

North - Western Province is rather scantily provided with roads. The major artery is the road from the Copperbelt to the Angolan border at Jwimbe. At the time of the survey the stretch from Kabompe river to Mwinilunga was in the process of being tarred, while east of the Kapombo river the road had been metalled from some time already. All other roads are either all-weather gravel roads or dirt roads. The main all-weather roads run from Mutanda to Kasempa, from Kasempa to Kaoma, from Kawana to Kalulushi and from Mwinilunga to Jwimbe. A number of minor roads serve localities like St. Francis mission, Ntambu, Shilanda, Chovwe, Chibwika etc.

On the whole these roads are fairly good, as they suffer little from damage caused by heavy lorries, but due to the unconsolideated nature of the Kalahari sand deposits roads passing through this region can be difficult to negotiate, especially during the rain season. Bridges are the main bottleneck on the secondary roads as they are not always being properly maintained. Some very long tracks penetrate the more remote areas. Most of these tracks were formed by geological survey parties. The tracks themselves are well passable, but problems occur at the sites of bridges. Apparently these are wantonly being burned or otherwise made unfit for use by poachers, who do not want to run the risk of being disturbed by game guard patrols. The result is that large parts of the project area cannot be reached other than by foot, although the population centres can, at least in the dry season, all be reached by vehicle. An outline of the road network is included in figure 1.

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## 1.3 POPULATION

North-Western Province is the least densely populated province of Zambia. That was true in 1963 (year of the first census) and still holds today. The population density for the province as a whole is 2.4 $km^2$, about one third of the national density which stands at 7.5 $km^2$. Large parts of the province are in fact completely uninhibited. They include national parks, game management areas, protected forests etc., but even outside these gazetted areas there remain vast empty spaces.

That in the past settlements must have been widely dispersed can be conluded from the study of aerial photographs, and can also be derived from signs of former habitation in the field. Nowadays, however, the population is concentrated along roads, near centres of administration, schools, hospitals etc. Landsat imagery abundantly shows that there are no cultivated fields that are situated far away from the present road network.

Of the three districts comprising the project area, Solwezi not only has the highest population (92.400 according to the 1980 census), but also has the fastest growing population (5.2% between 1969 and 1980). This growth rate can probably partly be attributed to the reopening of the Kanshanshi mine in the early seventies. The average growth rate for the province is 2.4%, which is also the growth rate for Kasempa and Mwinilunga districts. Table 1 shows the average population density as determined during the three censusses that have taken place in Zambia.

table 1 Population density (per $km^2$) and average annual growth

| | 1963 | 1969 | | 1980 | |
|---|---|---|---|---|---|
| Solwezi | 1.5 | 1.8 | (2.9%) | 3.1 | (5.2%) |
| Mwinilunga | 2.2 | 2.4 | (1.9%) | 3.2 | (2.5%) |
| Kasempa * | 0,8 | 0.8 | (-0.6%) | 0.9 | (2.4%) |

* includes present day Chizera district

The population of Solwezi is concentrated around Solwezi itself, Kanshanshi mine, Shilenda, Makumbi and St. Francis. Mwinilunga district, being the second most populous district, has several fairly densely populated areas. Chief amongst these are Mwinilunga, and the northwestern part of the district. Others include the Lwawu area Chbwika, Ntambu and Kakoma.

In Kasempa district (Population 29.800 in 1980) there are no major population concentrations other than around the district capital and near the settlement schemes.

The principal occupation of the population is farming, most of it subsistence cultivation under the chitimene system. The main crops are sorghum, millet and maize, and cassava in the more sandier parts of Mwinilunga district. Pineapple is an important cash crop in that district too, while rice is grown on the wetland soils along the Kabompo river near Ntambu. Hunting, fishing and the gathering of forest products like fruits, honey and mushrooms, still play an important part in the food supply of the local population.

Cattle keeping is practised on the sands of northern Mwinilunga district, where the Kalahari dambos provide vast but poor pastures. In many other parts of the project area it is not possible to keep domestic animals due to the incidence of tsetse fly.

# CHAPTER 2 ENVIRONMENTAL SETTING

## 2.1 GEOLOGY

The oldest rocks that form the geological basis of the project area date from the Precambrian, whereas the youngest formations may have been deposited as recently as the early Quaternary (very recent alluvial deposits excluded).

The Precambrian rocks, which belong to the so-called Basement Complex, are very much evident in the northern half of the project area, where they emerge from the surrounding younger formations in large dome like features. Lithologically they consist mostly of gneiss and granitic gneiss, becoming more granitic in the northern tip of Mwinilunga district. They are closely associated with pre-Katanga schists which particularly in the Mwembeshi dome constitute a major component. These schists, known as the Kabompo schist formation, are made up largely of phlogopite, muscovite and kyanite schists.

The Katanga supergroup, separated from the Basement complex by a regional unconformity, was formed during the late Precambrian. Important elements of this group in the project area are the meta-siltstones and quartzites of the Kundelungu series and the biotite schists of the lower Kundelungu. The former occupy large areas in Kasempa and southern Solwezi district, and can be found in scattered locations in western Mwinilunga district, while the latter is prevalent in northern Solwezi district and in large parts of Mwinilunga district. The whole of the Kundelungu series has been subjected to metamorphism, which has generally increased in intensity in northern and western directions. Quartzitic ridges are common, especially in Kasempa district.

Metamorphised Kundelungu carbonate rocks, partly Mwashia in age (pre-Kundelungu) are particularly common in the northern half of Solwezi district. As a result of solution-weathering they have developed into shallow basins. Elsewhere other limestones and dolomites of various ages occur.

Scattered occurrences of intrusive granites and gabbros can be found in Solwezi and Mwinilunga districts, but they are too small to have a major influence on the soils of the area, and have consequently been ignored in most cases. Similarly, the mudstone that marks the break between older formations and the relatively recent Kalahari deposits, and which o occurs along the Lalafuta river on the boundary with Western Province, have not been separated on the soil map, although the area underlain by these rocks can definitely been recognised by way of its drainage pattern.

On the other hand, the basalt resembling basic igneous rocks of the Lwawu area in Mwinilunga district is of a large enough occurrence to warrant separation as parent material on the soil map.

The youngest geological formation in the project area, apart from alluvial deposits, are the Kalahari sands that are widespread in Mwinilunga district. Their deposition, mainly by eolian processes, is believed to have started in the late Tertiary, and possibly continued on and off untill the early Quaternary. The present sand cover, varying in thickness from a thin veneer of a few metres to thick deposits of several tens of metres, is known as the Zambezi formation. It consists mainly of well sorted rounded loamy quartz sands, but becomes more loamy towards the northern margins of the district. This fining out is probably partly due to depositional sorting, and partly due to various forms of admixture with local materials.

The several lithological groups that form the basis of the division in soils are depicted in figure 1.

## 2.2 PHYSIOGRAPHY

Zambia forms part of the Central African Plateau, which is believed to be an uplifted remnant of a denudational plain that was probably shaped during the Miocene. This plateau is drained by two major river systems, the Congo, flowing into the Atlantic Ocean, and the Zambezi which debouches into the Indian Ocean. The northern boundary of the project area forms part of the watershed between these two drainage systems.

The elevation of the Central African Plateau is generally well over 1000 m. In the project area it ranges from less than 1200 m in the south to approximately 1450 m along the Zairen and parts of the Angolan border. Chafuguma hill, situated north of Solwezi close to the border with Zaire, forms with its 1684 m the highest point of the project area. Subsidence south of Kasempa has led to the formation of the Busanga swamps, which is the lowest point at circa 1170 m.

The general slope of the land is thus towards the south. It is relatively steeper in the south of Solwezi district and in Kasempa district than elsewhere. This is both because of the subsiding effect of the Busanga swamps, and also because the land in the western half of the project area has effectively been protected against erosion by a cover of Kalahari sands. So does the general elevation of the land all along the West Lunga river from Mwinilunga to Kanyilombi, a distance of nearly 100 km, remain fairly constant between 1350 and 1400 m.

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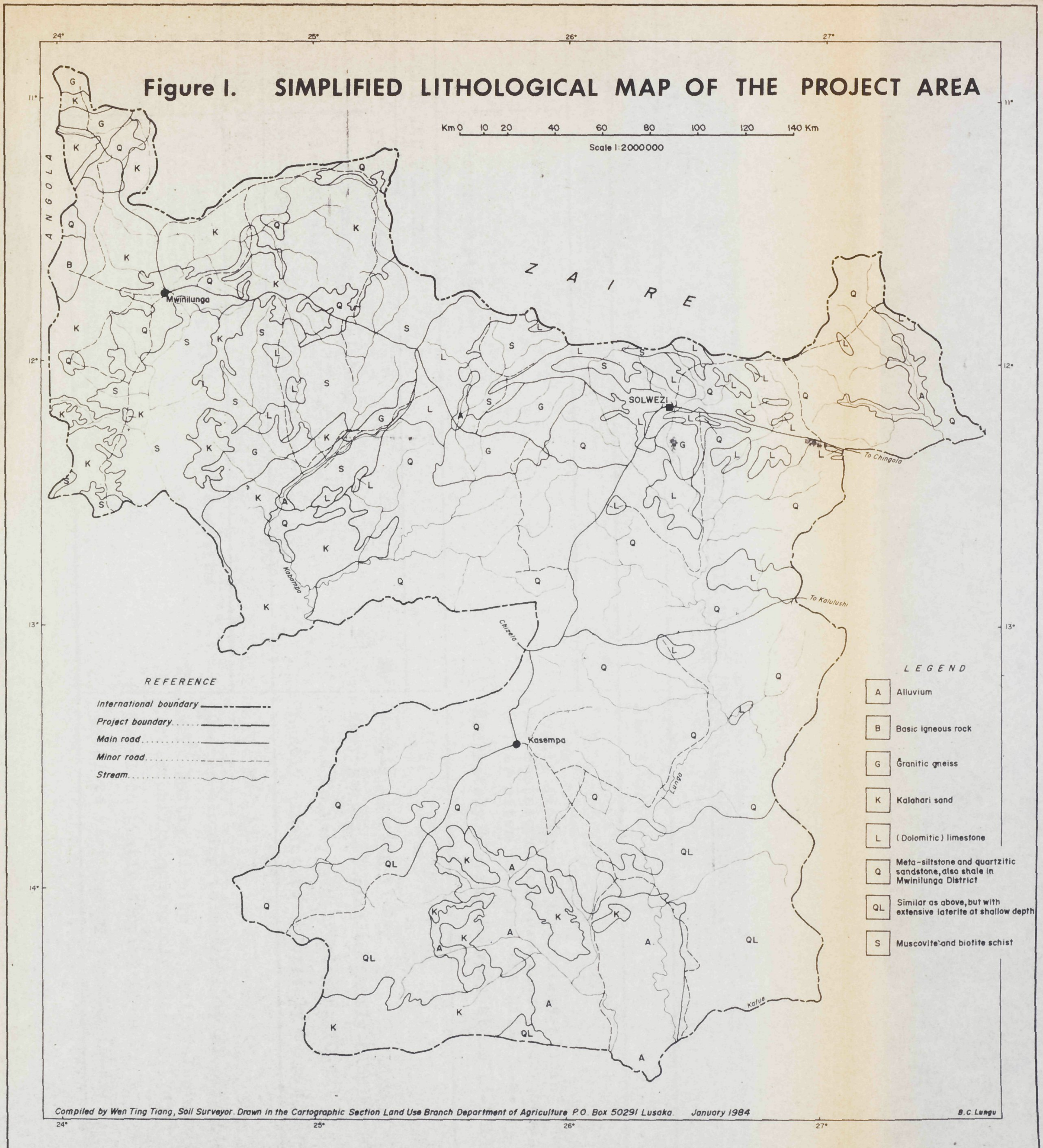


Figure I. SIMPLIFIED LITHOLOGICAL MAP OF THE PROJECT AREA

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## TABLE 2 PHYSIOGRAPHIC UNITS AND THEIR SLOPE RANGES.

| SYMBOL | *PHYSIOGRAPHIC UNIT | SLOPE RANGE |
|---|---|---|
| HILLS AND BROKEN COUNTRY | | |
| Hh | Hills | Gently sloping to moderately sloping (1-5%) for footslopes and piedmonts, very steep ( 12%, often 50%) for the hills s.s. |
| Hb | Broken country | Moderately sloping to very steep (3-12%) |
| PLATEAU AND PIEDMONT | | |
| Pp | Large piedmont | Gently sloping (1-3%) |
| Pu | Gently undulating plateau | Very gently sloping to gently sloping (0-3%) |
| Pn | Plateau with little or no relief | Level to very gently sloping (0-1%) |
| Pd | Strongly dissected plateau | Gently sloping to moderately sloping (1-5%) |
| DEPOSITIONAL LANDFORMS | | |
| Dk | Gently undulating fluvio-eolian deposits | Gently sloping to moderately sloping (1-5%) |
| Dd | Extensive dambos | Very gently sloping to gently sloping (0-3%), occasionally moderately sloping (3-5%) |
| Df | River floodplains and terraces | Level to gently sloping (0-3%) |
| Ds | Swamps and surrounding flats | Level to very gently sloping (0-1%) |

Apart from plateau, hills and landscapes covered by Kalahari sands, three more physiographic landscape units have been distinguished. These are: broken land, piedmont and alluvial landscapes. Table 1 lists all these physiographic units and subunits together with their slope ranges. Below follows a more detailed description of each of the units.

HILLS AND BROKEN COUNTRY

This physiographic unit brings together all landscape elements that are dominated by moderate slopes or steeper, and have relatively narrow interfluves of unequal elevation.

Hills (Hb)

Areas characterized by relatively steep slopes (in excess of 3[illegible]), often very steep (50% or more). Hill areas are mainly formed by resistant ridges that are jutting out above the surrounding landscape. Footslopes, where steep enough, are incorporated in the hill area. Where hill area is formed by clusters of residual hills the intervening, mostly gently sloping coalescing piedmont slopes are also included in this physiographic unit. The drainage density of hill areas is usually moderate. Soils are shallow and skeletal on the steeper parts, deep and well drained, occassionally skeletal in the footslopes. Hill areas occur in all three districts.

Broken country (Hb)

Groups of scattered low hills (mostly less than 30 m high), low cuestas, small dissected escarpments and highly irregularly dissected land have been combined under broken country. The slope of the land within this unit ranges from moderately sloping to very steep (over 55%). In between the steeper elements there is generally more gently sloping land than is the case within the hill areas. The density of the drainage channels, which locally are steeply incised, varies considerably, but is in some cases very high. Soils in broken country landscape have a high degree of variability. Broken country is mainly found in Kasempa district, in particular south of the district capital

PLATEAU AND PIEDMONT

This physiographic unit contains the major landscape forms of the project area. Plateau and piedmont, as used in this report, are characterized by predominantly gentle slopes. The two differ in their setting. Typical plateau features consist of an undulating landscape, with drainage provided by a network of dambos connected by small streams, and separated from each other by interfluves with low slope gradients and more or less similar crest elevations. Isolated hills or narrow ridges of more resistant rock provide some variation in an otherwise very monotonous landscape.

Large piedmont (Pp)

Relatively broad areas backed by a hill range and gently sloping down towards a stream or large dambo. Piedmonts are drained by a number if parallel drainage channels running nearly straight down the slope. Smaller piedmonts, which occur commonly at the foot of steep hills, have not been separated on account of the scale of mapping. Where they occur within a hilly area they have been included under hills. Elsewhere they form part of the plateau. The piedmont soils in the project area are mainly shallow soils. They occur in Kasempa district only.

Gently undulating plateau (Pu)

This is the physiographic unit in the project area that has the largest extent. Interfluve slope gradients are gentle, and interfluve crest gradients normally very gentle. In North -Western Province this type of landscape is best exemplified by the Kundulungu metasiltstone and quartzitic sandstone area. Here the relatively wide dambos lie on average 2.5 km from each other, while the interfluve slopes vary from 1 to 2%. The lower part of the dambos, and sometimes the middle part as well, contains a narrow ephimeral stream flanked by nearly flat grasslands. During the rainy season most of the dambos become waterlogged. Laterite near or on the surface is common along dambo fringes and along the upslope continuation of dambo heads. Height differences between dambo floor and interfluve crest can be several tens of metres. The density of the drainage network is moderate. Soils are deep to very deep and well drained.

Plateau with little or no relief (Pn)

In areas where extensive massive laterite underlies the soil mantle at shallow depth the landscape tends to become flatter, with slopes ranging from almost flat to very gently sloping (0 to 1%). Height differences between interfluve and dambo floor are consequently no more than 10 to 15 m. Dambo and streams lie wide apart, but in between seepage zones occur that are neither open grasslands nor close forests. These ill-defined zones have an intermediate vegetation, with groups of trees clustering on low mounds that are separated from each other by grassland. Dambos are somewhat deeper incised than these drainageways, but their density is rather low. Plateau areas with little or no relief are on their upstream side always bounded by gently undulating plateau. On their down stream side they mostly merge with other flat areas like floodplains or flats surrounding a swamp. The soils of this physiographic unit are largely shallow to moderately deep and tend to become ponded during the rainy season. They occur in Kasempa district around the Busanga swamps.

Strongly dissected plateau (Pd)

This physiographic unit has moderately sloping land forming a major component of its surface. Occassionally moderately steep slopes prevail, but generally the slopes are not as steep as those of the hilly areas and broken land. Interfluves are less broad than those found in a gently undulating plateau landscape, although adjoining interfluves also occupy approximately similar elevations. Due to the relatively steep slopes erodibility of the soil mantle is high and soils are therefore dominantly moderately deep. This type of plateau is particularly prevalent in Mwinilunga district where it is associated with schistaceous parent material. Drainage density of the rather narrow dambos and streams is high.

DEPOSITIONAL LANDSCAPES

Under this heading all landscapes that have formed in accumulated material, as opposed to the other physiographic units that have a denudational origin, are united. With the exception of very large dambos, dambos are not separated as they are too small to be mapped out individually.

Gently undulating fluvio-eolian deposits (Dk)

Kalahari sand deposits, very gently to gently sloping with very broad interfluves. The nature of the deposits varies considerably in the project area. In the west and south of Mwinilunga district they form high lying plateaus with elevations of over 1500 m and relief differences between interfluve and stream in excess of 50 m. Slope gradients on the platea like interfluves are less than 1%, but towards the deeply incised streams they may increase to moderately sloping (up to 5%). Drainage density is very low, streams usually lying more than 3 km apart. In the north of Mwinilunga district the Kalahari deposits are low lying, with interfluves situated some tens of metres above the local base level at the most. Slopes are very gently sloping to gently sloping (0 to 3%). On aerial photographs and Landsat images at relic east - west linear dune system of locally over 10 km in length can be discerned at places. The northern deposits merge gradually with the surrounding soils. Their drainage density is moderate.

Extensive dambos (Dd)

Dambos are basically rather flat open almost treeless grassy areas that become waterlogged during the rain season. The dambos that are shown on the map are mainly large to very large sandy dambos belonging to the Kalahari sand system. Sizes may vary from anything of 2 x 1 km up to 15 x 6 km. In the low lying sands of northern Mwinilunga they are very numerous and in many places dominate the landscape. Frequently zones of white sand with hardly any vegetation rim these dambos.

In the high sands they occur either on the nearly flat interfluve or occupy the valley slopes from crest to stream. It is believed that in most cases these large dambos are underlain by laterite, although this may be at varying depth. All dambo soils should be considered to be hydromorphic soils.

River floodplains and terraces (Df)

Flat strips of low lying land adjoining river channels. Most of this unit is formed in alluvium. It includes terraces, levees and backswamps. Terraces are not very conspicuous in the field as they have probably been reworked by erosive processes. Most of this unit is however formed by floodplains proper, which are nearly flat open grasslands with poorly drained soils, often having a thick dark surface horizon. The soils of the terraces are mostly imperfectly drained.

Swamps and surrounding flats (Ds)

This physiographic unit is made up of large to very large basins containing some perennial wet swampy areas surrounded by extensive grassy flats. Small streams from the surrounding countryside disappear into the swamps, but some large rivers like the Kafue continue to wind their way through them. Large parts of the open flats are underlain by laterite. Waterlogging occurs over most of flats during the rainy season. Levees and backswamps are common along the streams, although they only constitute a minor part of the total area of the swamps. Apart from the two major swamps, the Busanga and Jivundu swamps, some small swamps can be found along streams in the low lying Kalahari sand area of northern Mwinilunga district.

## 2.3 HYDROLOGY

Zambia's two main rivers, the Zambezi and the Kafue, both originate in the project area. The Zambezi rises in the north of Mwinilunga district, from where it flows in western direction into Angola, only to swing back into Zambia in Zambezi district. The Kafue, which has its headwaters in the east of Solwezi district, likewise flows for a short distance only through the district before it disappears into easterly direction into the Copperbelt. About 1/3 of the project area is part of the Kafue drainage system, the remainder draining direct intothe Zambezi. The watershed between these two basins runs approximately north-south some 20 km west of Mutanda, and follows the lower half of the Solwezi - Kasempa road. South of Kasempa it coincides with the road to Kaoma.

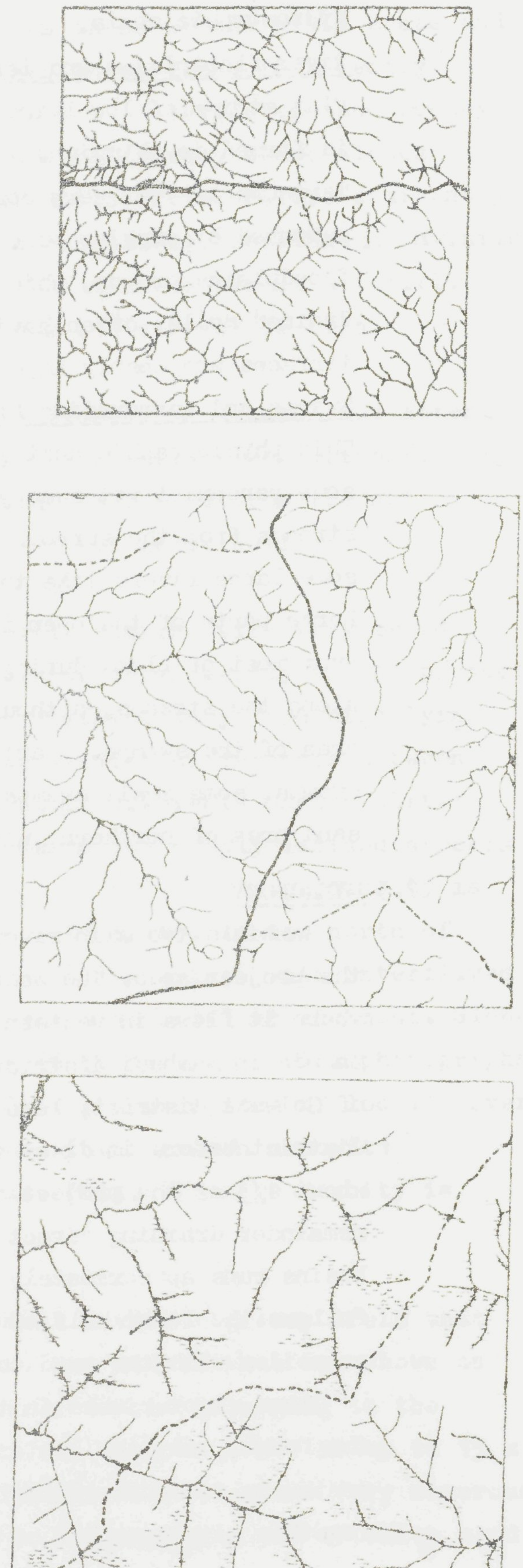
Other major rivers in the project area are the Kabompo, the West Lunga and the Lunga, only the latter draining into the Kafue. These rivers flow in a southerly to south-easterly direction, following the general slope of the land. Together with a number of larger streams they carry water throughout the year.

figure 2 Drainage densities

a) dissected plateau

b) gently undulating plateau

c) plateau with little or no relief



scale 1:500.000

Their annual discharge hydrograph is, however, strongly peaked in response to the outspoken seasonality of the precipitation. The smaller streams and dambos are liable to dry out at the end of the rains, or become reduced to a trickle only. But all the streams that drain the high lying Kalahari sands in Mwinilunga district are perennial.

By and large the drainage pattern is dendritic, as is to be expected in an area largely formed over sedimentary rocks and metamorphic rocks like schist and gneiss. Local variations include radial patterns around the domes (Solwezi and Kasempa districts), parallel in areas with strong folding (southwest of Mwinilunga, north of the Solwezi - Chingola road), rectangular in fault zones (Kasempa district) and tending to dearranged over the shallow laterites of Kasempa district.

Drainage densities vary greatly. They range from very low in the high lying Kalahari sands to very high in the schists around the West Lunga river. Figure 2 shows the drainage patterns for the three types of plateau that have been distinguished in the project area. The corresponding drainage densities, as measured on 1.250.000 Landsat images, are :

| | |
|---|---|
| dissected plateau | 0.69 |
| gently undulating plateau | 0.43 |
| plateau with little or no relief | 0.28 |

Drainage densities are low in the limestone areas as well, particularly in the northern part of Solwezi district where deep limestone weathering has created streamless polje-like basins.

Since the availability and reliability of water has an important bearing on the pattern of settlement, it is unfortunate that in the project area high potential soils such as those found in limestone areas figure poorly in this respect, whereas the Kalahari sands, which have very poor soils, possess highly reliable sources of surface water.

## 2.4 VEGETATION

The project area is basically covered by two vegetation types : Miombo woodland and Kalahari woodland. The latter is intermediate between evergreen Cryptosepalum forest and deciduous Miombo woodland, as Cryptosepalum trees are usually in the minority. More or less pure Cryptosepalum forest occurs also in the area, in particular in West Lunga National Park, and as a discontinuous cover of the high lying Kalahari sands in the western part of Mwinilunga district. This type of forest is as a rule surrounded by Kalahari woodland, which itself is believed to be largely the result of the destruction of Cryptosepalum forest and the subsequent invasion of Miombo species.

Minor occurrences were noted of Marquesia forest (Lwawu area, Mwinilunga district), Chipya forest (northeastern part of Mwinilunga district), both on low lying Kalahari sands, and Termitaria associated vegetation on the ill-defined drainage zones of the laterites in southern Kasempa district. According to the Vegetation Map of Zambia (Edmonds, 1976) Parinari forest fringes some of the limestone basins in Solwezi district, but this vegetation type was not encountered in the filed.

Miombo woodland is the most extensive vegetation type of the project area. It covers the whole of the plateau region, as well as the piedmont and hilly zones. Characteristic of Miombo woodland is a rather low density of trees, with only moderate growth in the larger part of the project area owing to the occurrence of laterite at relatively shallow depth. Consequently the forest canopy is rather open. By contrast, trees of the Kalahari woodland tend to be more vigorous in growth, have a denser canopy (the degree of which depends mainly on the share of Cryptosepalum trees), while there is often a light undergrowth.

The dominant tree species in Miombo woodland are the Brachystegia species, in particular B. boehmii, and to a lesser extent B. longifolia and B. spici-formis, as well as Julbernardia paniculata and Isoberlinia angolensis. Julbernardia was found to dominate in most of Kasempa district, whereas Brachystegia species constitute the majority in the other two districts, thus suggesting a relationship between rainfall and distribution of these two genera. This supports the findings of Trapnell and Clothier (1957) who noted that Julbernardia prospered better in the drier areas of the Miombo woodland zone, and Brachystegia in the wetter parts. Isoberlinia angolensis tends to become the foremost tree in poor miombo woodland, which on the plateau usually means woodland formed shallow and/or relatively poorly drained soils (see also Fanshawe 1971). Virtually pure stands of this species were observed locally near the margins of the Busanga swamp area.

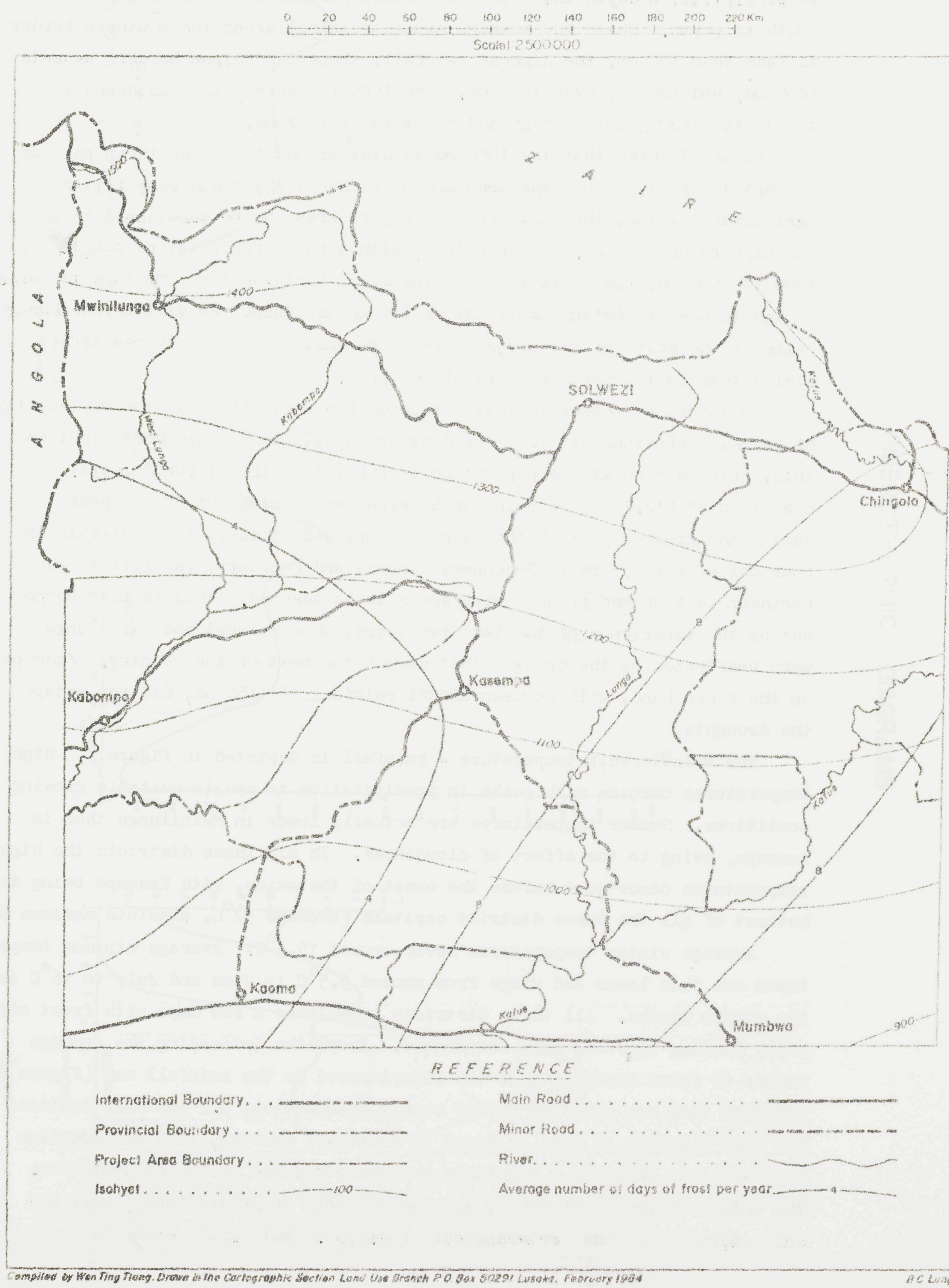
Large parts of the forested land are annually being burned, resulting in a more or less complete removal of the undergrowth. Together with the Chitemene system of cultivation that is still widespread being practised, and which involves a regular clearing of patches of forest, these disturbances give rise to a diversity of secondary tree species that makes it difficult to find meaningful relationships between the faunistic composition of the forests and soil characteristics.

## 2.5 CLIMATE

Zambia experiences a tropical savannah climate that is characterised by an outspoken division into a dry season and a rainy season. Rains start towards the end of the year and continue until March or April. The period from June to late September or early October is normally completely dry.

## Fig.3 MEAN ANNUAL RAINFALL IN MILLIMETRES

*( Based on period 1940–1970 )*




*Compiled by Wen Ting Tiang. Drawn in the Cartographic Section Land Use Branch P O Box 50291 Lusaka. February 1984* B C Langu

Although this applies to the whole of the country, there is a marked gradient in precipitation depth which in the western part of the country increases from south to north. While the average annual rainfall along the southern border is less than 700 mm, the highest rainfall, along the Zairen border exceeds 1400 mm, and locally even 1500 mm. The 1000 mm isohyet is considered to divide the country into a high and a low rainfall zone.

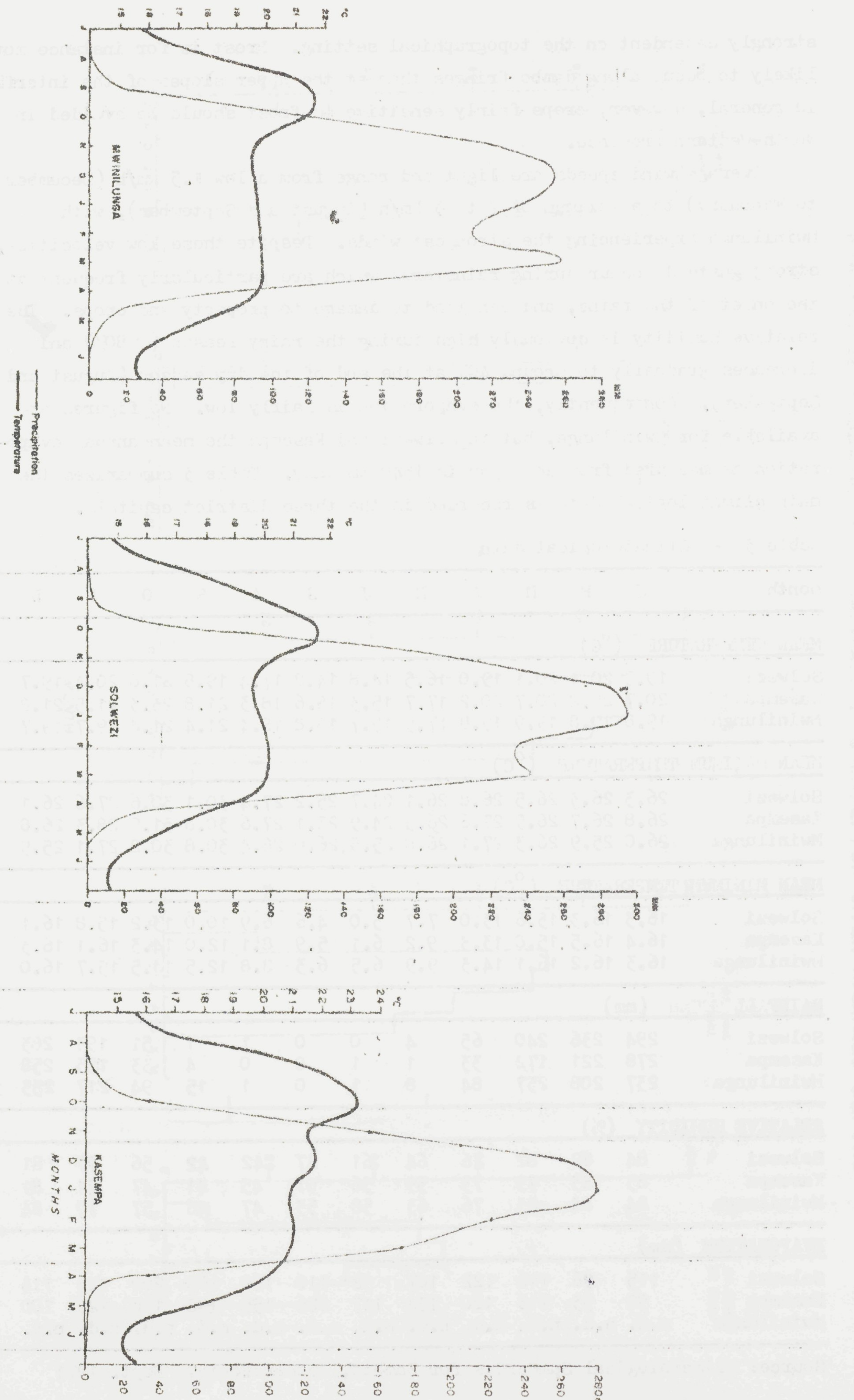
Figure 3 shows that the 1000 mm isohyet transects the southern part of Kasempa district. Since the area south of this isohyet has very little agricultural value, the whole of the project area may be considered to be in the high rainfall zone. Nevertheless, with annual precipitaions ranging from 1000 to 1500 mm, the variation in rainfall in North-Western Province is large enough to have important implications for agriculture. So will below-average rains in the south of the project area more easily have an adverse affect on yields than in the northern part of the area.

An important meteorological parameter for agriculture is the reliability of rains. Unfortunately very few data are available to shed some light on this. Figure 5 shows the percentage probability rainfall for Solwezi. As more than 5" (12.7 cm) of rain can be expected in nine out of ten years during the greater part of the rainy season, and at least 18 cm of rain in four our of five years in December, January and February, rainfall in the northern part of the project area seems to be assured. This is also borne out by the experience of the last two years, when Solwezi and Mwinilunga were unaffected by the drought that struck the rest of the country. Kasempa, on the other hand, with an mean annual rainfall of 1156 mm, did not escape the droughts.

The relationship temperature - rainfall is depicted in figure 4. High temperatures combine with peaks in precipitation to create suitable growing conditions. Summer temperatures are actually lower in Mwinilunga than in Kasempa, owing to the effect of cloudiness. In all three districts the highest temperatures occur just before the onset of the rains, with Kasempa being the hottest of all the three district capitals (average 32°C, absolute maximum 36°C)

Average winter temperatures hover around 15.5°C. Average minimum temperatures are much lower and range from around 5.5°C in June and July to 16°C in the summer months. All three districts experience a few days with frost each year, falling in June, July and August. Isopleths indicating the average number of frost days per year are superimposed on the rainfall map (figure 3). Although they are based on rather scanty information, and probably indicate too high a number of days of frost in southeast Kasempa, they do underline the fact that frost is a regularly recurring feature in the project area. The actual incidence of frost, and particularly of ground frost, will not only depend on the geographical location, but will also be

# OMBROTHERMIC DIAGRAMS



strongly dependent on the topographical setting. Frost is for instance more likely to occur along dambo fringes than at the upper slopes of the interfluve. In general, however, crops fairly sensitive to frost should be avoided in North-Western Province.

Average wind speeds are light and range from a low 1.5 km/h (December to February) to a maximum of 2 to 3 km/h (August and September), with Mwinilunga experiencing the strongest winds. Despite these low velocities, strong gusts do occur during rainstorms which are particularly frequent at the onset of the rains, and can lead to damage to property and crops. The relative humidity is obviously high during the rainy reason (> 80%) and decreases gradually to around 40% at the end of the dry season (August and September). Consequently, the evaporation is fairly low. No figures are available for Mwinilunga, but in Solwezi and Kasempa the mean annual evaporation as measured from an A pan is 1540 mm only. Table 3 summarizes the main climatological data as recorded in the three district capitals.

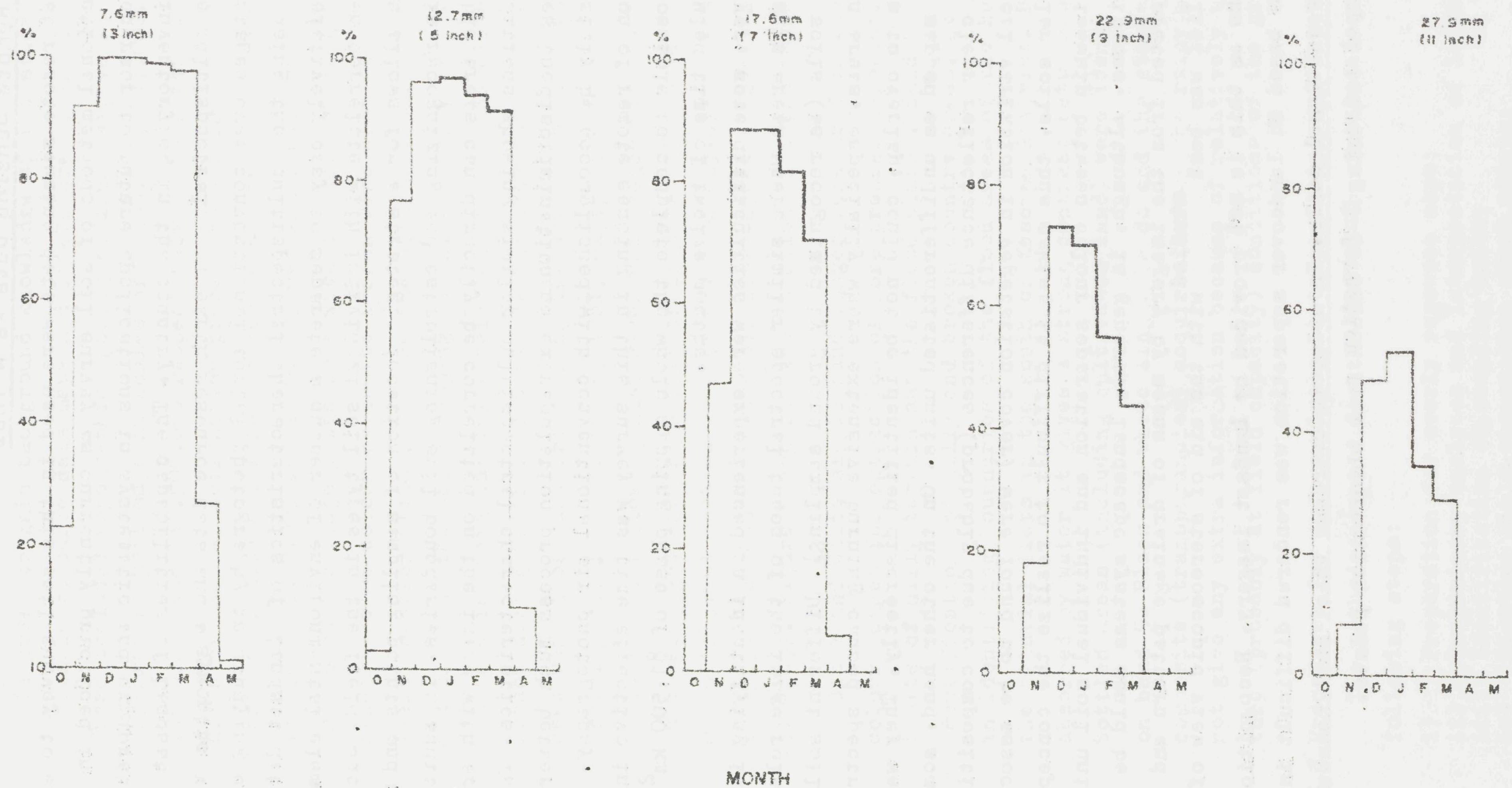
table 3 – Climatological data

| month | J | F | M | A | M | J | J | A | S | O | N | D | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN TEMPERATURE (°C) | | | | | | | | | | | | | |
| Solwezi | 19.9 | 20.1 | 20.1 | 19.0 | 16.5 | 14.8 | 14.8 | 17.4 | 19.8 | 21.8 | 20.4 | 19.7 | 18.7 |
| Kasempa | 20.7 | 20.2 | 20.7 | 20.2 | 17.7 | 15.3 | 15.6 | 18.3 | 21.8 | 23.3 | 21.5 | 21.8 | 19.8 |
| Mwinilunga | 19.8 | 19.8 | 19.9 | 19.8 | 17.9 | 15.7 | 15.8 | 18.4 | 21.4 | 21.4 | 19.7 | 19.7 | 19.2 |
| MEAN MAXIMUM TEMPERATURE (°C) | | | | | | | | | | | | | |
| Solwezi | 26.3 | 26.3 | 26.5 | 26.8 | 26.1 | 24.7 | 25.2 | 27.4 | 30.1 | 30.6 | 27.6 | 26.1 | 27.0 |
| Kasempa | 26.8 | 26.7 | 26.9 | 27.6 | 26.5 | 24.9 | 25.1 | 27.6 | 30.8 | 31.9 | 28.3 | 26.8 | 27.5 |
| Mwinilunga | 26.0 | 25.9 | 26.3 | 27.1 | 26.8 | 25.5 | 26.0 | 28.4 | 30.8 | 30.2 | 27.1 | 25.9 | 27.2 |
| MEAN MINIMUM TEMPERATURE (°C) | | | | | | | | | | | | | |
| Solwezi | 16.3 | 16.3 | 15.6 | 13.0 | 7.7 | 5.0 | 4.6 | 6.9 | 10.0 | 13.2 | 15.8 | 16.1 | 11.7 |
| Kasempa | 16.4 | 16.5 | 15.8 | 13.3 | 9.2 | 6.1 | 5.9 | 8.1 | 12.0 | 14.3 | 16.1 | 16.3 | 12.5 |
| Mwinilunga | 16.3 | 16.2 | 16.1 | 14.3 | 9.9 | 6.5 | 6.3 | 8.8 | 12.5 | 14.5 | 15.7 | 16.0 | 12.8 |
| RAINFALL TOTAL (mm) | | | | | | | | | | | | | |
| Solwezi | 294 | 236 | 240 | 65 | 4 | 0 | 0 | 1 | 1 | 51 | 193 | 283 | 1368 |
| Kasempa | 278 | 221 | 172 | 33 | 1 | 1 | 0 | 0 | 4 | 33 | 155 | 258 | 1156 |
| Mwinilunga | 237 | 208 | 257 | 84 | 8 | 1 | 0 | 1 | 15 | 94 | 217 | 255 | 1377 |
| RELATIVE HUMIDITY (%) | | | | | | | | | | | | | |
| Solwezi | 84 | 82 | 82 | 76 | 64 | 61 | 47 | 42 | 42 | 56 | 77 | 81 | 66 |
| Kasempa | 83 | 83 | 79 | 73 | 59 | 56 | 51 | 45 | 41 | 47 | 71 | 81 | 64 |
| Mwinilunga | 84 | 84 | 83 | 76 | 63 | 58 | 53 | 47 | 46 | 57 | 79 | 84 | 68 |
| EVAPORATION (mm) | | | | | | | | | | | | | |
| Solwezi | 115 | 96 | 116 | 122 | 107 | 92 | 110 | 160 | 169 | 200 | 123 | 114 | 1524 |
| Kasempa | 92 | 93 | 116 | 120 | 134 | 117 | 126 | 158 | 192 | 190 | 125 | 100 | 1563 |
| Mwinilunga | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |

Source: Climatological Summaries for Zambia, Meteorological Dept. 1971

Fig. 5

PERCENTAGE PROBABILITY OF RAINFALL IN SOLWEZI FOR GIVEN RAINFALL DEPTHS




FIGURES FROM DEPT. OF METEOROLOGY, CLIMATE DATA PUBLICATION 12 (1969) : THE CLIMATE OF SOLWEZI

# CHAPTER 3 METHODOLOGY

## 3.1 Landsat Remote Sensing Data As A Tool

3.1 Landsat remote sensing data were used in this soil survey to enhance the conventional methods of soil survey as currently practiced in Zambia and as precursor to future applications in systematic and exploratory soil resource inventorying in the country. The capabilities of Landsat imagery to provide multispectral and earth resource data and a synoptic view has some advantages over conventional aerial photography in studying extensive areas. By using the multispectral characteristics of Landsat data it becomes relatively easy to separate a number of environmental elements which often correlate with individual soil types in the field. Such a separation allows for a strategic location of sampling points and increased accuracy in recognizing and establishing soil boundaries. In addition, inaccessible areas can directly be correlated on the image with areas of known conditions showing similar multispectral characteristics. This facilitates the discrimination and extrapolation process much better than could possibly be accomplished with conventional air photography. The application of remote sensing in this survey was time effective in that it was possible to complete the whole mapping phase of 81,500 km$^2$ within the scheduled time of twelve months.

However, some difficulties were experienced in identifying individual soil types in areas where similar spectral tones of the image related to different soils (as recognized by ground sampling). Different soils in floodplain areas, especially where extensive burning caused spectral signatures to overlap, could not be identified discreetly. They were therefore mapped as undifferentiated units. On the other hand, some areas which had clear reflectance differences (probably due to compositional and phenological variation in vegetation cover) were found to be associated with similar soils, thus making it difficult to realize the concept of the relationship between colour separation and individual soil units under such conditions. Although, in general, landscape systems could be recognized and interpreted from the imagery by means of drainage pattern and texture, actual relief was best studied with the aid of stereoscopic view of aerial photographs as this is not provided by Landsat imagery. Recognition of soil boundaries based on landcover separation was rendered difficult in zones of gradual transitional soils. In order to overcome this, soil boundary lines were interpolated using information from observation points.

## 3.2 Data source

In order to gain background knowledge of the study area a number of available resource data maps and literature materials were examined. These included topographic, geologic, land use, vegetation and low level exploratory soil maps at scales of 1:250.000, 1:1.000.000, 1:750.000, 1:500.000 and 1:2.500.000 respectively. Documented literature on the soils of Zambia, soil survey procedures and land use planning guides were also studied. A full coverage of aerial photographs (at scale 1:60.000, 1:40.000 and 1:30.000) was examined. Location of aerial photographs on the imagery was done with the help of flight plan diagrams. Landsat false colour composite images were used at two scales; one for field location (1:500.000) and the other (1:250.000) for establishing and plotting the basic mapping units. The study area was covered by images which were carefully selected to coincide closely with the season during which fieldwork was being conducted. Therefore, the images used were those acquired during the dry season on three consecutive days from 12th to 14th September, 1981, except for one scene 22480-07395 of 6-11-81. The following list gives the images with path and row number that were used either in full or in part: 22424-07273 (185/68), 22424-07275 (185/69), 22424-07282 (185/70), 22425-07331 (186/68), 22426-07392 (187/69), 22426-07395 (187/70), 22427-07444 (188/68) and 22427-07451 (188/69). Figure 6 depicts the location of these images.

Black and white single band images were used in support of the false colour images for extraction of more precise information on extension limits of hilly terrain and the flood plains. Band 7 (B/W) was used for identification of hilly and broken country areas. It was also useful in identifying boundaries of the flood areas of the Busanga swamps and the alluvial flats in the south of Kasempa district. Because band 7 is absorbed by water it gives a strong contrast between wet and dry lands. Settled areas (including cultivated land) were identified easily on band 5. Black and white single bands and the standard false colour composite (transparancies) acquired during the rainy months of March did not give any extra information because of relatively uniform soil moisture (probably at field capacity) conditions of the ground.

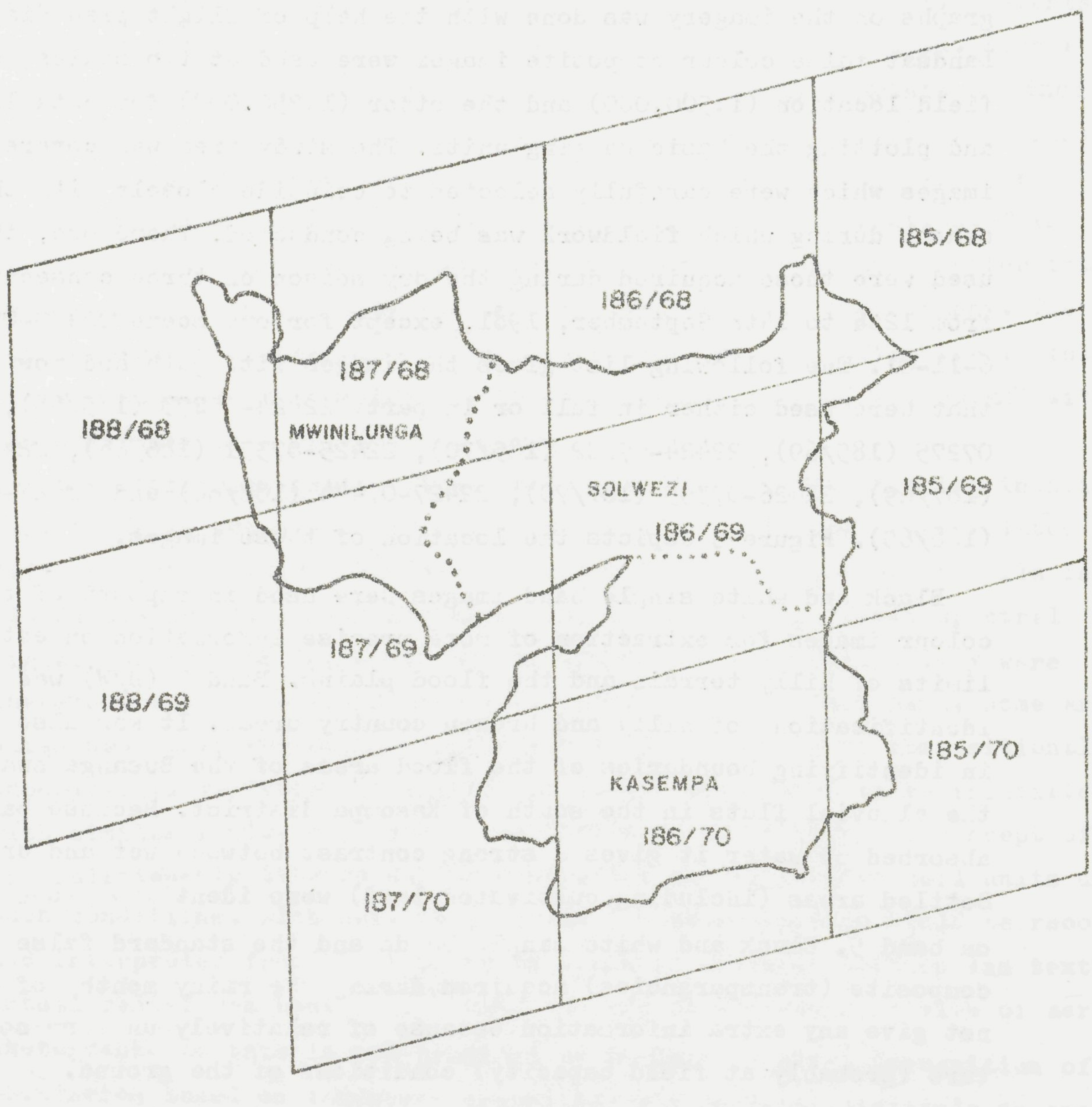
## 3.3 Procedures for data analyses, interpretation and mapping

The methods adapted for the use of the Landsat data involved the following steps:

i) Preparation for overly resource maps;
ii) Preliminary analyses and interpretation of Landsat images;
iii) Identification of sampling units;
iv) Plotting field observation check points;
v) Synthesis of preliminary interpretation and field data;
vi) Delineation of final soil mapping units.

Fig. 6

# LANDSAT COVER OF THE PROJECT AREA



Details of the field observation work, soil description and soil classification are dealt with in other chapters of the report. However, it should be mentioned here that field conditions relating to vegetation cover (plant canopy), ground surface and stage of leaf growth of trees (most of them were semi-evergreen) were recorded. This information was extrapolated over areas of apparently similar image characteristics, which, could not be visited because of poor accessibility and time limit.

The following procedures based on the above five steps were adapted in the development of soil association units (the final mapping units) using Landsat imagery as a base map.

3.4 Preparation for Resource Maps Overlay

Some background resource data maps were adjusted first to the field working scale of 1:250.000. This process involved the geological map which was enlarged from 1:1,000,000 to 1:250.000 using a reflecting projector (other equipments could be used), and detailed geological maps, for as far as available, which were reduced from 1:100.000 to the working scale. A physiographic map overlay was generated from the Landsat imagery with substantial stereoscopic interpretation and visual analysis of airphotos. During this exercise, topographic line maps (without contours) were used to relate the general location of hilly areas on the image. The airphotos, however, were quite useful in recognizing relief features especially in the absence of contoured maps. Such features as incised river channels, general slope gradient, details of flood plains (leeves, terraces, back swamps) and alluvial flats were best studied through aerial photo interpretation. Other resource maps such as vegetation, land use and exploratory soil data maps were used as spot and cross check reference during the process of identifying certain image features.

A drainage map overlay of Kasempa district was developed for the purpose of enhancing and studying drainage features. For disturbed areas, like areas of intensive human settlement and the floodplain areas, airphoto interpretation was used to obtain more precise information on drainage courses. This map made it possible to identify and separate three major drainage systems, viz. denditric, rectangular and deranged, the first one being dominant in the project area. These drainage systems were subdivided into six density classes, ranging from very coarse to fine. It was found that this set-up related well to the physiography and geology. Hence, the drainage map overlay was used to delineate the different physiographic and geologic regions more accurately. Indirect the drainage had therefore an important bearing on the soils of the project area as well.

3.5 Preliminary analysis and interpretation

Separation of landcover types was made on a Landsat image mosaic (false colour composite) at a working scale of 1:250.000. Delineations were based on (a) spectral tonal differences, (b) drainage pattern and density, (c) textural characteristics of the image, and (d) surficial geometry of the drainage channels. Other environmental elements such as: homogeneity of the image features, disturbances of vegetation due to human activities (cultivation and burning), floods, time of the season during which the Landsat data were acquired and available ground truth data, were taken into account. Image features which appeared similar or different were easily discriminated on the basis of these characteristics and each delineation was assigned a symbol according to the designed interpretation key.

The key was based on visual interpretation of the spectral tone (colour, chroma and hue) and texture as the main criteria. These were defined qualitatively. There were many ways this could be done. For instance, one had to be flexible on whether one used letter symbols or numbers. In this exercise, a combination of both was used. The letter symbols (B, R, Y) were used to denote the principal spectral colours (blue, red, yellow) of the delineation. This letter symbol was followed by a small number standing for the overtone colour. A symbol like $R_1$ would stand for deep red, while $R_2$ represented light red, $B_1$ deep blue etc. In addition, each delineation was given a serial identification number with a circle around it. This identification number was used to recognize different units during the process of mapping, composing (identifying individual soil units of the association) and describing different map units.

Air photos were examined, both stereoscopically and singly as second level ground truth, to obtain more information about observable environmental features on the image and to ascertain their actual boundaries in case of doubt. Aerial photos were also used to locate ground sampling points.

3.6 Identification of sampling units

By overlay interpretation general association units could be predicted by composing and synthesizing information on the integrated map overlay of geology and physiography.

This integrated map was superimposed over the Landsat base map. The landcover separation overlay was then laid on top of this integrated map overlay. This arrangement allowed for simultaneous study of the information on the three resource maps (i.e Landsat image, geological/physiographic and landcover separation map). Sampling points were then selected on the basis of reflectance differences of the image, geological and physiographic data and the inferred soil characteristics. For example, an obseration check point could be located on recognisable and uniformly representative wet spot; shallow or laterite duricrust, areas of dif erent vegetational canopy cover (indicated by distinct shades of infrared tone), known geological unit and physiographic position (interfluvial, upper, middle or lower slope). In addition, the observation check points were located in such a manner that the dominant soil of any given soil association could be expected to be struck. Because of the large extent of the study area and lack of access tracks to some of the places, the information obtained on the sampled units was extrapolated to other points of similar image characteristics where sampling was not conducted.

3.7 Plotting Field Observation Points

The selected observation check points on the imagery were transferred to the aerial photographs and also on a 1:500,000 image (where no photo cover was available). These were used for field Location. By doing so it became possible to locate accurately the check points in the field. Those recognizable ground features s such as river junctions, crossroads, streams, sharp road bends were used as reference. Air photographs were viewed stereoscopically to study the ground conditions in sufficient detail before the final location of the check points. This procedure was very important in flood plains and cultivated areas where ground features were not always clear on the image. All the field check points were plotted on a clear acetate film overlay using the Landsat image as a base. These points were numbered according to route and survey party.

3.8 Synthesis of Preliminary Interpretation With Field Data

Each soil observed was described according to standard Soil Survey Unit procedures. For each dif erent parent material soils with similar field cha acteristics were grouped together and classified according to both the FAO Soil Map of the World Legend and the Soil Taxonomy. This groupingwas adjusted where necessary, and the classification refined when the laboratory results became available. The range of characteristics for each soil thus distinguished was now described as well. All the soils, including the major phases were given a colour symbol with which they were identified and marked on the field observation point overlay. By superimposing the three overlay maps (geological-physiographic, field observation data and landcover separation) on top of the Landsat image all the assembled data were put together. It became then possible to analyse all this information from each location and conveniently synthesize the data through overlay interpretation.

The soil association units resulting from the initial interpretation were then revised. This was done by checking the relevance of the preliminary mapping unit boundaries against the established soils within each unit. Since all soil having a similar classification were grouped together and assigned a colour symbol, it was easy to recognize and compare their distribution with the corresponding tone and-or pattern on the image. However, most of the revised boundaries agreed closely with the preliminary separations.

## 3.9 Delineating Soil Mapping Units

The composition of the mapping units, in terms of percentage of individual soil units, was established on the assumption that there was a relationship between a given soil and its corresponding spectral tone and pattern on the image and also by taking into account the catenary sequences as observed in the field. An estimation of each association composition (by percentage) was achieved by comparing the proportions and distribution of environmental elements of the image which corresponded to the pattern of occurrence of the soil units in question. For example, if a certain soil unit, e.g. oxic paleustult (ferralic arenosol, FAO), could be associated with a bright and fine textured red tone on the image, and this colour element accounted for a quarter of the delineation, then this soil unit would represent 25% of the total area of that particular delineation. The proportion of the other remaining individual soil units within the delineation were assessed in the same way. Information pertaining to the identified mapping units was extrapolated to other apparently similar units where no observations had been made. However, the composition by area percentage of those extrapolated units had to be assessed individually.

In order to reduce the final number of mapping units those associations which were identified to be similar in terms of dominant soils and, where feasible, the associated soils, were grouped together (lumping). Apart from drastically reducing the final number of mapping units this grouping yielded units that were useful in determining land capability classes.

# CHAPTER 4 SOIL

## 4.1 Previous work

Before the present survey was initiated relatively little attention had been paid to the soils of North-Western Province. The very first map depicting the soils of the province was, of course, Trapnell's well known "Vegetation - Soil Map of Northern Rhodesia", sheet 1, which was published in 1957 (see figure 7), although fieldwork for this map was carried out in the early thirties. The legend for this map uses vegetation types to subdivide the land at the two highest levels, while the third and last level is broken down according to general soil groups. For the project area basically two groups of soils have been distinguished: the plateau soils and the Kalahari sands, together with some miscellaneous soils.

Red earths, however, were considered to differ enough from the average plateau soils to warrant their own mapping unit. Apparently they were mainly separated on account of being preferred by the local population for farming, although some of their characteristics, like depth and colour, were noticed to contrast with those of the other plateau soils. It was also recognized that the red earths occur chiefly over dolomite and feldspathic rock of the Katanga system.

The plateau soils sensu stricto and described as highly leached, of low organic matter content, with a weak granular structure in the upper horizons and with commonly laterite concretions in the lower subsoil. On the map no further subdivision is made in this class of soils, but the accompanying report distinguishes three subgroups. The Old Laterite Soils refer to the shallow "truncated" soils, pallid grey to yellowish, overlying massive laterite sheets, as they occur in southwest Kasempa district. Light Coloured Sandy Soils comprise the "sandveld" soils (light clayey soils with a very light, rather sandy topsoil), but no mention is made of them occurring in North-Western Province, though it was realized that they form over granites, gneisses and associated rocks. Yellow and Orange Clayey Soils concern the reddish brown clayey soils that occupy large parts of Solwezi and Kasempa districts, as well as occurring in Mwinilunga district.

The Kalahari sand soils are divided into Undifferentiated Kalahari soils (the Kalahari sands proper), the Transitional Sands, having a greyer or browner colour and being less acid, and the Kalahari Contact Soils with a more loamy texture. Thus, despite lacking several of the modern soil survey aids, and with far less accessibility to the area, Trapnell and associates were already able to distinguish the main soil groups that occur in North-Western Province, even though they did not manage to map their distribution.

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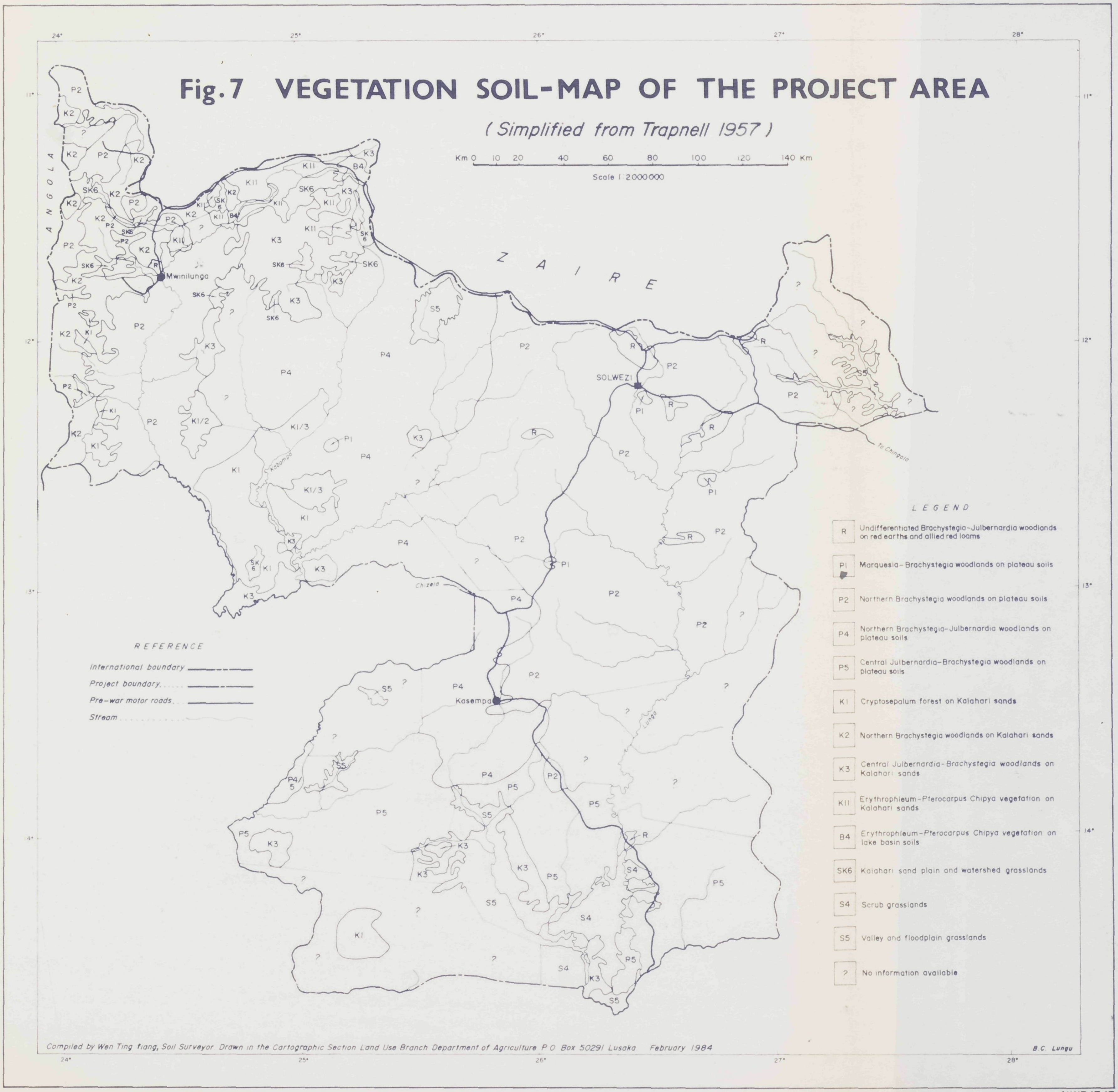



Fig.7 VEGETATION SOIL-MAP OF THE PROJECT AREA

NWP/3/3

in great detail.

The two other national soil maps that have been published since (Soils Map of the Federation of Rhodesia and Nyasaland, Causeway 1960, and Soils Map of the Republic of Zambia, Lusaka 1960), both at a scale of 1:2.500.000, do not provide any more information on the soils of the project area than does Trapnell's map. The older map divides the project area into a Kalahari sand belt and a Northern Plateau Soils area, with sandy to medium textured soils over a heavier subsoil, strongly leached with a very low inherent fertility and usually laterite at depth. The more recent map describes the plateau area as consisting of leached "sandveld" soils.

As far as could be ascertained, the first areas to be surveyed at a more detailed level were the Kafue headwaters. Here a fairly intensive survey at a scale of 1:50.000 was carried out in 1956 and 1957. The maps resulting from this survey are still on file, but it is not known whether any report was ever published to accompany these maps. Soils were differentiated according to two criteria: colour and depth. Some use has been made of these maps, especially in demarcating the very shallow soils and in plotting the deep red soils in the northeastern corner of Solwezi district.

In 1968 an American consultancy firm carried out an "Ultra Rapid Reconnaisance Survey" of the Kalahari sands in Zambia (Parson Corporation, 1969). Despite part of their mandate lying in the project area, this airborne survey (an aircraft and a helicopter were used) did not extend further than Zambezi. Consequently no useful information could be extracted from the report.

During the initial phase of the NORAD sponsored Soil Survey Project, North-Western Province was being looked after by the Soil Survey team based in Ndola. The first soil surveyor there, Dr. Heilmann, surveyed the proposed sites for two settlement schemes in 1977: Nyangombi (Mwinilunga district) and Jivundu (Solwezi district), both located close to the Solwezi-Mwinilunga road. The resulting combined soil-land capability maps were published in Soil Survey Reports 54 and 55 at a scale of 1:10.000 and 1:13.300 respectively. In 1979 Dr. Heilmann compiled an "Exploratory Soils Map" of Mwinilunga and Solwezi districts, together with a derived "Soil Potential Map" at a scale of 1:500.000. No report to accompany these maps was produced, but the summary profile descriptions (based on auger observations) and analytical data were published. Since fieldwork for this survey was completed in two weeks, and no satellite imagery had been available, the accuracy of this map is not very high. The broad grouping of the main soil types is, however, in agreement with what was found during the present survey.

Mr. Dalal-Clayton, successor to Dr. Heilmann in the Copperbelt, likewise took charge of two surveys in North-Western Province. These were the semi-detailed surveys of the Chafukuma area and of the Solwezi State Farm (Soil Survey Reports 89 and 90, 1982), at a scale of 1:30.000 and 1:20.000 respectively. In 1982 the then District Land Use Planning Officer, Mr. Broekhuis, surveyed the Chishala area southeast of Solwezi boma. The draft soil map (scale 1:30.000), profile descriptions and analytical data were all at hand for this survey, although the report has not yet been published.

Very fruitful use was made of these five semi-detailed soil surveys, both to ascertain the extent of the different soils and their characteristics, as well as to acquire a better insight in their catenary relationship. Apart from the Soil Survey Reports, some land capability maps of settlement schemes and a proposed State Farm in Kasempa district were consulted. The usefulness of these maps proved to be limited, but it was found more profitable to take their author, Mr. Simfukwe, Planning Assistent in Kasempa, along on field trips and draw on his extensive knowledge of the district.

4.2 The map

The type of mapping unit employed to compile a soil map depends to a large extent on the scale of the map. While soil series, being the basic unit of classification, can be used in medium and high intensity surveys, they are not suited to function as a mapping unit or the component soil thereof in low intensity surveys. The mapping units of this soil map consist of associations of soils, i.e. of groups of soils that have a defined relationship to each other. This relationship is in most cases of a catenary nature, in which drainage, depth and slope are major differentiating factors. The component soils have been classified up to the family level according to the Soil Taxonomy (Soil Survey Staff, 1975) and the "subgroup" level following the FAO/Unesco Soil Map of the World Legend (Unesco, 1975).

The associations themselves are organized into a dominant soil, a co-dominant soil and a number of major inclusions. Dominant soils occur in at least 30% of any delineation, co-dominant soils have an extent of at least 25%, while major inclusions occupy 10% or more. The average dominant soil covers in fact 48% of a delineation, a percentage that is obviously higher in uniform areas like the Kalahari sand zone, and less in more complicated areas like on some parts of the plateau. Co-dominant soils on average take up 28% of a delineation, and major inclusions 11%.

The landform approach was used in order to be able to correlate soil catenas to more easily identifiable landforms. In this manner the soil associations could be grouped according to the type of landscape in which they occur. In the project area this approach did not result in very outspoken subdivisions, due to the very old age of the land and the consequently very subdued landforms. Such morphologically uniform areas also contain numerous intermediate landforms, often of substantial extent, which cannot always be easily demarcated or separated from adjoining landscapes.

Hence the geology was used as the principal criterion to subdivide the mapping units, on the basis that different parent materials yield different soils, even though these may be similar in several aspects. This hypothesis was found to be valid in other parts of Africa, and could be confirmed in the project area. Most soil associations can therefore be considered to have developed over a single type of parent material.

The soils that make up the associations have been listed in a soil legend, which provides some information on a number of physical characteristics as well. This soil legend has been included on the soil map, together with the soil association legend.

## 4.3 Soil legend

Soils have been differentiated according to a number of criteria, the most important of which relates to the type of diagnostic horizon. Other criteria include parent material, drainage and depth, as well as some secondary chemical data. Depth was considered a phase where it concerned moderately deep to moderately shallow variants of deeper soils (suffix "d" added). Similarly, some variants of plateau soils that had relatively steep slopes were also considered as a phase (suffix "s").

International classification has been according to the FAO/Unesco Soil Map of the World Legend, and the Soil Taxonomy of the U.S. Department of Agriculture. Although the latter allows a more narrowly defined classification, as it spans four levels of differentiation (against two for the FAO/Unesco legend), this does not apply to the most ubiquitous soil of the project area, the ferralsol (oxisol in Soil Taxonomy parlance). This stems from the fact that due to the lack of sufficient data the oxisol order has not been fully developed in the Soil Taxonomy. Hence some of the soils are classified similarly according to the Soil Taxonomy, but differently according to the FAO/Unesco legend (e.g. soils 35 and 36), while the reverse occurs as well (e.g. soils 13 and 14). Soil Taxonomy classification is up to the family level, although because of space restrictions the legend on the map only indicates the suborder, with the textural class of the control section (in most cases between the lower boundary of the surface horizon and 1 m depth) given in a separate column.

The soil temperature regime has been considered to be isohyperthermic, based on data from van Wambeke and theoretical considerations of the Meteorological Department (Nyendwa, 1981). In reality the soil temperature regime probably straddles the isothermic/isohyperthermic boundary, as is suggested by some preliminary data from Solwezi (see table 4). These data give an isotable 4 Soil temperatures in Solwezi and Mwinilunga (°C)

| Station | Depth (cm) | J | F | M | A | M | J | J | A | S | O | N | D | year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solwezi (1975-1980) | 5 | 20.3 | 20.1 | 20.1 | 19.1 | 15.7 | 12.3 | 12.0 | 13.9 | 17.9 | 21.4 | 20.5 | 20.4 | 17.9 |
| | 10 | 20.7 | 20.5 | 20.6 | 19.7 | 16.9 | 13.8 | 13.6 | 15.4 | 19.2 | 21.3 | 20.5 | 20.7 | 18.6 |
| | 20 | 22.1 | 22.2 | 22.0 | 21.1 | 19.1 | 16.5 | 16.2 | 17.8 | 21.7 | 23.2 | 22.0 | 22.1 | 20.5 |
| | 50 | 22.5 | 22.8 | 22.7 | 22.2 | 21.1 | 19.1 | 18.8 | 18.9 | 22.1 | 23.3 | 23.1 | 23.0 | 21.6 |
| Mwinilunga (1974-1980) | 5 | 19.9 | 19.4 | 19.3 | 18.6 | 15.8 | 12.2 | 11.3 | 13.9 | 18.3 | 20.3 | 20.5 | 20.1 | 17.5 |
| | 10 | 20.0 | 19.7 | 19.6 | 19.4 | 17.3 | 14.5 | 13.6 | 16.1 | 19.6 | 20.8 | 20.4 | 19.7 | 18.4 |
| | 20 | 21.7 | 21.6 | 21.4 | 21.5 | 20.8 | 18.2 | 17.5 | 19.7 | 23.1 | 23.4 | 22.2 | 21.3 | 21.0 |
| | 50 | 22.1 | 22.2 | 22.1 | 22.6 | 22.8 | 20.8 | 20.1 | 20.8 | 23.5 | 23.5 | 23.3 | 22.2 | 22.2 |

data courtesy Meteorological Department

thermic soil temperature regime for Solwezi and an isohyperthermic one for Mwinilunga.

The Zambian classification has been according to the fourth approximation of the Key to Zambian Soil Series. This Key is still in the process of being set up, and the soil classification must therefore be regarded as very tentative. No definitions and names are as yet available at family level, although this would have been a more appropriate level of classification considering the scale of the map.

Table 5 is a copy of the soil legend as incorporated on the soil map, with an extra column added for the land capability rating of each soil. The individual soils will be dealt with below according to their FAO/Unesco classification, arranged as follows :

1 ferralsol
2 acrisol
3 luvisol
4 cambisol
5 arenosol
6 gleysol
7 regosol

### 4.3.1 Ferralsols

Ferralsols (oxisols according to the Soil Taxonomy) are soils with an oxic B horizon, which is characterised by a very low CEC (less than 16 me/100 g clay), a low base status (ECEC less than 10 me/100 g clay) and a rather uniform texture profile. The formation of an oxic B horizon is the result of a very long period of weathering coupled with very intensive leaching.

Ferralsols are normally several metres deep but, except for the red ferralsols, this is not the case with most of the ferralsols in the project area. The qualification "very deep" in the legend only indicates that they are more than 1.20 m deep, but some form of laterite or saprolite (weathered rock) is usually encountered in 2 m deep soil pits. The majority of the ferralsols in North-Western Province are actually believed to be underlain by a lateritic horizon.

table 5

| SOIL LEGEND | | | depth class | drainage class | dominant slope | texture control section | capability rating | represen-tative profile pit |
|---|---|---|---|---|---|---|---|---|
| SOIL CODE | FAO/UNESCO CLASSIFICATION | SOIL TAXONOMY CLASSIFICATION | | | | | | |
| 10 | rhodic ferralsol | typic and tropeptic haplustox | 1 | 4 | A | f | 35 | 2, 3, 26 |
| 11 | orthic ferralsol | typic haplustox | 1 | 4 | A | f | 35 | 11,16,37 |
| 12 | orthic ferralsol * | typic haplustox | 1 | 4 | A | f | 44 | 5, 10,30 |
| 13 | orthic ferralsol ** | tropeptic haplustox | 1/2 | 4 | A | f | 35 | 8 |
| 14 | orthic ferralsol | typic haplustox | 1 | 4 | A | fl | 30 | - |
| 15 | rhodic ferralsol * | tropeptic haplustox | 1/2 | 4 | A | f | 36 | 34 |
| 16 | acric ferralsol | haplic acrustox | 1 | 4 | A | f | 24 | 19, 32 |
| 17 | acric ferralsol | haplic acrustox | 1 | 4 | A | f | 38 | 7 ,38,39 |
| 18 | ferric acrisol | oxic paleustult | 2/1 | 4/3 | A | fl | 33 | 4 ,12,15 |
| 19 | gleyic ferric acrisol | aquic paleustult | 2/1 | 2 | A | f/fl | 25 | - |
| 20 | ferric acrisol | oxic paleustult | 2/1 | 4 | A | f | 40 | 20 |
| 21 | xanthic ferralsol | typic haplustox | 1 | 4 | A | f | 25 | 29 |
| 22 | xanthic ferralsol | ultic haplustox | 1 | 4 | A | l | 24 | 31 |
| 23 | orthic ferralsol | ultic haplustox | 1 | 4 | A | l | 21 | 27 |
| 24 | xanthic ferralsol | psammentic haplustox | 1 | 4/3 | A | l | 14 | - |
| 25 | gleyic ferralsol | epiaquic haplustox | 1 | 3 | O/A | fl | 32 | 46 |
| 26 | eutric gleysol | aeric tropaquept | 1 | 1 | A | f | 30 | - |
| 27 | dystric gleysol | aeric tropaquept | 1 | 1 | A/O | cl | 15 | 40 |
| 28 | ferralic luvic arenosol | oxic paleustult | 1 | 5 | A | cl | 17 | 25 |
| 29 | petroferric ferralic arenosol | petroferric ustipsamment | 2/3 | 4/3 | A | cl | 10 | - |
| 30 | mollic gleysol | typic haplaquoll | 1 | 0 | 0 | f | 0 | - |
| 31 | lithic dystric regosol | lithic ustorthent | 4/5 | 4 | B+ | f/fl | 0 | - |
| 32 | petroferric dystric regosol | petroferric ustorthent | 4/5 | 4 | A/B | f/fl | 0 | - |
| 33 | dystric gleyic cambisol | aquic dystrochrept | 2/1 | 3/2 | A | f | 0 | - |
| 34 | petroferric dystric regosol | petroferric ustorthent | 4 | 3/2 | O | f/fl | 28 | - |
| 35 | xanthic ferralsol | ultic haplustox | 1 | 4 | A | f | 26 | 28,43,47 |
| 36 | orthic ferralsol | ultic haplustox | 1 | 4 | A/B | f/fl | 21 | 22,33 |
| 37 | ferric luvisol | ultic paleustalf | 2/3 | 4 | A/B | f | 52 | 23 |
| 38 | orthic ferralsol | ultic haplustox | 1 | 4 | A | fl/f | 31 | 42 |
| 39 | fluvic gleyic cambisol | fluvaquentic dystrochrept | 1/2 | 3 | A | l | 0 | - |
| 40 | eutric and dystric gleysol | mollic tropaquent | 1 | 1 | A | f/fl | 0 | 51 |

* frequent gravels within 120 cm

** frequent gravels within 60 cm

a suffix 'd' indicates a moderately deep to moderately shallow phase

a suffix 's' indicates a slope phase of dominantly 'B' slopes table 5 continued

| LEGEND OF SOIL CHARACTERISTICS | | | |
|---|---|---|---|
| DRAINAGE CLASSES | | DEPTH CLASSES | |
| 0 | very pooly drained | 1 | very deep (more than 120 cm) |
| 1 | poorly drained | 2 | deep (90 - 120 cm) |
| 2 | imperfectly drained | 3 | moderately deep (60 - 90 cm) |
| 3 | moderately well drained | 4 | moderately shallow (30 - 60 cm) |
| 4 | well drained | 5 | shallow (less than 30 cm) |
| 5 | somewhat excessively drained | | |
| SLOPE CLASSES | | TEXTURE CLASSES | |
| 0 | very gently sloping (0 - 1%) | f | fine clayey |
| A | gently sloping (1 - 3%) | fl | fine loamy |
| B | moderately sloping (3 - 5%) | cl | coarse loamy |
| | | l | fine and coarse loamy |

A clayey control section is not required for an oxic B horizon, but in the project area nearly all of the ferralsols have a clayey control section as well as a clayey surface horizon, the only exception being the soils that have been classified as ultic haplustox according to the Soil Taxonomy. These soils have a light surface horizon, with a rather abrupt texture increase to fine loamy or fine clayey in the subsoil. All ferralsols occur on the plateau, and consequently have very gentle slopes and are well drained. An exception is the gleyic ferralsol from the Ntambu area. The mineralogy class is kaolinitic for the clayey classes and siliceous for the fine loamy classes.

Table 6 lists all the ferralsols, together with their physical and chemical properties and the parent material they are believed to have developed from.

Soil 16
- acric ferralsol (FAO)
- haplic acrustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Meheba series, acric phase (Key to Zambian Soil Series)
- typical profiles: 19 and 32

Extremely leached very deep red soils, formed over Kundulunga siltstone and carbonaceous shale. Clayey throughout, although soils with a somewhat lighter topsoil (sandy clay) occur in Mwinilunga district, probably on account of admixture with some Kalahari sand. Silt content is moderate for a soil develope over Kundulunga (less than 20%).

Very low pH in the upper part of the profile (4.0), that increases somewhat with depth to 4.4. The highly leached character of this soil is reflected in a CEC clay of less than 10 me per 100 g, and above all by a base saturation of less than 5%, a level which it already has in the surface horizon. Although the Al saturation is close to 90%, absolute amounts of exchangeable Al are not very high. The ECEC remains therefore below 1.5 me per 100 g clay in at least part of the subsoil.

This soil can be found mainly in Mwinilunga district, around the boma, with minor occurrences in Solwezi district.

Soil 17
- acric ferralsol (FAO)
- haplic acrustox, fine to very fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Chafuguma and Mumena series (Key to Zambian Soil Series)
- typical profiles: 7, 38, 39

Very deep red soil derived from carbonatic rock, mainly marble. The soil is clayey throughout, sometimes even very fine clayey (60% or more clay, as in profile 38). The upper part of profile 39 has an exceptional low clay content, which is possibly the result of an addition of colluvial material.

Even though CEC values per 100 g clay are low (about 10 me), the pH is invariably somewhat higher than that of other ferralsols, hovering around 4.6 (range 4.4 to 4.7). The base saturation is mostly less than 10%, but has been noted to rise to 30% in some pits. It is likely that this is due to a slightly impeded drainage in the lower part of the limestone solution basins table 6 Ferralsols and their properties

| | classification (FAO/Soil Taxonomy) | parent material | texture 1/ (topsoil) | texture 1/ (control section) | pH 2/ | CEC 3/ | CEC 4/ | ECEC 4/ | BS 5/ | Al 6/ |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | acric ferralsol haplic acrustox | Kundelungu (siltstone and shale) | C- SC | f | 4.1 | 5 | <10 | 1.5 | <5 | 90 |
| 17 | acric ferralsol hapl~~i~~c acrust~~o~~x | carbonatic rock | C- CL | f- vf | 4.6 | 6 | 10 | 1.5 | <10 | 70 |
| 10 | rhodic ferralsol typic haplustox | Kundelungu (phyllite and sandstone ?) | SC -C | f | 4.3 | 8 | 12 | 4 | 5- 15 | 70 |
| 15 | rhodic ferralsol tropeptic haplustox | basic igneous rock | C | f | 4.4 | 12 | <15 | 2 | <5 | >90 |
| 21 | xanthic ferralsol typic haplustox | Basement complex (granite) | C | f | 4.0 | 6 | 5- 10 | 2 | <5 | >90 |
| 22 | xanthic ferralsol ultic haplustox | Kalahari sand and Kundelungu (shale) | LS -SL | fl -cl | 4.3 | 2.5 | 10 -15 | 3.5 | 12 | 90 |
| 24 | xanthic ferralsol psammentic haplustox | Kalahari sand | LS | cl- fl* | 4.2 *) | 3* | 10 *) | nd | 10 *) | nd |
| 35 | xanthic ferralsol ultic haplustox | Basement complex (gneiss and schist) | SL | f | 4.2 | 4.5 | 8- 18 | 7 | 10 -15 | 70 |
| 11 | orthic ferralsol typic haplustox | Kundelungu (meta-siltstone) | C- CL | f | 4.2 | 6.5 | 8- 12 | 2 | 5- 10 | 70 |
| 12 | orthic ferralsol petroferric haplustox | Kundelungu (meta-siltstone) | C | f | 4.4 | 7 | 15 | nd | 15 | nd |
| 13 | orthic ferralsol petroferric haplustox | Kundelungu (meta-siltstone) | C | f | 4.1 | 7 | 15 | nd | 5 | nd |
| 14 | orthic ferralsol typic haplustox | Kundelungu (meta-siltstone) | SL | fl | 4.2 *) | 6* | 10 *) | nd | 10 *) | nd |
| 23 | orthic ferralsol ultic haplustox | Kalahari sand | SL | fl -cl | 4.0 | 3 | 10 | nd | <5 | nd |
| 36 | orthic ferralsol ultic haplustox | Kundelungu and Kalahari sand | SCL -SL | f- fl | 4.0 | 4 | 12 | 6 | 5- 10 | 90 |
| 38 | orthic ferralsol ultic haplustox | Basement complex (muscovite schist) | SL | f- fl | 4.1 | 4.5 | <10 | 3 | 10 | >70 |
| 25 | gleyic ferralsol epiaquic haplustox | Kalahari sand (reworked ?) | SL -LS | fl | 4.2 | 2 | <10 | nd | 25 | nd |

1/ texture topsoil and texture control section; 2/ pH ($CaCl_2$); 3/ per 100 g soil; 4/ per 100 g clay; 5/ base saturation (%); 6/ Al saturation (%); *) estimated values; the chemical parameters refer to the upper subsoil (50 - 100 cm depth)

in northern Solwezi district. Ca and Mg are the only two bases of importance, K and Na being negligible low. Soluble Al amounts are rather low, which correlates to a low exchangeable Al content. Thus, the Al saturation is not as high as in other ferralsols, ranging from 60 to 80%.

The Al saturation of profile pit 7 is not more than 40%, but this pit is exceptional in more than one respect. Its exchangeable Mg and K content are high compared to the other pits of this soil, it has a relatively low silt content, while its total Fe content is extremely high. Because of this, and because of the concentration of hematite dust observed near the pit site, free iron might be high enough to place this pit in the oxidic mineralogy class.

Associations dominated by this soil are mainly concentrated in Solwezi district, although they occur in Kasempa and, to a lesser extent, in Mwinilunga district as well. In the northern part of Solwezi district they form conspicious basins bounded by relatively steep scarps. A clear sample of such an escarpement is visible just outside Solwezi, on the road to Mutande, where the transition from the plateau to the limestone basin forms a prominent slope just north of the road. Elsewhere the areas underlain by limestone are more or less level with the surrounding plateau, but can be recognized on aerial photographs and Landsat by their lack of streams and by the well-developed woodland, the latter being consequent upon very deep soils and relatively little human disturbance.

Soil 10
- rhodic ferralsol (FAO)
- typic and tropeptic haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Mulonga and Meheba series (Key to Zambian Soil Series)
- typical profiles: 2, 3, 26

This is the red soil assumed to have developed over meta-siltstone, meta-argillite and quartzitic sandstone of the Kundelunga series. Due to the great depth of this soil the parent material, or even laterite layer, has not been observed in profile pits or auger holes, but a small quartzitic hill along the Mwinilunga - Chibwika road is mantled by a shallow soil of red clayey material. A deep to moderately deep phase was observed as well, containing frequent laterite gravels in the lower part of the profile, but its extent was too small to be included on the map. This phase usually occurs near the transition to another soil.

Profiles 2 and 26 are virtually structureless in the subsoil, but profile 3 was found to have some structure, reason why both typic and tropeptic subgroups have been recognized, although the former undoubtedly prevails. Particle size class is fine, tending to very fine as the clay content increases to over 60% with depth. The topsoil is sandy clay to clay (35 to 50% clay), while the silt content is moderately high (15 to 30%).

Soil reaction is strongly acid, with a pH of 4.3 or less. Exchangeable Al is high, and exchangeable bases are low, with Mg being the highest, and even K in excess of Ca, bearing out the metamorphic character of the parent material. The Al saturation is thus very high, already exceeding 70% in the top 10 cm. This soil occurs more or less randomly, often of a rather limited areal extent, in the region underlain by the sandstone and siltstone of the Kundelungu, where it is intimately associated with orthic ferralsol 11.

Soil 15
- rhodic ferralsol (FAO)
- tropeptic haplustox, fine, kaolinitic, isohyperthermic (Soil Taxon
- Chafuguma series, Lwawu variant (Key to Zambian Soil Series)
- typical profiles: 34, NWP/27/77

This soil occurs in the project area only along the Angolan border near Lwawu. It is a fairly deep red soil formed over igneous and meta-igneous basic rock, resembling basalt. Frequent laterite gravels are common below 90 cm. The profile shows some structure development.

A fine clayey texture was observed at all sites tested. The fine loamy texture of pit NWP/27/77 must be considered an exception. The high fine sand content of that profile indicates that it is probably an intergrade to the adjoining Kalahari sand soils.

Soil reaction is acid, between 4.3 and 4.5, reflecting the influence of the basic parent material. CEC is very low (less than 15 me/100 g clay), while the base content is extremely low. As a result the Al saturation reaches nearly 100% in the subsoil.

<u>Soil 21</u>
- xanthic ferralsol (FAO)
- typic haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Samfya series (Key to Zambian Soil Series)
- typical profile: 29 and NWP/15/77

Soil derived from granite, main area of occurrence lying in the north-western part of Mwinilunga district, with a smaller patch near Musele village along the Chovwe road. Brownish clayey soils that are characterised by a mostly 30 to 40 cm deep A horizon. The clay content increases slowly with depth. The relatively high content of coarse sand can be attributed to the texture of the parent material. Medium sand is high as well, in particular in the upper part of the profile. This can be ascribed to some admixture with Kalahari sand.

Chemically very poor soils, like most of the other ferralsols, with a very low pH (about 4.0), a low CEC clay (5 to 10 me per 100 g clay), a very low base saturation (less than 10%), and an Al saturation close to 100%.

<u>Soil 22</u>
- xanthic ferralsol (FAO)
- ultic haplustox, fine loamy to coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Nkolemfumu series (Key to Zambian Soil Series)
- typical profiles: 31, NWP/42/77

Yellowish brown soil, with a fine loamy control section, occassionally coarse loamy, formed in an admixture of residual weathering material derived from Kundelungu siltstone and shales, and allochtonous Kalahari sand. Texture is coarsest in the upper part of the profile, where it ranges from loamy sand to sandy loam, while it increases irregularly with depth to sandy loam and sandy clay loam. The rather wide textural range can be attributed to the complex origin. This soil differs from the orthic ferralsol 36 in having a greater component of Kalahari sand, especially at depth, and containing less iron, as is expressed by a more brownish colour.

Although the CEC clay is more than 10 me per 100 g, the low clay content makes that the CEC soil is not significant higher than that of other ferralsols. Base saturation is variable, from less than 5% to over 10%, but low, while the pH ranges from 4.1 to 4.5, and Al saturation is about 90%.

The occurrence of this soil is confined to the northern and northwestern parts of Mwinilungadistrict, where it is found in close association with other ferralsols.

Soil 24 - xanthic ferralsol (FAO)
- psammentic haplustox, coarse loamy and fine loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Mulubolo series (Key to Zambian Soil Series)

The classification of this brownish soil is tentative, as there is no profile pit to represent it. Basically this soil is a Kalahari sand soil variant, which has a slightly heavier texture than the typical soil formed in Kalahari sand, and is further characterised by a rather dark topsoil. It forms part of the low lying Kalahari sands, where it occupies the lower part of the catena. Hence the drainage of this soil is not as well as that of the other ferralsols. A fairly large part of its occurrence is moderately wel drained, locally even imperfectly drained. This relative wetness is borne out by the vegetation, which comprises an important element of Marquesia trees, a species otherwise not common at all on the Kalahari sands.

Topsoil texture is loamy sand, increasing to sandy loam in the subsoil. Chemical characteristics are likely to be similar to those of other ferralsols, with possibly a slightly higher CEC and base saturation. A good example of this soil can be found near Lwawu mission, Mwinilunga district.

Soil 35 - xanthic ferralsol (FAO)
- ultic haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Shilende series (Key to Zambian Soil Series)
- typical profiles: 28, 43, 47, NWP/3/82

Very deep reddish to brownish yellow soils formed over biotite gneiss and subordinate schists of the Basement complex, and characterized by a light sandy loam topsoil fairly abruptly overlying a subsoil that has a texture of sandy clay loam in the upper part, gradually increasing to sandy clay in the lower part. The thickness of the light surface layer is variable, from as little as 8 cm to 40 cm. These differences may have been brought about by cultivation attendant erosion in the past. The silt content of these soils is rather low, less than 20%. In the sand fraction the fine sand dominates (average about 30%) and there is a relatively high coarse sand component (about 5%).

The pH is very low, 4.1 to 4.3, CEC clay is relatively high (10 to 18 me per 100 g), and the base saturation varies from 10 to 15%, with K, Ca and Mg all being present. Al saturation is around 70%, and soluble Al is in the order of 10 ppm.

Profile 28 represents a somewhat eroded phase of this soil, located on a relatively steep slope towards the Lumwana stream. The main characteristics of this profile are similar to the other profiles, but the light topsoil has apparently been removed by erosion.

This soil covers the domes of Basement Complex formations in Mwinilunga and Solwezi districts. These domes are not inhabited and most of this soil type is therefore not under cultivation. One of the reasons for this is probably the low moisture holding capacity of the topsoil.

Soil 11
- orthic ferralsol (FAO)
- typic haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Kasempa series (Key to Zambian Soil Series)
- typical profiles: 11, 16, 37

As the name of this soil implies, it is the typical soil for a large part of Kasempa district. It is common in Solwezi district also, mainly west of the Mutanda river, and in Mwinilunga district, both south of Mwinilunga and in the Ikelenga area. This orthic ferralsol has been derived from pinkish meta-siltstone (weathered colour) and meta-argillites of the Kundelungu series. Weathered fragments of the parent material were encountered in the bottom of most pits. Very deep, but laterite gravels, quartz fragments and saprolite usually occurs within 2 m. Indurated laterite layers are rare in this soil.

Strongly acid, with a pH of less than 4.5. The CEC ranges from 5 to 16 me per 100 g clay. It is near the upper limit in the more hilly areas (cf. pit 16), between 10 and 14 in Kasempa district and the southern part of Solwezi district (pit 11), and decreasing to below 10 me in the more northern parts of Solwezi district (pit 37). Although the division between the last two groups coincides with the meta-siltstone and meta-argillite areas, it is probably the more intensive leaching resulting from an increase in rainfall (see fig. 3) that is responsible for the decrease in CEC, rather than the stronger metamorphosic nature of the parent material. Content of exchangeable bases is less than 20%, with potassium generally dominating the complex in the subsoil, and Ca being less than Mg. The influence of the metamorphic minerals must be held responsible for this. The Al saturation in the subsoil exceeds 70%.

<u>Soil 12</u>
- orthic ferralsol (FAO)
- petroferric haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Kasempa series, gravelly phase (Key to Zambian Soil Series)
- typical profiles: 5, 10

Soil 12 is a phase of the orthic ferralsol described above, with the upper boundary of a laterite horizonn occurring between 90 and 120 cm depth and often laterite gravels at even shallower depth. Because of this shallow petroferric contact, the pH of the subsoil is slightly higher than that of the orthic ferralsol described above (11), and with an attendant higher base status as well. The occurrence of this soil is mainly limited to Kasempa district, and the northwestern part of Mwinilunga district.

<u>Soil 13</u>
- orthic ferralsol (FAO)
- petroferric haplustox, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Kasempa series, gravelly phase (Key to Zambian Soil Series)
- typical profile: 8

This orthic ferralsol is also a phase of orthic ferralsol 11, with frequent laterite gravels within 60 cm, often already appearing within 20 cm depth. No indurated laterite is present in the typical profile. It is not known whether this is the rule or the exception, but as this soil has the same chemical properties as profile 11, an indurated layer seems to be lacking. Texturally the soil is also very similar to the Kasempa series proper, apart from a higher gravel content. This latter feature makes this soil less suitable for cultivation than the foregoing orthic ferralsols.

Soil 14
- orthic ferralsol (FAO)
- typic haplustox, fine loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Kasempa series, loamy phase (Key to Zambian Soil Series)

A fine loamy phase of orthic ferralsol 11. This soil only occurs southeast of Kasempa and has probably been derived from a locally more sandier siltstone. No profile pit represents this soil, but its chemical characteristics are believed to be similar to those of orthic ferralsol 11.

Soil 23
- orthic ferralsol (FAO)
- ultic haplustox, fine loamy and coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Misamfu series, Kalahari sand variant (Key to Zambian Soil Series)
- typical profile. 27

Very deep soil of the Kalahari contact zone. Probably developed in a mixture of eolian sand and residual soil material. Both fine loamy and coarse loamy variants occur. There is a marked increase in clay content with depth, but there are no indications that this might be on account of clay translocation Structureless subsoil, The colour range is fairly wide, with hues from 5YR to 10YR.

In line with most Kalahari sand soils, the pH is extremely low, ranging from 3.7 to 4.2. Hence the soil is nearly depleted of bases, and the base saturation is less than 5%.

Soil 36
- orthic ferralsol (FAO)
- ultic haplustox, fine clayey and fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)
- Misamfu series (Key to Zambian Soil Series)
- typical profiles: 22 and 33

Residual soil with a strong admixture of Kalahari sand, particularly in the upper part of the profile. This results in a strong textural gradient, with sandy loam topsoils that change fairly abruptly to sandy clay loam or sandy clay in the subsoil. The high fine sand content compared to the rather low silt content is a reflection of the Kalahari sand influence, and cannot be attributed to the underlying parent rock (most likely Kundelungu). Very deep structureless soils, whose main occurrence is south and west of Mwinilunga In this area the streams have incised fairly deep, so that slope phases are common.

Strongly leached soils with a very acid reaction (pH around 4.0), and a a base status that is only marginally better than that of orthic ferralsol 23 (5 to 10%). Al saturation is in excess of 85%.

Soil 38
- orthic ferralsol (FAO)
- ultic haplustox, fine clayey to fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)
- Mulobolo series (Key to Zambian Soil Series)
- typical profile 42

Soil developed over Basement Complex muscovite-kyanite schists, with a light topsoil abruptly overlying a heavier subsoil of sandy clay loam to sandy clay texture, increasing to clay in the lower part of the subsoil. This soil is as a rule not much deeper than 2 metre, with indurated laterite marking the boundary. Structure less in the subsoil.

Very acid soil reaction (pH around 4.1), a CEC of less than 10 me per 100 g clay, with potassium dominating the exchange complex, and with a base saturation of about 10%. The Al saturation increases from 40% in the top to double that value in the lower subsoil.

Soil 25
- gleyic ferralsoil (FAO)
- epiaquic haplustox, fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)
- Mayondo series, Kalahari variant (Key to Zambian Soil Series)
- typical profile: 46

Soil derived from Kalahari sand. It is not clear whether the parent material is original wind deposited sand, or has been reworked by fluvial action, so that it has a sedimentary rather than an eolian origin. The very high and irregular coarse sand content seems to favour the former explanation.

Topsoil texture is loamy sand or sandy loam, and there is a gradual increase in clay content with depth to sandy clay in the subsoil. The depth of the sandy clay varies, but was found to be usually within 1 m. In this respect the representative profile is rather a-typical.

The topography of the terrace is rather uneven. This has a bearing on the drainage characteristics, which vary from well drained on the higher parts to imperfectly drained in the lower lying areas. The internal drainage is impeded by the relatively heavy sandy clay in the subsoil, while the external drainage suffers during the rainy season from an excess of water from the much higher hinterland, and a poor discharge of water due to the flatness of the land.

The soil reaction is very low, (4.2) and decreases slightly with depth. CEC figures are low as well, although not as low as the pure Kalahari sands (cf. profile 25). The base saturation is, however, relatively high, with potassium being the dominant base. The phosphorus content is fairly high, which seems to be a special characteristic of wet sandy soils (cf. profile 40). This soil only occurs along the northern bank of the Kabompo floodplain near Ntambu in Mwinilunga district.

### 4.3.2 Acrisols

Acrisols are soils with a clay illuviation horizon (argillic horizon) which has a base saturation of less than 50% within 125 cm depth. Apart from the required clay increase an argillic horizon should contain at least 1% clay cutans. Although features resembling cutans are often observable in profile pits in the project area, they usually cannot unequivocally be identified as illuviation cutans. Thin sections have shown, however, that such clay cutans exist in at least some of the acrisols.

The base saturation of the acrisols in North-Western Province, although being less than 50%, is nevertheless higher than that of the ferralsols (20 to 30% versus 5 to 15%). Only the gleyic ferralsols have a base saturation that resembles the acrisols. Although ferralsols have, on the other hand, a higher CEC per 100 g soil, this does not completely compensate for their lower base saturation, as the acrisols in the project area contain still about 100% more bases per 100 g soil. Th pH of all the acrisols is about 4.5, again being somewhat better than that of the ferralsols.

Despite these comparatively favourable characteristics, acrisols do not seem to be very much sought after by local farmers. Two factors are probably responsible for this. Foremost must be the environmental conditions. The acrisol zone can be very wet during the rainy season, making it not only an unpleasant area to live in, but also severely restricting access to the area. Furthermore, sources for domestic water are generally scarce there, while the underlying laterite makes it difficult to dig wells. Secondly, the moisture holding capacity of the acrisols, and in particular of their topsoil, is lower than that of the more clayey ferralsols. Since most of the acrisols in the project area are situated in southern Kasempa district, where the rainfall is about 1,000 mm/year, this could be an important consideration for farmers when they have to decide where next to shift their fields.

The acrisols of North-Western Province are difficult to associate with a particular parent rock. It appears that they have been subjected to certain pedogenetic processes and even geogenetic processes that were superimposed on the normal in-situ weathering of the rock.

Soil 18
- ferric acrisol (FAO)
- oxic paleustult, fine loamy to coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Kahare series, Kasempa variant, and Ipafu series (Key to Zambian Soil Series)
- typical profiles: 4, 12, 15

Yellowish brown soils, very deep, initially probably formed over Kundelunga siltstone, but later modified as a result of hydromorphic processes, when the groundwater level must have been substantially higher than at present. Nowadays the drainage is moderately well, as is indicated by mottling between 50 and 100 cm. The topsoil is sandy loam to sandy clay loam, there is a moderate but unmistaken clay bulge in the profile. The clay increase varies from 30% to 100%, but this is only partly due to illuviation processes.

pH values are high in the toplayer (5.7), but drop to 4.5 and lower in the subsoil. The CEC/soil is not very high (about 4 me), but CEC per 100 g clay ranges from 12 to 20 me in the upper subsoil. Base saturation varies from 20 to 40%, exceeding 50% in the topsoil. The Al saturation is low, throughout the profile less than 25%.

This acrisol forms a transitional band between the orthic and rhodic ferralsols that prevail in most of Kasempa district, and the shallow rather wet soils (petroferric dystric regosols) that occur in the southern part of the district. Although this soil is still part of the gently undulating plateau, the undulating character becomes progressively less within this transitional zone.

Profile pit 15 is slightly deviating from pits 4 and 12, in having a higher clay content and being less deep, with frequent laterite gravels within 200 cm. It can be regarded as intermediate between the ferric acrisol and the gleyic ferric acrisol (soil 19).

Soil 19 - gleyic ferric acrisol (FAO)
- aquic pleustult, fine clayey to fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)
- Kado series, dry variant (Key to Zambian Soil Series)
- typical profile: NWP/2/82

This light brown soil has been formed in colluvial/alluvial material that has accumulated in periodically wet places. The topsoil texture varies from sandy loam to sandy clay, including clay loam. The subsoil is fine clayey or fine loamy. Laterite underlies the soil at relatively shallow depth, often already within one metre. The wetness of the soil is borne out by the vegetation, which ranges from stunted woodland to shrubbed open grassland.

Soil reaction, CEC/soil and base saturation are all very low. Al saturation is likely to be very high, as can be deducted from the single profile that has been analyzed. However, in view of the mode of formation of this soil, a fairly wide range of soil physical and chemical characteristics can be expected.

This acrisol is found in two distinct settings. It constitutes the "upland" dambos that occur over Basement Complex rocks. Such upland dambos are flat open areas that lack clearly identifiable drainage lines, and even may have B slopes (3 to 5%). It is also an important soil of the Kafue Headwaters zone. Here the soils, covered by poor miombo woodland, have a higher silt content than elsewhere, and have commonly laterite gravels in the profile that start already from very shallow depths.

Soil 20
- ferric acrisol (FAO)
- oxic paleustult, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Mayondo series (Key to Zambian Soil Series)
- typical profile: 20

Common brownish yellow soil of the dambo fringe zone in the gently undulating plateau area. Also occurs over Basement Complex schists. Deep to moderately deep, with sometimes laterite in the lower part of the profile. The texture is variable, especially in the upper part of the profile, where the topsoil texture ranges from sandy loam to sandy clay. Sandy clay loam is the most frequent topsoil texture, however. Subsoil texture is sandy clay to clay, occassionally coarser. The soil is normally well drained, but closer to the dambo it may change into moderately well drained.

The soil reaction is relatively high (4.5), but CEC/soil and base saturation values are low. Al saturation is around 60%.

Apart from being a common soil along dambo fringes, this soil is frequent all over the plateau near Mujimanzovu, south of Solwezi.

### 4.3.3 Luvisols

Like acrisols, luvisols are soils with an illuvial clay accumulation horizon. They differ from acrisols in having a base saturation of more than 50% in all of this argillic horizon. Luvisols are not very common in Zambia, and certainly not in the high rainfall zone. Nevertheless, in the southwestern part of Mwinilunga district there is a fairly wide area where luvisols prevail. The main properties of the acrisols and luvisols are listed in table 7.

table 7 Acrisols and luvisols and their properties

| | classification (FAO/Soil Taxonomy) | parent material | texture 1/ | | pH 2/ | CEC 3/ | CEC 4/ | ECEC 4/ | BS 5/ | Al 6/ |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | ferric acrisol<br>oxic paleustult | Kundelungu | SL-SCL | fl-f | 4.5-5 | 4 | 12-20 | 4 | 20-40 | 20 |
| 19 | gleyic ferric acrisol<br>aquic paleustult | alluvium/ colluvium | SL-SC | fl-f | 4.3 | 2-4 | 10-18 | nd | 5 | nd |
| 20 | ferric acrisol<br>oxic paleustult | Basement Complex (schist) and colluvium | SCL | f | 5.0 | 4 | 8 | 2 | 7-15 | 60 |
| 37 | ferric luvisol<br>ultic paleustalf | biotite schist | CL-SCL | f | 5.0 | 15-20 | 35 | 25 | 65 | <15 |

1/ texture topsoil and texture control section; 2/ pH ($CaCl_2$); 3/ per 100 g soi
4/ per 100 g clay; 5/ base saturation (%); Al saturation (%); the chemical para-meters refer to the upper subsoil (50 to 100 cm)

This soil has developed from a quartzite rich biotite schist which has imparted a rather high silt content to the soil. The weathered parent rock directly underlies the soil, without any laterite or laterite gravel marking the boundary, and often at a rather shallow depth. The area where this soil occurs belongs to the strongly dissected plateau. Because of this slope phases are common, these are usually moderately deep as well. Only on the crests do deep soils occur. The high silt content is largely responsible for this, as it makes the soil susceptible to erosion. So has it been noticed that cultivated fields on the whole are more shallow than where the soil is still covered by woodland, even though many of the trees have already been felled one way or the other.

The chemical characteristics of this soil are outstanding in the context of the project area. The pH is close to 6.0, and consequently very little exchangeable Al is present (less than 15%). The CEC per 100 g clay is around 35 me, indicating that kaolinite is not the only major clay mineral. The base saturation is well over 60%, with Ca and Mg strongly dominating the exchange complex. K is, however, very low, which is surprising in view of the schistaceous nature of the parent material. Also, both soluble Al and Mn are rather high when compared to the more acid soils of the project area.

### 4.3.4 Cambisols

Soils with a weak profile development, resulting in a so-called cambic horizon, are grouped under the cambisols. The two cambisols recognized in the project area are both inferred, as they have not been investigated in detail.

Soil 33
- dystric gleyic cambisol (FAO)
- aquic dystrochrept, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Kado series, wet variant (Key to Zambian Soil Series)

Pale alluvial soil of the ill-defined drainage zones that are common on the plateau with little or no relief. Laterite usually within 2 metre, often less. Imperfectly drained, but moderately well drained occurs too in the transitional belt to the gently undulating plateau. Fine clayey in the subsoil with a loamy sand to sandy clay loam topsoil. These are the soils of the "termitary associated vegetation" (Edwards, 1976), covered by open grassland and groups of trees on low mounds.

Chemical data from similar soils in Kaoma district (south of Kasempa district) give low pH values (4.1), a CEC per 100 g clay of 10 to 18 and a base saturation of 15 to 30% (see also table 8).

Soil 39 - fluvic gleyic cambisol (FAO)
- fluvaquentic dystrochrept, fine loamy and coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Luangwa series, Busanga variant (Key to Zambian Soil Series)

A sandy clay over loamy sand profile, at the edge of the flats surrounding the Busanga swamps, adjoining Kalahari sand deposits. The sand is assumed to be colluvial material from these Kalahari sands, while the covering 20 cm thick clayey layer is an alluvial deposit. Imperfectly and at the lower margin poorly drained soil due to the rise of the water level in the swamps during the rainy season. Chemically very poor soil on account of its sandy substratum.

4.3.5 Arenosols

Arenosols are very weakly developed sandy soils. Their profile consists of a topsoil overlying the "unaltered" parent material (C horizon). Arenosols in the project area have formed in Kalahari sand deposits.

Soil 28 - ferralic luvic arenosol (FAO)
- oxic paleustult, coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Chinsali series, Kalahari variant (Key to Zambian Soil Series)
- typical profile: 25

This is the typical Kalahari sand soil of the project area. Very deep soils, covered either by Cryptosepalum forest or, where disturbed by man, by Kalahari woodland. Topsoil loamy sand to sandy loam, subsoil mostly sandy loam. The subsoil displays a fairly abrupt but small increase in clay content with depth, which could be due to a translocation of clay within the profile. The hue is either 10 YR or 5 YR, with 3/4 and 4/4 being the most common value and chroma combination.

Very poor soils, with a very acid reaction, even in the topsoil (4.0). Low organic matter content, low CEC per 100 g soil and extremely low base saturation pointing to a soil virtually depleted of bases (see also table 8).

Soil 29 - petroferric ferralic arenosol (FAO)
- petroferric ustipsamment, coarse loamy, siliceous (Soil Taxonomy)

Relatively shallow soil, formed in colluviated sand over laterite at the edge of the Busanga swamps. No further details available.

### 4.3.6 Gleysols

Soil with hydromorphic properties, i.e. with the groundwater within 50 cm for a long enough period to create a reducing moisture regime. Obviously gleysols are common in dambos, but these have in most cases not been separated on the map. Pure gleysols, developed from different parent materials, have been identified in the project area. Their properties have been summarized in table 8, together with those of some of the cambisols, arenosols and regosols.

table 8 Gleysols, cambisols, arenosols and th... properties

| | classification (FAO/Soil Taxonomy) | parent material | texture 1/ | | pH 2/ | CEC 3/ | CEC 4/ | BS 5/ |
|---|---|---|---|---|---|---|---|---|
| 33 | dystric gleyic cambisol aquic dystrochrept | alluvium | LS-SCL | f | 4.1 | 4 | 10-18 | 15-30 |
| 28 | ferralic arenosol oxic paleustult | Kalahari sand | LS-SL | cl | 4.0 | 2 | 10-18 | <5 |
| 26 | eutric gleysol aeric tropaquent | limestone derived colluvium and alluvium | CL | f-fl | 5-6.5 | >10 | >24 | 50-100 |
| 27 | dystric gleysol aeric tropaquent | Kalahari sand | S-LS | cl | 4.6 | 1 | 20 | <25 |
| 40 | eutric gleysol mollic tropaquent | alluvium | SL-SC | f-fl | > 4.5 | 8-14 | 15-35 | >50 |
| 34 | petroferric dystric regosol; petroferric ustorthent | alluvium | SiC - SCL | f-fl | 5.0 | 5-10 | 20-30 | 30-50 |

1/ texture topsoil and texture control section; 2/ pH ($CaCl_2$); 3/ per 100 g soil; 4/ per 100 g clay; 5/ base saturation (%); the chemical parameters refer to the upper subsoil (50 to 100 cm depth)

Soil 26 - eutric gleysol (FAO)
- aeric tropaquent, fine, kaolinitic, isohyperthermic (Soil Taxonomy)
- Chalibana series (Key to Zambian Soil Series)

This gleysol forms the lowest part in a number of limestone solution depressions in Solwezi district. These have not been visited due to their remote location. From Landsat and aerial photographs it has been observed that they are quite extensive, the Jivundu swamps even being much larger than 100 $km^2$. They have been distinguished from the other dambos as it is believed that they have more favourable chemical characteristics on account of being saturated with lime-rich water during the rainy season. This is corroborated by data from Jivundu Settlement Scheme (Heilmann 1978) and the analytical results from auger samples taken from a semi-dambo (physiography and vegetation similar to a dambo, but soil shows no signs of waterlogging) a few hundred metres down from the site of pit 38.

The soil at this location can be regarded as being intermediate between a limestone upland soil and the soil of a real limestone dambo, and as such the data from these auger samples provide an indication of the characteristics of the limestone dambo soils.

The texture of the topsoil is clay loam, the texture of the control section is usually fine clayey, occassionally fine loamy. The pH varies from 5 to 6.5, CEC per 100 g clay probably in excess of 24 me, while the CEC/soil is 10 me or more, and the base saturation is higher than 50% and can go up to 100%. Ca is the major base, followed by Mg. Potassium is very low, sodium can be relatively high.

Soil 27
- dystric gleysol (FAO)
- aeric tropaquept, coarse loamy, siliceous, isohyperthermic (Soil Taxonomy)
- Mwinilunga series (Key to Zambian Soil Series)
- typical profile 40

This soil is to be found in the interfluve dambos (Mulapo dambos) on the Kalahari sands in Mwinilunga district. These completely open grasslands, most likely underlain by sheet laterite, become water-logged to close to the surface during the wet months. The topsoil texture is very fine sand, the subsoil is very fine sand, occassionally fine sand, increasing to loamy sand or even sandy loam in the lower parts.

The pH is around 4.5, but lower in the surface horizon. Although this horizon does not contain much organic matter, due to the annual burning of the grass cover, the organic matter content in the subsoil is relatively high. Hence the CEC values of the soil and available pH remain at rather high levels. The base saturation is very low, about 15%.

Soil 30
- mollic gleysol (FAO)
- typic haplaquoll, fine clayey, mixed, isohyperthermic (Soil Taxonomy)
- Lochinvar II series (Key to Zambian Soil Series)

Very poorly drained soil of the Busanga swamps. Unripe clay soils, rich in organic matter, permanently waterlogged, covered by grasses and sedges. The pH is believed to be neutral, the CEC of both soil and clay relatively high, and the base saturation more than 50%. The swamp forest soils of the Kalahari sand region in Mwinilunga district have been included in this unit, although these soils are strictly speaking probably not gleysols. As these forests occur in rivers and streams, their soil moisture regime is unlikely to be reducing, and accordingly these soils should be classified as fluvisols (aquic ustifluvents). They occupy only very small areas.

Soil 40 - eutric and dystric gleysol (FAO)
- mollic tropaquent, fine clayey to fine loamy, mixed, isohyperthermic (Soil Taxonomy)
- Khimbwi and Dambo series (Key to Zambian Soil Series)
- typical profile: 51

Dambo soils exhibit a very wide range in textural and chemical characteristics. This can be explained by their largely alluvial, and to some extent colluvial mode of formation. The textural composition of a dambo is therefore not only determined by the soil from which the material has been eroded, but also by the depositional conditions. Even within a single dambo there can be quite a variation in texture along the cross and long sections. Generally, however, dambo soils are coarser at the dambo head than downstream, while dambos in gneiss and granite areas tend to be rather sandy, although displaying an increase in clay content with depth. Dambos in schist and metasiltstone areas are more silty, but are normally also clayey in the subsoil. Even the dambos in areas with clayey soils have often a lighter and more loamy topsoil.

The drainage class of dambos varies from moderately well drained along the upper dambo edges to very poorly drained along the drainage line or inside the seepage zone. Most upland dambos can, however, be described as imperfectly to poorly drained, on accountof drying out during the dry season and being wet in the rainy season. Some large dambos are wet for a considerable period of the year, these must therefore be considered poorly to very poorly drained. As only such large dambos have been indicated on the map this drainage class has been assigned to the mapping unit.

With the exception of dambos in the Kalahari sand region, the pH, CEC and base saturation of dambo soils is usually somewhat higher than that of the adjoining upland soils. Again, it depends on several factors, including the length of period of waterlogging, how much more elevated these values are.

Profile 51 is located in one of the very large dambos in the southeast of Solwezi district. The dambo is wet for quite some time after the rains have halted, but dries up in most parts towards the end of the dry season. The texture profile indicates a break in the depositional history: an early period during which a heavy clay was deposited, and a more recent period with slowly moving water which sedimented a more coarser material.

The chemical characteristics have been derived from pit 51 and from auger samples from a second large dambo nearby. Organic carbon is high throughout, resulting from the development from alluvial sediments. pH values are neutral, CEC soil and clay are both fairly high and the base saturation is more than 50%, all thanks mainly to the high organic matter content. For the same reason, these gleysols are close to the fluvisols (typic or fluvaquentic tropaquept), and could therefore also have been classified as fluvic eutric and dystric gleysol, in keeping with what has been done with cambisol no. 39.

### 4.3.7 Regosols

Soils without any diagnostic horizon and more than 10 cm deep, as well as lacking any other special features, are accomodated under the regosols. The regosols in the project area are rather shallow soils over either weathered rock or over more or less extensive laterite sheets.

Soil 31 - lithic dystric regosol (FAO)
- lithic ustorthent, fine clayey to fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)

This is the soil of the hill slopes in the project area. These soils are seldom deep, and rock and/or laterite outcrops are frequent. Often the soils are gravelly too. Tree growth is nevertheless reasonable, because the roots apparently manage to utilize crevices in the bedrock.

It has been noted that soils over shallow rock, or close to rock outcrops (including laterite) are often preferred by farmers. This seems to be due to more favourable characteristics of such soils compared to the surrounding more acid soils. At one such a field at Fkenyauna Settlement Scheme, Kasempa district, the pH was found to be 1.5 unit higher, the CEC/clay nearly double and the base saturation 30% against 12% of the nearby dominant soil.

Soil 32 - petroferric dystric regosol (FAO)
- petroferric ustorthent, fine clayey to fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)

Shallow soils over laterite, well drained. These soils are particularly common as inclusions in the associations over Kundelungu parent material on the gently undulating plateau and piedmonts of Kasempa district. They become the dominant soil in some of the mapping units of the plateau with little or no relief. Blocks of laterite occur commonly at the surface within these units.

Soil 34 - petroferric dystric regosol (FAO)
- petroferric ustorthent, fine clayey to fine loamy, kaolinitic, isohyperthermic (Soil Taxonomy)

Wet variant of soil 32, but as no reducing moisture regime is thought to prevail when the soil is ponded, this soil has not been placed in the gleysol category. It has a higher silt content than soil 32 (up to 50% silt in one sample). It is the most important soil of the plateau with little or no relief. Some of its characteristics are given in table 8.

## 4.4 Mapping units

The mapping units on the soil map consist mostly of soil associations, although some pure soils and soil complexes are included as well (e.g. see units Pu 17/1 and Dk 28/1 for examples of pure soils, and Pu 22/1 for an example of a soil complex). This section gives a brief description of each soil association, indicating the relationship of the constituent soils to each other, and giving the average percentage of each soil within the association. The total extent of each mapping unit is given in square kilometres, with behind this figure in brackets the breakdown according to district (K being Kasempa, S being Solwezi and M standing for Mwinilunga). Apart from the total extent per district the areal extent outside national parks and forests is shown as well where applicable. For instance, (S 250/200) means that the mapping unit concerned occupies 250 km$^2$ in Solwezi district, 200 km$^2$ of which falls outside gazetted areas.

### 4.4.1 Soils developed over metasiltstones, meta-argillites and sandstones

Hh 31/1 - C5d

dominant soil : lithic dystric regosol (31) ......... 45 %
co-dominant soil : orthic ferralsol (12) ............... 35 %
major inclusions : orthic ferralsol (11d) ............. 20 %

extent : 1498 km$^2$ (K)

Association of the hill ranges in northeastern Kasempa district, with very shallow soils on the upper and middle slopes, and deeper soils covering the footslopes. Surrounded in northern Kasempa district by associations dominated by orthic ferralsols (11), and east of Kasempa boma by broken country with somewhat shallower and gravellier orthic ferralsol (12), as well as pediments covered by shallow soils.

Hh 31/2 - C5d

dominant soil : lithic dystric regosol (31) ......... 60 %
co-dominant soil : orthic ferralsol (11d) ............. 30 %
major inclusions : orthic ferralsol (12) ............... 10 %

extent : 513 km$^2$ (K)

Association of hill ranges in southeastern Kasempa district, containing more shallower soils than association Hh 31/1, while also being surrounded by regosols, mostly with a shallow petroferric contact (soils 31, 32 and 34).

Hh 14 - C4

dominant soil : orthic ferralsol (14) ............... 50 %
co-dominant soil : lithic dystric regosol (31) ......... 30 %
major inclusions : orthic ferralsol (11d) ............. 20 %

extent : 125 km$^2$ (k 18; M 107)

Association of hill ranges in northeastern Kasempa district and northern Mwinilunga district. The soils of this association are deeper than those of the other associations that occur on hills. They are also more loamy as a result of colluvial processes.

Hb 12/1 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (12) ............... | 50 % |
| co-dominant soil | : orthic ferralsol (11d) .............. | 30 % |
| major inclusions | : lithic dystric regosol (31) ......... | 20 % |

extent : 436 km$^2$ (K)

Soil association of broken country, south and east of Kasempa boma. The broken country character of this unit has been brought about mainly by deep incision of streams. Erosion has resulted in relatively shallow soils, with laterite commonly outcropping along the slopes.

Hb 12/2 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (12) ............... | 50 % |
| co-dominant soil | : orthic ferralsol (13) ............... | 25 % |
| major inclusions | : ferric acrisol (20s) ................ | 15 % |
| | petroferric dystric regosol (32) .... | 10 % |

extent : 554 km$^2$ (K 304; S 250)

Both relatively deep stream incision and the presence of a number of residual hills are responsible for the broken country landscape in Kasempa and Solwezi districts in which this association occurs. Soils are very variable, with a high percentage rather loamy soils due to colluviation. Ferric acrisols (tentative) have formed in thick colluvial deposits. Soils on dipslopes tend to be shallower than soils on slopes cutting across the bedding planes, and are more likely to have gravels in their subsoil.

Hb 12/3 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (12) ............... | 35 % |
| co-dominant soil | : orthic ferralsol (11d) .............. | 30 % |
| major inclusions | : rhodic ferralsol (10) ............... | 20 % |
| | lithic dystric regosol (31).......... | 15 % |

extent : 358 km$^2$ (K)

Soil association of broken country limited to Kasempa district. This unit, irre-gularly dissected by streams and containing scattered isolated hills, forms a transition from the more hilly areas towards the more regularly dissected plateau landscape. Deeper soils do occur, in particular along the interfluves. Relatively few soils in slope deposits, and with shallow regosols close to the dambos and streams.

Hb 14 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (14) ............... | 50 % |
| major inclusions | : lithic dystric regosol (31) ......... | 20 % |
| | rhodic ferralsol (10) ................ | 15 % |
| | orthic ferralsol (12) ............... | 15 % |

extent : 125 km$^2$ (K)

Soil association east of Kasempa boma, where it intergrades between very low dome-like structures and a group of hills. Soils are loamy because of colluviation and possibly also due to the admixture with more coarse weathering material from granites, which outcrop within the boundaries of this association. Patchy occurrence of red soils (10) along the lower parts of the slopes, and rather deeply incised streams in the southern part of the association. Numerous small and very low hills contribute to a high percentage of shallow rocky soils.

Pp 11d - C3

dominant soil : orthic ferralsol (11d) .............. 35 %
co-dominant soil : orthic ferralsol (12) .............. 35 %
major inclusions : petroferric dystric regosol (32) .... 20 %
lithic dystric regosol (31) ......... 10 %

extent : 254 km$^2$ (K)

Soil association along the Lunga and Mushingashi riversin Kasempa district. Moderately deep soils on the interfluves in between the more or less parallel streams running down the piedmont, interspersed with laterite outcrops. More gravelly and shallower soils closer to the streams.

Pp 31 - C5d

dominant soil : lithic dystric regosol (31) ......... 50 %
co-dominant soil : petroferric dystric regosol (32) .... 40 %
major inclusions : gleyic ferric acrisol (19) .......... 10 %

extent : 366 km$^2$ (K)

Piedmont soil association in Kasempa district along Lunga and Mufwashi rivers. Very shallow soils dominate, over either laterite or rock (A slopes in both cases), which can only support thin stunted forests and grasslands.

Pu 11/1 - C1

dominant soil : orthic ferralsol (11) ............... 70 %
major inclusions : rhodic ferralsol (10) ............... 10 %
orthic ferralsol (11d) .............. 10 %
petroferric dystric regosol (32) .... 10 %

extent : 2556 km$^2$ (K 2169; S 387)

The major soil association of Kasempa district, occurring mainly in its northern part. Very uniform soil cover, occassionally interrupted by patches of red soils (10), and with more shallow soils occurring near the dambos, which usually have a clayey texture. Mostly surrounded by soil associations in which the orthic ferralsol 11 dominates, like Pu 11d/1, Pu 11/2, Pu 11/3 and Pu 11/4. The transitions between these associations are very gradual.

Pu 11/2 - C2

dominant soil : orthic ferralsol (11) ............... 60 %
co-dominant soil : orthic ferralsol (11d) .............. 25 %
major inclusions : petroferric dystric regosol (32) .... 15 %

extent : 1244 km$^2$ (K 1109/1074; S 135/30)

Soil association which has its main occurrence in Kasempa district, where it is closely linked to association Pu 11/1. It differs from the latter in having more moderately deep and shallower soils, and lacking patches of red soils. This association forms "islands" within association Pu 11/1, as well as constituting the main association bordering the hilly areas in northern Kasempa district. The delineation east of the Lunga along the Kasempa-Mumbwa road has probably formed over Karoo sandstone rather than Kundelunga sandstone and siltstone.

Pu 11/3 - C2

dominant soil : orthic ferralsol (11) ............... 40 %
co-dominant soil : orthic ferralsol (14) ............... 30 %
major inclusions : rhodic ferralsol (10) ............... 20 %
ferric acrisol (20) ................. 10 %

extent : 714 km$^2$ (K)

The low "dome-like" structures east of Kasempa boma are covered by this association, in which loamy soils occupy an important part. Rhodic ferralsols occur mostly along the margins of the northern half of the domes (e.g. Mkenyauna settlement scheme). Ferric acrisols form belts along the dambos.

Pu 11/4 - C2

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11) ............... | 30 % |
| co-dominant soil | : orthic ferralsol (13) ............... | 25 % |
| major inclusions | : petroferric dystric regosol (32) .... | 20 % |
| | orthic ferralsol (11d) .............. | 15 % |
| | rhodic ferralsol (10) ............... | 10 % |

extent : 3223 km$^2$ (K 2816/2489; S 407/362)

The major soil association of central Kasempa district. Soils of this association are predominantly less than 1.20 m deep, and contain often frequent laterite gravels within 60 cm. These soils should be considered to be more eroded than the soils of associations Pu 11/1 and Pu 11/2, but pockets of red soil (10) nevertheless persist. In the north usually bounded by associations in which the orthic ferralsol (11) dominates, while along their southern boundary associations with different soils are common, like Pu 18, Pn 32 and Df-u.

Pu 11/5 - C1

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11) ............... | 40 % |
| co-dominant soil | : rhodic ferralsol (10) ............... | 30 % |
| major inclusions | : orthic ferralsol (11d) .............. | 20 % |
| | orthic ferralsol (13) ............... | 10 % |

extent : 1307 km$^2$ (S 1307/1080)

Soil association in southern Solwezi district which includes a high percentage of red soils (10). It cannot be excluded that at least some of these red soils are acric ferralsols developed over carbonatic rock (17) rather than rhodic ferralsols of the Kundelungu series. Patches of gravelly and shallow soils are common.

Pu 11/6 - C2

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11) ............... | 40 % |
| co-dominant soil | : orthic ferralsol (11d) .............. | 25 % |
| major inclusions | : ferric acrisol (20) ................. | 15 % |
| | gleyic ferric acrisol (19) .......... | 10 % |
| | orthic ferralsol (13d) .............. | 10 % |

extent : 1697 km$^2$ (S 1697/1222)

Soil association of eastern Solwezi district. Compared to association Pu 11/1, this association contains considerably more shallow soils. The acrisols, which in other associations occur only along dambo margins (e.g. Pu 11/3), have expanded to the extent that they can be found over a wider area than only near dambos, in particular in the associations in southeastern Solwezi district. The associations situated in northwestern Solwezi district can be expected to include some acric ferralsols over limestone and marls (soil 17). This association is closely related to the Pu/11d associations.

Pu 11d/1 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11d) .............. | 45 % |
| co-dominant soil | : petroferric dystric regosol (32) .... | 30 % |
| major inclusions | : orthic ferralsol (12) ............... | 15 % |
| | orthic ferralsol (13) ............... | 10 % |

extent : 5876 km$^2$ (K 1234/779; S 4642/4107)

Major soil association of Solwezi district (northeast, and just north of the boundary with Kasempa) and Kasempa district (northwest). Mainly shallow soils, locally gravelly, with patches of laterite being very common. The largest delineation of this association forms an approximately eastwest running belt along the boundary with Kasempa district.

Pu 11d/2 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11d) | 40 % |
| co-dominant soil | : orthic ferralsol (11) | 25 % |
| major inclusions | : petroferric dystric regosol (32) | 15 % |
| | ferric acrisol (19) | 10 % |
| | gleyic ferric acrisol (20) | 10 % |

extent : 3630 km$^2$ (S 3630/2682)

Soil association mainly occurring in the eastern part of Solwezi district, where it usually adjoins association Pu 11d/1, although the soils of this association are generally deeper. Acrisols are particularly prevalent in the Kafue headwater region, where they commonly contain gravels in their subsoil. Both associations have a fairly dense network of dambos and streams.

Pu 12 - C2

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (12) | 65 % |
| co-dominant soil | : xanthic ferralsol (22) | 25 % |
| major inclusions | : dystric gleysol (27) | 10 % |

extent : 322 km$^2$ (M)

Soil association in northwestern Mwinilunga district. Around the margins of the delineations the influence of the Kalahari sands can be recognized in lighter textured soils (22), and the occurrence of Kalahari sand dambos (27).

Pu 13 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (13) | 30 % |
| co-dominant soil | : orthic ferralsol (11d) | 25 % |
| major inclusions | : orthic ferralsol (12) | 20 % |
| | petroferric dystric regosol (32) | 15 % |
| | ferric acrisol (18) | 10 % |

extent : 268 km$^2$ (K)

Belt of relatively shallow soils along the Lufupa stream north of Kasempa boma, and surrounded by associations Pu 11/1, Pu 11/3 and Pu 11/4. Outcrops of laterite along dambos, acrisols on low lying areas close to the dambos, higher up gravelly ferralsols.

Pu 16/1 - C3

| | | |
|---|---|---|
| dominant soil | : acric ferralsol (16) | 50 % |
| co-dominant soil | : orthic ferralsol (36) | 25 % |
| major inclusions | : orthic ferralsol (11) | 15 % |
| | xanthic ferralsol (22) | 10 % |

extent : 662 km$^2$ (M)

Soil association east of Mwinilunga boma, with more or less pure residual soils (orthic ferralsol (11) and acric ferralsol) randomly alternated by soils that contain a high component of Kalahari sand admixture (orthic ferralsol (36) and xanthic ferralsol). The soils derived from Kundelungu (11 and 22) are more prevalent in the northern tongue of the association.

Pu 16/2 - C3

| | | |
|---|---|---|
| dominant soil | : acric ferralsol (16) ................ | 35 % |
| co-dominant soil | : orthic ferralsol (11) .............. | 25 % |
| major inclusions | : ferric acrisol (20) ................ | 20 % |
| | orthic ferralsol (11d) ............. | 10 % |
| | petroferric dystric regosol (32) .... | 10 % |

extent : 1455 km$^2$ (S 1167/960; M 288/288)

Main occurrence of this soil association is north of Maheba, Solwezi district. Acric ferralsols and orthic ferralsols, some of the latter being moderately deep, are the main soils on the interfluves. Soils on slopes, in particular on the long slope towards the Mutanda river, have been transformed into ferric acrisols. Shallow soils over laterite can be found along dambos.

Pu 18/1 - C3

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (18) ................ | 55 % |
| co-dominant soil | : gleyic ferric acrisol (19) .......... | 25 % |
| major inclusions | : petroferric dystric regosol (34) .... | 10 % |
| | orthic ferralsol (13) ............... | 10 % |

extent : 1376 km$^2$ (K 1376/1313)

Soil association of southern Kasempa district, with well drained ferric acrisols (18) and minor inclusions of orthic ferralsols (13) on the higher parts of the plateau, and imperfectly drained acrisols (19) in the lower parts and drainageways, where shallow soils over laterite (34) can also be found.

Pu 18/2 - C3

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (18) ................ | 45 % |
| co-dominant soil | : orthic ferralsol (11d).............. | 25 % |
| major inclusions | : orthic ferralsol (13) .............. | 20 % |
| | petroferric dystric regosol (32) .... | 10 % |

extent : 262 km$^2$ (K 262/187)

Transitional soil association from upland area (association Pu 11/2) to more eroded areas, with most of the soils being deep to moderately deep.

Pu 18/3 - C4

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (18) ................ | 60 % |
| major inclusions | : gleyic ferric acrisol (19) .......... | 25 % |
| | petroferric dystric regosol (32) .... | 15 % |

extent : 258 km$^2$ (K)

Soil association along the Lalafuta river in southwest Kasempa district, parent material probably mudstone.

Pu 18/4 - C3

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (18) ................ | 30 % |
| co-dominant soil | : orthic ferralsol (11) .............. | 25 % |
| major inclusions | : ferric acrisol (20) ................ | 20 % |
| | gleyic ferric acrisol (19) .......... | 15 % |
| | orthic ferralsol (11d) .............. | 10 % |

extent : 1681 km$^2$ (K 221/221; S 1460/1362)

Large soil association in southwest Solwezi district, intermediate between associations Pu 18/1 and Pn 34/1, containing less deep soils than the former, but more and better drained soils than the latter.

Pu 19 - 04

dominant soil : gleyic ferric acrisol (19) .......... 45 %
co-dominant soil : orthic ferralsol (11d) .............. 25 %
major inclusions : orthic ferralsol (11) ............... 20 %
orthic ferralsol (13) ............... 10 %

extent : 1467 km$^2$ (K 222/222; S 1245/1132)

Soil association that occurs at different places in Kasempa and Solwezi districts, more wetter than association Pu 18/4. to which it is related. The acrisols (19) in the Kafue headwater area are gravelly within 60 cm.

Pu 22/1 - 03

dominant soil : xanthic ferralsol (22) .............. 60 %
major inclusions : ferric acrisol (18) ................. 15 %
dystric gleysol (27) ................ 15 %
orthic ferralsol (12) ................ 10 %

extent : 483 km$^2$ (M)

Soil association of northern Mwinilunga district that integrades between residual soils (12 and 18) and soils with a strong Kalahari sand admixture (22), while the dambos are typical Kalahari sand (27). These two types of soils are intimately related and difficult to separate in the field.

Pu 22/2 - 03

dominant soil : xanthic ferralsol (22) .............. 40 %
co-dominant soil : dystric gleysol (27) ................ 25 %
major inclusions : gleyic ferric acrisol (19) .......... 20 %
gleyic ferralsol (25) ............... 15 %

extent : 697 km$^2$ (S 667; M 30)

Wetter variant of association Pu 22/1, occurring mostly along the east bank of the Kabompo river in Solwezi district.

Pu 32 - 05d

dominant soil : petroferric dystric regosol (32) .... 70 %
major inclusions : lithic dystric regosol (31) .......... 20 %
orthic ferralsol (11d) ............... 10 %

extent : 846 km$^2$ (K)

This soil association consist mostly of patches of shallow soils over laterite, hemmed in by other upland soil associations containing deeper soils. The large delineration in eastern Kasempa district is transitory to soil association Pn 32/2.

Pn 18 - 05d

dominant soil : ferric acrisol (18) .................. 40 %
co-dominant soil : dystric gleyic cambisol (33) ........ 35 %
major inclusions : petroferric dystric regosol (32) .... 25 %

extent : 803 km$^2$ (K 803/228)

Soil association in western Kasempa district, where there is a gradual change from deeper soils (18) to shallow soils over laterite (32), the former dominate in the northern half of the delineation, the latter in the southern half, where open grasslands provide most of the drainageways (soil 33).

Pn 31 - C5d

| | | |
|---|---|---|
| dominant soil | lithic dystric regosol (31) ......... | 40 % |
| co-dominant soil | petroferric dystric regosol (32) .... | 25 % |
| major inclusions | orthic ferralsol (11d) .............. | 20 % |
| | petroferric dystric regosol (34) .... | 15 % |

extent : 611 km² (K 611/456)

Soil association occupying large area in southeast Kasempa district, east of the Lunga river. Predominantly shallow soils, over rock and laterite, with isolated hillocks covered by some deeper soils and strewn with boulders.

Pn 32/1 - C5d

| | | |
|---|---|---|
| dominant soil | petroferric dystric regosol (32) .... | 60 % |
| co-dominant soil | petroferric dystric regosol (34) .... | 30 % |
| major inclusions | ferric acrisol (20d) ................ | 10 % |

extent : 1348 km² (K 1348/1236)

Soil association in southwest Kasempa district, consisting mainly of very shallow soils over laterite, some of them imperfectly drained.

Pn 32/2 - C5d

| | | |
|---|---|---|
| dominant soil | petroferric dystric regosol (32) .... | 50 % |
| major inclusions | orthic ferralsol (11d) .............. | 20 % |
| | orthic ferralsol (12) ............... | 15 % |
| | ferric acrisol (20d) ................ | 15 % |

extent : 2823 km² (K)

Similar soil association as Pn 32/1, but containing more somewhat deeper soils and being on the whole better drained. In southeast Kasempa district.

Pn 34/1 - C4

| | | |
|---|---|---|
| dominant soil | petroferric dystric regosol (34) .... | 70 % |
| co-dominant soil | petroferric dystric regosol (32) .... | 30 % |

extent : 1419 km² (K)

Soil association in southern Kasempa district, being made up of predominantly very shallow soils over laterite, mostly imperfectly drained. Closely associated to Pn 32/1 and Pn 32/2, but poorer drained.

Pn 34/2 - C4

| | | |
|---|---|---|
| dominant soil | petroferric dystric regosol (34) .... | 40 % |
| co-dominant soil | ferric acrisol (20d) ................ | 25 % |
| major inclusions | ferric acrisol (18) ................. | 15 % |
| | petroferric dystric regosol (32) .... | 10 % |
| | dystric gleyic cambisol (33) ........ | 10 % |

extent : 863 km² (K)

Transitional soil association in southern Kasempa district, between deeper soils (20d and 18) and shallow soils over laterite. The former occur as fairly large "islands" surrounded by shallow soils, and drained by termitaria vegetated strips of land (soil 33).

Pd 11 - C2

| | | |
|---|---|---|
| dominant soil | orthic ferralsol (11) ............... | 45 % |
| co-dominant soil | orthic ferralsol (11d) .............. | 30 % |
| major inclusions | orthic ferralsol (11s) .............. | 15 % |
| | acric ferralsol (16) ................ | 10 % |

extent : 326 km² (S 177; M 149)

Soil association that is a variant of Pu 11/2, it differs in containing a greater proportion moderately deep soils and/or relatively steep slopes on account of being situated along rather deeply incised streams (Lunga river in Solwezi district and Kasanjiku river in Mwinilunga district).

Pd 11d - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11d) | 35 % |
| co-dominant soil | : ferric acrisol (20) | 25 % |
| major inclusions | : acric ferralsol (16) | 20 % |
| | lithic dystric regosol (31) | 20 % |

extent : 102 km$^2$ (S)

This soil association, encompassing a large part of the Mutanda river's headwaters, has been mainly delineated on account of the dissected landscape. Within the delineation a number of different geological formations meet, which result in a variety of soils (11 and 16), while soil degradation on slopes has probably brought about the formation of an acrisol (16). Shallow soils with bedrock outcrops are common near the streambanks (31).

Pd 12 - C2

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (12) | 30 % |
| co-dominant soil | : orthic ferralsol (11s) | 25 % |
| major inclusions | : ferric luvisol (37s) | 15 % |
| | rhodic ferralsol (10) | 20 % |
| | orthic ferralsol (14) | 10 % |

extent : 466 km$^2$ (M)

Large soil association south of Mwinilunga boma, dominated by rather silty soils over metasiltstones, strongly dissected, with few very deep soils, mostly moderately deep to moderately shallow. Red soils occur as minor patches. Ferric luvisols in the southern part of the delineation.

Pd 36s - C4

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (36s) | 45 % |
| co-dominant soil | : orthic ferralsol (36) | 25 % |
| major inclusions | : orthic ferralsol (11) | 10 % |
| | acric ferralsol (16) | 10 % |
| | xanthic ferralsol (22) | 10 % |

extent : 81 km$^2$ (M)

Minor soil association just south of Mwinilunga boma, where the Kalahari sand cover thins out, and intergrades to residual soils are common (36). Isolated patches of deep red soils occur along the southern fringe of the delineation.

### 4.4.2 Soils developed over gneiss

Pu 21/1 - C3

| | | |
|---|---|---|
| dominant soil | : xanthic ferralsol (21) | 60 % |
| major inclusions | : xanthic ferralsol (21d) | 20 % |
| | ferric acrisol (20) | 10 % |
| | dystric gleyic cambisol (33) | 10 % |

extent : 63 km$^2$ (S)

Minor soil association in eastern Solwezi district along the Chovwe road, over granite.

Pu 21/2 - C3

dominant soil : xanthic ferralsol (21) .............. 40 %
co-dominant soil : xanthic ferralsol (22) .............. 25 %
major inclusions : orthic ferralsol (23) .............. 15 %
lithic dystric regosol (31) ......... 10 %
dystric gleyic cambisol (33) ........ 10 %

extent : 464 km$^2$ (M)

Soil association over granite in the far northwestern lobe of Mwinilunga district. The surrounding soils are mainly Kalahari sands, and integrades with these soils (22 and 23) form a large part of this mapping unit. Shallow soils over bedrock near the streams.

Pu 35/1 - C3

dominant soil : xanthic ferralsol (35) .............. 65 %
co-dominant soil : xanthic ferralsol (35s) ............. 25 %
major inclusions : dystric gleyic cambisol (33) ........ 10 %

extent : 575 km$^2$ (S 575/167)

Soil association covering the eastern part of the Mwembeshi dome, relatively little dissected.

Pu 35/2 - C4

dominant soil : xanthic ferralsol (35) .............. 45 %
co-dominant soil : xanthic ferralsol (35s) ............. 25 %
major inclusions : dystric gleyic cambisol (33) ........ 20 %
ferric acrisol (18) ................. 10 %

extent : 1985 km$^2$ (M 778/570; S 1207/800)

The major soil association of the gneisses of the basement complex domes, relatively strongly dissected with a large proportion rather steeply sloping soils (35s), imperfectly drained soils (33, some also on slopes) and degraded soils (18).

Pd 35s - C4

dominant soil : xanthic ferralsol (35s) ............. 40 %
co-dominant soil : xanthic ferralsol (35) .............. 30 %
major inclusions : dystric gleyic cambisol (33) ........ 20 %
ferric acrisol (18) ................. 10 %

extent : 319 km$^2$ (M)

Variant soil association of Pd 35/2, even more dissected, west of the Kabompo river. Soil are dominantly moderately deep (35s) to moderately shallow (33), the latter soils also occurring on slopes. This association is mostly surrounded by soils in Kalahari sands, and their intergrades to residual soils.

## 4.4.3 Soils over carbonate and other basic rocks

Hb 10 - C2

dominant soil : rhodic ferralsol (10) .............. 60 %
co-dominant soil : acric ferralsol (17s) .............. 25 %
major inclusions : acric ferralsol (17d) .............. 15 %

extent : 87 km$^2$ (S)

Soil association around Chafuguma hill, where the hill, scarps and solution lowered basins create a broken landscape. The relation parent material - soil is not clear, but only the red soils in the basin are believed to be underlain by carbonatic rock.

Pu 15 - C2

dominant soil : rhodic ferralsol (15) ............... 65 %
major inclusions : xanthic ferralsol (22) .............. 20 %
lithic dystric regosol (31) ......... 15 %

extent : 188 km$^2$ (N)

Soil association in west Mwinilunga district over basic igneous rock, Kalahari sand deposits bound the association, and intergrades with soils occurring therein are common along the fringes of the association (soil 22). Some small ridges are covered by shallow and rocky soils (31).

Pu 17/1 - C1

dominant soil : acric ferralsol (17) ............... 80 %
major inclusions : acric ferralsol (17d) .............. 10 %
eutric gleysol (26) ................ 10 %

extent : 1452 km$^2$ (N 157/157, S 1295/1245)

Soil over limestone, predominantly in northern Solwezi district, with minor occurrences in Kasempa district. Very homogeneous association.

Pu 17/2 - C1

dominant soil : acric ferralsol (17) ............... 60 %
co-dominant soil : acric ferralsol (17d) .............. 25 %
major inclusions : eutric gleysol (26) ................ 15 %

extent : 1658 km$^2$ (S 1357/1220; N 301/301)

Soil association in central Mwinilunga district and central and western Solwezi district. Less homogeneous than Pu 17/1, with relatively shallow soil (17d) being common on scarps, where solution basins exist, or rather randomly where the physiography is more flat (Mwinilunga district). Gleysols occupy the lowest part of the basins.

Pu 17/3 - C2

dominant soil : acric ferralsol (17) ............... 45 %
co-dominant soil : eutric gleysol (26) ................ 30 %
major inclusions : acric ferralsol (17d) .............. 15 %
orthic ferralsol (11d) ............. 10 %

extent : 1422 km$^2$ (S 1422/1162)

Soil association of northern Solwezi district, where it occupies mostly the poorer drained solution basins, with commonly a dambo or string of dambos at the lower part of the basin. Inclusions of orthic ferralsols (11d) occur in the northeastern part of the district, where the association adjoins associations Pu 11d and Pu 19.

Pu 26 - C4

dominant soil : eutric gleysol (26) ................. 70 %
major inclusions : acric ferralsol (17) ............... 20 %
acric ferralsol (17d) .............. 10 %

extent : 155 km$^2$ (S 155/135)

Large dambos in limestone areas in Solwezi district, internally drained, and desiccated during the dry season.

4.4.4 Soils developed over schists

Hb 38d - C4

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (38d) | 40 % |
| co-dominant soil | : lithic dystric regosol (31) | 30 % |
| major inclusions | : orthic ferralsol (38s) | 20 % |
| | orthic ferralsol (38) | 10 % |

extent : 195 $km^2$ (S 30/20; N 165/135)

Low quartzite ridges of the lower Roan, dominated by moderately deep and shallower soils, the deeper soils mostly occurring along the footslopes. Rocky in places.

Hb 11s - C5d

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11s) | 35 % |
| co-dominant soil | : lithic dystric regosol (31) | 25 % |
| major inclusions | : rhodic ferralsol (10) | 20 % |
| | dystric gleyic cambisol (33) | 10 % |
| | ferric luvisol (37) | 10 % |

extent : 555 $km^2$ (N 555/198)

Soil association largely situated east of the Lunga river in Mwinilunga district. Parent material rather schistaceous, area fairly deeply incised, with soils dominantly rather shallow and relatively steep (11s). Common isolated or small groups of low quartzitic hills (31), deeper soils on broader interfluves, occassionally also on slopes.

Pu 10/1 - C2

| | | |
|---|---|---|
| dominant soil | : rhodic ferralsol (10) | 40 % |
| co-dominant soil | : orthic ferralsol (11d) | 30 % |
| major inclusions | : dystric gleyic cambisol (33) | 20 % |
| | ferric acrisol (20) | 10 % |

extent : 1781 $km^2$ (S 920/747; N 861/858)

Soil formation over (psammitic) biotite schists of the Mine series. Large patches with deep red soils (10), which become shallower near ridges, transitions to different parent materials, etc.. Small patches with shallower soils, imperfectly drained over laterite, in particular in Mwinilunga district.

Pu 20 - C3

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (20) | 35 % |
| co-dominant soil | : orthic ferralsol (13) | 25 % |
| major inclusions | : orthic ferralsol (11d) | 15 % |
| | dystric gleyic cambisol (33) | 15 % |
| | rhodic ferralsol (10) | 10 % |

extent : 900 $km^2$ (S)

Soil association around Mukimba, Solwezi district. Light coloured gravelly (13) and non-gravelly soils on the interfluves, shallower soils on the slopes and narrow interfluves (11d).

Pu 20d - C3

| | | |
|---|---|---|
| dominant soil | : ferric acrisol (20d) | 30 % |
| co-dominant soil | : ferric acrisol (18) | 25 % |
| major inclusions | : orthic ferralsol (11d) | 20 % |
| | gleyic ferric acrisol (19) | 15 % |
| | rhodic ferralsol (10) | 10 % |

extent : 120 $km^2$ (S 120/77)

Soils association closely related to association Pu 20, but fringing lime-stone solution depressions. Contains more eroded soils (20d and 11d) and more poorly drained soils (18 and 19) in the lower parts of the association.

Pu 37 - C1

| | | |
|---|---|---|
| dominant soil | : ferric luvisol (37) | 30 % |
| co-dominant soil | : ferric acrisol (20) | 30 % |
| major inclusions | : ferric luvisol (37s) | 20 % |
| | xanthic ferralsol (22) | 20 % |

extent : 165 km$^2$ (M 165/100)

Soil association that occupies stream valleys in the Kalahari sand region. Underlying consolidated parent material has been exposed, consisting of schists (soil 37 and 37s) and metasiltstones more upstream (soil 20). Integrades with Kalahari sand soils are common along the higher parts of the valley slopes (soil 20). Less steeply dissected than association Pu 37s.

Pd 10 - C2

| | | |
|---|---|---|
| dominant soil | : rhodic ferralsol (10) | 35 % |
| co-dominant soil | : dystric gleyic cambisol (33) | 25 % |
| major inclusions | : orthic ferralsol (11s) | 15 % |
| | xanthic ferralsol (22) | 15 % |
| | ferric luvisol (37) | 10 % |

extent : 166 km$^2$ (M 166/139)

Soil association in south-western Mwinilunga district, surrounded by Kalahari sands (integrades result in soil 22). The higher parts of the association are covered by deep red soils (10), locally relatively steep (10s), while the lower parts adjoin small streams and are dominantly imperfectly drained (33), they are probably largely alluvial in origin. Orthic ferralsols (11s) occur on the transition between these two soil types.

Pd 37s - C1

| | | |
|---|---|---|
| dominant soil | : ferric luvisol (37s) | 50 % |
| co-dominant soil | : ferric luvisol (37) | 25 % |
| major inclusions | : rhodic ferralsol (10) | 15 % |
| | lithic dystric regosol (31) | 10 % |

extent : 1312 km$^2$ (M 1312/702)

Large homogeneous soil association in the south of Mwinilunga district. Strongly dissected area, with slope phases (soil 37s) prevailing, and soils on the crests only being less than 3 % sloping (37). Soils are moderately deep, and locally even shallower (31).

Pd 38 - C4

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (38) | 55 % |
| co-dominant soil | : orthic ferralsol (38s) | 25 % |
| major inclusions | : lithic dystric regosol (31) | 10 % |
| | petroferric dystric regosol (32) | 10 % |

extent : 1735 km$^2$ (S 792/507; M 943/943)

Soil association over schists of the basement complex, strongly dissected with a large content of relatively shallow soils that occur mostly in the lower parts of the landscape. Laterites are common at slope breaks.

Pd 38d - C4

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (38d) | 30 % |
| co-dominant soil | : orthic ferralsol (38) | 25 % |
| major inclusions | : petroferric dystric regosol (32) | 20 % |
| | ferric acrisol (20) | 15 % |
| | dystric gleyic cambisol (33) | 10 % |

extent : 570 km$^2$ (S 212, N 358)

Soil association around headwaters of Kabompa river in a more stronger dissected landscape than association Pd 33, with a higher proportion of relatively shallow soils (38d and 32), which often have relatively steep slopes as well. Semi-dambos (soil 33) and associated degraded soils (20) are fairly common on the lower parts of the slopes.

#### 4.4.5 Soils developed over metaconglomerate

Pd 11s - C4

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (11s) ............... | 35 % |
| co-dominant soil | : rhodic ferralsol (10) ................ | 25 % |
| major inclusions | : ferric acrisol (20d) .................. | 25 % |
| | petroferric dystric regosol (32) .... | 15 % |

extent : 68 km$^2$ (S)

Soil association along a deeply incised tributary of the Solwezi river, with deep red soils on the upper part of the slope, and more shallow and yellower soils on the middle and lower segments.

#### 4.4.6 Soils developed over carbonaceous shale

Pu 10/2 - C3

| | | |
|---|---|---|
| dominant soil | : rhodic ferralsol (10) ............... | 45 % |
| co-dominant soil | : acric ferralsol (17) ................ | 30 % |
| major inclusions | : orthic ferralsol (11d) .............. | 15 % |
| | gleyic ferric acrisol (19) ........... | 10 % |

extent : 235 km$^2$ (S)

Soil association in northeastern Solwezi district, over carbonaceous shale surrounded by limestone, both covered by red soils, possibly acric ferralsol. Close to the Kafue floodplain more yellow (11d) and wetter soils (19).

#### 4.4.7 Soils developed in Kalahari sands

Dk 23/1 - C3

| | | |
|---|---|---|
| dominant soil | : orthic ferralsol (23) ................ | 55 % |
| co-dominant soil | : dystric gleysol (27) ................ | 25 % |
| major inclusions | : ferralic luvic arenosol (28)......... | 10 % |
| | gleyic ferralsol (25) ................. | 10 % |

extent : 2454 km$^2$ (M 2454/2107)

Important soil association of the low lying Kalahari sands in northern Mwinilunga district. Relatively dense drainage network connecting the numerous small and large sandy dambos (soil 27). Vestiges of the original Kalahari sands remain particularly in the northwestern delineations, where they are recognizable by their more dense Cryptosepalum vegetation. Gleyic ferralsols are more common close to the streams in the northeastern delineations. The association is dominated by fine loamy soils, but coarse loamy soils are frequent as well, especially on the relatively higher lying parts of the landscape.

Dk 23/2 - C4

| | | |
|---|---|---|
| dominant soils | : orthic ferralsol (23) ................ | 45 % |
| co-dominant soil | : ferralic luvic arenosol (28) ........ | 35 % |
| major inclusions | : dystric gleysol (27) ................ | 20 % |

extent : 1293 $km^2$ (M 1293/783)

This association is transitional to the more pure Kalahari sands. It occurs in central and southwestern Mwinilunga district, where it constitutes north-south aligned tongues surrounded and partitioned by areas with residual soil. The central part of the delineations consists of arenosols (28), while the margins and intrusions are made up of the more finer ferralsols (23) and gleysols (27).

Dk 24 - C4

| | | |
|---|---|---|
| dominant soil | : xanthic ferralsol (24) .............. | 50 % |
| co-dominant soil | : dystric gleysol (27) ................ | 25 % |
| major inclusions | : orthic ferralsol (23) ............... | 15 % |
| | ferralic luvic arenosol (28) ........ | 10 % |

extent : 1062 $km^2$ (M 1062/802)

Soil association in the northern part of Mwinilunga district. Low lying Kalahari sands, moderately well drained in the somewhat higher parts to poorly drained in the lowest parts of the catena. The association is highly fragmentated by numerous sandy dambos, often fringed by bare white sands. Arenosols (28) and orthic ferralsols (23) are to be found in small packets on the relatively higher parts.

Dk 25 - C3

| | | |
|---|---|---|
| dominant soil | : gleyic ferralsol (25) ............... | 75 % |
| major inclusions | : dystric gleysol (27) ................ | 15 % |
| | xanthic ferralsol (22) .............. | 10 % |

extent : 633 $km^2$ (M)

Soil association along the west bank of the Kabompo river, with moderately well to imperfectly drained loamy soils derived from Kalahari sands. Gleysols (27) in the rather wide floodplains of the streams traversing the delineations, and the dambos near the western boundary of the association, where the better drained soils (22) can be found as well.

Dk 28/1 - C4

| | | |
|---|---|---|
| dominant soil | : ferralic luvic arenosol (28) ........ | 80 % |
| major inclusions | : petroferric ferralic arenosol (29) ... | 20 % |

extent : 726 $km^2$ (K 726/443)

Soil of rather pure Kalahari sand deposits around the Busanga swamps, with shallow sands over laterite around the fringes of the delineations.

Dk 28/2 - C5d

| | | |
|---|---|---|
| dominant soil | : ferralic luvic arenosol (28) ........ | 50 % |
| co-dominant soil | : petroferric ferralic arenosol (29) .. | 40 % |
| major inclusions | : dystric gleysol (27) ................ | 10 % |

extent : 461 $km^2$ (K)

Soil association closely linked to association Dk 28/1, occurring in the same region, but containing a higher percentage of shallow (colluvial) sands over laterite.

Dk 28/3 - C4

| | | |
|---|---|---|
| dominant soil | : ferralic luvic arenosol (28) ........ | 55 % |
| major inclusions | : xanthic ferralsol (22) .............. | 15 % |
| | xanthic ferralsol (24) .............. | 15 % |
| | dystric gleysol (27) ................ | 15 % |

extent : 3387 $km^2$ (M 3387/2150)

The major soil association of the Kalahari sands, occurring in the western and northern part of Mwinilunga district. Red and yellow coarse loamy sands, with fine loamy soils, both well (soil 22) and moderately well (soil 24) drained in the lower parts of the landscape.

Dk 28/4 - C4

dominant soil : ferralic luvic arenosol (28) ........ 40 %
co-dominant soil : dystric gleysol (27) .................. 30 %
major inclusions : petroferric ferralic arenosol (29) ...20 %
petroferric dystric regosol (34) .... 10 %

extent : 658 $km^2$ (K 658/562)

Soil association of southwest Kasempa district, being more eroded than association Dk 28/2. Shallow soils over laterite (29 and 34) around the deeper Kalahari sand soils (28), with intrusions of dambos containing wet soils (27).

Dk 29 - C5d

dominant soil : petroferric ferralic arenosol (29) .. 50 %
co-dominant soil : dystric gleysol (27) .................. 30 %
major inclusions : ferralic luvic arenosol (28) ........ 20 %

extent : 831 $km^2$ (K 831/226)

Variant of soil association Dk 28/4, occurring in the same region, but includin more shallow soils over laterite.

Dd 27/1 - C5w

dominant soil : dystric gleysol (27) .................. 90 %
major inclusions : ferralic luvic arenosol (28) ........ 10 %

extent : 622 $km^2$ (M 622/542)

Soil of the Kalahari sand dambos, occurring in various physiographic positions. Shallow soils over laterite, or even laterite outcrops, are locally common in some of them.

Dd 27/2 - C5w

dominant soil : dystric gleysol (27) .................. 70 %
major inclusions : orthic ferralsol (23) ................ 20 %
ferralic luvic arenosol (28) ........ 10 %

extent : 2313 $km^2$ (S 354/354; M 1959/826)

Soil association of the Kalahari sand dambos, less pure than soil Dd 27/1. It occurs in the low lying Kalahari sands in northern Mwinilunga district, and along the stream bounded fringes of the Kalahari sands in the southern part of the district. Patches of white vegetation-less sands are common. Also included are eastwest running dunes (northern Mwinilunga). Boundary with surrounding well drained sands not always as clear as with soil Dd 27/1, and intergrades (soil 23) are frequent along the margins of the delineations.

4.4.8 Soils developed in alluvial deposits

Df 39 - C5d

dominant soil : fluvic gleyic cambisol (39) ......... 80 %
major inclusions : petroferric dystric regosol (32) .... 20 %

extent : 240 $km^2$ (K 240/55)

Soil locally occupying the transition between Kalahari sand deposits and flats of the Busanga swamps, where deposition of eroded sand has been important. The lateritic soils (32 and also 34) form the lower boundary of the association.

Df 40 - C5w

dominant soil : eutric and dystric gleysol (40)

extent 1598 $km^2$ (K 8/8; S 1347/1027; M 243/243)

Soil association of the river floodplains. Soils are under grass, and liable to flooding during and after the rainy season. Some of the larger dambos in southeastern Solwezi district are included. Textures are medium to heavy, organic matter content is relatively high. Topsoils are occassionally mucky. Fluvisols are probably common within this association. The areal extent of this unit is less than indicated, particularly in Mwinilunga district (possibly as much as one half in that district), due to cartographic exaggeration of some of the delineations concerned.

Df-u - C5w

Undifferentiated soils of the larger floodplains that debouch into the flats of the Busanga swamps.

extent : 1444 $km^2$ (K 1431/1414; M 13/13)

This unit consists of dominantly medium textured imperfectly to poorly drained soils. Finer textured soils occur close to the drainage channels, while moderately well drained soils, supporting chipya type woodland, can be found on the slighty more elevated parts of the landscape. The alluvial character of the soils is borne out by the rather large textural changes with depth that have been noted in most of the soils of this unit.

Ds 30 - C5w

dominant soil : mollic gleysol (30)

extent : 137 $km^2$ (K 85/68; M 52/52)

Soil of the swamps. Peaty to mucky, permanently water-logged soils covered by swamp grasses and sedges. The largest occurrence is in the Busanga swamps, smaller swamps occur along some of the streams in the Kalahari sand region in northern Mwinilunga district. Swamp forests occur at several places in the Kalahari sands, but they are usually restricted in extent and only the larger ones have been mapped separately.

Ds-u - C5w

Undifferentiated soils of the swamps.

extent : 4141 $km^2$ (K 3756/76, S 385/385)

This unit is made up of the soils of the flats surrounding the two major swamps in the project area, the Busanga swamps and the Jivundu swamps. The permanently waterlogged soils of the swamps are, where large enough, excluded from this unit. The larger part comprises medium textured relatively shallow soils over laterite near the margins and deeper, finer textured soils towards the centre. Perennial and ephemeral streams flowing through these areas are lined by heavy backswamp soils (including vertisols) and numerous light textured levees. Except for the latter, nearly all the soils within this unit are seasonally waterlogged.

## 4.5 Soil genesis

This survey had a strong bias towards the land suitability for agriculture, and no particular attention was paid to soil formation. Nevertheless, because of the considerable time spent in the field and the large amount of data collected, some remarks can be made with respect to soil genesis. This is not purely of academic interest. A clearer insight in the soil forming processes active in a particular area, and the relationship between soils and their parent material, is of great benefit to a soil surveyor. More accurate mapping will be possible, the behaviour of the soils under different types of management can be predicted with more confidence, and an improved classification and correlation will result.

### 4.5.1 Soil forming processes

All the upland soils in the project area are leached. The very great age of the parent rock, the underlying stable geological shield and sufficient rainfall (which may have been higher during certain periods in the past) have contributed to this state of affairs. Leaching implies more than only a we ing out of bases. It also involves a gradual transformation of clay minerals like illite and smectite to kaolinite and, when strong leaching continues, a breakdown of kaolinite and partial removal of the weathering products until a soil rich in sesquioxides (Fe and Al oxides and hydrates) together with secondary silica remains. This last stage has not (yet ?) been reached in the project area, although the red oxisols (rhodic and acric ferralsols) seem well on their way, as they are not only very strongly leached, but have been shown in thin section to contain extremely weathered quartz grains, with accumulations of secondary silica in the subsoil. X-ray analysis did also not show any goethite, hematite or gibbsite in the clay fraction of four different ferralsols (see table 9). Only in the orthic ferralsol do other clay minerals than kaolinite appear to be of any significance.

Removal of the bases means that aluminium and hydrogen can occupy the abandonded sites at the exchange complex. However, no hydrogen was found in the four ferralsols analyzed by the Royal Tropical Institute in Amsterdam. Aluminium, on the other hand, accounts for more than 70%, and in several cases more than 90%, of the effective cation exchange capacity (ECEC, see table 6). of the ferralsols. The acrisols (ultisols) have a somewhat lower Al saturation than the ferralsols, although the value of 20% given in table 7 for soil 18 is probably on the low side.

table 9 Mineralogical composition of the clay fraction of selected pits

| depth (cm) | kaolinite | illite | montmo-rillonite | vermi-culite | mixed layer | talc* |
|---|---|---|---|---|---|---|
| Profile 11 (orthic ferralsol) | | | | | | |
| 0- 11 | xxx | x | | x | x | |
| 11- 26 | xxx | x | | x | x | |
| 26- 82 | xxx | x | | x | x | |
| 82-123 | xxx | x | | x | x | |
| 123-190 | xxx | x | | x | x | |
| Profile 26 (rhodic ferralsol) | | | | | | |
| 0- 8 | xxxx | tr | | tr | tr | tr |
| 8- 22 | xxxx | x | | | tr | tr |
| 22- 80 | xxxx | x | | | tr | tr |
| 80-130 | xxxx | tr | | | tr | tr |
| 200-250 | xxxx | tr | | | tr | tr |
| Profile 39 (acric ferralsol) | | | | | | |
| 0- 12 | xxxx | tr | | | tr | |
| 12- 30 | xxxx | tr | | | tr | |
| 30- 73 | xxxx | tr | | tr | tr | |
| 73-120 | xxxx | tr | | tr | tr | |
| 120-170 | xxxx | tr | | tr | tr | |
| 255-275 | xxxx | tr | | tr | tr | |
| Profile 47 (xanthic ferralsol) | | | | | | |
| 0- 13 | xxxx | tr | tr | | | |
| 13- 38 | xxxx | tr | | tr | tr | |
| 38- 68 | xxxx | tr | | tr | tr | |
| 68-105 | xxxx | tr | | tr | tr | |
| 105-150 | xxxx | tr | | tr | x | |
| 150-185 | xxxx | x | | x | x | |

xxxx = predominant, xxx = large amounts, xx = moderate amounts,
x = small amounts, tr = traces; * = suspect

X-ray diffraction with Kalpha radiation from orientated samples without pretreatment, performed by Royal Tropical Institute in Amsterdam.

The CEC of the ferralsols is thus very low. A relationship between this parameter and the amount of rainfall may still exist, as it has been noted that for orthic ferralsol no. 11 the CEC per 100 g clay in northern Solwezi is significantly lower than in central Kasempa district (8 versus 14 meq, cf pits 37 and 11).

Termite activity is very strong in the ferralsols and acrisols, both field observations and the study of thin sections bear this out. These thin sections (courtesy professor Moormann) also show that some clay illuviation takes place in the ferralsols, although the process is not outspoken and the ferri-argillans (clay cutans) observed are not only small and usually diffuse, but may in fact be relic features. But in the one acrisol studied in thin section (profile 15) frequent thin and thick faint channel ferri-argillans were noted in the upper part of the soil, against none in the lower part. An argillic horizon seems well established here, although there is little the textural data show in a way of a clay bulge, only a clay increase.

The colour of the upland soils is closely related to the amount of free iron which, in its turn, is governed by the chemical composition of the parent material and any deferritization processes that may have taken place in the soil. Table 10 gives the colour of the soil and the free iron content, as extracted with dithionite.

table 10 Relationship soil colour (moist) and free iron content

| depth (cm) | colour (moist) | $Fe_d$ (%) | depth (cm) | colour (moist) | $Fe_d$ (%) |
|---|---|---|---|---|---|
| Profile 11 (orthic ferralsol) | | | Profile 26 (rhodic ferralsol) | | |
| 0- 11 | 7.5YR 4/4 | 2.9 | 0- 8 | 5YR 4/6 | 6.7 |
| 11- 26 | 5YR 4/8 | 2.7 | 8- 22 | 2.5YR 3/4 | 8.5 |
| 26- 82 | 5YR 4/8 | 2.6 | 22- 80 | 2.5YR 3/6 | 9.5 |
| 82-123 | 5YR 4/8 | 2.4 | 80-130 | 2.5YR 3/6 | 9.4 |
| 123-190 | 5YR 4/6 | 3.0 | | | |
| Profile 39 (acric ferralsol) | | | Profile 47 (xanthic ferralsol) | | |
| 0- 12 | 5YR 4/6 | 6.4 | 0- 13 | 10YR 4/2 | 0.3 |
| 12- 30 | 2.5-5YR 3/4 | 7.6 | 13- 38 | 10YR 4/3 | 0.3 |
| 30- 73 | 2.5YR 3/6 | 8.2 | 38- 68 | 7.5YR 4/6 | 0.7 |
| 73-120 | 2.5YR 3/7 | 7.9 | 68-105 | 7.5YR 6/6 | 0.5 |
| 120-170 | 2.5YR 3/7 | 7.1 | 105-150 | 7.5YR 6/6 | 0.7 |
| 255-275 | 2.5YR 3/7 | 8.2 | 150-185 | 7.5YR 6/6 | 0.7 |

Several of the upland soils have a laterite layer in the subsoil or on their substratum. This layer consist either of frequent (more than 40% by volume) well rounded discrete small gravel, or a more continuous layer which, however, normally contains a fair amount of cemented gravel. The presence of these gravels, which probably have acquired their well rounded shape by abrasion while being displaced, is indicative of movements of soil material during the long period over which soil formation took place. Thus, few of the upland soils in the project area can strictly be considered to be in-situ soils. Nevertheless, it is believed that the translocation of soil material has not been over such large distances that the relationship soil - parent material has been fundamentally disturbed.

### 4.5.2 Relationship soil - parent material

This section deals with the genetic relationship between the soil and its parent material, but only the upland soils are being considered. With the exception of the carbonatic and basic igneous rock, all the parent material of the upland soils is either intermediate (the schists, for as far as not being psammentic) or acid (more than 40% quartz).

Kundelungu series

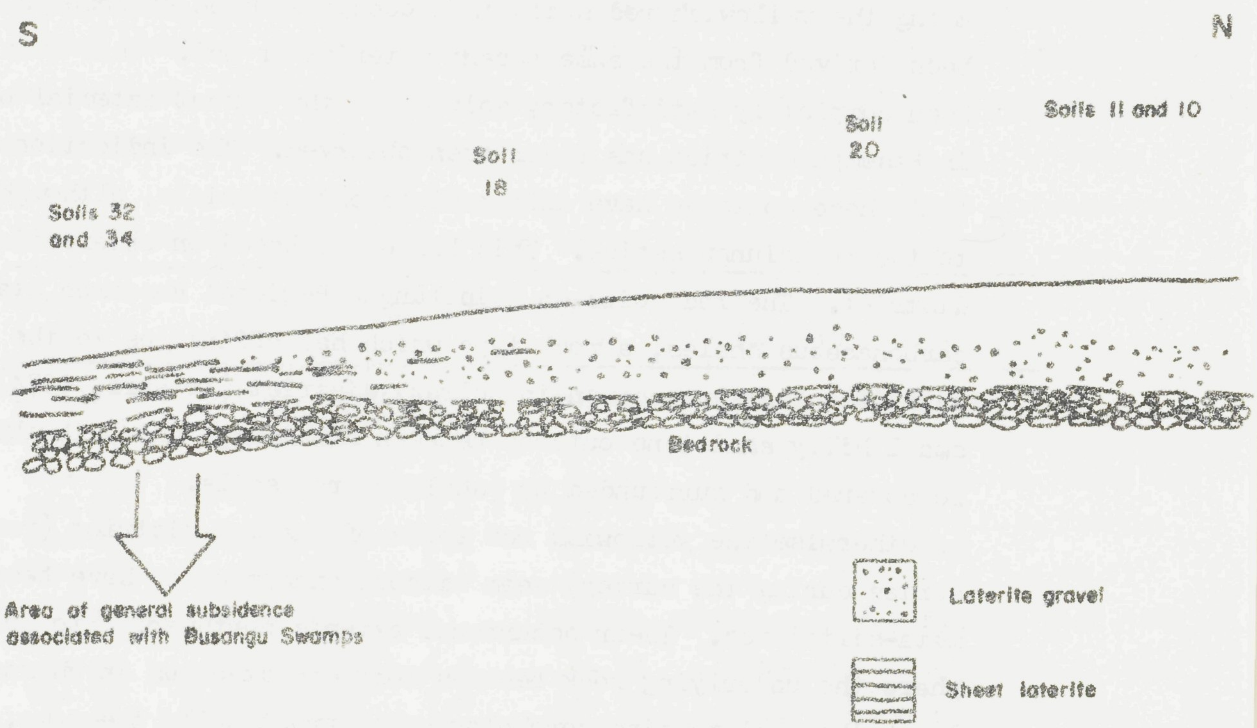
The question which in the beginning of the survey haunted the soil surveyors very much was whether the red soils which were frequently found interspersed among the yellowish red soils that occupy so much of Kasempa district have to been derived from the same parent material or not. This question has not been completely satisfactory solved, as the parent material of the red soils in Kasempa district has never been observed. The indications are, however, that these soils do have different parent materials, although all belonging to the Kundelungu series. This belief is based on observations in Mwinilunga district. The red soils on Mwinilungua Regional Research Station overlie carbonaceous shales, a rock type which has affinities to the slates and phyllites that are common in Solwezi district (Arthurs, 1974). Also, a small hilly sandstone outcrop between Mwinilunga and Chibwika was noted to be covered and surrounded by (shallow) red soils.

Otherwise the yellowish red soils of Kasempa district (renamed Kasempa series during the survey) seem without exception to have been formed over meta-siltstones. Their occurrence extends northward into Solwezi district, where the underlying rock becomes more schistaceous in character. Nevertheless, the soil remains morphologically practically the same, and chemically as well, apart from a more leached character which has been attributed to a higher rainfall.

A noteworthy feature of the Kasempa series, and contrasting sharply with the rhodic ferralsols, is the relative shallowness and lack of an outspoken laterite layer in the subsoil. This shallowness is probably consequent upon a high silt content of the soil, which makes it very erosion-prone. Laterite gravels do occur in a number of profiles, and indurated laterite was seen in one of the pits, but it is by far not as common in the rhodic ferralsols as in the other ferralsols of the project area. No attempt will be made to explain this phenomenon, although factors like shallowness, chemical composition of the parent material, groundwater flow etc. have obviously an important bearing upon it.

According to the relevant geological maps, ferric acrisols 18 and 20 (and also gleyic acrisol 19) occur over Kundelungu as well. There are no indicatio that their underlying bedrock is lithologically different from that of the yellowish red orthic ferralsols. Taking into account their physiographic position in relation to the other soils, then it appears that they have in fact been derived from these yellowish red soils. Reworking of these acrisols, accompanied by deferritization, has resulted in a coarsening of the texture through a washing out of clay, especially in the topsoil, with some of the clay moving down the profile. Ferric acrisols were thus formed (e.g. profile 20). With a progressive coarsening of the soils they became more

FIGURE 8 Catenary sequence of soils formed over Kundelungu meta-siltstone, quarzitic sandstone and meta-argillite.




erosive, and as a result of this more shallow, while at the same time signs of waterlogging began to appear (cf. soil 18). Laterite now could develop (as in profile 15). This laterite becomes more common until it forms a more or less continuous sheet stretching over several tens of kilometres nearly up till the Lalafuta river. The little soil that nowadays covers this laterite sheet must be regarded as alluvial, as the indurated laterite gives rise during the rainy season to a perched water table that often will reach the surface, and causes extensive ponding. The iron which has created the laterites must have been derived, at least partly, from the deferritization of the yellowish red soils, a process that thus has led to the formation of the ferric acrisols.

As an hypothesis, a toposequence is proposed that is illustrated in figure 8. Both the subsidence underlying the formation of the Busanga swamps and a more humid climate than at present are thought to have been instrumental in the development of this toposequence.

Basic rock

All the soils over basic rock, independent of whether this is in the form of marble, dolomitic limestone, more or less pure limestone or basic igneous rock, are very deep, dark red and clayey. Topsoils are clayey too, except where slopes are relatively steep. In northern Solwezi district characteristic solution basins have formed that are normally bounded by at least one scarp. The larger of these basins have hydromorphic soils at their lowest point; the smallest basins do not exhibit any change in soil across the catena.

In southern Solwezi and Kasempa district soils over carbonatic rock do not physiographically differ from the surrounding soils. They can still be distinguished, though, by a very low drainage density, sometimes by dambos lacking an outlet, and by their very well developed vegetation.

Chemically all soils over basic rock have a pH that is about one half of a unit higher than commonly found in the other ferralsols of the project area. Their exchangeable Ca and Mg figures are obviously high, while they have a very low exchangeable potassium content.

Granite

Soils over granite, although being clayey with a clay topsoil, have a relatively high coarse sand content which reflects the textural composition of their parent material. Despite this, the granites are probably not very rich in quartz, but rather have a high content of feldspars and micas which weather into clay. The iron content of the granite is low, which is also borne out by the brownish colour of the soil. The reason for the thick A horizon which these soils in northern Mwinilunga have is not clearly understood. It could be related to local land use practices, in particular to the cultivation of cassava. No such thick topsoil occurs over the granite soils near Musele village, where no cassava is being grown.

Basement complex

The soils derived from Basement complex rocks are typical "sandveld" soil (i.e. soils with a light topsoil fairly abruptly overlying a heavier subsoil), independent of whether they have formed over gneiss or schists of the Kabompo formation. The exact genesis of the light topsoil remains something of a puzzle. Processes vaguely known as "appauvissement" (Duchaufour, 1970) are held responsible for it, they seem to entail a selective lateral washing out of clay and - to a lesser extent - silt from the surface horizons. Apparently these processes only take place in soils with a rather low silt and a high fine and medium sand content, as they are not operative in more clayey or silty soils.

Soils having biotite as an important mineral in their parent material tend to be somewhat redder, due to the biotite's iron content, whereas the soils over muscovite-kyanite schist are not only more browner, but also somewhat more leached and with a higher aluminium saturation. This is probably on account of the high aluminium content of their parent rock. All these "sandveld" soils display a relatively high exchangeable potassium and magnesium content.

Biotite schist

The exact placement of the biotite schist, over which the ferric luvisols (soil 37) have developed, in the stratigraphy of Zambia is not clear. According to the geological map of Appleton (no date), the whole area where these soils occur belongs to the West Lunga formation, which subordinates to the Kundelungu series. No schists have, however, been incorporated in this formation. Therefore it seems more logic that the Luigishi or Wamikumbi formations, which both adjoin the West Lunga formation on Appleton's map, and are both largely made up of biotite schists, should be considered the parent material of this soil.

Ferric luvisols are relatively moderately leached soils. This feature is not an attribute that can be ascribed to the parent rock. Instead it has to do with the intensity and the length of period the soil has been subjected to leaching. The ferric luvisols occur in a region where Kalahari sand deposits are common. These can be found all around this particular soil, and even within the area of occurrence vestiges of Kalahari sand remain as islands on high lying crest positions. It is therefore not too bolt to assume that there must have been a blanket of Kalahari sand that has protected the underlying soil and rock against weathering and erosion. Only after this material became exposed could soil forming processes become fully active again. It is thus the relative "youth" of this soil that is responsible for its rather good chemical properties. Whether rejuvenation through local uplift has played a role as well is not known.

Kalahari sand

Soils developed in Kalahari sand are obviously sandy. However, according to the Soil Taxonomy particle-size classification they are not sandy but coarse loamy or even fine loamy (texture loamy very fine sand, very fine sand or finer). Generally, the soils in Kalahari sand in North-Western province are less coarse than their counterparts in Western province. In the project area, a fining out was noted when going into northern direction. Although the possibility cannot be ruled out that this fining out results from a gradual decrease in size of the wind-borne particles with increasing distance from their source, such an explanation leaves unanswered why relatively fine and relatively coarse sands can be found in close proximity to each other. The occurrence of red and brown Kalahari sands next to each other indicates already that these sands are not a homogeneous deposit, but that several phases of deflation and accumulation have succeeded each other. Therefore it seems more likely that, as far as these textural differences can be attributed to depositional variation, local reworking by both eolian and fluvial action has been more important than sorting by long distance winds.

Apart from this possibility, it is clear that a certain amount of mixing of eolian material and residual soil has taken place. The influence of Kalahari sand in orthic ferralsol 33 is undeniable, even though it is limited to the upper part of the soil. But due to pedoturbation by the soil fauna no clear stratification of the wind deposited material has persisted. As very little mixing, if any, has apparently taken place between the Kalahari sand and the soil it covers in the southern part of Mwinilunga district, it seems that mixing could only take place if certain conditions were fulfilled. One is of course that sufficient soil material should have been available to allow mixing with the overlying Kalahari sand. Another one is that a very gradual deposition in thin layers would facilitate mixing very much. This implies that, in upward direction, the soil would get more coarser as the more clayey soil component would decrease. Indeed, the Kalahari sands in the north of Mwinilunga district often display a textural gradation, which is less outspoken in the sandy soils of the southern part of the district. As this is all very speculative, no further attention will be paid to possible environmental conditions which could have been conducive to a very gradual deposition versus a more quicker accumulation of sand. The formation of the Kalahari sands, and the source of the material, is still very much an unsolved problem that will need a lot more attention before it can be unravelled.

## 4.6 Soil classification

All the soils have been classified according to the FAO Legend, the soil Taxonomy and the Key to the Zambian Soil Series. The FAO Soil Map of the World Legend (FAO-Unesco, 1974) classifies soils at two levels, although by combining the qualifiers for the second level, when applicable, a third level can be created. This has been done in a few cases in the Soil Legend (e.g. dystric gleyic cambisol). Furthermore, the following modifications were applied to the FAO Legend:

- the acric soil unit of the ferralsols was redefined in line with the acric subgroup of the Soil Taxonomy, so that soils with an ECEC of less than 1.5 me per 100 g soil would also fall into this soil unit;
- a gleyic ferralsol was created, with hydromorphic properties within 100 cm of the surface, to match the aquic and epiaquic subgroups of oxisols in the Soil Taxonomy;
- petroferric and lithic soil units have been recognized to separate the soils with a petroferric or lithic contact within 100 cm of the surface;

- a fluvic unit was added to the cambisols in order to indicate the recent alluvial or colluvial influence on the soil, and as a couterpart to the fluvaquentic subgroups of the inceptisols. Some of the gleysols can be regarded as fluvic as well, to indicate their intergrading to the fluvisols.

Altogether 18 soil units have been distinguished according to the FAO's system.

The other major international soil classification system used is the Soil Taxonomy (Soil Survey Staff, 1975). All the soils have been classified according to this system up to the family level. A number of subgroups have been recognized that are not mentioned as such in the Soil Taxonomy. In nearly all cases it concerns great groups that have not yet been fully developed due to lack of sufficient relevant soil descriptions and analytical data. In such cases the subgroups were "borrowed" from more or less similar great groups. So is there only a typic paleustult in the Soil Taxonomy, but there are eight subgroups under the haplustult. Thus, oxic and aquic paleustults were recognized on the basis of the requirements for the oxic and aquic haplustults. Similarly aeric and mollic tropaquents were derived from the corresponding haplaquents, and a haplic acrustox was formed analogous to the haplic acrorthox. Extragrade subgroups were created for soils with shallow rock or laterite contacts: the lithic and petroferric subgroups. So at subgroup level a total of 21 soils were recognized in the project area, hardly more than according to the FAO Legend..

The Key to the Zambian Soil Series is still in its formative stage. The version used for this report, which is the fourth preliminary approximation (Veldkamp, 1982), goes up to the series level, but these series have not yet been assembled into families. Although most soil profiles fitted reasonably well to one of the series, phases and variants had to be used too. Variants refer to soils that correspond fairly well to a particular series, but deviate from it with regard to its concept. For instance a soil in Kalahari sand may be very similar to a dambo fringe soil series, but cannot possibly be considered as one and the same because it probably differs with respect to some parameters that have not yet been defined (e.g. mineralogy, moisture holding capacity, etc.). Such a soil would then become the Kalahari variant of that particular soil series, until such a time that sufficient data have been gathered to decide whether they can be lumped together or have to be separated. In a number of instances a soil is represented by two series, which bears out the inadequacy of series for mapping at this level of intensity.

Important new data for the refinement of the oxisol section was contributed by this soil survey. The Kasempa series and Chafuguma series were not only renamed, but also redefined, while a Mwinilunga series was created to cater for the typical Kalahari sand dambos of North-Western province.

# CHAPTER 5 Land evaluation

## 5.1 Introduction

The aim of this survey is to assess the agricultural potential of the project area, and identify soils with a particular high potential. Agricultural potential in itself is rather vague expression. To be more meaningful it has to be specified in terms of type of agricultrue and type of crop. In short, the land utilization type (FAO, 1976) should ideally be defined. However, the scale of the map and the time available did not allow for such an approach. Therefore, the soil potential was evaluated with respect to rural development in general, i.e. with the small scale farmer rather than the large scal commercial farmer in mind. This implies that no mechanization and a low level of inputs had to be taken into account.

This chapter has been divided into two sections, the first one dealing with the land capability, while in the second one the suitability for specific crops in evaluated.

## 5.2. Land capability

The soil potential has been assessed by compiling a land capability map. This map thus not only gives cognizance to soil-related parameters, but also to the wider aspects of the land. The compilation of this map involved two steps. The first one was the agriculural potential rating of each of the soils that had been identified. The second step consisted of classifying the soil associations on the basis of the ratings of the individual component soils.

The existing land capability system in use with the Land Use Branch (Soil Survey Unit, 1981) was thought not to be suitable for the purpose of this survey. This LUB system was not only set up for land classification for commercial farmers, but it also has to cater for the whole country, reason why it was considered to be too general for the project area. A more appropriate system was found in the land capability classification for the humid tropics by Sys and Frankart (1971). This classification system takes into account a number of parameters, each of which is given a rating. A soil potential index Cs is then arrived at by calculating the product of the individual ratings and multiplying the result by 100. The following six parameters are being employed:

A indice related to profile development (based on presence of diagnostic horizons and structure);

B indice related to texture (presence of laterite gravels is also taken into consideration);

C indice related to soil depth;

D indice related to drainage (distinguishes also between red and yellow well drained soils);

E indice related to pH and base saturation;

F indice related to the organic topsoil development.

Parameters C and D have two sets of ratings, one for perennial crops with a deep rooting system, and one for annual crops with a superficial root system. The latter was used for the soils under consideration. The system of Sys and Frankart was conscientiously adhered to, apart from the following minor adjustments:

- The pH and base saturation parameter distinguishes 5 levels, rated from 1.0 (pH more than 5.8 throughout) to 0.6 (pH topsoil less than 4.5, base saturation less than 15%). A sixth level was added, for a pH of 4.0 or less, and a base saturation of 10% or less.
- Parameter F has three sets of ratings: for savannah, forest and cultivated land. Basically the last two were used as applicable, while for abandoned fields with regrowth the savannah rating was used, as the severity of this rating is intermediate between the forest and cultivated field ratings. This paratmeter is assessed on the basis of colour and thickness of the A horizon, with ratings ranging from 1.25 to 0.4. A second column with ratings was added for topsoils that met the required depth, but, although being clearly darker than the subsoil, were not dark enough. The ratings in this column were established at a slightly lower level.
- An erosion index was added for soils with a high silt content in the topsoil. If this was more than 25% they were given a rating of 0.9, otherwise the rating would be 1.0.

All the soil profiles, including those not indicated on the map, were rated according to above system. Each parameter was estimated separately for the few soils that did not have a pit to characterize them, while for soil units represented by more than one profile pit the soil potential indices Cs were averaged. The result was a set of soil potential indices that ranged from 10 to 52 (see table 5 ).

Sys and Frankart give suitability classes for different groups of crops, which is reproduced in table 11. This classification did not suit the soils of the project area very much, as the soil potential indices are clustered in the 20 to 40 range, which according to the original table would not give enough differentation.

Table 11 Suitability classes for different groups of crops according to Sys and Frankart (1971)

| Suitability classes | Value of the soil potential index | | |
|---|---|---|---|
| | Exacting crops | Moderately exacting crops | Less exacting crops |
| Excellent suitability | +90 | +85 | +75 |
| Very suitable | 70-90 | 65-85 | 50-75 |
| Suitable | 50-70 | 45-65 | 35-50 |
| Moderately suitable | 35-50 | 30-45 | 25-35 |
| Slightly suitable | 25-35 | 15-30 | 10-25 |
| Unsuitable | -25 | -15 | -10 |

A more area-specific suitability classification was therefore devised which is given in table 12. Incidentally, this classification does not deviate very much from the classification for less exacting crops as developed by Sys and Frankart.

table 12 - Soil suitability classes for low input sustained dryland farming in North-Western Province

| suitability class | Cs rating |
|---|---|
| very suitable | 51 and more |
| suitable | 35 - 50 |
| moderately suitable | 21 - 34 |
| slightly suitable | 11 - 20 |
| non suitable | 10 and less |

The suitability class for each soil is listed in table 16 . These results show that only one soil in the project area can be regarded as possessing reasonable agricultural potential, having been rated as very suitable. This is the ferralic luvisol in Mwinilunga district. Most of the ferralsols are rated as suitable, including one of the ferric acrisols (soil 20). The light textured ferralsols and the other acrisols are considered moderately suitable. Few soils fall in the slightly suitable range, they are mostly soils developed in Kalahari sand. Soils with severe limitations due to wetness or shallowness are listed as non suitable for dryland farming. Slope and depth phases of soils were assessed as being one suitability class lower than the original soil, e.g. the slope and depth phases of orthic ferralsol 11 (soils 11s and 11d respectively) would be moderately suitable against suitable for the original soil.

This suitability classification does not give an indication as to the suitability of the soils for wetland crops, in particular flooded rice. The soils listed in table 13 are considered to possess some suitability for this crop.

table 13 - Soils suitable for flooded rice

| Soil code | Soil classification | Soil suitability |
|---|---|---|
| 40 | eutric and dystric gleysol | very suitable to moderately suitable |
| 33 | dystric gleyic cambisol | moderately suitable to slightly suitable |
| 34 | petroferric dystric regosol | slightly suitable |
| 26 | eutric gleysol | very suitable |

The land capability map had to be compiled from the individual soil suitability classification according to the composition of the soil association. Initially this was done by calculating the weighted average for each association. This yielded a map that showed very little differentiation, as averaging resulted in the dissappearance of the very good and very poor soils. In fact, the map became dominated by class 3 soils (moderately suitable).

A different approach was therefore chosen. The land capability classes were now so designed that especially the very suitable and suitable soils would be shown to their full advantage. This was accomplished by making land capability classes to include a minimum percentage of soils of a certain potential. The lowest class (class 5), containing less than 35% low potential soils, has been split into associations dominated by freely drained soils and associations dominated by wetland soils. Amongst the latter group soils can be found that are suitable for flooded rice cultivation. Table 14 presents the resulting land capability classification.

table 14 - Land capability classification for low input sustained farming in North-Western Province

| Land capability class | Definition |
|---|---|
| class 1 | associations with high and moderately high potential soils (more than 24% of high potential soils or more than 64% of high and moderately high potential soils) |
| class 2 | associations with moderately high potential soils (at least 35% moderately high potential soils) |
| class 3 | associations with moderately low potential soils (at least 65% moderately low potential soils) |
| class 4 | associations with low potential soils (at least 65% low potential soils) |
| class 5w | associations with soils unsuited for dryland farming (less than 35% low potential soils and dominated by hydromorphic soils) |
| class 5d | associations with soils unsuited for arable farming (less than 35% low potential soils and dominated by freely drained soils) |

The land capability map based upon this classification shows that there is a high proportion of class 1 land capability area in central and south Solwezi district, in the north of Kasempa district and in the southeast of Mwinilunga district. These areas are dominated by red soils over limestone (soil 17), by orthic luvisols (soil 11), or have at least one quarter where ferralic luvisols (soil 37) occur. Areas with a moderate land capability occur scattered throughout these districts, although they are less common in Mwinilunga district. Basically the same soils, but in a less high proportion, dominate these areas as those of class 1 land capability. The remaining area in Solwezi and Kasempa districts is mainly occupied with class 3 land capability areas, with the exception of the Busanga swamp region, where the predominant land capability class is 5w. In Mwinilunga district there is a large proportion of class 4 land capability, which is commensurate with the occurrence of poor Kalahari sand. Table 15 gives the distribution of the land capability classes per district, excluding national parks and gazetted forests.

table 15 - Land capability per district ($km^2$)

| | Kasempa | Solwezi | Mwinilunga | total | percent |
|---|---|---|---|---|---|
| C1 | 2331/ 2331 | 4341/ 3931 | 1778/ 1103 | 8450/ 7365 | 10/ 11 |
| C2 | 4638/ 4276 | 5095/ 4038 | 2153/ 2122 | 11886/10436 | 15/ 16 |
| C3 | 4836/ 4244 | 14002/11457 | 5015/ 4667 | 23853/20368 | 29/ 31 |
| C4 | 4165/ 3788 | 4083/ 3320 | 8519/ 6274 | 16767/13382 | 20/ 20 |
| C5d | 11682/10032 | 93/ 93 | 567/ 210 | 12342/10335 | 15/ 16 |
| C5w | 3848/ 151 | 2086/ 1766 | 2868/ 1655 | 8802/ 3572 | 11/ 6 |
| total | 31500/24822 | 29700/24605 | 20900/16031 | 82100/65458 | 100/100 |

the figure before the stroke indicates the total extent, while the figure behind the stroke gives the extent after deduction of national parks and forests.

table 16 Soils arranged according to their suitability class

| suitability class | soil | soil code |
|---|---|---|
| very suitable | ferric luvisol | 37 |
| suitable | rhodic ferralsol | 10, 15 |
| | orthic ferralsol | 11, 12, 13 |
| | acric ferralsol | 17 |
| | ferric acrisol | 20 |
| moderately suitable | orthic ferralsol | 14, 23, 36, 38 |
| | acric ferralsol | 16 |
| | xanthic ferralsol | 21, 22, 35 |
| | gleyic ferralsol | 25 |
| | ferric acrisol | 18 |
| | gleyic ferric acrisol | 19 |
| | eutric ferralsol | 26 |
| slightly suitable | xanthic ferralsol | 24 |
| | ferralic luvic arenosol | 28 |
| | petroferric dystric regosol | 34 |
| | dystric gleysol | 27 |
| non suitable | dystric gleyic cambisol | 33 |
| | fluvic gleyic cambisol | 39 |
| | petroferric ferralic arenosol | 29 |
| | lithic dystric regosol | 31 |
| | petroferric dystric regosol | 32 |
| | mollic gleysol | 30 |
| | eutric and dystric gleysol | 40 |

## 5.3 Agronomic aspects

This section deals with soil properties that have an important bearing on the agricultural performance of the soils. After having discussed the physical and chemical properties, a general crop suitability for groups of soils will be indicated in the final section.

### 5.3.1 Physical properties

Texturally there is quite a range of soils in North-Western Province, both in the topsoil and the control section. Soils with a coarse loamy control section are limited to the Kalahari sand zone, fine loamy soils occur mainly over Basement Complex, in colluvial material and in some of the alluvial sediments. Clayey soils comprise the soils derived from basic parent materials, schist, meta-siltstones and alluvium.

As far as topsoils are concerned, most Kalahari sand soils are covered by a sandy loam to loamy sand topsoil, which also applies to most of the Basement Complex soils (xanthic ferralsols). Loamy topsoils (sandy clay loam and clay loam) are common over colluvial soils, dambo soils and soils derived from meta-siltstones. They have also developed over some soils with a fine clayey control section in the Mwinilunga area, due to the addition of wind-blown material. Clayey topsoils are found covering the orthic, acric and rhodic ferralsols.

The silt content is high in soils that have developed from metamorphised parent material. Together with a sand fraction that with very few exceptions consist mainly of fine sand (0.2 - 0.02 mm) this makes that these soils are fairly erodible. In particular the soils derived from meta-siltstones and fine grained schists (most of the orthic ferralsols and ferric luvisols), which are made up of 40 to 50% silt and fine sand, are very erosive. Also, once brought under cultivation, their topsoils can be expected to develop a tendency to slake quickly under the impact of heavy rains.

The structural development of all the soils is very subdued, with only the ferric luvisol of Mwinilunga district displaying a moderately developed structure. Otherwise structures are weak to very weak, often having been described as porous massive, moderately to weakly coherent. Topsoil structures are only marginally better, the grade of structure being mainly a function of the amount of organic matter that is present in the surface horizons. Not much difference was found in this respect between soils under forest and cultivated soils, due to the regular burning of shrub layer, which prevents any significant build-up of organic matter in the soil.

Nevertheless, most of the ferralsols possess often a strong microaggregation in their profile. These soils behave therefore as if they were more coarser textured. This is, amongst others, borne out by the high permeability of these dominantly clayey soils. Despite the high rainfall intensities that occur from time to time, there are no signs that the movement of water through the soil is impeded in one way or the other.

No hardpans or similar horizons obstructing the movement of water and the growth of roots were encountered in the soils of the project area, other then laterite layers at depth. Experience from elsewhere in Zambia has shown, however, that thin hardpans can develop within a relatively short time below the plough layer of sandveld soils, once these soils are taken into cultivation. Attention should be paid to this aspect when development of these soils, which in the project area are represented by orthic ferralsol (38) and xanthic ferralsols (35), is being considered.

Textures are normally closely related to available water holding capacities. To see whether this hold for North-Western Province as well, and to obtain some insight in this parameter, the soil moisture retention curves of 4 soils was determined (see figure 9). The available water holding capacity, being defined as the amount of water held by the soil between field capacity and wilting point, has been derived from these graphs. Wilting point was taken at 15 bar suction, and field capacity at 0.1 bar, the latter suction giving the best agreement with the actual amount of water being retained by the soil at field capacity (Maclean, 1970). Table 17 gives the amounts of available water for the 4 profiles.

table 17 - Available water holding capacity (AWHC) for the topsoil and subsoil of four profiles

| profile number | soil type | parent material | texture 1/ | texture 2/ | AWHC (%) 1/ | AWHC (%) 2/ |
|---|---|---|---|---|---|---|
| 2 | rhodic ferralsol | Kundelungu | SC | C | 22 | 11 |
| 11 | orthic ferralsol | metasiltstone (Kundelungu) | C | C | 12 | 21 |
| 27 | orthic ferralsol | Kalahari sand | SL | SCL | 11 | 13 |
| 47 | xanthic ferralsol | schist (Basement Complex) | SL | SCL | 12 | 9 |

1/ topsoil at 20 cm depth, 2/ subsoil between 50 and 75 cm depth

FIG. 9a

# SOIL MOISTURE RETENTION CURVES

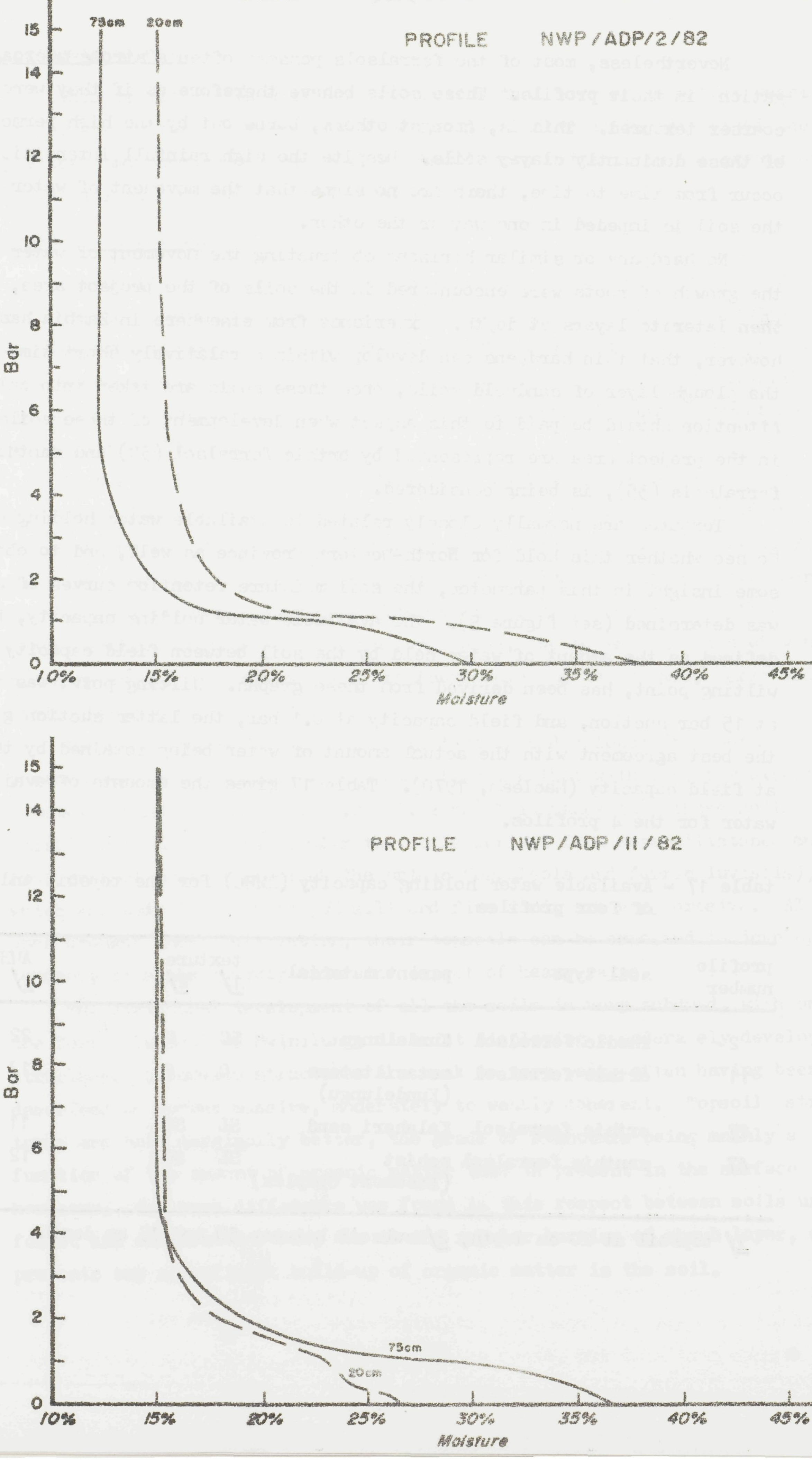
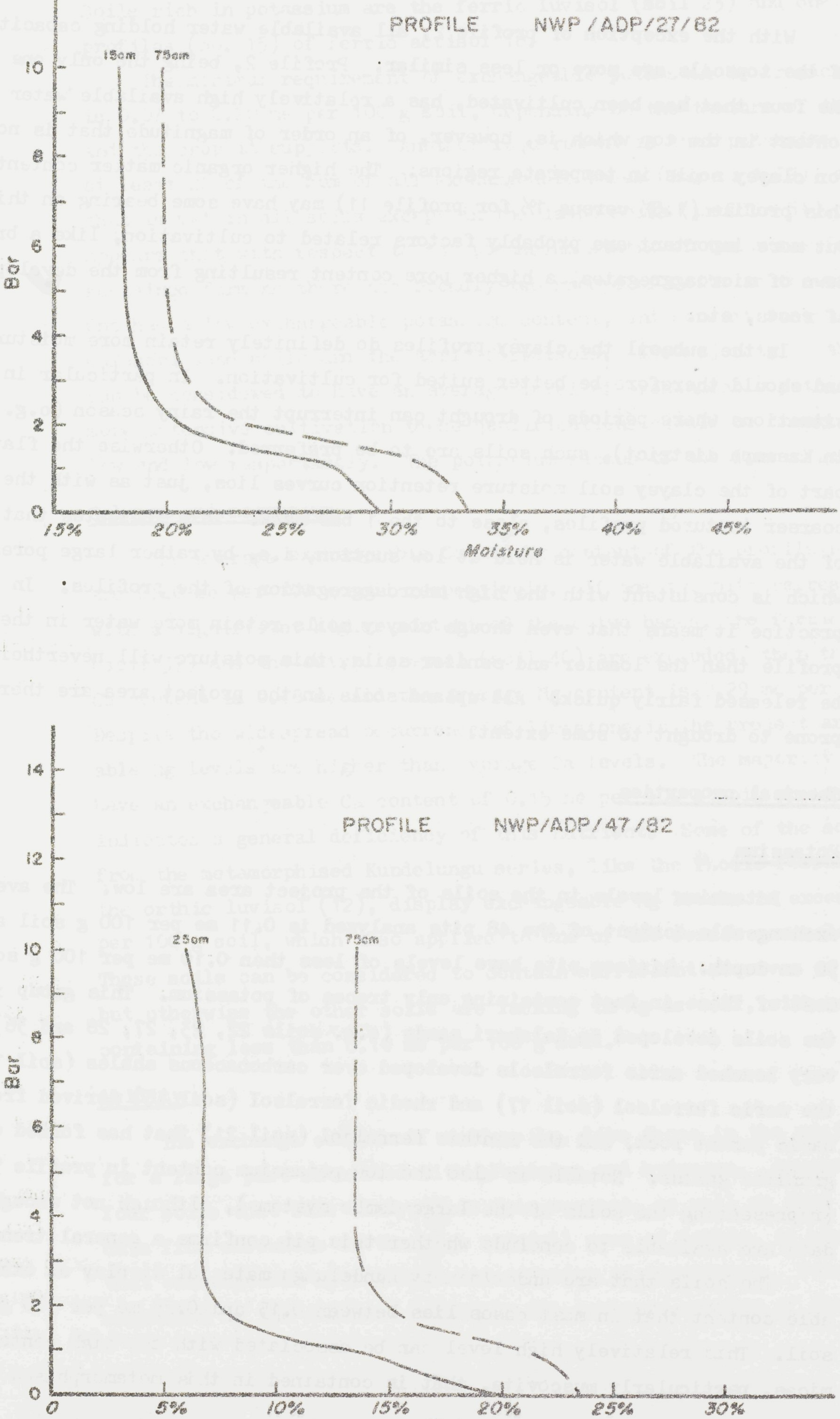


FIG. 9b

SOIL MOISTURE RETENTION CURVES



With the exception of profile 2, all available water holding capacities of the topsoils are more or less similar. Profile 2, being the only one of the four that has been cultivated, has a relatively high available water content in the top which is, however, of an order of magnitude that is normal for clayey soils in temperate regions. The higher organic matter content of this profile (1.5% versus 1% for profile 11) may have some bearing on this, but more important are probably factors related to cultivation, like a breakdown of microaggregates, a higher pore content resulting from the development of roots, etc.

In the subsoil the clayey profiles do definitely retain more moisture, and should therefore be better suited for cultivation. In particular in situations where periods of drought can interrupt the rainy season (e.g. in Kasempa district), such soils are to be preferred. Otherwise the flattest part of the clayey soil moisture retention curves lies, just as with the more coarser textured profiles, close to the 1 bar mark. This indicates that most of the available water is held at low suction, i.e. by rather large pores, which is consistent with the high microaggregation of the profiles. In practice it means that even though clayey soils retain more water in their profile than the loamier and sandier soils, this moisture will nevertheless be released fairly quick. All upland soils in the project area are therefore prone to drought to some extent.

### 5.3.2 Chemical properties

#### Potassium

Potassium levels in the soils of the project area are low. The average exchangeable content of the 48 pits analyzed is 0.11 me per 100 g soil at 50 cm depth. Sixteen pits have levels of less than 0.10 me per 100 g soil, most of these in fact containing only traces of potassium. This group includes the soils developed in Kalahari sands (e.g. soils 22, 23, 27, 28 and 36), the very leached acric ferralsols developed over carbonaceous shales (soil 16), the acric ferralsol (soil 17) and rhodic ferralsol (soil 15) derived from basic parent rock, and the xanthic ferralsol (soil 21) that has formed over granitic gneiss. Notable is also the low potassium content in profile 51 (representing the soils of the large dambo systems), although not enough data are available to conclude whether this pit confirms a general trend.

The soils that are underlain by Kundelungu material display an exchangeable content that in most cases lies between 0.15 and 0.25 me per 100 g of soil. This relatively high level can be associated with the high content of micas, particularly muscovite, that is contained in this metamorphised rock.

Soils rich in potassium are the ferric luvisol (soil 23) and one of the profiles (no. 15) of ferric acrisol 18.

The minimum requirement of exchangeable potassium in tropical soils is 0.07 to 0.20 me per 100 g soil, depending on the texture of the soil and the crop it supports. Another requirement is that potassium must be at least 2% of the sum of all exchangeable bases (Bayer, 1972), a requirement that is met in all soils except in the dambo soils (profile 51). It thus appears that with respect to the potassium status of the soils for low input sustained farming there are broadly two groups of soils in the project area. One has a low exchangeable potassium content, and consist basically of the Kalahari sand soils and the acric ferralsols. The majority of the soils can be considered to have an average level of exchangeable potassium. For more intensive cultivation these qualifications should be downgraded to very low and low respectively. The potassium status of the ferric luvisol is good.

Calcium and magnesium

The average exchangeable Ca and Mg content of the profile pits is 0.35 me and 0.40 me per 100 g soil respectively. If the two pits representing soils with a significant higher content of these two bases, the ferric luvisol (soil 37) and the eutric gleysol (soil 40) are excluded, then the average Ca content is 0.18 me and the average Mg content is 0.29 me per 100 g soil. Despite the widespread occurrence of limestone in the project area, exchangeable Mg levels are higher than average Ca levels. The majority of the soils have an exchangeable Ca content of 0.15 me per 100 g soil or less, which indicates a general deficiency of this nutrient. Some of the soils derived from the metamorphised Kundelungu series, like the rhodic ferralsol (10) and the orthic luvisol (12), display exchangeable Mg levels in excess of 0.5 me per 100 g soil, which also applies to one of the ferric acrisols (profile 15). These soils can be considered to contain sufficient reserves of this nutrient, but otherwise the other soils are lacking in Mg as well, with most of them containing less than 0.10 me per 100 g soil.

Acidity

The exchange complex of acid soils, like those in the project area, is for a large part saturated with aluminium and hydrogen. However, from the four soils that were analyzed in this respect, as well as from other relevant data from elsewhere in the high rainfall zone of Zambia, it has become evident that exchangeable hydrogen is not a factor of importance. Consequently, aluminium is the dominant cation on the exchange complex of the acid soils.

Table 6 already showed that the oxisols in the project area are for 70% to 90% saturated with Al, while the acrisols derived from Basement Complex have a similar high Al saturation. Table 18 shows the average Al data for the project area. Exchangeable Al is in fact higher in the topsoil than in the subsoil, but this is being offset by a higher content of bases in the upper part of the profile which results in an average Al saturation of 45% in the surface layer of the soil, against 66% in the upper part of the subsoil. Nevertheless, an Al saturation of 45% is still toxic to most crops, and acceptable yields are only possible if the aluminium toxicity is neutralized.

table 18 - Average alumi ium characteristics of strongly acid soils (pH ($CaCl_2$) equal or less than 4.5), n=19

| | topsoil (0-10 cm) | subsoil (50-75 cm) |
|---|---|---|
| soluble Al (ppm) | 9.2 | 8.2 |
| exchangeable Al (me/100 g soil) | 1.5 | 1.2 |
| Al saturation (%) | 45.0 | 66.0 |

Under traditional farming neutralization is achieved by the release of bases following the burning of vegetative matter (chitemene system). More modern farming practices call for liming, an average of 1.65 tons of $CaCO_3$ equivalent lime per ha being required for every milliequivalent of exchangeable Al to reduce the aluminium saturation in such soils (Sanchez 1976). There are, however, ample indications that while liming reduces the Al saturation in the topsoil to a level harmless to most crops, this does not apply to the Al toxicity in the subsoil. Numerous studies (e.g. Messick et al., 1984 and Friesen et al. 1982) and experiments (Fenney et al. 1981) have shown that the beneficial effects of liming do not extend to the subsoil of highly leached soils.

Lime applied to the topsoil either remains there in an immobile form, or is leached through the profile without replacing the Al at exchange sites with Ca or Mg. As a result, the Al saturation of the subsoil remains at toxic levels, inhibiting the penetration of roots into the subsoil. Plants are therefore not able to utilize the moisture stored in the subsoil, and may suffer from drought stress, even when the deeper layers of the soil are still moist.

No clear chemical or physical clue could be found to explain the preference farmers have for red soils. It could be that the soluble Al concentration, which consequent upon a higher leached status is lower in the red soils than in the reddish brown ferralsols, might be the reason as, despite a high Al saturation, a lower Al concentration will be more easily neutralized.

Manganese

Soluble manganese was determined for 19 pits. The average content was 12.8 ppm in the surface horizon (range trace to 55.4 ppm) and 11.1 ppm in the subsoil (range trace to 50.0), hence there is little variation within the profiles but much variation between them. Other than aluminium, manganese is a nutrient, and thus a minimum amount has to be present in the soil to prevent deficiency phenomena in the crops. However, at high levels Mn becomes toxic to the plants. Sanchez (1976) puts the optimum level in tropical soils at 1 to 4 ppm in the soil solution.

On this basis the soils developed in Kalahari sand, or containing a strong Kalahari sand component, should be regarded as lacking sufficient manganese, as they contain for the most part only traces of Mn (pits 29, 31 and 33). Another soil apparantly deficient in this nutrient is xanthic ferralsol 35, but as only one pit representing the sandveld soils has Mn data available, it cannot be stated whether or not this applies to these soils in general.

Soils high in Mn, with contents reaching toxic proportions, are the deep red soils (2.5 YR). Their average content is 17.7 and 14.9 ppm for the topsoil and subsoil respectively. These values are even higher when two red pits which strangely enough only contain very little Mn (pits 2 and 48) are excluded: 28.3 ppm and 24.3 ppm respectively.

The remaining soils (11, 20, 35, 42) have Mn contents within or close to the suggested optimum range, although the Mn concentration of soils with a colour of 5 YR tend to approach toxic levels (e.g. pit 23). Generally it can be stated that, in the project area, the redder the soil colour the higher (and more toxic) the concentration of soluble Mn in the acid clayey and fine loamy soils. Otherwise the Mn content is rather variable and displays wide ranges even with similar soil types.

Phosphorus

It is well known that savannah soils are as a rule deficient in phosphorus. The subsoil of nearly all the pits analyzed contained less than 5 ppm of available phosphate. Topsoil contents varied considerably, the effect of fertilization and chitemene practices being responsible for this. The available phosphate in the topsoil of undisturbed soils is estimated to lie within the 5 to 15 ppm range in the project area. Sandveld soils (xanthic ferralsols 35 and 38) appear to have a slightly better available phosphate concentration in their soil solution than the more clayey ferralsols, with 5 to 6 ppm in the subsoil and more than 10 ppm in the topsoil. Otherwise the less well drained coarse textured soils are the only ones with somewhat elevated levels of available phosphate. So has pit 40 (dystric gleysol, coarse loamy) more than 10 ppm throughout its first 100 cm, while pit 46 (gleyic ferralsol, fine loamy) contains on average 6 ppm over the same depth. Disregarding these particular soils it can be concluded that in general the phosphate status of the upland soils in the project area is rather poor, and only incidentally can it be described as moderate.

table 19 - Phosphate retention (%) and free iron content (%) of four ferralsols

| profile number | soil | horizon | depth | retention | free iron |
|---|---|---|---|---|---|
| 11 | orthic ferralsol | Ah | 00- 11 | 24.3 | 2.27 |
| | | Bws1 | 11- 26 | 27.1 | 2.68 |
| | | Bws2 | 26- 82 | 29.6 | 2.61 |
| | | Bws3 | 82-123 | 31.6 | 2.42 |
| | | Bcs | 123-150 | 30.3 | 2.95 |
| 26 | rhodic ferralsol | Ah | 0- 8 | 28.4 | 6.72 |
| | | BA | 8- 22 | 37.3 | 8.51 |
| | | Bws | 22- 50 | 41.7 | 9.53 |
| | | Bws | 50-100 | 39.4 | 9.42 |
| | | Bws | 100-150 | 35.6 | 9.50 |
| 39 | acric ferralsol | Ah | 0- 12 | 33.3 | 6.41 |
| | | BA | 12- 30 | 38.3 | 7.59 |
| | | Bws1 | 30- 73 | 35.7 | 8.19 |
| | | Bws2 | 73-125 | 35.4 | 7.90 |
| | | Bws3 | 125-160 | 34.7 | 7.12 |
| | | | 230-280 | 34.7 | 8.19 |
| 47 | xanthic ferralsol | Ah | 0- 13 | 7.0 | 0.29 |
| | | AB | 13- 38 | 8.3 | 0.32 |
| | | Bws1 | 38- 68 | 21.7 | 0.69 |
| | | Bws2 | 68-105 | 14.6 | 0.54 |
| | | Btg | 105-150 | 20.5 | 0.69 |
| | | Btg | 150-200 | 21.7 | 0.73 |

Soils rich in sesquioxides have a high phosphate fixation capacity. Table 19 shows that the phosphate retention of four selected profiles, together with their free iron content. This table demonstrates clearly that indeed the amount of phosphate being fixed by soils with a high iron content is substantially higher than for soils low in iron. For instance, the subsoil of profile 47 (xanthic ferralsol) contains only half the amount of phosphate fixed as the subsoil of profiles 26 and 39 (rhodic and acric ferralsols), while the amount of phosphate fixed in the topsoil of profile 47 is comparatively even less. This is probably also on account of the more sandier character of this topsoil.

Although coarse textured soils have a relatively low phosphate fixing capacity, they do more easily lose phosphate through leaching than more finer textured soils. In general, therefore, the soils of the project area, both fine and coarse textured, need rather large amount of P fertilizer in order to raise the concentration of available phosphate enough for a crop to respond.

Micronutrients

table 20 - Concentrations of extractable Cu, Zn, Mo and B in four ferralsols

| profile number | soil | horizon | depth (cm) | Cu | Zn | Mo | B |
|---|---|---|---|---|---|---|---|
| | | | | (ppm) | | | |
| 11 | orthic ferralsol | Ah | 0-11 | 2.28 | 7.90 | 2.23 | 0.12 |
| | | Bws1 | 11-26 | 1.52 | 5.12 | 0.91 | 0.07 |
| | | Bws2 | 26-82 | 0.51 | 1.44 | 0.20 | 0.07 |
| 26 | rhodic ferralsol | Ah | 0- 8 | 4.95 | 18.7 | 2.74 | 0.14 |
| | | BA | 0-22 | 3.05 | 16.7 | 0.91 | 0.15 |
| | | Bws | 22-50 | 1.78 | 8.94 | 2.24 | 0.09 |
| 39 | acric ferralsol | Ah | 0-12 | 8.27 | 8.22 | 2.54 | 0.12 |
| | | BA | 12-30 | 4.06 | 2.26 | 1.83 | 0.05 |
| | | Bws1 | 30-73 | 2.66 | 1.19 | 0.20 | 0.05 |
| 47 | xanthic ferralsol | Ah | 0-13 | 2.26 | 10.1 | 0.30 | 0.35 |
| | | AB | 13-38 | 0.75 | 9.87 | 1.51 | 0.57 |
| | | Bws1 | 38-68 | 0.50 | 18.8 | 0.10 | 0.05 |

Table 20 gives the micronutrient status of the three uppermost horizons of four reference profiles in the project area. Cu, Zn and Mo were extracted with EDTA, and boron (B) with hot water. The surface horizon of all four profiles contain sufficient amounts of copper, while it drops to rather low levels in profile 47 only. Pit 26 has a reasonable zinc level in its surface layers, but otherwise all the other soils must be considered low in their available zinc content, in some cases even very low (subsoils of profiles 11 and 39). This is in keeping with results from elsewhere in Zambia, where it is generally found that the soils of the high rainfall area are deficient in zinc.

All the soils appear to be relatively rich in molybdenum, although profile 47 shows a somewhat strange sequence with low to very low Mo levels in the Ah and Bws1 horizons, and a high Mo content in between. With regard to boron, profile 47 is the only one which contains high amounts, but these are limited to the first 35 cm. The subsoil of this xanthic ferralsol, together with the other soils, is severely deficient in boron.

As far as these results can be considered representative for the project area (they probably are for the clayey soils, as three out of the four profiles are clayey, more caution is warranted for the loamy soils), the conclusion is that the soils contain sufficient copper and molybdenum, although reserves of both are not very large. Most of the soils have very little boron, while they are potentially deficient in available zinc as well. When taken into continuous production, additional amounts of micronutrients will have to be added to the soil (or plant where applicable) in order to maintain reasonable yields.

## 5.4 Crop suitability

Up till very recently the project area has been under traditional agriculture, with chitimene as the major farming system. Long fallow periods could regenerate enough nutrients through the recycling of vegetative matter for subsistence crops to be grown.

The need for increased agricultural output not only implies the demise of the chitemene system, but also means that higher yields will have to be produced than was normal under the traditional system. Maintaining the nutrient status of the soils at the level just after clearing is not enough. Intensified land use requires that the soils be managed in such a manner so as to be capable of producing higher yields on a more permanent basis.

The foregoing part of this chapter has shown that there are several macronutrient and micronutrient deficiencies in the soils of the project area, and that on top of that aluminium and manganese toxicities pose serious limitations to the cultivation of several crops. Management practices exist to overcome many of these problems, but in most cases it will be economically not justifiable to implement such techniques. Increased agricultural production can thus not rely on soil management only, but will be strongly dependent on growing crops that are suited to the prevailing soil (and climatic) conditions.

Table 21, giving the main soil-related constraints of the upland soils, abundantly shows that aluminium toxicity and a very low nutrient level are the most common shortcomings of the soils. Based on this table the soils have been grouped with respect to their crop suitability (see table 22). It should be noted that upland rice is only possible where there falls more than 1200 mm of rain per year.

table 21 - Soil-related constraints to rainfed low-input dryland farming on the upland soils of North-western Province

| soil code | soil | low AWHC | major nutrient deficiency | Al toxicity | coarse texture | prone to erosion | |
|---|---|---|---|---|---|---|---|
| 10 | rhodic ferralsol | - | xx | xx | - | - | |
| 11 | orthic ferralsol | - | xx | xx | - | x | |
| 12 | orthic ferralsol | - | xx | xx | - | x | d/ |
| 13 | orthic ferralsol | - | xx | xx | - | x | |
| 14 | orthic ferralsol | - | xx | xx | x | xx | |
| 15 | rhodic ferralsol | - | xx | xx | - | - | d/ |
| 16 | acric ferralsol | - | xx | xx | - | - | |
| 17 | acric ferralsol | - | xx | x | - | - | |
| 18 | ferric acrisol | - | x | x | x | - | |
| 19 | gleyic ferric acrisol | - | xx | x | x | - | w/ |
| 20 | ferric acrisol | - | xx | xx | - | - | |
| 21 | xanthic ferralsol | - | xx | xx | - | - | |
| 22 | xanthic ferralsol | x | xx | xx | x | - | |
| 23 | orthic ferralsol | x | xx | xx | x | - | |
| 24 | xanthic ferralsol | xx | xx | xx | x | x | |
| 25 | gleyic ferralsol | x | xx | xx | x | - | w/ |
| 28 | ferralic arenosol | xx | xx | xx | xx | x | |
| 35 | xanthic ferralsol | x | x | xx | x | x | |
| 36 | orthic ferralsol | x | xx | xx | - | x | |
| 37 | ferric luvisol | - | - | - | - | xx | d/ |
| 38 | orthic ferralsol | x | xx | xx | x | x | |

x minor constraint; xx major constraint; d/ depth constraint and w/ wetness constraint for deep rooting crops.

The soil that is most versatile is the ferric luvisol. This is the only soil that can produce very reasonable yields of maize without liming, while it can also support a wide range of other crops, provided they are grown on the more level parts. Acric ferralsol 17, owing to its somewhat higher pH, is thought to be capable of reasonable performance after liming. It could support maize, but otherwise will be mainly suited for acid tolerant crops. This applies also to a group of soils that is similar in many respects to acric ferralsol 17, but has a lower pH and is therefore more difficult to ameliorate through liming.

Soils susceptible to erosion, capping etc., and soils with an extremely low native fertility (like acric ferralsol 16) are considered to be only suitable for acid tolerant crops like cassave, tea (where the soil is deep enough) and upland rice. They could, however, grow less acid tolerant crops as well under intensive management. Drought sensitive soils, i.e. mainly those with a sandy loam topsoil, are under a low input regime basically only suited for cassava. Where these soils occur in positions that can provide moisture for most of the time, as is sometimes the case close to a dambo, pineapple could be cultivated as well.

t ble 22 - Crop suitability for groups of soils

| group | soil | soil code | suitable crops |
|---|---|---|---|
| group 1 | ferric acrisol | 37 | maize, groundnut, sunflower, all other main crops |
| group 2 | acric ferralsol | 17 | maize (with liming), millet, sorghum, tea, cassava, upland rice |
| group 3 | rhodic ferralsol | 10, 15 | similar as group 2, excluding maize |
| group 4 | orthic ferralsol<br>xanthic ferralsol<br>acric ferralsol | 11, 12, 13<br>21<br>16 | cassava, tea, upland rice, pineapple |
| group 5 | orthic ferralsol<br><br>xanthic ferralsol<br>gleyic ferralsol<br>ferric acrisol<br>gleyic ferric acrisol | 14, 23, 36, 38<br>22, 35<br>25<br>18, 20<br>19 | cassave, pineapple |

The potential for arabica coffee in the project area is not very great, in particular not under conditions of low input farming. Most of the soils are too poor in nutrients, while the ferric luvisol, which is chemically well suited for coffee, is too shallow to give a good crop. The high acidity makes the area also not attractive for the establishment of orchards, although the ubiquitous banana tree can stand the acidity as long as there is enough moisture and nutrients available. Another exception could be cashew, which probably would do well in the area near Lwawu on xanthic ferralsol 24, provided it is planted in a position where it is sheltered from nightfrost.

The crop suitability groups indicated above correspond basically to the first three soil suitability classes. Group 1 obviously is similar to the very suitable soils, groups 2 and 3, and part of group 4 include the soils that have been rated as suitable, while the moderately suitable soils can be equated with the remainder of crop suitability group 4 and the whole of group 5.

## RECOMMENDATIONS FOR FURTHER SURVEYS

Detailed surveys will be carried out in a number of areas to obtain a more complete picture of the soils, their interrelationships and their agricultural potential. The locations of these areas should be based upon two considerations:

- the agricultural potential of their soils, and
- the size of the population that is supported by their soils.

Obviously, in soilswise more complicated areas there is a greater need for a more detailed study than in areas where the disposition of soils is more clearcut. In this respect Mwinilunga district, owing to the interaction of Kalahari sand with residual weathering material, offers a more intricate picture, while Kasempa has a fairly simple soil pattern. On the other hand, the soils in Kasempa district show less differences in their characteristics than elsewhere. Consequently, there is a need to find out more about these soils, in particular because despite the chemical likeliness, some are clearly more favoured than others by the farming population.

The following recommendations are made for further surveys:

Kasempa district

(a) The red soils near Ingwe, detailed study of both the soil and its distribution. A small part of the area north of the Kalulushi road can be included, as despite the general shallowness of the soils there they support a relatively large population.

(b) In-depth study, in conjunction with (a), of the orthic ferralsol (soil 11) of Kasempa district. A small area along the Kawana - Kasempa road can be selected.

Solwezi district

(c) A dambo survey of one of the large dambos in the southeastern part of the district, along the Kalulushi road, to assess its suitability for rice under flooded conditions. This survey shoudl preferably be accompanied by a monitoring of groundwater over at least one wet/dry season cycle.

(d) Survey of one of the poorly drained soils in a limestone depression, also with rice as a possible crop. Such a survey should not be undertaken, however, if there are indications that settlement might not be possible on account of a lack of suitable domestic water supply.

(e) For a more detailed investigation in a xanthic ferralsol (soil 35) over Basement complex, the Kisalala area previously surveyed by Broekhuis can be extended towards the inner part of the dome.

Mwinilunga district

(f) The ferric luvisol (soil 37) should be subjected to a more detailed and extensive survey. This survey would aim at establishing the full range of soils in the area and their characteristics, and establishing the proportion of slope and depth phases that occur. An important aspect to which attention should be paid is the susceptibility to erosion of this area.

(g) An area north of Mwinilunga, for instance around Ikelenge, should be selected to investigate the range of soils in the Kalahari contact zone, and their properties and relationships.

[illegible]

<u>Mwinilunga District:</u>

(4) The ferric luvisol (unit 7) should be subjected to a more detailed and extensive survey. This survey would aim at establishing the full range of soils in the area and their characteristics, and establishing the proportion of clays and depth phases that occur. An important aspect to which attention should be paid is the susceptibility to erosion of this area.

(5) An area north of Mwinilunga, for instance around Ikelenge, should be selected to investigate the range of soils in the Kalahari contact zone, and their properties and relationships.

APPENDIX I Methods of analysis

Particle size After pretreatment with hydroxen peroxide and hydrochloric acid samples were dispersed by sodium pyrophosphate. Coarse and medium sand was separated by wet sieving, while clay and silt were determined by hydrometer method, the remainder being taken as fine sand. No allowance was made for organic matter, which appears as an excess in the sand fraction.

Organic carbon Oxidation of sample with potassium dichromate in sulphuric acid, the excess $K_2Cr_2O_7$ being determined by titration (Walkley Black method).

Soil reaction The pH was measured by inserting a twin electrode system in a 1:2 v/v soil : distilled water or 0.01M $CaCl_2$ mixture. The suspensions were stirred several times and left overnight before measurement.

Phosphorus Colourimetric determination of sample extracted with ammonium fluoride in acid solution (Bray 1 method).

Cation exchange capacity Treatment of sample with ammonium acetate at pH 7.0, removal of excess acetate with ethanol. The adsorbed ammonium was replaced by sodium from a 10% NaCl solution, after which the desorbed ammonium was measured by titration with hydrochloric acid. No corrections have been made for organic matter, which especially in the topmost horizons of the soil contributes significantly to the cation exchange capacity.

Exchangeable cations Extraction of sample with an 1N ammonium acetate solution buffered at pH 7.0. Calcium and magnesium were determined by atomic adsorption, while potassium and sodium were assessed by flame photometry.

Aluminium and manganese Technical problems made it initially impossible to determine exchangeable aluminium in the Soil Survey and Advisory Laboratory at Mt. Makulu. Instead soluble Al was measured, together with soluble Mn, by extracting a sample on a 2:1 v/v basis with 0.02M $CaCl_2$, and determining Al and Mn by atomic adsorption spectrometry.

Samples from four pits (11, 26, 39 and 47) were analyzed at the Royal Tropical Institute in the Netherlands for exchangeable Al. They were reported as having been extracted with 0.6N $BaCl_2$. It was believed that these results would be comparable to extraction with 1N KCl, the standard procedure for determining exchangeable Al. Regression between these exchangeable Al figures and soluble Al figures showed a very high degree of correlation with r=0.96 at a 97.5% confidence level (Wen, 1984), so that the exchangeable Al could be calculated for all samples that had their soluble Al determined.

Later some doubt was cast on the assumption that extraction with 0.6N $BaCl_2$ and 1N KCl would yield comparable figures, as widely different results were obtained when both methods were used at the Royal Tropical Institute on selected samples from Mutanda Regional Research Station in North-western Province. This appeared to be caused not so much by the different extractants as by differences in the way of extraction (leaching versus shaking).

However, when the exchangeable Al of the samples from above four pits was determined direct in 1N KCl at the Soil Survey and Advisory Laboratory, Al levels were obtained that were very similar to what was earlier reported by the Royal Tropical Institute (see table 23). It appears that either the Institute used 1N KCl rather than 0.6 $BaCl_2$, or they did indeed employ 0.6N $BaCl_2$ but treated the samples in the same manner as with the 1N KCl method, i.e. extracting the Al by shaking rather than by leaching.

Whatever the case, the exchangeable Al figures given in this report, whether obtained by direct measurement or derived from soluble Al figures, can be considered to be of the correct order of magnitude. This is corroborated by exchangeable Al figures from samples taken elsewhere in the high rainfall zone in Zambia and analyzed at different laboratories.

table 23 Exchangeable Al (me per 100 g soil) extracted with 0.6N $BaCl_2$ as compared to exchaneable Al extracted with 1N KCl

| pit 11 depth | 1/ | 2/ | pit 26 depth | 1/ | 2/ | pit 39 depth | 1/ | 2/ | pit 47 depth | 1/ | 2/ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0- 11 | 1.63 | 1.72 | 0- 8 | 1.75 | 1.47 | 0- 12 | 2.90 | 1.80 | 0- 13 | 1.28 | n.d. |
| 11- 26 | 1.71 | n.d. | 8- 22 | 2.26 | 2.16 | 12- 30 | 1.80 | 1.39 | 13- 38 | 1.03 | 0.68 |
| 26- 82 | n.d. | n.d. | 22- 50 | n.d. | 1.78 | 30- 73 | 0.88 | 0.57 | 38- 68 | 1.63 | 1.17 |
| 82-123 | 0.56 | n.d. | 50-100 | 1.83 | 1.83 | 73-125 | 0.54 | 0.33 | 68-105 | 1.47 | 1.65 |
| 123-190 | 1.14 | 1.14 | 100-150 | 1.79 | 1.76 | 125-160 | 0.35 | 0.26 | 105-150 | 1.38 | 1.43 |
| | | | 250-300 | 1.71 | n.d. | | | | 150-200 | 1.24 | 1.30 |

1/ extracted with 0.6N $BaCl_2$ ; 2/ extracted with 1N KCl

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## APPENDIX II Soil profile pits and analytical data from pits opened during the survey of the project area

The full profile descriptions and analytical data of the soil pits that were opened up during the survey, and have been used in this report, are given below. Twelve more pits have been investigated but their details are not reproduced here since the soils in which these pits were dug are already adequately represented by other profile pits. The date of these twelve pits have, however, been used in the calculation of parameters like average exchangeable bases content, soil suitability ratings etc.

Soil profiles have been described according to the Soil Survey Guide (Veldkamp and Wen, 1982) and the Guidelines for Soil Profile Description (FAO, 1977). Where there was disagreement between these two guides, preference has been given to the former. E.g. the term porous massive has been used repeatedly to describe the soil structure rather than (very) weak subangular blocky.

Under the heading Land capability class the LUB (Land Use Branch) classification is given first, determined according to the Land Use Planning Guide (Soil Survey Unit, 1981), followed by the suitability class of the soil as determined on the basis of the data of the pit (see section 5.2 for a description of the method used). The suitability class for a particular soil has been derived from the average suitability rating of all the pits belonging to that soil, so that the suitability class of a certain profile is not necessarily the same as the suitability class of the soil to which that pit belongs.

In most cases the pits that were opened during the survey are identified in the text by the first group of digits of their profile number only, e.g. by 27 when reference is made to pit MWP/ADE/27/82.

Pit No!

| | |
|---|---|
| Profile no.: | NWP/ADP/2/82 |
| Soil name : | Mulonga series |
| Int. classification : | rhodic ferralsol (FAO), typic haplustox (USDA) |
| Soil map unit : | 10 |
| Date of description : | 26-8-1982 |
| Described by : | G.M. Ngosa and Wen Ting-tiang |
| Location : | along the track (N) north of Kasempa airport to Ndonda National Forest, UTM grid 3579 - 5196 (sheet 1325B3) |
| Elevation : | 1300 m a.s.l. |
| Landform : | gently undulating plateau, crest, slope 2% (S) |
| Vegetation and land use : | fairly dense miombo woodland, pit sited in cleared strip for tzetze control; locally subsistence cultivation with sorghum and finger millet as main crop, the latter being cultivated under the chitimene system |
| Anthills : | combined pinnacle mound type, red, with an average base of 5 m, an average diameter of 1.5 m, and an average total height of 4.5 m, on average 65 m apart |
| Human influence : | hoe cultivation and regular burning of vegetation |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | probably meta-argillite and quartzitic sandstone of the Kundulungu series |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | dry, just moist below 2 m |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 F F F F / A - -(2.5YR 3/6) |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | - 0 - 175 cm pit, augering below<br>- few narrow (less than 1 cm) cracks . |

extending from a depth of 50cm downwards to the bottom of the pit
-no clay cutans have been observed
-the field texture is sandy clay in all but the Ah orizons

PROFILE DESCRIPTION (NWP/ADP/2/82)

| | | |
|---|---|---|
| Ah | 0 - 6 cm | dark reddish brown (5YR 3/4, moist) and yellowish red (5YR 4/8, dry) sandy clay (field texture sandy clay loam) with a weak coarse crumb structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine and common fine inped pores; many very fine and fine, common medium and few coarse roots; transition clear and smooth |
| BA | 6 - 24 cm | dark reddish brown (2.5YR 3/5, moist) and red (2.5YR 4/6, dry) clay with a weak medium to coarse subangular blocky structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine, common fine and few medium and coarse inped pores; many very fine and fine, common medium and few coarse roots; transition gradual and smooth |
| Bws1 | 24 - 90 cm | dark red (2.5YR 3/6, moist) clay with a moderate coherent porous massive structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine, common fine, few medium and coarse pores; many very fine few fine and medium roots; transition diffuse and smooth |
| Bws2 | 90 - 150cm | dark red (slightly redder than 2.5YR 3/6, moist) clay with a moderate coherent porous massive structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine, few fine, medium and coarse pores; few very fine and fine roots; transition diffuse and smooth |
| Bws3 | 150 - 250cm | dark red (slightly redder than 2.5YR 3/6, moist) clay with a moderate coherent porous massive structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine, few fine, medium and coarse pores; few very fine, fine and medium roots |
| Bws4 | 250 -285+cm | identical to Bws3, but with very few very fine blackish gravel (max. 2 mm) |

**ANALYTICAL DATA** Profile no. NWP/ADP 2/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 6 | 36 | 18 | 25 | 16 | 5 | sandy clay |
| 10 - 20 | 44 | 14 | 26 | 12 | 4 | clay |
| 40 - 50 | 50 | 15 | 20 | 11 | 4 | clay |
| 70 - 80 | 64 | 17 | 6 | 8 | 5 | clay |
| 100 -110 | 60 | 15 | 15 | 7 | 3 | clay |
| 130 -140 | 66 | 15 | 7 | 8 | 4 | clay |
| 160 -170 | 62 | 19 | 9 | 7 | 3 | clay |
| 240 -280 | 72 | 15 | 6 | 4 | 3 | clay |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 6 | 6.3 | 5.1 | 2.01 | 25 | 22.8 | 0.2 |
| 10 - 20 | 5.0 | 4.1 | 1.01 | 3 | 16.8 | T |
| 40 - 50 | 5.1 | 4.2 | 0.45 | 2 | 21.2 | 0.4 |
| 70 - 80 | 5.4 | 4.2 | 0.15 | T | 23.0 | 0.2 |
| 100 -110 | 5.8 | 4.2 | 0.06 | T | 1.6** | 6.4 |
| 130 -140 | 5.4 | 4.3 | n.d | 2 | T** | 11.6 |
| 160 -170 | 5.8 | 4.2 | n.d | 2 | 12.6 | 5.0 |
| 240 -280 | 5.8 | 4.2 | n.d | 2 | n.d | n.d |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 6 | 3.39 | 1.91 | 0.53 | 0.03 | 2.82 | 9.1 | 25 | 21.3 | 54 | 37 |
| 10 - 20 | 0.21 | 0.47 | 0.19 | 0.01 | 2.08 | 6.5 | 15 | 6.7 | 14 | 70 |
| 40 - 50 | 0.12 | 0.60 | 0.19 | 0.02 | 2.62 | 5.5 | 11 | 7.1 | 17 | 74 |
| 70 - 80 | 0.07 | 0.75 | 0.19 | 0.01 | 2.8 | 6.1 | 10 | 6.0 | 17 | 74 |
| 100 -110 | 0.14 | 0.67 | 0.18 | 0.01 | 0.20 | 6.0 | 10 | 2.0 | 17 | 17 |
| 130 -140 | 0.14 | 0.54 | 0.13 | 0.01 | T | 5.4 | 8 | 1.7 | 14 | -- |
| 160 -170 | 0.10 | 0.58 | 0.13 | 0.01 | 1.56 | 5.5 | 9 | 3.8 | 15 | 66 |
| 240 -280 | 0.12 | 0.57 | 0.18 | 0.01 | n.d. | 6.0 | 8 | n.d | 15 | n.d. |

* derived from soluble Al

** data suspect

| | |
|---|---|
| Profile no.: | NWP/ADP/3/82 |
| Soil name : | Mulonga series |
| Int. classification : | rhodic terralsol (FAO); tropeptic haplustox (USDA) |
| Soil map unit : | 10 |
| Date of description : | 13-9-82 |
| Author : | R.N. Magai and Wen Ting-tiang |
| Location : | NW corner of Rural Council Farm, Kasempa, utm grid 3727-5169 (sheet 132584) |
| Elevation : | 1275 m e.s.l. |
| Landform : | gently undulating plateau, upper slope, 0.5% (E) |
| Vegetation and land use: | medium dense miombo woodland with Julbernardia as dominant species, moderately developed trees; locally shifting cultivation under the chitimene system is practised, with sorghum, finger millet and cassava as main crops; on the R.C. farm only maize is grown (yield 1.8 t/ha) |
| Anthills : | anthills are of the combined mound-pinnacle type, brownish red coloured, with an average base of 7 m, an average height of 6 m, and 35 to 50 m apart; very few 20 cm high anthills |
| Human influence : | none at the pit site, but the R.C. farm is ploughed, and 3.5 bag D compound and 5 bag $NH_4NO_3$ per ha are applied each year |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | probably meta-siltstone and sandstone of Kandulungu series |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderate throughout |
| Moisture state : | just moist below 2.5 m depth |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible erosion |
| LUB code : | 1 C F F F / 0 --(2.5YR 3/6) |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | - 0 - 180 cm pit, 180 - 320 augering |

PROFILE DESCRIPTION (NWP/ADP/3/82)

| | | |
|---|---|---|
| Ah | 0 - 5 cm | dark reddish brown (5YR 3/4, moist and 5YR 5/6 dry) clay (field texture sandy clay loam) with a weak fine to medium subangular blocky structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, common medium and few coarse inped and exped pores; many very fine, fine and medium, few coarse roots; transition clear and smooth |
| BA | 5 - 25 cm | dark reddish brown (2.5YR 3/4, moist and 2.5YR 4/6, dry) clay with a weak fine and medium subangular blocky structure; hard (dry), friable (moist), slightly plastic and sticky (wet); many very fine and fine, few medium and coarse pores; many fine, common very fine, few medium and coarse roots; transition gradual and smooth |
| Bws1 | 25 - ,90 cm | dark red (2.5YR 3/6, moist) clay with a weak fine to medium subangular blocky structure; hard (dry), friable (moist), slightly plastic and sticky (wet); possibly thin patchy cutans; many few fine, few fine, medium and coarse pores; common very fine and fine, few medium and coarse roots; transition diffuse and smooth |
| Bws2 | 90 - 280 cm | dark red (2.5YR 3/6, moist) clay with a weak fine to medium subangular blocky structure; slightly hard (dry), friable (moist), slightly plastic and sticky (wet); many very fine, few fine, medium and coarse pores; few very fine, fine, medium and coarse roots |
| Bws3 | 280 - 320 cm | similar to Bws2, except for few faint orange mottles |

## ANALYTICAL DATA

Profile no. NWP/ADP/3/82

### Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 5 | 42 | 26 | 28 | 2 | 2 | clay |
| 5 - 25 | 62 | 27 | 8 | 1 | 2 | clay |
| 25 - 60 | 70 | 16 | 11 | 1 | 2 | clay |
| 60 - 90 | 67 | 22 | 9 | 1 | 1 | clay |
| 90 -135 | 62 | 24 | 12 | 1 | 1 | clay |
| 135 -180 | 62 | 19 | 17 | 1 | 1 | clay |

### Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 5 | 5.3 | 4.4 | 1.12 | 29 | n.d. | n.d. |
| 5 - 25 | 5.2 | 4.2 | 0.44 | 6 | n.d. | n.d. |
| 25 - 60 | 5.4 | 4.2 | 0.23 | 6 | n.d. | n.d. |
| 60 - 90 | 5.7 | 4.4 | 0.13 | 2 | n.d. | n.d. |
| 90 - 135 | 5.6 | 4.2 | 0.05 | 1 | n.d. | n.d. |
| 135 -180 | 5.7 | 4.2 | n.d | 1 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 5 | 0.48 | 0.70 | 0.30 | 0.03 | n.d. | 10.4 | 25 | n.d. | 15 | n.d |
| 5 - 25 | 0.14 | 0.42 | 0.24 | 0.04 | n.d. | 8.4 | 14 | n.d. | 10 | n.d |
| 25 - 60 | 0.16 | 0.52 | 0.20 | 0.03 | n.d. | 9.2 | 13 | n.d. | 10 | n.d |
| 60 - 90 | 0.17 | 0.79 | 0.18 | 0.03 | n.d. | 8.5 | 13 | n.d. | 14 | n.d |
| 90 -135 | 0.17 | 0.66 | 0.14 | 0.02 | n.d. | 8.4 | 13 | n.d. | 12 | n.d |
| 135 -180 | 0.19 | 0.50 | 0.10 | 0.03 | n.d. | 8.1 | 13 | n.d. | 11 | n.d |

| | |
|---|---|
| Profile no.: | NWP/ADP/4/82 |
| Soil name : | Kahare series, Kasempa variant |
| Int. classification : | ferric acrisol (FAO) oxic paleustult (USDA) |
| Soil map unit : | 18 |
| Date of description : | 14-9-82 |
| Author : | Wen Ting-tiang and J.F. Broekhuis |
| Location : | along Kasempa - Kaoma road, about 9 km S of turn-off to Mushima, UTM grid 3437-4878 (sheet 1325D1) |
| Elevation : | 1195 m a.s.l. |
| Landform : | gently undulating plateau, interfluve, slope 0.5% (SE) |
| Vegetation and land use : | medium dense miombo woodland with Isoberlinia angolensis and Brachystegia boehmii as dominant species, also Julbernardia paniculata and Pericopsis angolensis, moderate growth; locally chitimene farming is practised, with sorghum, finger millet and cassava as main crops |
| Anthills : | mound type anthills, greyish brown coloured, with an average base of 5 m, an average height of 2 to 3 m, and about 100 m apart |
| Human influence : | none recognizable at the pit site |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | probably meta-siltstone and fine grained sandstone of Kundulungu series |
| Soil depth : | very deep |
| Drainage : | moderately well drained |
| Permeability : | rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible erosion |
| LUB code : | 1 B C C E / OW1-(10YR 5/6) |
| Land capability class : | : S2w (LUB);3 |

Remarks : 0 - 170cm pit, 170-280cm augering
- variations in consistence occur over short distances in the profile, both horizontally and vertically, due to the activities of termites; the consistence given is the one dominating in the horizon
- no clay cutans have been observed, but an argillic horizon is assumed on account of the clay increase

PROFILE DESCRIPTION (NWP/ADP/4/82)

| | | |
|---|---|---|
| Ah | 0 - 6 cm | dark brown (10YR 3/3,moist and 10YR 4/2,dry) sandy clay loam (field texture sandy loam) with a weak medium to coarse crumb structure; slightly hard (dry), very friable (moist), non-plastic andnon-sticky; many very fine, common fine and medium and few coarse, mostly inped pores; many very fine and fine, common medium and few coarse roots; transition clear and smooth |
| BA | 6 - 20 cm | dark brown (7.5YR 4/4,moist and 7.5YR 5/4,dry) sandy clay loam (field texture loam) with a weak fine subangular blocky structure; slightly hard (dry), friable (moist), non-plastic and non-sticky; many very fine andfine, common medium and few coarse pores; many very fine, common fine and medium and few coarse roots; transition smooth and gradual |
| Bt1 | 20 - 60 cm | yellowish brown (10YR 5/6,moist) sandy clay loam (field texture sandy loam) with a weak fine subangular blocky structure;many medium faint brownish (10YR 4/4,moist) mottles, hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, common medium and few coarse pores, but locally many medium pores; common very fine, fine and medium roots; transition wavy and gradual |
| Bt2 | 60 - 160 cm | yellowish brown (10YR 5/6,moist) sandy clay loam to sandy clay with a porous massive, weakly coherent structure; common medium faint to distinct brown mottles, also few, locally common, fine to medium reddish yellow (7.5YR 6/6, moist) mottles in the lower part of the profile, slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, few medium and coarse pores; few very fine, fine, medium and coarse roots |
| Bw | 160 - 200 cm | brownish yellow (10YR 6/6,moist) sandy clay to sandy clay loam with a porous massive, moderately coherent structure; few fine to medium, faint to distinct reddish yellow (7.5YR 6/6,moist) mottles, and few very faint |

light grey mottles; hard (dry), friable (moist), slightly plastic and slightly sticky (wet); few fine roots

Bg 200 - 280+cm similar in texture and matrix colour to Bw, but with common, medium and distinct white (5YR 8/1,moist) mottles, and with common, decreasing to few in the lower part of the horizon, fine to medium, distinct reddish yellow mottles

ANALYTICAL DATA Profile no. NwP/ADP/4/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 6 | 30 | 22 | 33 | 12 | 3 | sandy clay loam | - |
| 6 - 20 | 24 | 24 | 37 | 12 | 3 | sandy clay loam | - |
| 20 - 60 | 36 | 17 | 30 | 13 | 4 | sandy clay | - |
| 60 -110 | 32 | 23 | 31 | 10 | 4 | sandy clay loam to clay loam | 0.6 |
| 110 -160 | 33 | 18 | 36 | 9 | 4 | sandy clay loam | 0.4 |
| 160 -200 | 35 | 19 | 36 | 7 | 3 | sandy clay to sandy clay loam | 0.2 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 6 | 6.6 | 5.8 | 1.16 | 30 | 0.4 | 18.0 |
| 6 - 20 | 5.7 | 4.7 | 0.31 | 7 | 1.0 | 18.4 |
| 20 - 60 | 5.3 | 4.3 | 0.08 | 4 | 2.3 | 35.0 |
| 60 -110 | 5.7 | 4.6 | 0.15 | 1 | 1.2 | 18.4 |
| 110 -160 | 5.8 | 4.9 | n.d. | 1 | T | 11.6 |
| 160 -200 | 5.9 | 5.3 | n.d. | 1 | T | 4.6 |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 6 | 2.49 | 0.88 | 0.37 | 0.03 | 0.05 | 8.2 | 27 | 12.7 | 46 | 1 |
| 6 - 20 | 0.36 | 0.64 | 0.24 | 0.03 | 0.12 | 4.5 | 19 | 5.8 | 28 | 9 |
| 20 - 60 | 0.29 | 0.41 | 0.26 | 0.03 | 0.28 | 4.4 | 12 | 3.5 | 22 | 22 |
| 60 -110 | 0.09 | 0.48 | 0.17 | 0.02 | 0.15 | 4.5 | 14 | 4.7 | 30 | 10 |
| 110 -160 | 0.69 | 0.63 | 0.13 | 0.03 | T | 4.4 | 13 | 4.5 | 34 | T |
| 160 -200 | 0.56 | 0.80 | 0.12 | 0.03 | T | 4.2 | 12 | 4.3 | 36 | T |

derived from solube Al

| | |
|---|---|
| Profile no.: | NWP/ADP/5/82 |
| Soil name : | Kasempa series, gravelly phase |
| Int. classification : | xanthic ferralsol (FAO); petroferric haplustox (USDA) |
| Soil map unit : | 12 |
| Date of description : | 17-9-1982 |
| Described by : | R.N. Magai |
| Location : | along Kalulushi Rd. approx. 7.5 km E of Ingwe, UTM grid 4410-5600 (sheet 1326A2) |
| Elevation : | approximately, 1240 m a.s.l. |
| Landform : | gently undulating plateau, middle slope, slope 1% (NE) |
| Vegetation and land use : | pit sited in disturbed miombo woodland with Brachystegia microphylla Isoberlinia angolensis as main species; cultivation is mainly under the chitemene system |
| Anthills : | mound type anthills, with an average base of 10 m an average height of 4 m and on average 100 m apart, brown colour |
| Human influence : | disturbing of vegetation by burning and cutting, the pit site has most likely been cultivated by hoe in the past |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | fine grained sandstone and meta-siltstone |
| Soil depth : | deep |
| Drainage : | well drained |
| permeability : | moderately rapid |
| Moisture state : | 0 - 98 cm dry, just moist below |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | $\frac{1\ E\ F\ F\ F}{A\ -\ -\ (7.5YR\ 5/8)}$ |
| Land capability class | C1 (LUB);2 |
| Remarks : | - no clay cutans have been observed |

PROFILE DESCRIPTION (NWF/ADP/5/82)

| | | |
|---|---|---|
| Ah | 0 - 8 cm | dark yellowish brown (10YR 4/6, moist and 10YR 7/4, dry) clay with a weak fine to medium subangular blocky structure; slightly hard (dry), very firm (moist), slightly plastic and slightly sticky (wet); common fine, few medium and coarse pores; many very fine and fine, few medium and coarse roots; transition smooth and clear |
| BA | 8 - 20 cm | strong brown (7.5YR 5/6, moist and 7.5YR 6/6, dry) clay with a weak fine to medium subangular blocky structure; hard (dry), friable (moist), slightly plastic and sticky (wet); many very fine and fine, few medium and coarse pores; common fine, few medium and coarse roots; transition smooth and clear |
| Bws | 20 - 98 cm | strong brown (7.5YR 5/8, moist and 7.5YR 6/8, dry) clay with a weak fine to medium subangular blocky structure; hard (dry), very friable (moist), plastic and sticky (wet); many very fine, common fine, few medium and coarse pores; few fine, medium and coarse roots; possibly patchy thin cutans; transition clear and wavy |
| Bcs | 98 - 165+ cm | strong brown (7.5YR 5/8, moist) clay; structureless; few fine and medium roots; very frequent small ironstone gravel; very few large quartz gravel |

ANALYTICAL DATA — Profile no. NWP/ADP/5/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 20 - 60 | 48 | 28 | 22 | 1 | 1 | clay | 1.0 |
| 60 - 90 | 48 | 36 | 14 | 1 | 1 | clay | 6.7 |
| 90 -165 | 44 | 37 | 15 | 1 | 3 | clay | 77.2 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 20 - 60 | 5.4 | 4.3 | 0.06 | 2 | n.d. | n.d |
| 60 - 90 | 5.4 | 4.2 | 0.08 | 1 | n.d. | n.d. |
| 90 -165 | 5.6 | 4.3 | n.d. | 2 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 20 - 60 | 0.08 | 0.72 | 0.40 | 0.03 | n.d. | 8.0 | 17 | n.d | 15 | n.d |
| 60 - 90 | 0.11 | 0.57 | 0.44 | 0.04 | n.d. | 7.9 | 17 | n.d | 15 | n.d |
| 90 -165 | 0.05 | 0.72 | 0.44 | 0.03 | n.d. | 9.3 | 21 | n.d | 15 | n.d |

| | |
|---|---|
| Profile no.: | N.P/ADP/7/82 |
| Soil name : | Mumuna series |
| Int. classification : | acric ferralsol (FAO); haplic acrustox (USDA) |
| Soil map unit : | 17 |
| Date of description : | 18-9-1982 |
| Author : | R.N. Magai |
| Location : | along the track from Ingwe towards the Lunga, about 6 km S of the turn-off from the Kalulushi road; UTM grid-4355-5518(sheet 1326A2) |
| Elevation : | approx. 1280 m a.s.l. |
| Landform : | gently undulating plateau, interfluve, slope 1% (E) |
| Vegetation and land use : | medium dense miombo woodland with Julbernardia paniculata as dominant species, no farming activities occur in the neighbourhood of the pit site, but towards the Kalulushi road there is intensive small scale farming with cassava and sorghum as main crops |
| Anthills : | mound type, reddish brown, with an average base of 5 m, an average height of 7 m and on average 50 m part |
| Human influence : | the surrounding of the pit appear never to have been under cultivation, but the undergrowth is regularly burnt |
| Climate : | tropical savannah with an unimodal rainfall of circa 1275 mm/year |
| Parent material : | fine grained sandstone or siltstone according to the Geological Map of Zambia, but dolomitic limestone is suspected |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | very locally very few ironstone outcrops, common hematite dust concentrations on the track |
| Erosion : | none visible |

LUB code : - A16 - 1 F F F F / A - - (10R 3/6)

Land capability class : C1 (LUB),3

Remarks : - no clay cutans were observed

PROFILE DESCRIPTION (NWP/ADP/7/82)

| | | |
|---|---|---|
| Ah | 0 - 6 cm | dark reddish brown (2.5YR 3/4,moist and 2.5YR 4/6,dry) clay (field texture sandy clay) with a weak, fine subangular blocky structure; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, few medium and coarse pores; many fine, common medium and few coarse roots, many very fine roots; transition smooth and clear |
| AB | 6 - 30 cm | dark reddish brown (slightly redder than 2.5YR 3/4, moist and 2.5YR 4/6,dry) clay with a weak fine to medium subangular blocky structure; slightly hard (dry), very friable (moist), plastic and slightly sticky (wet); possibly few thin patchy cutans; many very fine, common fine and few medium and coarse pores; many very fine, common fine, few medium and coarse roots; transition smooth and gradual |
| Bws1 | 30 - 69 cm | dark red (10R 3/5,moist) clay with a weak fine and medium subangular blocky structure; slightly hard (dry), very friable (moist), plastic and sticky (wet),possibly thin patchy cutans; common very fine, few fine, medium and coarse pores; few fine, medium and coarse roots; transition smooth and diffuse |
| Bws2 | 69 -190+ cm | dark red (10R 3/6,moist) clay with a weak fine and medium subangular blocky structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet), possibly few thin patchy cutans; few fine, medium and coarse pores; few fine, medium and coarse roots |

## ANALYTICAL DATA

Profile no. NWP/ ADP/7/82

### Particle size distribution (%)

| depth | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| | | | | | | | - |
| 0 - 6 | 47 | 25 | 14 | 11 | 3 | clay | - |
| 6 - 30 | 56 | 21 | 12 | 8 | 3 | clay | 0.6 |
| 30 - 69 | 58 | 17 | 16 | 6 | 3 | clay | - |
| 69 -130 | 55 | 21 | 14 | 7 | 3 | clay | - |
| 130 -190 | 59 | 22 | 11 | 5 | 3 | clay | - |

### Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 6 | 5.2 | 4.4 | 1.73 | 6 | 4.0 | 37.0 |
| 6 - 30 | 5.3 | 4.4 | 0.52 | 3 | 4.4 | 25.4 |
| 30 - 69 | 5.7 | 4.5 | 0.18 | 2 | 2.2 | 20.0 |
| 69 -130 | 5.9 | 4.5 | 0.19 | 1 | 2.0 | 14.2 |
| 130 -190 | 5.9 | 4.5 | n.d | 1 | 0.6 | 9.6 |

| depth (cm) | exch. Ca | exch Mg | exch. K | exch. Na | exch. Al * | CEC | CEC | ECEC | base | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 6 | 0.40 | 0.76 | 0.37 | T | 0.49 | 11.5 | 25 | 7.2 | 13 | 32 |
| 6 - 30 | 0.08 | 0.53 | 0.17 | T | 0.54 | 7.7 | 14 | 1.4 | 10 | 69 |
| 30 - 69 | 0.07 | 0.64 | 0.16 | T | 0.27 | 7.5 | 13 | 1.5 | 12 | 31 |
| 69 -130 | 0.08 | 0.62 | 0.13 | T | 0.25 | 6.4 | 12 | 1.6 | 13 | 29 |
| 130 -190 | 0.08 | 0.55 | 0.13 | T | 0.07 | 6.8 | 12 | 1.4 | 11 | 8 |

*derived from soluble Al

| | |
|---|---|
| Profile no. : | NWP/ADI /8/82 |
| Soil name : | Kasempa series, gravelly phase |
| Int.classification | orthic ferralsol (FAO), petrofferic haplustox (USDA) |
| Soil map unit : | 13 |
| Date of description : | 15-9-1982 |
| Described by : | R.N. Magai |
| Location : | along the track from Ingue towards the Lungo, about 24 km S of the turn-off from the Kalulushi Rd; UTM grid 4466-5395 (sheet 132681) |
| Elevation : | approx. 1235 m a.s.l. |
| Landform : | interfluve in gently undulating plateau |
| Vegetation and land use : | pit sited in medium dense miombo woodland, with Julbernardia paniculata as dominant species; the area is uninhabited |
| Anthills : | mound type, brownish colour, with an average base of 10 m, an average height of 6 m and on average 30 m apart |
| Human influence : | burning of the undergrowth |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | fine grained sandstone and meta-siltstone, possibly partly colluviated |
| Soil depth : | deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 F F F F / A - - (5YR 5/8) |
| Land capability class : | C1 (LUB); 3 |
| Remarks : | - no clay cutans were observed |

## PROFILE DESCRIPTION (NWP/ADP/8/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | yellowish red (5YR 5/6, moist and 5YR 6/6, dry) clay with a weak to moderate fine to medium subangular blocky structure; hard (dry), very firm (moist), plastic and sticky (wet); common very fine, few fine, medium and coarse pores; many very fine, common fine and few medium and coarse roots; transition smooth and gradual |
| Bws | 10 - 24 cm | yellowish red (5YR 5/8, moist and 5YR 6/6, dry) clay with a weak fine and medium subangular blocky structure; very hard (dry), friable (moist), plastic and sticky (wet); few fine, medium and coarse pores; very few small ironstone gravel; few fine, medium and coarse roots; transition clear and wavy |
| Bcs | 42 - 77 cm | yellowish red (5YR 5/8, moist) clay with moderately coherent porous massive structure; very hard (dry), very friable (moist), plastic and sticky (wet), few fine and coarse pores; frequent small ironstone gravel; very few fine, medium and coarse roots; transition clear and wavy |
| BCcs | 77 - 106 cm | red (2.5YR 5/8, moist) clay with a moderately coherent porous massive structure; hard (dry), friable (moist), plastic and sticky (wet); few fine pores; frequent small ironstone gravel; frequent small weathered siltstone fragments; few fine, medium and coarse roots; transition wavy and gradual |
| C | 106 - 190+ cm | red (2.5YR 5/8, moist) clay with a moderately coherent porous massive structure; few fine roots; few small weathered siltstone fragments; few small ironstone gravel |

ANALYTICAL DATA

Profile no. NWP/ADP/8/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | texture class | gravel |
|---|---|---|---|---|---|---|---|
| | | | | | | | - |
| 0 - 10 | 50 | 32 | 14 | 2 | 2 | clay | - |
| 10 - 37 | 50 | 39 | 9 | 1 | 1 | clay | 4.1 |
| 37 - 76 | 54 | 32 | 12 | 1 | 1 | clay | 47.2 |
| 76 -106 | 42 | 36 | 20 | 1 | 1 | clay | 32.4 |
| 106 -190 | 47 | 37 | 14 | 1 | 1 | clay | 27.8 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P | sol. Al | sol. Mn |
|---|---|---|---|---|---|---|
| | | | | (ppm | | ) |
| 0 - 10 | 5.0 | 4.2 | 1.37 | 5 | n.d. | n.d. |
| 10 - 37 | 5.0 | 4.1 | 0.38 | 2 | n.d. | n.d. |
| 37 - 76 | 4.9 | 4.1 | 0.33 | 2 | n.d. | n.d. |
| 76 -106 | 5.2 | 4.0 | 0.13 | 3 | n.d. | n.d. |
| 106 -190 | 5.0 | 4.1 | n.d. | 2 | n.d. | n.d. |

| depth | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | (meq/100 g soil | | | | ) | | (meq/100 g clay) | | (% | ) |
| 0 - 10 | 0.32 | 0.60 | 0.45 | T | n.d. | 8.8 | 18 | n.d | 15 | n.d. |
| 10 - 37 | 0.11 | 0.21 | 0.21 | T | n.d. | 7.4 | 15 | n.d | 7 | n.d. |
| 37 - 76 | 0.09 | 0.08 | 0.14 | T | n.d. | 6.8 | 13 | n.d | 5 | n.d. |
| 76 -106 | 0.11 | 0,07 | 0.14 | T | n.d. | 7.1 | 17 | n.d | 5 | n.d. |
| 106 -190 | 0.14 | 0.09 | 0.08 | T | n.d. | 8.0 | 17 | n.d | 4 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/10/82 |
| Soil name : | Kasempa series gravelly phase |
| Int.classification : | orthic ferralsol (FAO); petroferric haplustox (USDA) |
| **Soil map unit** | 12 |
| Date of description : | 21-9-82 |
| Author : | Wen Ting-tiang |
| Location : | field at Kasempa Farming Training Centre, UTM grid 38325082 (sheet 132584) |
| Elevation : | about 1220 m a.s.l. |
| Landform : | plateau, upper slope, slope 1½% (N) |
| Vegetation and land use : | pit sited in arable field, which is planted every other year to maize (average yield 4 t/ha), alternated with sunhemp as green manure; in the villages around the FTC chitemene cultivation is practised, with sorghum as principal crop, while there are also some emerging farmers who obtain yields of about 2 ton maize/ha |
| Anthills : | mound type, reddish brown with an average base of 15 m, an average height of 4 m and on average 35 m apart |
| Human influence : | the field is ploughed yearly, and 4 bags D compound (basal dressing) and 8 bags $NH_4NO_3$ (topdressing) per ha are applied |
| Climate : | tropical savannah with an unimodal rainfall of about 1250 mm/year |
| Parent material : | fine grained sandstone |
| Soil depth : | deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | none visible |
| LUB code: | 1 C E E E / A --(5YR 3/6) |
| Land capability class : | C1 (LUB), 2 |
| Remarks : | - no clay cutans have been observed |

PROFILE DESCRIPTION (NWP/ADP/10/82)

| | | |
|---|---|---|
| AP | 0 - 15 cm | dark reddish brown (5YR 3/4,moist and 5YR, dry) clay (field ttexture sandy clay loam) with a weak fine to medium subangular blocky structure; hard (dry), friable (moist), slightly plastic and non-sticky; many very fine and fine, common medium and few mostly inped pores; many very fine and few fine roots; very few dine quartz gravel; transition clear and smooth |
| BA | 15 - 30 cm | dark reddish brown (5YR 3/6, moist and 5YR 5/6, dry) clay (field texture sandy clay) with a weak fine to medium subangular blocky structure; slightly hard to hard (dry), friable (moist), plastic and slightly sticky (wet); many very fine to fine, common medium inped pores; few very fine roots; very few fine quartz gravel; transition smooth and gradual |
| Bws | 30 - 100 cm | dark reddish brown (slightly redder than 5YR 3/6, moist and 5YR 5/8,dry) clay to clay loam with a weak medium to coarse subangular blocky structure; slightly hard (dry), very friable (moist), plastic and sticky (wet); many very fine, common fine, few medium and coarse inped pores; few fine quartz gravel very locally some concentrations of quartz rubble similar as in the Cu2 horizon; few very fine roots; transition clear and wavy |
| Cu1 | 100 - 130 cm | 80% fine and coarse angular quartz gravel, 5% weathered sandstone fragments, grey and ye yellow, of which the latter has a silty texture, the remaining consists of clay loam soil similar to the B horizon; transition gradual and wavy |
| Cu2 | 130 - 190+ cm | 85% fine and coarse angular quartz gravel, the remaining consists of clay loam soil similar to the B horizon |

ANALYTICAL DATA — Profile no. / NWP/ADP/10/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 15 | 42 | 29 | 21 | 5 | 3 | clay | 1.7 |
| 15 - 35 | 44 | 31 | 19 | 3 | 3 | clay | 1.5 |
| 35 - 55 | 40 | 27 | 28 | 3 | 2 | clay to clay loam | 2.5 |
| 55 -100 | 42 | 25 | 27 | 4 | 2 | clay | 26.0 |
| 130 -150 | 37 | 28 | 22 | 4 | 9 | clay loam | 55.3 |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 15 | 5.1 | 4.3 | 1.09 | 15 | n.d. | n.d. |
| 15 - 35 | 5.0 | 4.2 | 0.79 | 3 | n.d. | n.d. |
| 35 - 55 | 5.1 | 4.4 | 0.30 | 3 | n.d. | n.d. |
| 55 -100 | 5.6 | 4.9 | 0.20 | 2 | n.d. | n.d. |
| 130 -150 | 5.7 | 5.1 | n.d. | 2 | n.d. | n.d. |

| depth (cm) | exch Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 15 | 0.99 | 0.44 | 0.35 | T | n.d. | 8.5 | 20 | n.d. | 21 | n.d. |
| 15 - 35 | 0.97 | 0.40 | 0.20 | T | n.d. | 8.2 | 19 | n.d. | 19 | n.d. |
| 35 - 55 | 0.89 | 0.52 | 0.16 | T | n.d. | 7.0 | 18 | n.d. | 22 | n.d. |
| 55 - 100 | 1.13 | 0.70 | 0.06 | T | n.d. | 6.2 | 15 | n.d. | 30 | n.d. |
| 100 - 150 | 1.21 | 0.79 | 0.06 | T | n.d. | 6.3 | 17 | n.d. | 33 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/11/82 |
| Soil name : | Kasempa series |
| Int. classification : | orthic ferralsol (FAO), typic haplustox (USDA) |
| Soil map unit : | 11 |
| Date of description : | 20-9-82 |
| Author : | G.M. Noose and Wen Ting-tiang |
| Location : | along Kasempa - Kawena Road, 11.2 km N of Chinaqofube stream: UTM grid 3789-5388 (sheet 1325B2) |
| Elevation : | about 1320 m a.s.l. |
| Landform : | plateau, upper slope, slope ≤1% (S) |
| Vegetation and land use : | pit sited in miombo woodland with Julbernardia particulata and Brachystegia species as dominant species, also Uapaca species and Lannea stuhlmanii; locally the chitemene system is practised with sorghum, finger millet and casave as main crops |
| Anthills : | mound type, brown with an average base of 9 m, an average height of 6 m and on average 35 m apart; pinnacle type, an average diameter of 1 m, an average height of 5 m and on average over 100 m apart, occurs also on top of mounds, but then on average only 1 m high; few small (15 cm high) anthills |
| Human influence : | the surroundings of the pit appear never to have been under cultivation, but the undergrowth is regularly burned |
| Climate : | tropical savannah with an unimodal rainfall of circa 1150 mm/year |
| Parent material : | probably meta-siltstone and fine grained sandstone of Kundulungu series |
| Soil depth : | deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | none visible |

LUB code : 1 F F F F
0 --(5YR 4/8)

Land cpability class : C1 (LUB); 2
Remarks : - no clay cutans have been observed

PROFILE DESCRIPTION (NWF/ADP/11/82)

| | | |
|---|---|---|
| Ah | 0 - 11 cm | dark brown (7.5YR 4/4, moist and 7.5YR 5/4, dry) clay with a weak fine to medium subangular blocky structure; slightly hard (dry), friable (moist), plastic and sticky (wet); many very fine and fine, common medium and few coarse pores; many very fine and fine, common medium and few coarse roots; transition smooth and clear |
| Bws 1 | 11 - 26 cm | yellowish red (5YR 4/8, moist and 5YR 5/6, dry) clay with a weak fine to medium subangular blocky structure; slightly hard (dry), friable (moist), plastic and sticky (wet); many very fine and fine, common medium and few coarse pores; many fine, common medium and few coarse roots; very few fine laterite gravel; transition diffuse and smooth |
| Bws2 | 26 - 82 cm | yellowish red (5YR 4/8, moist and 5YR 6/6, dry) clay with a moderately coherent porous massive structure; soft (dry), very friable (moist), slightly plastic and slightly sticky (wet) many very fine, common fine, few medium and coarse pores, common fine, few medium roots; few fine laterite gravel; transition diffuse and smooth |
| Bws3 | 82 - 123 cm | yellowish red (5YR 5/8, moist and dry) clay with a moderately coherent porous massive structure; soft (dry), friable (moist), plastic and sticky (wet); many very fine, common fine, few medium and coarse pores; few fine laterite gravel; transition clear and smooth |
| Bcs | 123 - 190+ cm | yellowish red (5YR 4/6, moist and 5YR 6/6, dry) clay with very frequent fine laterite gravel and very few fine and coarse quartz gravel |

ANALYTICAL DATA

Profile no. /NWP/ADP/11/ 82

| depth | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 11 | 54 | 34 | 8 | 2 | 2 | CLAY | 1.2 |
| 11 - 26 | 62 | 27 | 9 | 1 | 1 | clay | 2.4 |
| 26 - 82 | 53 | 33 | 12 | 1 | 1 | clay | 3.1 |
| 82 - 123 | 50 | 36 | 12 | 1 | 1 | clay | 3.9 |
| 123 - 190 | 57 | 32 | 5 | 2 | 4 | clay | 65.6 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | micronutrients Cu (ppm) | Zn (ppm) | Mo (ppm) | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 11 | 5.0 | 4.1 | 1.24 | 5 | 9.6 | 6.2 | 2.28 | 7.90 | 2.23 | 0.14 |
| 11 - 26 | 5.0 | 4.1 | 0.78 | 3 | 12.8 | 2.4 | 1.52 | 5.12 | 0.91 | 0.07 |
| 26 - 82 | 5.4 | 4.2 | 0.30 | 2 | 5.4 | 2.2 | 0.51 | 1.44 | 0.20 | 0.07 |
| 82 - 123 | 5.7 | 4.4 | 0.12 | 2 | 2.8 | 3.0 | n.d. | n.d. | n.d | n.d. |
| 123 - 190 | 5.6 | 4.3 | n.d. | 2 | 5.4 | 4.6 | n.d. | n.d. | n.d | n.d. |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC (meq/100 g clay) | ECEC | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 11 | 0.32 | 0.53 | 0.70 | 0.01 | 1.63 | 11.0 | 20 | 5.9 | 14 | 51 |
| 11 - 26 | 0.07 | 0.22 | 0.34 | T | 1.71 | 10.2 | 16 | 3.8 | 6 | 73 |
| 26 - 82 | 0.11 | 0.31 | 0.26 | T | n.d. | 8.5 | 16 | n.d | 8 | n.d. |
| 82 - 123 | 0.11 | 0.07 | 0.19 | T | 0.56 | 6.9 | 14 | 1.9 | 5 | 60 |
| 123 - 190 | 0.10 | 0.06 | 0.23 | 0.01 | 0.14 | 7.8 | 14 | 2.7 | 5 | 74 |

| | |
|---|---|
| Profile no.: | NWP/ADP/12/82 |
| Soil name : | Mehare series, Kasempa variant |
| Int. classification : | ferric acrisol (FAO), oxic paleustult (USDA) |
| Soil map unit : | 18 |
| Date of description : | 20-9-82 |
| Author : | Wen Ting-tiang |
| Location : | along old Kasempa-Kaoma road, 21.5 km S of the nearest school; UTM grid 3304-4658 (sheet 1325 D4) |
| Elevation : | 1200 m a.s.l. |
| Landform : | gently undulating plateau, lower slope, slope 0.5% (SE) |
| Vegetation and land use : | pit sited in rather open miombo woodland with Isoberlinia angolensis as dominant species, also Brachystegia boehmii and Albizia zygia; at present there is no cultivation in the neighbourhood of the pit |
| Anthills : | mound type, brown-grey with an average base of 10 m an average height of 2.5m and on average 80 m apart |
| Human influence : | non recognizable |
| Climate : | tropical savannah with an unimodal rainfall of circa 1150 mm/year |
| Parent material : | possibly sandstone of Kundelungu series |
| Soil depth : | very deep |
| Drainage : | moderately well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | 0 - 300cm dry, just moist below |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | none visible |
| LUB code : | 1 X B C E / 0 W1-(10YR 6/5) |
| Land capability class : | S2w (LUB); 3 |
| Remarks : | - 0 - 190 cm pit, 190 - 320 cm augering<br>- no clay cutans were observed, but an argillic horizon is assumed on account of the clay increase |

PROFILE DESCRIPTION (NWP/ADG/12/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | dark grayish brown (10YR 4/2,moist and 10YR 6/2, dry), sandy loam (field texture loamy sand) with a weak fine to medium subangular blocky structure; soft (dry), very friable (moist), nonsticky and non-plastic (wet); many very fine, common fine and few medium and coarse mostly inped pores; many very fine and fine, common medium roots; transition smooth and clear |
| BA | 10 - 30 cm | dark yellowish brown (10YR 4/4,moist and 10YR 6/3, dry) sandy loam with a weak medium subangular to angular blocky structure, tending to porous massive; soft (dry), very friable (moist), non-sticky and non-plastic (wet); many very fine, common fine, few medium and coarse inped pores; common very fine and fine, few medium and coarse roots; transition smooth and gradual |
| Bt1 | 30 - 60 cm | dull yellow orange (10YR 6/5,moist) sandy loam with a massive porous, moderately coherent structure; slightly hard (dry), very friable (moist), non-sticky and non-plastic (wet); many very fine and fine, few medium pores; common fine, few very fine, medium and coarse roots; transition smooth and gradual |
| Bt2 | 60 - 85 cm | brownish yellow (10YR 6/6,moist) sandy clay loam with common fine distinct yellowish brown (10YR 5/6,moist) mottles; porous massive structure, moderately coherent; slightly hard (dry), very friable (moist), slightly plastic and none sticky (wet); many very fine, common fi fine and few medium pores; few very fine, fine, medium and coarse roots; transition wavy and gradual |
| Cg1 | 85 - 115 cm | light yellowish brown (10YR 6/4,moist) sandy clay loam (field texture loamy sand) with few fine distinct yellowish brown (10YR 5/6, moist) mottles, and common fine to medium faint pinkish grey (5YR 7/2,moist) mottles; porous massive structure, moderately coherent; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine and few medium pores; many very fine, fine, medium and coarse roots; few small black hard Mn/Fe concretions; transition smooth and gradual |
| Cg2 | 115 - 165 cm | light yellowish brown (10YR 6/4,moist) sandy clay loam (field texture sandy clay) with common fine to medium faint pinkish gray (5YR 7/2,moist) mottles; porous massive structure, moderately coherent; slightly hard (dry), very friable (moist) slightly plastic and slightly sticky (wet); many very fine, few fine and medium pores; few very fine, fine and medium roots; transition smooth and gradual |

| | | |
|---|---|---|
| Cg3 | 165 - 280 cm | pink (7.5YR 7/4,moist and rubbed) sandy clay loam (field texture sandy clay) with many medium to coarse distinct pinkish grey (5YR 7/2,moist) mottles, and common fine to medium distinct yellowish red (5YR 5/8,moist) mottles, changing gradually into yellowish brown (10YR 5/8,moist) with depth ;massive porous structure, moderately coherent; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet), many very fine, few fine and medium pores; few very fine, fine and medium roots; frequent small fairly hard Fe/Mn concretions, developed from the reddish brown mottles and decreasing with depth |
| Cg4 | 280 - 320+cm | similar to Cg3 but without concretions and with many medium to coarse prominent yellowish brown (10YR 5/8,moist) mottles, as well as the pinkish grey mottles |

ANALYTICAL DATA Profile no. NWP/ADP/12/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 19 | 20 | 44 | 15 | 2 | sandy loam | 4.3 |
| 10 - 30 | 14 | 20 | 49 | 15 | 2 | sandy loam | - |
| 30 - 60 | 18 | 13 | 49 | 16 | 4 | sandy loam | - |
| 60 - 85 | 28 | 19 | 41 | 10 | 2 | sandy loam loam | - |
| 85 -115 | 27 | 17 | 42 | 12 | 2 | sandy clay loam | 1.7 |
| 115 -165 | 26 | 20 | 42 | 10 | 2 | sandy clay loam | 1.8 |
| 165 -190 | 28 | 17 | 41 | 12 | 2 | sandy clay loam | 0.7 |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 10 | 6.6 | 5.5 | 0.98 | 10 | n.d | n.d |
| 10 - 30 | 5.9 | 5.2 | 0.22 | 3 | n.d | n.d |
| 30 - 60 | 6.0 | 5.1 | 0.21 | 3 | n.d | n.d |
| 60 - 85 | 5.5 | 4.4 | 0.14 | 2 | n.d | n.d |
| 85 -115 | 5.4 | 4.4 | 0.18 | 2 | n.d | n.d |
| 115 -165 | 5.6 | 4.4 | n.d | 2 | n.d | n.d |
| 165 -190 | 5.3 | 4.1 | n.d | 2 | n.d | n.d |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil | | | | | ) | (meq/100 g clay) | | (%) | |
| 0 - 10 | 2.67 | 0.79 | 0.13 | 0.01 | n.d | 6.2 | 32 | n.d | 74 | n.d |
| 10 - 30 | 0.69 | 0.52 | 0.05 | T | n.d | 2.6 | 18 | n.d | 49 | n.d |
| 30 - 60 | 0.55 | 0.81 | 0.05 | 0.01 | n.d | 3.6 | 20 | n.d | 40 | n.d |
| 60 - 85 | 0.37 | 0.92 | 0.06 | 0.02 | n.d | 4.5 | 16 | n.d | 30 | n.d |
| 85 -115 | 0.14 | 0.99 | 0.04 | 0.02 | n.d | 4.1 | 15 | n.d | 29 | n.d |
| 115 -165 | 0.03 | 0.78 | 0.03 | 0.01 | n.d | 3.3 | 13 | n.d | 26 | n.d |
| 165 -190 | 0.06 | 0.32 | 0.03 | 0.04 | n.d | 3.9 | 14 | n.d | 12 | n.d |

| | |
|---|---|
| Profile no.: | NWP/ADP/15/82 |
| Soil name : | Ipafu series |
| Int. classification : | ferric acrisol (FAO); oric paleustult (USDA) |
| Soil map unit : | 18 |
| Date of description : | 24-9-1982 |
| Described by : | G.M. Ngosa and Wen Ting-tiang |
| Location : | along Mushima - Musonweji road, 26.6 km SW of clinic<br>UTM grid LQ 1074 (sheet SD 35-5) |
| Elevation : | 1150 m a.s.l. |
| Landform : | plateau with very little relief, slope 1% |
| Vegetation and land use : | pit sited in open miombo woodland, with Isoberlinia angolensis as dominant species, other species include Uapaca kirkiana and nitida, Julbernardia paniculata, Monotes ssp., Anisophyllea boehmii, somewhat poor growth; the area is presently uninhabited, but gardens must have been common up to about 15 - 20 years ago |
| Anthills : | mound type, greyish brown, with an average base of 10 m, an average height of 3 m, and on average 50m apart, few small greyish anthills with an average height of 20 cm and an average diameter of 15 cm |
| Human influence : | burning |
| Climate : | tropical savannah with an unimodal rain-fall of circa 1250 mm/year |
| Parent material : | unknown |
| Soil depth | very deep |
| Drainage : | moderately well drained |
| Permeability : | rapid to moderate throughout |
| Moisture state : | 0 - 100 cm dry, just moist below |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | no evidence |
| LUB code : | 1 8 D D D<br>0 W1-(10YR 6/4) |
| Land capability class : | C2w (LUB); 4 |

Remarks :
- no cutans have been observed
- moderate termite activity
- area is inhibited by elephants
- no clear clay cutans have been observed, but an argillic horizon is assumed on account of the clay increase, which has been confirmed in thin section

PROFILE DESCRIPTION (NWP/ADP/15/82)

| | | |
|---|---|---|
| Ah | 0 - 9 cm | dark grayish brown (10YR 4/2,moist and 10YR 6/2,dry) very fine sandy loam with a weak fine to medium subangular blocky structure; slightly hard (dry), very friable (moist), non-plastic and non-sticky (wet); many very fine, common fine and medium, few coarse inped and exped pores; many very fine, common fine and medium, few coarse pores; transition clear and smooth |
| AB | 9 - 17 cm | brown (10YR 5/3,moist and 10YR 7/2,dry)very fine sandy loam with a weak fine to medium subangular blocky structure; hard (dry), very friable (moist), slightly plastic and non-sticky (wet); many very fine and fine, few medium and coarse inped pores; many fine, common very fine and medium, few coarse roots; transition gradual and smooth |
| BA | 17 - 31 cm | light yellowish brown (10YR 6/4,moist and 10YR 7/2,dry) clay loam with a moderately coherent porous massive structure; hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine, few medium and coarse pores; common fine, few very fine and medium roots; transition gradual and smooth |
| Bt1 | 31 - 100 cm | light yellowish brown (10YR 6/4,moist and 10YR 7/3,dry) clay to clay loam with a moderately coherent porous massive structure; hard (dry), very friable (moist), slightly plastic and sticky (wet); many very fine, few fine, medium and coarse pores; few very fine, fine, medium and coarse roots; transition diffuse and smooth |
| Bt2 | 100 - 155 cm | very pale brown (10YR 7/4,moist and 10YR 7/3, dry) clay loam with a moderately coherent porous massive structure; few small distinct light gray (10YR 7/1) mottles; hard (dry), very friable (moist), slightly plastic and sticky (wet); many very fine, few fine, medium and coarse pores; few very fine, fine and medium roots; few soft and hard (some like mottles) small reddish Fe concretions; transition clear and wavy |

Bcs 155 - 165+ cm similar to Bt2, but with frequent reddish hard large Fe concretions and very frequent round laterite gravels

ANALYTICAL DATA Profile no. NWP/ADP/15/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0- 9 | 10 | 26 | 51 | 10 | 3 | very fine sandy loam | - |
| 9- 17 | 18 | 30 | 42 | 8 | 2 | very fine sandy loam to loam | - |
| 17- 31 | 36 | 24 | 33 | 6 | 1 | clay loam | - |
| 31-100 | 40 | 23 | 29 | 7 | 1 | clay loam to clay | 1.1 |
| 100-155 | 36 | 24 | 33 | 5 | 2 | clay loam | 4.7 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P | sol. Al | sol. Mn |
|---|---|---|---|---|---|---|
| | | | | (—— | ppm | ——) |
| 0- 9 | 6.7 | 5.9 | 0.78 | 8 | n.d. | n.d. |
| 9- 17 | 5.3 | 4.4 | 0.32 | 4 | n.d. | n.d. |
| 17- 31 | 5.2 | 4.2 | 0.24 | 4 | n.d. | n.d. |
| 31-100 | 5.4 | 4.3 | 0.17 | 3 | n.d. | n.d. |
| 100-155 | 5.5 | 4.4 | n.d. | 2 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (—— | —— | meq/100 g soil | —— | ——) | | (meq/100 g clay) | | (—— % | ——) |
| 0- 9 | 2.15 | 0.75 | 0.28 | T | n.d. | 5.3 | 53 | n.d. | 60 | n.d. |
| 9- 17 | 0.49 | 0.67 | 0.19 | T | n.d. | 3.7 | 21 | n.d. | 36 | n.d. |
| 17- 31 | 0.26 | 0.71 | 0.26 | T | n.d. | 3.1 | 9 | n.d. | 40 | n.d. |
| 31-100 | 0.70 | 0.79 | 0.38 | T | n.d. | 6.5 | 16 | n.d. | 29 | n.d. |
| 100-155 | 0.86 | 0.87 | 0.27 | T | n.d. | 6.1 | 17 | n.d. | 33 | n.d. |

| | |
|---|---|
| Profile no.: | NWF/ADF/16/82 |
| Soil name : | Kasempa series |
| Int. classification : | orthic ferralsol (FAO); typic haplustox (USDA) |
| Soil map unit : | 11 |
| Date of description : | 24-9-1982 |
| Described by : | Wen Ting-tiang amd G.M. Ngosa |
| Location : | Kawana, 2.7 km S of Kalulushi turn-off, UTM grid 3899-542 (sheet 1325B4) |
| Elevation : | about 1355 m a.s.l. |
| Landform : | hills, midslope, simple slope, uniform to somewhat concave, 4.5% (N) |
| Vegetation and land use : | medium dense miombo woodland, with Julbernardia paniculuata as dominant species, also Brachystegia bussei, Isoberlinia angolensis, Anisopyllea boehmii, Uapaca ssp., the trees are moderately well developed; the hills are not cultivated but chitimene cultivation is practised at the foot of the hills |
| Anthills : | mound type, brown, with an average base of 8 m, an average height of 3.5 m and on average 25 m apart, some having 1 m high pinnacle type anthills on top, common small (15 cm high) anthills |
| Human influence : | burning |
| Climate : | tropical savannah with an unimodal rainfall of circa 1300 mm/year |
| Parent material : | meta siltstone locally rich in biotite |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | dry throughout |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | no evidence |
| LUB code : | 1 E E F F / B - - (7.5YR 5/8) |
| Land capability class | C2S(LUB); 2 |

Remarks :

- no cutans have been observed
- the occurrence of well shaped quartz crystals in the Bws3 may indicate new formation of these minerals

PROFILE DESCRIPTION (NwP/ADP/16/82)

| | | |
|---|---|---|
| Ah | 0 - 5 cm | dark yellowish brown (slightly redder than 10YR 4/4, moist and 10YR 6/4, dry) clay loam with a weak fine subangular blocky structure; hard (dry), friable (moist), non-plastic and slightly sticky (wet); many very fine and fine, common medium and few coarse mostly inped pores; many very fine and fine and few medium roots; very few fine laterite gravels; transition clear and smooth |
| BA | 5 - 25 cm | dark brown (7.5YR 4/6, moist and 7.5YR 6/6, dry) clay loam with a weak medium to coarse subangular blocky structure; hard (dry), friable (moist), slightly plastic and sticky (wet); many very fine and fine, few medium and coarse inped pores; many fine, few very fine, medium and coarse roots; very few fine laterite gravels; transition gradual and smooth |
| Bws1 | 25 - 55 cm | strong brown (slightly redder than 7.5YR 5/8, moist and 7.5YR 6/8, dry) clay with a weakly coherent porous massive structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine, few medium and coarse pores; many fine, few medium and coarse roots; very few small reddish slightly hard Fe concretions; very few fine laterite gravels; transition diffuse and smooth |
| Bws2 | 55 - 150 cm | similar in colour, texture, structure and consistence as Bws1; many very fine, few fine, medium and coarse pores; few fine, medium and coarse roots; very few small reddish slightly hard Fe concretions; few fine laterite gravels; transition gradual and wavy |
| Bws3 | 150 - 165+ cm | yellowish red (slightly browner than 5YR 5/8, moist and 5YR 6/8, dry) clay with a weakly coherent porous massive structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine, few fine, medium and coarse pores; few fine and medium roots; frequent fine laterite gravels, including some coarse weathered quartz fragments as well as well shaped fine quartz crystals; transition gradual and wavy |
| BC | 165+ cm | red (2.5YR, moist) clay with frequent weathered fine grained sandstone fragmente |

ANALYTICAL DATA Profile no. NWP/ADP/16/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 5 | 30 | 33 | 31 | 4 | 2 | clay loam | 0.7 |
| 5 - 25 | 38 | 40 | 20 | 1 | 1 | clay loam | 1.7 |
| 25 - 55 | 48 | 33 | 17 | 1 | 1 | clay | 4.0 |
| 55 -100 | 43 | 31 | 16 | 9 | 1 | clay | 2.6 |
| 100 -150 | 50 | 37 | 11 | 1 | 1 | clay | 13.1 |
| 150 -170 | 42 | 36 | 19 | 2 | 1 | clay | 3.1 |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 5 | 5.5 | 4.7 | 1.39 | 13 | n.d. | n.d. |
| 5 - 25 | 5.3 | 4.2 | 0.37 | 4 | n.d. | n.d. |
| 25 - 55 | 5.5 | 4.2 | 0.15 | 3 | n.d. | n.d. |
| 55 -100 | 5.7 | 4.2 | 0.07 | 2 | n.d. | n.d. |
| 100 -150 | 5.2 | 4.1 | n.d. | 2 | n.d. | n.d. |
| 150 -170 | 5.4 | 4.2 | n.d. | 2 | n.d. | n.d. |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 5 | 0.73 | 0.91 | 0.51 | T | n.d | 8.9 | 30 | n.d. | 24 | n.d. |
| 5 - 25 | 0.06 | 0.39 | 0.31 | T | n.d | 8.5 | 22 | n.d. | 9 | n.d. |
| 25 - 55 | 0.56 | 0.74 | 0.33 | T | n.d | 8.5 | 18 | n.d. | 19 | n.d. |
| 55 -100 | 0.03 | 0.13 | 0.30 | T | n.d | 8.1 | 19 | n.d. | 6 | n.d. |
| 100 -150 | 0.04 | 0.07 | 0.12 | T | n.d | 8.7 | 17 | n.d. | 3 | n.d. |
| 150 -170 | 0.02 | 0.18 | 0.12 | T | n.d | 8.2 | 20 | n.d. | 4 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/19/82 |
| Soil name : | Mehebə series, acric phase |
| Int. classification : | acric ferralsol (FAO), haplic acrustox (USDA) |
| Soil map unit : | 16 |
| Date of description : | 8-10-1982 |
| Author : | Wen Ting-tiang and W.J. Veldkamp |
| Location : | proposed Mutanda Research Station, UTM grid 4139-6265 (sheet 1226A3) |
| Elevation : | approximately 1300 m a.s.l. |
| Landform : | plateau, upper slope, slope 1% (w) |
| Vegetation and land use : | fairly dense miombo woodland with Brachystegia boehmii as dominant species, also Erythrophleum Africanum and Brachystegia longifolia, moderate growth; the area is relatively uninhabited |
| Anthills : | mound type, reddish coloured with an average base of 9 m, an average height of 4.5 m and on average 35 m apart; very few pinnacle type, on average 2.5 m high with an average diameter of 1.5 m; common reddish small anthills with an average height of 30 cm and an average diameter of 30 cm |
| Human influence : | the surroundings of the pit appear to have never been cultivated, but the undergrowth is regularly burned |
| Climate : | tropical savannah with an unimodal rainfall of circa 1350 mm/year |
| Parent material : | feldspatic sandstones, schist and phyllite of the Solwezi biotite formation |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | 0 - 130 cm dry, just moist below |
| Groundwater : | not reached |
| Surface stones : | nil |
| Erosion : | no evidence |
| LUB code | $\frac{\text{1 E F F F}}{\text{0 --(2.5YR 3/6)}}$ |
| Land capability class | C1 (LUB); 2 |

Remarks : - the soil has a strong microaggregation
- rooting throughout the profile and probably deeper as well
- moderate termite activity
- no clay cutans have been observed

PROFILE DESCRIPTION (NWP/ADP/19/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | dark reddish brown (5YR 3/6,moist and 5YR 4/6,dry) sandy clay with a moderate fine subangular blocky structure; hard (dry), friable (moist), non-plastic and slightly sticky (wet); many very fine, few fine, medium and coarse mostly inped pores; many very fine, fine and medium, few coarse roots; transition abrupt and smooth |
| BAu1 | 10 - 25 cm | dark reddish brown (slightly redder than 5YR 3/6,moist and 5YR 4/6,dry) sandy clay with a week fine subangular blocky structure; hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine, few medium and coarse inped pores; common very fine and fine, few medium and coarse roots; transition clear and smooth |
| BAu2 | 25 - 40 cm | dark red (2.5YR 3/6,moist and 2.5YR 4/6,dry) clay with a weak fine to medium subangular blocky structure; very hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine, few fine, medium and coarse inped pores; common very fine, but locally many very fine, common fine, few medium and coarse roots; transition gradual and smooth |
| Bws | 40 - 200+cm | dark red (2.5YR 3/6,moist, but slightly redder than the BAu2, and 2.5YR 4/8,dry) clay with a porous massive moderately coherent structure; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine, few fine (but more than in BAu2) and medium pores; few very fine, fine, medium and coarse roots |

ANALYTICAL DATA — Profile no. NM/ADP/19/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 66 | 22 | 6 | 3 | 3 | clay | - |
| 10 - 25 | 59 | 20 | 18 | 2 | 1 | clay | - |
| 25 - 40 | 59 | 15 | 23 | 2 | 1 | clay | - |
| 40 - 100 | 55 | 18 | 24 | 1 | 2 | clay | - |
| 100 - 150 | 59 | 16 | 21 | 2 | 2 | clay | - |
| 150 - 200 | 60 | 14 | 23 | 2 | 1 | clay | - |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 10 | 4.9 | 4.0 | 1.76 | 6 | 8.2 | 6.2 |
| 10 - 25 | 4.9 | 4.0 | 1.30 | 2 | 4.6 | 4.6 |
| 25 - 40 | 5.1 | 4.1 | 0.82 | 1 | 3.8 | 3.6 |
| 40 - 100 | 5.8 | 4.2 | 0.46 | 1 | 4.2 | 13.4 |
| 100 - 150 | 6.1 | 4.4 | n.d. | 1 | 4.0 | 7.4 |
| 150 - 200 | 6.2 | 4.4 | n.d. | 1 | 4.0 | 8.8 |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 10 | 0.08 | 0.12 | 0.16 | T | 1.01 | 8.3 | 13 | 2.1 | 4 | 74 |
| 10 - 25 | 0.09 | 0.20 | 0.17 | T | 0.57 | 6.8 | 11 | 1.8 | 5 | 55 |
| 25 - 40 | T | 0.07 | 0.04 | 0.01 | 0.47 | 5.2 | 9 | 1.0 | 2 | 80 |
| 40 - 100 | T | T | 0.04 | 0.03 | 0.52 | 4.5 | 8 | 1.1 | 2 | 88 |
| 100 - 150 | 0.08 | 0.05 | 0.03 | 0.01 | 0.49 | 3.7 | 6 | 1.1 | 5 | 74 |
| 150 - 200 | T | T | 0.03 | T | 0.49 | 3.1 | 5 | 0.9 | 1 | 94 |

* derived from soluble Al figures

Profile no.: NWP/ADP/20/82
Soil name : Mayondo series
Int. classification : ferric acrisol (FAO); oxic pleustult (USDA)
Soil map unit : 20
Date of description : 8-10-1982
Authors : W.J. Veldkamp and Wen Ting-tiang
Location : proposed Mutanda Agricultural Research Station, UTM grid 4126 -6265 (sheet 1226 A3)
Elevation : approximately 1300 m a.s.l.
Landform : plateau, lower slope, slope about 1% (N), microrelief is slightly uneven
Vegetation and land-use : pit sited in light miombo woodland with Brachystegia longifolia and Brachystegia microphylla as dominant species, also Brachystegia speciformis, Uapaca kirkiana, Anisophyllea boehmii, Protea and Ekebergia Benguelensis, tree development is medium to somewhat stunted; the area is uninhibited
Anthills : mound type with a brownish grey colour, an average heitht of 5 m and on average 40 m apart; many small anthills, yellowwish brown coloured, with an average height of 25 cm and an average diameter of 15 cm
Human influence : burning
Climate : tropical savannah with an unimodal rainfall of circa 1350 mm/year
Parent material : the soil has probably formed in colluvium or alluvium derived from soils developed over sandstone, schist and phyllite of the Solwezi biotite formation
Soil depth : very deep
Drainage : moderately well drained
Permeability : moderate throughout
Moisture state : 0 - 100 cm dry, just moist below
Groundwater : not reached
Surface stones : nil
Erosion : the occurrence of slightly elevated isolated tussocks of grass indicates that some erosion of surface material takes place during heavy rains

LUB code : **1 C C C C**

A E1 w1 (10YR 5/6)

Land capability class C2we (LUB); 4

Remarks :
- moderate termite activity
- no clay cutans have been observed but an argillic horizon is assumed on account of the clay increase
- 0 - 180 cm pit, 180 - 250 cm augering

PROFILE DESCRIPTION (NWP/ADP/20/82)

| | | |
|---|---|---|
| Ah | 0 - 6 cm | very dark grayish brown (10YR 3/2,moist and 10YR 5/1,dry) loam with a moderate fine subangular blocky structure; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine and few medium inped and exped pores; many very fine and fine, few medium and coarse roots; transition clear and smooth |
| AB | 6 - 12 cm | brown (10YR 5/3,moist and 10YR 6/2, dry) clay loam with a weak to moderate fine subangular blocky structure, tending to angular blocky; hard (dry), friable (moist), plastic and sticky (wet); many very fine, few fine and medium inped pores; many very fine, common fine and few medium roots; transition clear and smooth |
| BA | 12 - 20 cm | yellowish brown (10YR 5/6,moist and 10YR 7/3, dry) clay loam to clay with many brown (10YR 4/3,moist) colourations, the rubbed colour is yellowish brown (10YR 5/4,moist); weak to moderate fine and medium subangular to angular blocky; slightly hard (dry), very friable (moist), plastic and slightly sticky (wet); many very fine, common fine and few medium inped pores; common very fine and fine, few medium roots; very few small soft red Fe concretions; transition clear and smooth |
| Bu1 | 20 - 62 cm | yellowish brown (slightly redder than 10YR 5/6, moist and 10YR 7/6,dry) clay loam to clay with common decreasing to few faint dull yellowish brown colourations; weak fine and medium subangular blocky tending porous massive; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet), many very fine, common fine and few medium inped pores; common very fine, few fine and medium roots; transition gradual and smooth |
| Bu2 | 62 - 160 cm | strong brown (slightly browner than 7.5YR 5/6, moist and 7.5YR 7/6,dry) clay loam with a moderately coherent porous massive structure; slightly hard (dry), slightly plastic and slightly sticky (wet); many very fine, few fine and medium pores; common very fine, few fine and medium roots; transition clear and smooth |

Bg 160 - 230 cm brownish to olive yellow (10YR to 2.5Y 6/6, moist and rubbed) clay with few fine prominent yellowish red (5YR 5/6, moist) and few, increasing with depth to common, fine faint to distinct light yellowish brown (2.5Y 6/4 moist) mottles, the red mottles increasing with depth to many and becoming plinthitic in character; moderately coherent porous massive; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); common very fine and fine, few medium pores; few very fine, few to common fine and few medium roots; very few fine rounded laterite gravels, increasing with depth to frequent

Bcsg 230 - 250+cm generally similar to Bg, but with very frequent fine rounded laterite gravels and without red mottles

ANALYTICAL DATA Profile NWP/ADP/20/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0- 6 | 33 | 23 | 41 | 1 | 2 | clay loam | - |
| 6- 20 | 50 | 21 | 26 | 2 | 1 | clay | 12.7 ** |
| 20- 62 | 50 | 18 | 28 | 2 | 2 | clay | 16.5 ** |
| 62-110 | 49 | 21 | 27 | 1 | 2 | clay | - |
| 110-150 | 47 | 20 | 29 | 2 | 2 | clay | 13.1 |
| 150-200 | 41 | 18 | 28 | 2 | 1 | clay | 18.5 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0- 6 | 5.8 | 5.0 | 2.17 | 19 | 3.2 | 5.6 |
| 6- 20 | 5.7 | 4.6 | 0.78 | 2 | 3.4 | 5.0 |
| 20- 62 | 5.8 | 4.4 | 0.32 | 1 | 3.0 | 2.6 |
| 62-110 | 6.1 | 4.5 | 0.32 | 1 | 4.0 | 1.8 |
| 110-150 | 6.2 | 4.5 | n.d. | 1 | 4.8 | 0.8 |
| 150-200 | 6.1 | 4.4 | n.d. | 1 | 3.6 | T |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al * | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0- 6 | 1.98 | 0.67 | 0.24 | 0.03 | 0.40 | 7.4 | 22 | 10.1 | 39 | 12 |
| 6- 20 | 0.94 | 0.40 | 0.09 | 0.02 | 0.42 | 5.1 | 10 | 3.7 | 28 | 22 |
| 20- 62 | 0.26 | 0.23 | 0.14 | 0.01 | 0.37 | 4.1 | 8 | 2.0 | 16 | 37 |
| 62-110 | 0.06 | 0.16 | 0.07 | T | 0.49 | 4.0 | 8 | 1.6 | 7 | 63 |
| 110-150 | 0.10 | 0.18 | 0.14 | 0.02 | 0.59 | 3.4 | 7 | 2.2 | 13 | 57 |
| 150-200 | 0.05 | 0.13 | 0.09 | 0.01 | 0.47 | 3.4 | 7 | 1.8 | 8 | 63 |

* derived from soluble Al figures

** data suspect

| | |
|---|---|
| Profile no.: | NWP/ADP/22/82 |
| Soil name : | Misamfu series |
| Int. classification : | orthic ferralsol (FAO), ultic haplustox (USDA) |
| Soil map unit : | 36 |
| Date of description : | 16-10- 1982 |
| Author : | R.M. Ngosa and Wen Ting-tiang |
| Location : | along Mwinilunga -Chibwika road, about 3.8 km west of the Lunga bridge; UTM grid 2174-6975 (sheet 1124C4) |
| Elevation : | about 1390 m a.s.l. |
| Landform : | strongly dissected plateau, upper slope, slope 1% (SE), but steeper sloper (8) are locally dominant |
| Vegetation and land use : | pit sited in secondary miombo woodland, more than 5 years old, with Isoberlinia angolensis as dominant species, also Pericopsis angolensis and Diplorhynchus condylocarpon; the area is fairly heavily cultivated, mostly under the chitemene system, with cassava as main crops |
| Anthills | combined mound-pinnacle type, brownish coloured with an average base of 7 m, an average height of 4 m and on average 80 m apart, the pinnacles are on average 1.5m high and 1 m in diameter |
| Human influence : | burning and fuelwood gathering |
| Climate : | tropical savannah with an unimodal rainfall of circa 1300 mm/year |
| Parent material : | meta-argillite, meta-siltstone and sandstones of the Kundulungu series, with a strong admixture of Kalahari sand |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | 0 - 58 cm moist, 58 - 78 cm just moist, dry below after rains |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 B C C C / A - - (5YR 4/6) |

Land capability class : S1 (LUC); 3

Remarks : - 0 - 185 cm pit, 185 + cm augering
- no clay cutans have been observed
- moderate termite activity
- sand grains are mostly uncoated, although there is a slight increase in coating with depth

PROFILE DESCRIPTION (NWP/ADP/22/82

| | | |
|---|---|---|
| Ah | 0 - 7 cm | brownish black (7.5YR 3/3, moist) and 7.5YR 4/3, dry) sandy loam to sandy clay loam with a weak fine to medium subangular blocky structure; soft (dry), very friable (moist); many very fine, fine and medium, few coarse mostly exped pores; many very fine and fine, few medium roots; transition clear and smooth |
| AB | 7 - 15 cm | dark brown (5YR 4/4, moist and 5YR 5/6, dry) sandy loam to sandy clay loam with a weak fine to medium subangular blocky structure; soft (dry), very friable (moist); many very fine and fine, common medium mostly inped pores; many very fine and fine, common medium and coarse roots; transition gradual and smooth |
| BA | 15 - 58 cm | reddish brown (5YR 4/6, moist) sandy clay loam with a moderately coherent porous massive structure; slightly hard (dry), friable (moist), non-plastic and non-sticky (wet); many very fine and fine, common medium pores; common very fine, fine and medium, few coarse roots; transition diffuse and smooth |
| Bws1 | 58 - 78 cm | dark reddish brown (slightly redder than 5YR 3/6, moist and 5YR 4/6, dry) sandy clay loam with a moderately coherent porous massive structure; slightly hard (dry), friable (moist), non-plastic and non-sticky (wet); many very fine and fine, common medium pores; common very fine and fine, few medium roots; transition diffuse and smooth |
| Bws2 | 78 - 300+ cm | reddish brown (2.5YR 4/8, moist) sandy clay loam with a moderately coherent porous massive structure; slightly hard (dry); friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, few medium pores; common very fine and fine, few medium and coarse roots. |

ANALYTICAL DATA

Profile no. NWP/ADP/22/82

## Particle size distribution (%)

| depth | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 7 | 21 | 15 | 38 | 24 | 2 | sandy clay loam to sandy loam |
| 7 - 15 | 19 | 10 | 21 | 47 | 3 | sandy loam to sandy clay loam |
| 15 - 58 | 29 | 11 | 31 | 26 | 3 | sandy clay loam |
| 58 - 78 | 32 | 9 | 23 | 35 | 1 | sandy clay loam |
| 78 -130 | 32 | 21 | 13 | 33 | 1 | sandy clay loam |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 7 | 4.9 | 4.0 | 1.68 | 19 | n.d. | n.d. |
| 7 - 15 | 4.7 | 3.9 | 0.92 | 11 | n.d. | n.d. |
| 15 - 58 | 4.8 | 4.0 | 0.53 | 5 | n.d. | n.d. |
| 58 - 78 | 5.0 | 4.1 | 0.39 | 3 | n.d. | n.d. |
| 78 -130 | 5.2 | 4.1 | n.d. | 3 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 7 | 0.48 | 0.27 | 0.15 | - | n.d | 9.2 | 44 | n.d. | 10 | n.d. |
| 7 - 15 | 0.14 | 0.08 | 0.07 | - | n.d | 6.1 | 32 | n.d. | 5 | n.d. |
| 15 - 58 | 0.14 | 0.11 | 0.01 | 0.03 | n.d | 5.0 | 17 | n.d. | 6 | n.d. |
| 58 - 78 | 0.67 | 1.45* | 0.02 | 0.02 | n.d | 4.3 | 14 | n.d. | 5 | n.d. |
| 78 -130 | 0.07 | 0.02 | 0.02 | 0.02 | n.d | 3.7 | 11 | n.d. | 4 | n.d. |

* data suspect

| | |
|---|---|
| Profile no.: | NWP/ADP/23/82 |
| Soil name : | Mazabuka series |
| Int. classification : | ferric luvisol (FAO), ultic paleustalt (USDA) |
| Soil map unit : | 37 |
| Date of description : | 16-10-1982 |
| Described by : | Wen Ting-tiang |
| Location : | along Mwinilunga-Kabompo road, about [illegible] N of Uniwoma school, UTM grid 2025-6430 (sheet 1224A4) |
| Elevation : | about 1280 m a.s.l. |
| Landform : | strongly dissected plateau, watershed between two tributuries of Mwoji stream, slope 1 - 3% (NNE), the slope is somewhat irregular, with relative height differences of a few m |
| Vegetation and land use : | pit sited in thinned miombo woodland, with Brachystegia boehmii, longifolia and spiciformis as dominant species, also Diospyros kirkii, Piliostigma thonningii and Faurea speciosa, the trees are moderately well developed; local cultivation is mainly cassava under the chitimene system, while onions and sweet potatoes are grown in the fairly wide dambos bordering the streams |
| Anthills : | mound type anthills, brownish coloured with an average base of 5 m, and average height of 2 m and on average 80 m apart |
| Human influence ; | burning and cutting of vegetation |
| Climate : | tropical savannah with an unimodal rainfall of circa 1225 mm/year |
| Parent material : | thinly bedded silty schist, with inclusions of quartz concentrations |
| Soil depth : | very deep at the pit site, the soil depth varies over short distances from very deep to moderately shallow, predominantly moderately deep |
| Drainage : | well drained |
| Permeability : | 0 - 110 cm rapid, moderate from 110 cm |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | very locally (shallow soils) 5 - 10% |

mostly quartz gravel at the surface

Rock outcrops : very locally the parent material is exposed in the form of 1 m high outcrops

Erosion : at the pit site there are no signs of erosion, but the geomorphological position makes the land susceptible to strong erosion if the vegetation is cleared completely and no conservation measures would be taken

LUB code : 1 E F F F / B - - (5YR 4/6)

Land capability class : C2s (LUB),1

Remarks : nil

PROFILE DESCRIPTION (NWP/ADP/23/82)

Ah 0 -- 11 cm dark brown (10YR 3/3,moist and 10YR 5/3,dry) loam (field texture sandy clay) with a weak fine subangular blocky structure; very friable (moist), non-plastic and slightly sticky (wet); many fine, common very fine, few medium and coarse mostly exped pores; many very fine and fine, common medium roots; transition clear and smooth

Bt1 11 - 73 cm yellowish red (5YR 4/6,moist) clay with a moderate medium to coarse subangular blocky structure, tending to angular blocky; friable (moist), plastic and sticky (wet); patchy thin cutans, slightly redder in colour than the matrix; common very fine and fine, few medium and coarse inped pores; many very fine, common fine and medium, few coarse roots; few very small (1 - 2 mm) whitish rock fragements; transition gradual and smooth

Bt2 73 - 110 cm yellowish red (5YR 4/6,moist and rubbed) clay, the colour being a combination of a reddish brown (5YR 4/4, moist) matrix and broken moderately thick yellowish red (5YR 4/8,moist) cutans; moderate (less well developed than in Bt1) fine to medium subangular blocky; friable (moist), plastic and sticky (wet); many very fine, common fine and few medium inped pores; many very fine and medium, few fine and coarse roots; frequent very small (1 - 2 mm) whitish rock fragments; very few red small soft Fe concretions; transition gradual and smooth

Bt3 110 - 128 cm dark brown (7.5YR 4/4,moist) clay with a weak fine to medium subangular blocky structure; firm (moist), plastic and sticky (wet); patchy moderately thick cutans; common very fine and few fine inped pores; common very fine, few fine, medium and coarse roots; frequent hard large black Fe/Mn concretions (rock like); frequent fine and coarse quartz gravel; transition clear and smooth

Bt4 128 - 155+ cm dark brown (7.5YR 4/4,moist) clay with a strongly coherent porous massive structure; firm (moist), plastic and sticky (wet) patchy mod-thick clay cutans;few very fine, fine and medium roots; few hard large black Fe/Mn concretions (rock like); very frequent fine and coarse quartz gravel and weathered schist fragments, partly stained by Fe

ANALYTICAL DATA  Profile NWP/ADP/23/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0- 11 | 22 | 43 | 33 | 1 | 1 | loam |
| 11- 73 | 58 | 29 | 7 | 3 | 3 | clay |
| 73-110 | 56 | 30 | 8 | 3 | 3 | clay |
| 110-155 | 56 | 31 | 9 | 2 | 2 | clay |
| 155-165 | 52 | 34 | 13 | - | 1 | clay |

Chemical data

| depth (cm) (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P | sol. Al. | sol. Mn |
|---|---|---|---|---|---|---|
| | | | | (——— | ppm | ———) |
| 0- 11 | 5.9 | 5.2 | 1.91 | 16 | 10.0 | 17.0 |
| 11- 73 | 5.1 | 4.4 | 0.40 | 1 | 10.6 | 18.6 |
| 73-110 | 5.5 | 4.9 | 0.28 | 1 | 9.8 | 12.4 |
| 110-155 | 5.5 | 5.0 | n.d. | T | 10.2 | 7.2 |
| 155-165 | 5.6 | 5.0 | n.d. | T | 10.4 | 6.6 |

| depth (cm) | exch. Ca | exch. Mag | exch. K | exch. Na | exch. Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (——— | | meq/100 g soil | | ——— | ) | (meq / 100 g clay) | | (——— % | ———) |
| 0- 11 | 5.29 | 3.30 | 0.53 | 0.02 | 1.24 | 13.7 | 62 | 47.2 | 67 | 12 |
| 11- 73 | 5.04 | 4.02 | 0.41 | 0.05 | 1.31 | 18.4 | 32 | 18.7 | 52 | 12 |
| 73-110 | 8.01 | 4.37 | 0.26 | 0.04 | 1.21 | 19.0 | 34 | 24.8 | 67 | 9 |
| 110-155 | 8.93 | 4.82 | 0.20 | 0.05 | 1.26 | 20.4 | 36 | 27.3 | 69 | 8 |
| 155-165 | 9.75 | 5.23 | 0.20 | 0.03 | 1.28 | 20.9 | 40 | 31.7 | 73 | 8 |

* derived from soluble Al figures

| | |
|---|---|
| Profile no.: | NWP/ADP/25/82 |
| Soil name : | Chinsali, Kalahari phase |
| Int. classification : | ferralic luvic arenosal (FAO), oxic paleustult (USDA) |
| Soil mapping unit : | 28 |
| Date of description | 19-10-1982 |
| Described by : | Wen Ting-tiang |
| Location : | along Chibuka - Kamupanda road, about 8.5 km W of the turn-off at Chibuka, UTM grid 1974-6652 (sheet 1224A1) |
| Elevation : | about 1460 m a.s.l. |
| Landform : | plateau, upper slope, slope 2% (E) |
| Vegetation and land use : | pit sited in Kalahari woodland, with Brachystegia boehmii as dominant species, also Diplorhynchus condylocarpon, Cryptosepalum exfoliatum and Brachystegia spiciformis; the area is not inhibited at present |
| Anthills : | very few 15 cm high small anthills |
| Human influence : | non observable |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | Kalahari sand, |
| Soil depth : | very deep |
| Drainage : | somewhat excessively drained |
| Permeability : | rapid throughout |
| Moisture state : | 0 - 53 cm moist, 53 - 142 cm just moist, below 142 cm dry |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible erosion |
| LUB code : | $\frac{1\ X\ B\ B\ B}{A\ -\ -\ (5YR\ 3/6)}$ |
| Land capability class : | S3t (LUB);4 |
| Remarks : | - no cutans have been observed but an argillic horizon is assumed on account of the clay increase<br>- few fine charcoal mottles below 32 cm<br>- 0 - 175 cm pit, 175 - 300 cm augering |

PROFILE DESCRIPTION (NWP/ADP/25/82)

| | | |
|---|---|---|
| Ah | 0 - 5 cm | dark reddish brown (5YR 3/2,moist and 5YR 5/3, dry) loamy sand with about 50% uncoated sand grains single grain; loose (dry), very friable (moist); many very fine and fine pores; many very fine and fine, few medium roots; transition clear and smooth |
| BA | 5 - 18 cm | yellowish red (5YR 4/6,moist) loamy sand to sandy loam with about 60% uncoated sand grains weak fine subangular blocky, tending to porous massive; soft (dry), very friable (moist); many very fine and fine, few medium pore; many very fine and fine, common medium roots; transition gradual and smooth |
| Bw1 | 18 - 32 cm | dark reddish brown (5YR 3/6,moist) sandy loam with about 30% uncoated sand grains; weakly coherent porous massive; very friable (moist); many very fine and fine, few medium pores; many very fine, common fine and medium roots; transition gradual and smooth |
| Bw2 | 32 - 53 cm | dark reddish brown (slightly redder than 5YR 3/6,moist) sandy loam with about 10% uncoated sand grains; weakly coherent porous massive; very friable (moist), many very fine, common fine and few medium pores; many very fine, common fine and medium, few coarse roots; transition diffuse and smooth |
| Bw3 | 53 - 142 cm | red (slightly browner than 2.5YR 4/6,moist) fine sandy loam with very few uncoated sand grains; weakly coherent porous massive; very friable (moist); many very fine and few fine pores; many very fine, common fine and medium, few coarse roots; transition diffuse and smooth |
| Bw4 | 142 - 300+cm | red (2.5YR 4/6, moist) fine sandy loam; weakly coherent porous massive; slightly hard (dry), very friable (moist); many very fine and few fine pores; common very fine, few fine, medium and coarse roots |

ANALYTICAL DATA

Profile no. NWP/ADP/25/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 5 | 5 | 19 | 24 | 50 | 2 | sandy loam to loamy sand |
| 5 - 18 | 6 | 18 | 25 | 48 | 3 | sandy loam to loamy sand |
| 18 - 32 | 14 | 14 | 27 | 42 | 3 | sandy loam |
| 32 - 53 | 12 | 14 | 24 | 48 | 2 | sandy loam |
| 53 -100 | 12 | 14 | 44 | 28 | 2 | fine sandy loam |
| 100 -160 | 16 | 18 | 61 | 4 | 1 | fine sandy loam |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 5 | 5.1 | 4.1 | 0.80 | 13 | n.d. | n.d. |
| 5 - 18 | 4.6 | 3.8 | 0.54 | 4 | n.d. | n.d. |
| 18 - 32 | 4.8 | 4.0 | 0.51 | 2 | n.d. | n.d. |
| 32 - 53 | 5.0 | 4.1 | 0.35 | 4 | n.d. | n.d. |
| 53 -100 | 5.0 | 4.2 | n.d. | 2 | n.d. | n.d. |
| 100 -160 | 5.0 | 4.1 | n.d. | 3 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC (meq/100 g clay) | ECEC | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | | | | |
| 0 - 5 | 0.38 | 0.16 | 0.05 | - | n.d | 3.7 | 76 | n.d. | 16 | n.d. |
| 5 - 18 | 0.02 | 0.02 | 0.02 | 0.02 | n.d | 3.2 | 54 | n.d. | 2 | n.d. |
| 18 - 32 | 0.06 | 0.01 | 0.01 | 0.02 | n.d | 2.5 | 18 | n.d. | 4 | n.d. |
| 32 - 53 | 0.05 | T | 0.01 | - | n.d. | 2.0 | 17 | n.d. | 3 | n.d. |
| 53 -100 | 0.08 | 0.02 | T | - | n.d. | 1.6 | 13 | n.d. | 6 | n.d. |
| 100 -160 | 0.04 | T | T | 0.02 | n.d. | 1.4 | 9 | n.d. | 4 | n.d. |

| | |
|---|---|
| Profile no.: | NwP/ADP/026/82 |
| Soil name : | Mehebo series |
| Int. classification : | rhodic ferralsol (FAO), typic haplustox (USDA) |
| Soil map unit : | 10 |
| Date of description : | 19-10-1982 |
| Described by : | Wen Ting-tiang |
| Location : | along Mwinilunga - Kabompo road, about 3 km S of Chibwika school, UTM grid 2059-GG1G (sheet 1224A2) |
| Elevation : | about 1305 m a.s.l. |
| Landform : | dissected plateau, near crest of minor watershed, convex slope 1½% (E), |
| Vegetation and land use : | pit sited in cleared miombo woodland, with Brachystegia boehmii, Brachystegia speciformis and Isoberlinia angolensis as dominant species, also Diplorhynchus condylocarpon moderate to somewhat stunted groth land use is mixture of chitemene farming (cassava as main crop) and small scale permanent farming (maize as main crop) |
| Anthills : | combined mound and pinnacle type, reddish, with the mounds having an average base of 8 m, an average height of 25 m, and on average 70 m apart, the pinnacles having an average diameter of 1½ m and an average height of 1½ m; common small 50 cm high anthills with a diameter of 20 cm |
| Human influence : | cutting and burning in the forest, hoe cultivation on cleared land |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | probably meta-argillite and meta-siltstone of Kundelungu series |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | 0 - 50 cm moist, just moist below (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |

Rock outcrops : nil

Erosion : no evidence of actual erosion, but the amount of washed material at places where the land has been cleared by bull-dozer for road widening seems to indicate that these soils are **fairly** erosive

LUB code : 1 F F F F
A - - (2.5YR 3/6)

Land capability class : C1 (LUB) ; 2

Remarks :
- no clay cutans have been observed
- moderate termite activity
- slight micraggregation

PROFILE DESCRIPTION (NWP/ADP/26/82)

Ah 0 - 8 cm dark reddish brown (slightly redder than 5YR 3/6, moist, and 5YR 4/6, dry) clay with a weak very fine to fine subangular blocky structure; slightly hard (dry), friable (moist), plastic and slightly sticky (wet); common very fine and fine, few medium and coarse inped and exped pores; many very fine and fine, few medium roots; transition smooth and clear

BA 8 - 22 cm dark reddish brown (2.5YR 3/4, moist) clay with a weak fine subangular blocky structure; very friable (moist), plastic and sticky (wet); many very fine and fine, few medium inped pores; many very fine, common fine and few medium roots; transition smooth and diffuse

Bws 22 - 165+ cm dark reddish brown (2.5YR 3/6, moist) clay with a moderately coherent porous massive structure; very friable (moist), plastic and sticky (wet); many very fine, common fine and few medium pores; common very fine, fine and medium roots; very few fine quartz gravel

ANALYTICAL DATA Profile no. NWP/ADP/26/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 8 | 52 | 35 | 11 | 1 | 1 | clay | - |
| 8 - 22 | 63 | 33 | 2 | 1 | 1 | clay | - |
| 22 - 50 | 68 | 24 | 6 | 1 | 1 | clay | - |
| 50 - 100 | 68 | 24 | 6 | 1 | 1 | clay | - |
| 100 - 150 | 56 | 19 | 11 | 10 | 4 | clay | - |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P | sol Al | sol Mn | Cu | Zn | Mo | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ( | | | ppm | | | ) |
| 0 - 8 | 5.1 | 4.2 | 1.70 | 6 | 5.6 | 20.2 | 5.0 | 18.7 | 2.7 | 0.14 |
| 8 - 22 | 5.0 | 4.1 | 0.64 | 3 | 13.6 | 13.8 | 3.1 | 16.7 | 0.9 | 0.15 |
| 22 - 50 | 5.6 | 4.2 | 0.34 | T | 9.8 | 9.4 | 1.8 | 8.9 | 2.2 | 0.09 |
| 50 - 100 | 5.5 | 4.2 | 0.46 | T | 10.4 | 12.4 | n.d. | n.d. | n.d | n.d. |
| 100 - 150 | 5.4 | 4.0 | n.d. | 2 | 17.8 | 1.0 | n.d | n.d | n.d | n.d. |
| 250 - 300 | 5.3 | n.d | n.d | n.d | n.d | n.d | n.d | n.d | n.d | n.d |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | ( | | meq/100 g soil | | ) | | (meq/100 g clay) | | (% | ) |
| 0 - 8 | 0.32 | 0.83 | 0.38 | 0.03 | 1.75 | 11.2 | 22 | 6.4 | 14 | 53 |
| 8 - 22 | 0.06 | 0.40 | 0.23 | 0.02 | 2.26 | 11.0 | 17 | 4.7 | 6 | 76 |
| 22 - 50 | 0.17 | 0.27 | 0.19 | 0.02 | n.d. | 9.8 | 14 | n.d | 7 | n.d. |
| 50 - 100 | 0.09 | 0.23 | 0.34 | 0.01 | 1.83 | 9.8 | 14 | 3.7 | 7 | 73 |
| 100 - 150 | 0.08 | 0.03 | 0.01 | 0.01 | 1.79 | 9.7 | 14 | 3.4 | 2 | 93 |
| 250 - 300 | n.d. | n.d. | n.d | n.d. | 1.71 | n.d | n.d | n.d | n.d | n.d |

| | |
|---|---|
| Profile no.: | NLF/ADF/27/82 |
| Soil name : | Nisamfu series, Kalahari phase |
| Int. classification : | orthic ferralsol (FAO), ultic haplustox (USDA) |
| Soil map unit : | 23 |
| Date of description : | 20-10-1982 |
| Described by : | J.F. Broekhuis |
| Location : | near Kanongesha, Mwinilunga, UTM grid 1966 - 7029 (sheet 1124C1) |
| Elevation : | 1400 m a.s.l. |
| Landform : | gently undulating plateau, interfluve, slope 1.5% (SW) |
| Vegetation and land use : | Kalahari woodland with Cryptosepalum exfoliatum, Brachystegia boehmii and Brachystegia spiciformis as dominant species, tree cover generally dense but locally medium (as at pit site), moderate growth; shifting cultivation with cassava as main crop |
| Anthills : | mound type, reddish brown, with an average height of 6 m, an average base of 6m, and an average distance of 200 to 300 m |
| Human influence : | none at pit site |
| Climate : | tropical savannah with an unimodal rainfall of circa 1325 mm/year |
| Parent material : | Kalahari sand |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | 0 - 70 cm moist, 70 - 165 cm dry, 165 - 210 cm moist, just moist below (after rains) |
| Groundwater | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no evidence at pit site |
| LUB code | 1 B C C C / A - - (5YR 4/8 ) |
| Land capability class : | S3t (LUB), 3 |
| Remarks : | - no clay cutans have been observed<br>- 0 - 185 cm profile pit, augering below<br>- 0 - 150 cm common krotovinas and old |

root channels filled with dark greyish material

PROFILE DESCRIPTION (NWP/ADP/27/82)

| | | |
|---|---|---|
| Ah | 0 - 15 cm | very dark brown (7.5YR 2/3, moist and 7.5YR 3/2, dry) sandy loam with a weak fine to medium subangular blocky structure; very friable (moist); many very fine and fine, common medium and coarse inped and exped pores; many very fine and fine, common medium and coarse roots; transition smooth and clear. |
| BA | 15 - 35 cm | reddish brown (5YR 4/4, moist and 5YR 4/6, dry) fine sandy loam with a weak medium subangular blocky structure; very friable (moist); many very fine and fine, common medium and few coarse, mainly inped pores; many very fine, fine and medium, common coarse roots; transition smooth and gradual. |
| Bws1 | 35 - 70 cm | yellowish red (5YR 4/6, moist) sandy clay loam with a weak medium subangular blocky structure; very friable (moist); many very fine and fine, common medium and few coarse, mainly inped pores; many fine, common very fine, few medium and coarse roots; transition clear and wavy. |
| Bws2 | 70 - 210 cm | reddish brown (5YR 4/8, moist and 5 YR 6/8, dry) sandy clay loam with a massive porous, moderately coherent structure; hard (dry), very friable (moist), slightly plastic and non-sticky (wet); many very fine, common fine, few medium and coarse pores; few very fine, fine, medium and coarse pores |
| Bws3 | 210 - 300+ cm | red (2.5 YR 4/8, moist) sandy clay loam gradually changing to sandy clay at 300 cm; friable (moist), slightly plastic and non sticky (wet) |

ANALYTICAL DATA — Profile no. NWP/ADP/27/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 15 | 16 | 22 | 28 | 31 | 3 | sandy loam |
| 15 - 35 | 14 | 30 | 20 | 34 | 2 | fine sandy loam |
| 35 - 70 | 24 | 18 | 30 | 27 | 1 | sandy clay loam |
| 70 -125 | 25 | 21 | 26 | 25 | 3 | sandy clay loam |
| 125 -180 | 26 | 16 | 33 | 23 | 2 | sandy clay loam |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 15 | 4.6 | 3.7 | 1.76 | 13 | n.d. | n.d. |
| 15 - 35 | 4.8 | 3.9 | 0.80 | 3 | n.d. | n.d. |
| 35 - 70 | 4.8 | 4.0 | 0.35 | 2 | n.d. | n.d. |
| 70 - 125 | 4.8 | 4.0 | n.d. | 2 | n.d. | n.d. |
| 125 -180 | 5.2 | 4.2 | n.d. | 2 | n.d. | n.d. |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g clay) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 15 | 0.19 | 0.11 | 0.08 | - | n.d. | 10.7 | 67 | n.d. | 4 | n.d. |
| 15 - 35 | 0.09 | 0.01 | 0.01 | 0.02 | n.d. | 3.9 | 28 | n.d. | 3 | n.d. |
| 35 - 70 | 0.07 | T | T | - | n.d. | 3.3 | 14 | n.d. | 2 | n.d |
| 70 -125 | 0.05 | 0.01 | T | 0.03 | n.d. | 2.2 | 9 | n.d. | 4 | n.d. |
| 125 -180 | 0.06 | 0.03 | T | 0.03 | n.d. | 2.1 | 8 | n.d. | 6 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/28/82 |
| Soil name : | Mulobolo series, gravelly phase |
| Int. classification : | xanthic ferralsol (FAO), petrofferic haplustox (USDA) |
| Soil map unit : | 35 |
| Date of description : | 20-10-1982 |
| Described by : | Wen Ting-tiang |
| Location : | along Solwezi - Mwinilunga road, about 1 km W of Lumwana west stream, UTM grid 2949-6925 (sheet 1125 C3) |
| Elevation : | about 1455 m a.s.l. |
| Landform : | rolling hills, upper middleslope, slope 2½% (NE) |
| Vegetation and land use : | pit sited in disturbed miombo woodland, with Brachystegia boehmii and Brachystegia spiciformis as dominant species, also Uapaca kirkiana and Diplorhynchus condylocarpon, vegetation cover light and tree growth moderate to poor; local land use is chitemene with cassava as main crop |
| Anthills : | mound type anthills, greyish brown coloured with an average base of 7 m, an average height of 4 m and on average 50 m apart, some with a small pinnacle type anthill on top |
| Human influence : | cutting and burning of vegetation |
| Climate : | tropical savannah with an unimodal rainfall of circa 1150 mm/year |
| Parent material : | granitic gneiss of the Basement complex |
| Soil depth : | deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | moist in Ah horizon, just moist below (after rains) |
| Groundwater : | not reached |
| Surface stones : | locally some fine and coarse quartz gravel (about 0.1%) |
| Rock outcrops : | nil |
| Erosion : | no visible erosion |
| LUB code : | 1 C E F F / A - - (10YR 5/6) |
| Land capability class : | C1 (LUB); 4 |

Remarks : - no cutans have been observed

- moderate termite activity

PROFILE DESCRIPTION (NWP/ADP/28/82)

| Horizon | Depth | Description |
| --- | --- | --- |
| Ah | 0 - 10 cm | dark yellowish brown (10YR 4/4, moist and 10YR 5/2, dry) sandy clay loam with a weak coarse crumb structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, few medium and coarse inped and exped pores; many very fine and fine, few medium roots; transition clear and smooth |
| AB | 10 - 22 cm | brown (10YR 5/3, moist) sandy loam with a weak fine to medium subangular blocky structure; very friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine and few medium inped pores; common very fine, few fine and medium roots; transition smooth and gradual |
| BA | 22 - 34 cm | yellowish brown (10YR 5/4, moist) sandy clay loam to sandy loam with a weak medium subangular blocky structure, tending to angular blocky; friable (moist), plastic and slightly sticky (wet); many very fine, common fine and few medium inped pores; common very fine, few medium and coarse roots; very few small soft red Fe concretions; transition gradual and smooth |
| Bws | 34 - 90 cm | yellowish brown (10YR 5/6, moist) sandy clay loam with a weak medium to coarse subangular blocky structure; friable (moist), plastic and sticky (wet); many very fine, common fine and few medium inped pores; few very fine, fine, medium and coares roots; very few small soft red Fe concretions; transition clear and wavy |
| Bcs | 90 - 100+ cm | yellowish brown (10YR 5/6, moist) sandy clay with very frequent small and large hard Fe concretions, moderately well rounded and badly sorted; few fine quartz gravels |

ANALYTICAL DATA

Profile no. NWP/ADP/28/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 10 | 26 | 17 | 35 | 14 | 8 | sandy clay loam |
| 10 - 22 | 18 | 26 | 30 | 17 | 9 | sandy loam |
| 22 - 34 | 20 | 18 | 33 | 18 | 11 | sandy clay loam to sandy loam |
| 34 - 90 | 32 | 21 | 26 | 11 | 10 | sandy clay loam |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 10 | 5.3 | 4.4 | 1.56 | 16 | n.d. | n.d. |
| 10 - 22 | 5.0 | 4.1 | 0.83 | 6 | n.d. | n.d. |
| 22 - 34 | 5.2 | 4.1 | 0.28 | 4 | n.d. | n.d. |
| 34 - 90 | 5.3 | 4.1 | 0.21 | 3 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq / 100 g clay) | | (%) | |
| 0 - 10 | 0.39 | 0.49 | 0.27 | 0.04 | n.d. | 6.8 | 26 | n.d | 18 | n.d |
| 10 - 22 | 0.09 | 0.20 | 0.15 | 0.04 | n.d. | 4.4 | 24 | n.d | 11 | n.d |
| 22 - 34 | 0.09 | 0.26 | 0.21 | 0.03 | n.d. | 5.3 | 27 | n.d | 11 | n.d |
| 34 - 90 | 0.09 | 0.16 | 0.27 | 0.01 | n.d. | 5.9 | 18 | n.d | 9 | n.d |

| | |
|---|---|
| Profile no.: | NWP/ADF/29/82 |
| Soil name : | Samfya series |
| Int. classification : | xanthic ferralsol (FAO), typic haplustox (USDA) |
| Soil map unit : | 21 |
| Date of description : | 21-10-1982 |
| Described by : | J.F. Brockhuis |
| Location : | 3.5 km west of Jimbe border post, UTM grid 1785 - 7697 (sheet 1124A1) |
| Elevation : | 1185 m a.s.l. |
| Landform : | gently undulating plateau, upper slope, slope 1.5% (S) |
| Vegetation and land use : | medium to light miombo woodland with Brachystegia boehmii, Marquesia macroura, Pterocarpus angolensis and Erythrophleum africanum as main species, also Uapaca-kirkiana and Syzygium guineense, moderate growth; small scale commercial farming (pineapple) and shifting cultivation with cassava as main crop |
| Anthills : | mound type, yellowish coloured, with an average height of 8 m, an average base of 8 m and on average 100 m apart |
| Human influence : | the pit site has probably been cultivated by hoe in the past |
| Climate : | tropical savannah with an unimodal rainfall of circa 1425 mm/year |
| Parent material : | granite of the Basement complex, possibly with some admixture of Kalahari sand |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid from 0 - 45 cm, moderately rapid below |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no evidence at pit site |
| LUB code : | 1 F F F F / A - - (10YR 5/6) |

Land capability class : C1 (LUB); 3

Remarks : - 0 - 140 cm pit, augering below
- frequent root channels and animal burrows throughout the profile filled with darker soil material
- no clay cutans observed
- all the horizons have a gritty feel due to a coarse sand component that decreases with depth to 150 cm, and from there increases again

PROFILE DESCRIPTION (NWP/ADP/29/82

| | | |
|---|---|---|
| Ah | 0 - 12 cm | dark brown (10YR 3/3,moist and 10YR 5/3,dry) clay (field texture: sandy clay) with a weak medium to coarse subangular blocky structure; friable (moist), slightly plastic and non sticky (wet); many very fine and fine, common medium and few coarse inped pores; many very fine and fine, common medium and few coarse roots; transition smooth and clear |
| AB | 12 - 45 cm | dary yellowish brown (10YR 3/4,moist and 10YR 6/3, dry) clay with a weak medium to coarse subangular blocky structure; friable (moist), slightly plastic and non -sticky (wet); patchy thin cutans; many very fine and fine, common medium and few coarse, mainly inped, pores; many very fine, common fine and few coarse roots; boundary smooth and clear. |
| Bws1 | 45 - 70 cm | yellowish brown (10YR 5/6, moist) clay, with a massive porous, weakly coherent structure; friable (moist), plastic and slightly sticky (wet); broken thin cutan like features; many very fine, common fine, few medium and coarse pores; common very fine and fine, few medium roots; boundary smooth and gradual. |
| Bws2 | 70 - 170 cm | brownish yellowish (10YR 6/6, moist) clay, with a massive porous, weakly to moderately coherent structure; slightly firm (moist), plastic and sticky (wet); broken thin cutan like features; common very fine and fine, few medium and coarse pores; common very fine, few fine, medium and coarse roots; frequent grayish colouration; transition gradual and smooth |
| Bws3 | 170 - 250+ cm | reddish yellow (7.5YR 6/8, moist) clay; hard (dry), slightly firm (moist), plastic and sticky (wet); frequent grayish colourations |

ANALYTICAL DATA

Profile no. NWP/ADP/29/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 12 | 48 | 19 | 14 | 9 | 10 | clay | - |
| 12 - 45 | 28 | 17 | 21 | 21 | 13 | sandy clay loam** | - |
| 45 - 70 | 56 | 25 | 5 | 7 | 7 | clay | 11.1 |
| 70 -120 | 58 | 17 | 8 | 8 | 9 | clay | - |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 12 | 4.9 | 4.0 | 1.14 | 12 | 25.0 | T |
| 12 - 45 | 4.7 | 4.0 | 0.58 | 3 | 22.0 | T |
| 45 - 70 | 4.8 | 4.0 | 0.35 | 2 | 6.0 | 3.8 |
| 70 -120 | 5.1 | 4.1 | n.d. | 2 | 16.2 | T |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al* (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 12 | 0.15 | 0.11 | 0.09 | 0.02 | 3.09 | 6.5 | 14 | 7.2 | 6 | 89 |
| 12 - 45 | 0.06 | 0.02 | 0.02 | 0.03 | 2.72 | 6.3 | 23 | 10.2 | 2 | 95 |
| 45 - 70 | 0.03 | 0.01 | 0.01 | 0.01 | 0.74 | 5.7 | 10 | 1.4 | 1 | 93 |
| 70 -120 | 0.02 | 0.01 | 0.01 | 0.01 | 2.00 | 5.7 | 10 | 3.5 | 1 | 98 |

* derived from soluble Al figures

** data suspect

| | |
|---|---|
| Profile no.: | NWP/ADP/030/82 |
| Soil name : | Kasempa series, gravelly phase |
| Int. classification : | xanthic ferralsol (FAO); petroferric haplustox (USDA) |
| Soil map unit : | 12 |
| Date of description : | 21-10-1982 |
| Described by : | J.F. Broekhuis |
| Location : | along Ikelenge Mwininyilamba road (E), 2.7 km from Ikelenge Kalene Hills turn-off, UTM grid 1965-7564 (sheet 1124A1) |
| Elevation : | 1370 m a.s.l. |
| Landform : | minor midslope interfluve, in a gently undulating plateau area that adjoins a small dissected hill range; slope 2.5% (NE) |
| Vegetation and land use : | pit sited in disturbed medium dense miombo woodland, with Brachystegia boehmii and longifolia, and Erythrophleum africanum as dominant species, growth is medium to poor; small scale commercial farming (pineapples) and chitimene cultivation with cassava as main crop |
| Anthills : | mound type, yellowish orange, with an average base of 15 m, an average height of 7 m and on average 80 m apart |
| Human influence : | the pit site has most likely been subjected to hoe cultivation in the past; burning of undergrowth and fuelwood gathering |
| Climate : | tropical savannah with an unimodal rainfall of circa 1375 mm/year |
| Parent material : | fine grained sandstone and siltstone |
| Soil depth : | deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | 0-30 cm moist, below 30 cm just moist (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |

| | |
|---|---|
| Erosion : | no visible evidence |
| LUB code : | 1 D F F F / A - - (7.5YR 6/8) |
| Land capability clas : | C1 (LUB); 2 |
| Remarks : | - no clay cutans have been observed |

PROFILE DESCRIPTION (NWP/ADP/30/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | dark yellowish brown (10YR 3/4, moist and 10YR 4/3, dry) clay loam with a weak medium and coarse subangular blocky structure; friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, common medium and few coarse pores; many very fine, fine and medium and common coarse roots; transition smooth and clear |
| BA | 10 - 30 cm | dark yellowish brown (10YR to 7.5YR 4/6, moist) and 10YR to 7.5 YR 6/6, dry) clay with a weak medium and coarse subangular blocky structure; friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, common medium and few coarse pores; many very fine and fine, common medium and coarse roots; transition smooth and gradual |
| Bws | 30 - 110 cm | reddish yellow (7.5YR 6/8, moist) clay with a moderately coherent porous massive structure; friable (moist), plastic and sticky (wet); patchy thin cutan like features; many very fine, common fine and medium and few coarse pores; common very fine, fine and medium, and few coarse roots; very few small ferruginous sandstone gravel; smooth and abrupt |
| Bms | 110+ cm | massive laterite |

ANALYTICAL DATA

Profile no. NWP/ADP/30/82

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 38 | 29 | 26 | 6 | 1 | clay loam | - |
| 10 - 30 | 66 | 19 | 12 | 2 | 1 | clay | - |
| 30 - 80 | 64 | 23 | 11 | 1 | 1 | clay | - |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 10 | 5.4 | 4.4 | 2.58 | 15 | n.d. | n.d. |
| 10 - 30 | 5.0 | 4.1 | 0.69 | 2 | n.d. | n.d. |
| 30 - 80 | 5.3 | 4.2 | 0.44 | 1 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 10 | 0.99 | 1.14 | 0.43 | 0.05 | n.d. | 15.7 | 41 | n.d. | 17 | n.d. |
| 10 - 30 | 0.08 | 1.13 | 0.15 | 0.03 | n.d. | 8.5 | 13 | n.d. | 5 | n.d. |
| 30 - 80 | 0.06 | 0.04 | 0.16 | 0.02 | n.d. | 7.2 | 12 | n.d. | 3 | n.d. |

* derived from soluble Al figures

Profile No.: NWP/ADP/31/82

Soil name : Nkolemfumu series

Int. classification : xanthic ferralsol (FAO); ultic haplustox (USDA)

Soil map unit : 22

Date of description : 21-10-82

Described by: J.F. Broekhuis

Location : along Mwinilunga - Ikelenge Road (E), 1.6 km S of the Zambezi source turn-off, UTM grid 2042-7389 (sheet 1124A4)

Elevation : 1480 m a.s.l.

Landform : watershed between Zambezi and Congo drainage basins, gently undulating plateau in a transitional Kalahari sand/ hard rock environment, the former mantling the interfluves and the latter outcropping along stream channels; slope<2% (SW)

Vegetation and land use : pit sited in disturbed, light miombo woodland, with Brachystegia spiciformis and boehmii, and Albizia adianthifolia as dominant species, also Parinari curatellifolia and Periocopsis angolensis ; small scale commercial farming (pineapple) and shifting cultivation with cassava as main crop.

Anthills : nil

Human influence : pit is sited in an old field, which has been cultivated by hoe; burning of undergrowth and fuelwood gathering

Climate : tropical savannah with an unimodal rainfall of circa 1350 mm/year

Parent material : Kalahari sand, possibly reworked

Soil depth : very deep

Drainage : well drained

Permeability : rapid throughout

Moisture state : 0 - 45 cm moist, 45 - 75 cm just moist, below 75 cm dry (after rains)

Groundwater : not reached

Surface stones : nil

Rock outcrops : nil

Erosion : no visible evidence

LUB code : 1 L r _ C / A -- (10YR 5/4)

Land capability class : S1 (LUB); 3

Remarks : - no clay cutans were observed,
- in all horizons there are common root channels filled in with dark A material
- 0 - 195 cm pit, augering below

PROFILE DESCRIPTION (NUP/ADF/31/82)

| | | |
|---|---|---|
| Ah | 0 - 20 cm | dark brown (10YR 3/3,moist and 10YR 4/2,dry) sandy loam with a weak medium and coarse crumb structure; very friable (moist); many very fine, fine and medium, common coarse pores; many very fine, fine and medium, common coarse roots; transition smooth and diffuse |
| AB | 20 - 45 cm | brown (10YR 4/3,moist and 10YR 5/3)dry sandy loam with a weak medium and coarse subangular blocky structure; very friable (moist); many very fine, fine and medium,common coarse pores; many very fine, fine and medium, common coarse roots; transition smooth and gradual |
| BA | 45 - 75 cm | yellowish brown (10YR 5/4, moi t) sandy cl y loam with a weak medium and coarse subangular blocky structure; very friable (moist), non-plastic and non-sticky (wet); many very fine and fine, common medium and few coarse pores; many very fine and fine, common medium and few coarse roots; transition smooth and gradual |
| Bws1 | 75 - 125 cm | brownish yellow (10YR 6/6,moist and 10YR 7/6, dry) clay loam with a moderately coherent porous massive structure; slightly hard (dry), very friable (moist), non-plastic and non-sticky (wet); many very fine and fine, common medium and few coarse pores; common very fine and fine, few medium and coarse roots; tr nsi-tion smooth and gradual |
| Bws2 | 125 - 240 cm | brownish yellow (10YR 6/6,moist) sandy clay loam with few fine, locally coarse faint light gray m t l , and few fine distinct red mottles; moderately coherent porous massive structure; slightly hard (dry), friable (moist), slightly plastic and non-sticky; patchy thin cutan like features; many very fine and fine, common medium and few coarse pores; common very fine, few fine and medium roots |
| Bg1 | 240 - 280 cm | brownish yellow (10YR 6/6,moist) sandy clay with common fine distinct red mottles, |
| Bg2 | 280+ cm | very pale brown (10YR 7/4,moist) sandy clay with many medium to coarse prominent red mottles |

ANALYTICAL DATA — Profile no. NWP/ADP/31/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 10 | 18 | 23 | 17 | 41 | 1 | sandy loam |
| 10 - 20 | 16 | 24 | 19 | 39 | 2 | sandy loam |
| 20 - 45 | 22 | 20 | 32 | 24 | 2 | sandy clay loam |
| 45 - 75 | 30 | 24 | 13 | 31 | 2 | clay loam to sandy clay loam |
| 75 -125 | 34 | 23 | 19 | 22 | 2 | clay loam |
| 125 -175 | 30 | 24 | 21 | 22 | 3 | clay loam to sandy clay loam |

Chemical data

| depth | pH ($H_2O$) | pH ($CaCl_2$) | org. C | avail. P | sol. Al | sol. Mn |
|---|---|---|---|---|---|---|
| (cm) | | | (%) | (——— | ppm | ———) |
| 0 - 10 | 5.5 | 4.4 | 2.19 | 62 | 13.8 | T |
| 10 - 20 | 4.8 | 4.0 | 0.89 | 8 | 14.0 | T |
| 20 - 45 | 4.9 | 4.1 | 0.70 | 4 | 5.6 | T |
| 45 - 75 | 4.9 | 4.1 | n.d. | 3 | 9.2 | T |
| 75 -125 | 5.6 | 4.3 | n.d. | 1 | 7.8 | 11.2 |
| 125 -175 | 5.2 | 4.2 | n.d. | 2 | 11.0 | 11.4 |

| depth | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | (——— | meq/100 | g | soil | ———) | ( | meq/100 g clay | ) | (—— | %——) |
| 0 - 10 | 1.22 | 0.58 | 0.03 | 0.03 | 1.70 | 10.5 | 58 | 21.8 | 20 | 43 |
| 10 - 20 | 0.05 | 0.03 | 0.03 | 0.01 | 1.73 | 5.8 | 36 | 11.6 | 2 | 94 |
| 20 - 45 | 0.08 | 0.01 | 0.02 | 0.03 | 0.69 | 5.1 | 23 | 3.8 | 3 | 83 |
| 45 - 75 | 0.07 | 0.04 | 0.01 | 0.02 | 1.14 | 3.5 | 12 | 4.3 | 4 | 89 |
| 75 -125 | 0.07 | 0.02 | T | - | 0.96 | 2.5 | 7 | 3.1 | 4 | 91 |
| 125 -175 | 0.06 | 0.01 | 0.01 | 0.02 | 1.36 | 4.5 | 15 | 4.9 | 2 | 93 |

derived from soluble Al figures

Profile no.: NUF/ADP/32/82
Soil name : Mcheba series, acric phase
Int. classification : rhodic ferralsol (FAO), haplic acrustox (USDA)
Taxonomic map unit : 16
Date of description : 22-10-1983
Described by: J.F. Brockhuis and S. Susiku
Location : along Mwinilunga - Solwezi road, about 18 km E of the bridge over the Lunga, UTM grid 2369 - 7021 (sheet 1124D1)
Elevation : 1425 m a.s.l.
Landform : gently undulating plateau, crest; slope about 1 % (NW)
Vegetation and land use : medium dense miombo woodland with Brachystegia longifolia and Isoberlinia angolensis as dominant species, also Erythrophleum africanum, moderate growth; local cultivation according Chitimene system with cassava as main crop
Anthills : mound type anthills, red, with an average height of 8 m, an average base of 10m and an average distance of 90 m
Human influence : fuelwood gathering and burning of undergrowth
Climate ; tropical savannah with an unimodal rainfall of circa 1250 mm/year
Parent material : meta-argillite, meta-siltstone and quartzite of the West Lunga formation (Kundelungu series), possibly with some admixture of Kalahari sand, esp. in the upper part
Soil depth : very deep
Drainage : well drained
Permeability : 0 - 35 cm rapid, moderately rapid below
Moisture state : 0 - 35 cm moist, 35 - 135 cm just moist, dry below (after rains)
Groundwater : not reached
Surface stones : nil
Rock outcrops : nil
Erosion : no visible evidence
LUC code : 1 E F F F / A - - (10 R 3/4)

Land capability class : C1 (LLB); 3

Remarks :
- moderate microaggregation throughout
- no clear clay cutans have been observed
- 0 - 170 cm profile pit, augering below

PROFILE DESCRIPTION (NWF/ADF/32/82)

**Ah** 0 - 9 cm: dark reddish brown (2.5YR 2/4,moist and 5YR 4/6 dry) sandy clay loam with a weak medium subangular blocky structure; very friable (moist), slightly plastic and slightly sticky(wet) many very fine, fine and medium,common coarse pores; many very fine, fine and medium, few coarse roots; transition smooth and gradual

**BA** 9 - 35 cm: dusky red (10R 3/4,moist and 2.5YR 4/8,dry) clay with a weak medium subangular blocky structure; friable (moist), slightly plastic and slightly sticky; thin patchy cutans; many very fine and fine, common medium and few coarse pores; many very fine, fine and medium, common coarse roots; transition smooth and diffuse

**Bws1** 35 - 135 cm: dusky red (10YR 3/4,moist) clay with a weak medium subangular blocky structure, tending to porous massive; slightly hard (dry), friable (moist), plastic and sticky (wet); patchy thin cutan like features; many very fine and fine, common medium and few coarse pores; many very fine, common fine and medium, few coarse roots; transition smooth and gradual

**Bws2** 135 - 290+ cm: dark red (10YR 3/6,moist) clay with a moderately coherent porous massive structure; hard (dry), friable (moist), plastic and sticky (wet); many very fine, common fine, medium and coarse pores; common very fine, few fine, medium and coarse roots

ANALYTICAL DATA      Profile no. NWP/ADP/32/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 9 | 34 | 10 | 35 | 16 | 5 | sandy clay loam | - |
| 9 - 35 | 48 | 9 | 20 | 14 | 9 | clay | - |
| 35 -100 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 100 -150 | 58 | 13 | 22 | 5 | 2 | clay | - |
| 150 -170 | 56 | 13 | 23 | 6 | 2 | clay | - |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 9 | 5.0 | 4.2 | 1.54 | 18 | n.d. | n.d. |
| 9 - 35 | 4.8 | 4.0 | 0.85 | 5 | n.d. | n.d. |
| 35 -100 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 100 -150 | 5.4 | 4.2 | n.d. | 3 | n.d. | n.d. |
| 150 -170 | 5.6 | 4.3 | n.d. | 3 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 9 | 0.42 | 0.31 | 0.17 | 0.22 | n.d. | 11.1 | 33 | n.d. | 10 | n.d |
| 9 - 35 | 0.16 | 0.03 | 0.04 | 0.01 | n.d. | 6.7 | 14 | n.d. | 3 | n.d |
| 35 -100 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| 100 -150 | 0.24 | 0.02 | 0.01 | T | n.d. | 4.6 | 8 | n.d. | 6 | n.d. |
| 150 -170 | 0.08 | T | 0.01 | T | n.d. | 4.1 | 7 | n.d. | 2 | n.d. |

| | |
|---|---|
| Profile No.: | NwP/ADP/33/82 |
| Soil name : | Misamfu series |
| Int. classification : | orthic ferralsol (FAO); ultic haplustox (USDA) |
| Soil map unit : | 36 |
| Date of description : | 22-11-1983 |
| Described by : | Wen Ting-tiang and G.M. Ngosa |
| Location : | along Mwinilunga - Solwezi road, 23 km E of the bridge over the Lunga; UTM 2384 - 7006 (sheet 1124D1) |
| Elevation : | 1450 m a.s.l. |
| Landform : | gently undulating plateau, upper slope; slope 0 - 1% (S) |
| Vegetation and land use : | relatively undisturbed miombo woodland, with Brachystegia spiciformis and Marquesia macroura as dominant species, also Isoberlinia angolensis and Erythrophleum africanum, density medium with moderately developed trees; local land use is chitimene with cassava, sorghum and maize as main crops |
| Anthills : | combined pinnacle and mount type, reddish brown, with an average base of 8 m, an average diameter of 0.75 m and an average total height of 5 m, on average 50 m apart; few 30 cm high brownish grey small anthills |
| Human influence : | fuelwood gathering and burning of undergrowth |
| Climate : | tropical savannah, with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | meta-argillite, meta-siltstone and quartzite of the West Lunga formation, with a strong admixture of Kalahari sand |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid throughout |
| Moisture state : | Ah moist, 10 - 135 cm just moist, 135-250 cm dry, below 250 cm just moist (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |

Erosion : no visible evidence

LUB code 1 B C C E

A - - (2.5YR 3/6)

Land capability class : S1 (LUB); 3

Remarks : - 0 - 190 cm profile pit, 190 - 290 augering
- moderately strong microaggregation throughout
- few, fine charcoal fragments in BA and Bws horizons
- no clay cutans observed

PROFILE DESCRIPTION (NWP/ADP/33/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | dark reddish brown (5YR 3/5,moist and 5YR 4/6, dry) sandy loam with a weak fine and medium subangular blocky structure;soft (dry),very friable (moist); common very fine and fine, few medium and coarse inped pores; many very fine and fine, few medium roots; transition smooth and gradual |
| BA | 10 - 45 cm | dark red (slightly browner than 2.5YR 3/6,moist and 2.5YR 4/6, dry) sandy clay loam with a weak fine subangular blocky structure, tending to porous massive; slightly hard (dry), friable (moist), slightly plastic and non-sticky (wet); many very fine, common fine and few medium inped pores; many very fine, common fine and medium andfew coarse roots; transition smooth and diffuse |
| Bws | 45 - 290+cm | dark red (2.5YR 3/6,moist and 2.5YR 4/7,dry) sandy clay loam, increasing gradually to sandy clay, with a moderately coherent porous massive structure; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine and few fine pores; common very fine and fine, few medium and coarse roots |

ANALYTICAL DATA                                        Profile no. NWP/ADP/33/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 16 | 12 | 28 | 37 | 7 | sandy loam | - |
| 10 - 45 | 28 | 20 | 22 | 23 | 7 | sandy clay loam | - |
| 45 -100 | 34 | 7 | 8 | 45 | 6 | sandy clay loam | - |
| 100 -150 | 38 | 8 | 7 | 37 | 10 | sandy clay | - |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 10 | 4.7 | 3.8 | 1.27 | 10 | 15.8 | 1.0 |
| 10 - 45 | 4.8 | 4.1 | 0.70 | 5 | 16.2 | 0.8 |
| 45 -100 | 5.1 | 4.1 | 0.16 | 2 | 15.6 | T |
| 100 -150 | 5.4 | 4.2 | n.d | 1 | 14.4 | 0.4 |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 10 | 0.14 | 0.07 | 0.08 | 0.03 | 1.95 | 8.0 | 50 | 14.3 | 4 | 86 |
| 10 - 45 | 0.08 | 0.04 | 0.03 | 0.01 | 2.00 | 4.7 | 17 | 7.7 | 3 | 93 |
| 45 -100 | 0.17 | 0.16 | 0.01 | - | 1.93 | 3.3 | 10 | 6.7 | 10 | 85 |
| 100 -150 | 0.08 | 0.03 | 0.02 | - | 1.78 | 3.1 | 8 | 5.0 | 4 | 93 |

derived from soluble Al figures

| | |
|---|---|
| Profile no.: | NWP/ADP/34/82 |
| Soil name : | Chafugume series, Lwawu phase |
| Int. classification : | rhodic ferralsol (FAO); tropeptic haplustox (USDA) |
| Soil map unit : | 15 |
| Date of description : | 8-11-1982 |
| Described by : | W.J. Veldkamp and Wan Ting-tiang |
| Location : | South of Lwawu mission, UTM grid 1789 - 6063 (sheet 1124C1) |
| Elevation : | 1340 m a.s.l. |
| Landform : | gently undulating plateau, middle slope; convex slope 1 - 3% (N) |
| Vegetation and land use : | fairly intensively cultivated area, pit sited in fallow land with some low scrubs, main crop is cassava |
| Anthills : | mound type anthills, red, with an average height of 5 m, an average base of 8m and on average 30 m apart |
| Human influence : | hoe cultivation |
| Climate : | tropical savannah with an unimodal rainfall of circa 1350 mm/year |
| Parent material | basic igneous rock |
| Soil depth : | very deep, elsewhere deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | 0 - 30 cm moist, just moist below (just after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 F F F F / A -- (2.5YR 4/8) |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | - very frequent ironstone gravel occurs in this soil at varying depth below 60 cm<br>- no clay cutans have been observed |

PROFILE DESCRIPTION (NWP/ADF/34/82)

| | | |
|---|---|---|
| Ah | 0 - 15 cm | dark red (2.5YR 3/6, moist and 2.5YR 4/6, dry) clay with a weak fine subangular blocky structure, tending to crumb; very friable (moist), plastic and sticky (wet); many very fine and common fine inped pores; many very fine and fine, few medium roots; transition smooth and clear |
| Bws1 | 15 - 30 cm | red (2.5YR 4/7, moist and 2.5YR 4/8, dry) clay with a weak fine and medium subangular blocky structure; very friable (moist), plastic and sticky (wet); many very fine, few fine and medium inped pores; common very fine, few fine and medium roots; very few hard, small rounded ironstone gravel; transition smooth and gradual |
| Bws2 | 30 - 140 cm | red (2.5YR 4/8, moist and 2.5YR 5/8 dry) clay with a weak fine and medium subangular blocky structure, tending to angular blocky; slightly hard (dry), friable (moist), plastic and sticky (wet); many very fine and few fine inped pores; few very fine roots; few hard, small rounded ironstone gravel; transition wavy and abrupt |
| Bws3 | 140 - 160+ cm | identical to Bws2, but with frequent hard, small rounded ironstone gravel |

ANALYTICAL DATA , Profile no. NWP/ADP/34/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 15 | 62 | 16 | 13 | 7 | 2 | clay |
| 15 - 30 | 64 | 17 | 13 | 4 | 2 | clay |
| 30 - 80 | 58 | 25 | 12 | 2 | 3 | clay |
| 80 - 130 | 60 | 21 | 12 | 3 | 4 | clay |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 15 | 5.2 | 4.4 | 2.10 | 6 | 4.6 | 11.2 |
| 15 - 30 | 5.2 | 4.3 | 1.06 | 3 | 4.2 | 11.4 |
| 30 - 80 | 5.8 | 4.5 | 0.38 | 2 | 9.0 | 14.4 |
| 80 - 130 | 5.9 | 4.5 | n.d. | 2 | 11.6 | 8.0 |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | (meq/100 g) | (meq/100 g clay) | | (%) | |
| 0 - 15 | 0.54 | 0.35 | 0.15 | 0.02 | 0.57 | 10.5 | 17 | 2.6 | 10 | 35 |
| 15 - 30 | 0.05 | 0.02 | 0.04 | 0.02 | 0.52 | 9.1 | 14 | 1.0 | 1 | 80 |
| 30 - 80 | 0.07 | T | 0.02 | T | 1.11 | 6.0 | 12 | 2.1 | 1 | 93 |
| 80 - 130 | 0.07 | 0.01 | 0.01 | T | 1.43 | 6.5 | 11 | 2.5 | 1 | 94 |

derived from soluble Al figures

| | |
|---|---|
| Profile no.: | NWP/ADP/37/82 |
| Soil name : | Kasempa series |
| Int. classication : | orthic ferralsol (FAO), typic haplustox (USDA) |
| Soil map unit : | 11 |
| Date of description : | 23-11-1982 |
| Described by : | R.N. Magai and G.M. Ngoma |
| Location : | along Solwezi - Chingola road, about 35km east of Solwezi, UTM grid 4677 - 6478 (sheet 122681) |
| Elevation : | 1345 m. a.s.l. |
| Landform : | gently undulating plateau, upper slope, in between the head of two minor dambos; slope 0 - 1% (u) |
| Vegetation and land use : | pit sited in old chitemene clearing with light secondary miombo regrowth (Brachystegia and Julbernardia species), area under intensive subsistence cultivation with sorghum, cassava and millet as main crops |
| Anthills : | mound type, greyish brown, with an average height of 5m, an average base of 10 m and on average 100 m apart |
| Human influence : | hoe cultivation and burning of vegetation |
| Climate : | tropical savannah with an unimodal rainfall of circa 1425 mm/year |
| Parent material : | meta-siltstone and fine grained sandstone of the Kundulungu series |
| Soil depth : | very deep |
| Drainage : | well drained, tending to moderately well drained |
| Permeability : | moderate throughout |
| Moisture state : | 0 - 75 cm moist, just moist below (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | $\frac{1\ F\ F\ F\ F}{A\ -\ -\ (7.5YR\ 5/8)}$ |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | - no clay cutans observed |

PROFILE DESCRIPTION (NWP/ADP/37/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | dark brown (10YR 3/3,moist and 10YR 5/4,dry) clay to clay loam with a crumb structure; very friable (moist), slightly plastic and slightly sticky (wet); common very fine and few medium pores; common very fine and fine, and few medium and coarse roots; transition smooth and clear |
| BA | 10 - 26 cm | strong brown (slightly browner than 7.5YR 5/6, moist and 7.5YR 6/6,dry) clay with a weak fine and medium subangular blocky structure; friable (moist), plastic and sticky (wet); many very fine, common fine and few medium and coarse pores; common very fine, fine and medium roots; transition smooth and gradual |
| Bws1 | 26 - 75 cm | strong brown (7.5YR 5/8,moist) clay with a weak fine and medium subangular blocky structure; few fine faint yellowish mottles (10YR - 2.5Y 7/6,moist) around root channels in lower part of horizon; friable (moist), plastic and sticky (wet); many very fine, common fine, few medium and coarse pors; very fine, fine and medium roots; transition smooth and diffuse. |
| Bws2 | 75 - 149 cm | reddish yellow (7.5YR 6/8,moist) clay with a weak fine and medium subangular blocky structure; yellowish mottles as in Bws1; friable (moist), plastic and sticky (wet); many very fine and fine, few medium and coarse pores; few fine, medium and coarse roots; transition wavy and gradual |
| BC | 149 - 186+ cm | strong brown (7.5YR 5/8,moist) clay with a weak fine and medium subangular blocky structure; few medium yellowish mottles (10YR - 2.5Y 7/6, moist); common faint to distinct medium yellowish red (5YR 5/8,moist) mottles; friable (moist), slightly plastic and slightly sticky (wet); common very fine and fine, few medium and coarse pores; few fine, medium and coarse roots; few fine pinkish weathered rock fragments (siltstone) |

ANALYTICAL DATA | Profile no. NWP/ADP/37/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 40 | 25 | 31 | 3 | 1 | clay to clay loam | - |
| 10 - 26 | 48 | 27 | 23 | 1 | 1 | clay | - |
| 26 - 75 | 60 | 18 | 21 | 0 | 1 | clay | 0.3 |
| 75 -149 | 54 | 25 | 20 | 0 | 1 | clay | 0.3 |
| 149 -186 | 54 | 27 | 17 | 1 | 1 | clay | 0.3 |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P | sol. Al | sol. Mn |
|---|---|---|---|---|---|---|
| | | | | (ppm | | ) |
| 0 - 10 | 5.1 | 4.3 | 2.11 | 15 | n.d. | n.d. |
| 10 - 26 | 5.2 | 4.2 | 0.81 | 6 | n.d. | n.d. |
| 26 - 75 | 5.5 | 4.3 | 0.27 | 5 | n.d. | n.d. |
| 75 -149 | 5.7 | 4.3 | 0.19 | 4 | n.d. | n.d. |
| 149 -186 | 5.8 | 4.4 | n.d. | 4 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil | | | | ) | (meq/100 g clay | | ) | | |
| 0 - 10 | 0.64 | 0.63 | 0.40 | 0.03 | n.d. | 12.1 | 30 | n.d | 14 | n.d |
| 10 - 26 | 0.16 | 0.13 | 0.22 | T | n.d. | 5.7 | 12 | n.d | 9 | n.d. |
| 26 - 75 | 0.20 | 0.18 | 0.25 | T | n.d. | 5.1 | 8 | n.d. | 12 | n.d. |
| 75 -149 | 0.12 | 0.19 | 0.25 | T | n.d. | 4.3 | 8 | n.d. | 13 | n.d. |
| 149 -186 | 0.13 | 0.09 | 0.22 | T | n.d. | 4.3 | 8 | n.d. | 10 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADF/38/82 |
| Soil name : | Chafuguma series |
| Int. classification : | acric ferralsol (FAO), ruptic haplic acrustox (USDA) |
| Soil map unit : | 17 |
| Date of description : | 22-11-1983 |
| Described by : | R.N. Magai |
| Location : | along Mumera - Mujimanzovu road, 4.6 km from junction with Mutanda - Kawana road; UTM grid 4149 - 6166 (sheet 1226D1) |
| Elevation : | approximately 1285 m a.s.l. |
| Landform : | fairly large relatively deep depression, lower slope, slope 0 - 1% (E) |
| Vegetation and land use : | pit sited in undisturbed miombo woodland with Brachystegia and Julbernardia sp. as dominant trees; local land use is chitimene with cassava and sorghum as main crops |
| Anthills : | red mound type anthills, with an average height of 3 m, an average base of 10 m and an average 100 m apart |
| Human influence : | nil |
| Climate : | tropical savannah with an unimodal rainfall of circa 1300 mm/year |
| Parent material : | marble |
| Soil depth : | moderately deep to very deep |
| Drainage : | well drained |
| Permeability : | moderately rapid in A horizon, moderate in lower horizons |
| Moisture state : | 0 - 93 cm moist, just moist below (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | fairly rocky (about 2%) at the pit site, higher up the slope there are no outcrops |
| Erosion : | no visible evidence |
| LUB code | 1 F F F F / A - - (2.5YR 3/6) |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | - no clay cutans have been observed |

h **PROFILE DESCRIPTION** (NWP/ADP/38/82)

| | | |
|---|---|---|
| Ah | 0 - 24 cm | yellowish red(5YR 4/6,moist) and dark reddish brown (5YR 3/4,dry) clay with a weak fine subangular blocky structure; very friable (moist), non-plastic and non-sticky (wet); common very fine and fine, few medium and coarse pores; many very fine and fine, common medium and few coarse roots; transition smooth and gradual |
| AB | 24 - 36 cm | dark reddish brown(slightly redder than 5YR 3/6,moist) clay with a weak fine subangular blocky structure; very friable (moist), slightly plastic and slightly sticky (wet); common very fine, few fine and medium pores; common very fine, few fine, medium and coarse roots; transition smooth and gradual |
| Bws1 | 38 - 93 cm | dark red (2.5YR 3/6,moist) clay with a weak fine subangular blocky structure; very friable (moist), slightly plastic and slightly sticky (wet); patchy thin cutans; many very fine common fine and few medium and coarse pores; few very fine, fine medium and coarse roots; transition smooth and diffuse |
| Bws2 | 93 - 178+ cm | dark red (2.5YR 3/6,moist) clay with a weak fine and medium subangular blocky structure; friable (moist), slightly plastic and slightly sticky (wet); patchy thin cutans; few very fine and fine pores; few very fine, fine, medium and coarse roots |

ANALYTICAL DATA Profile no. NWP/ADP/38/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 24 | 58 | 31 | 7 | 2 | 2 | clay | 0.9 |
| 24 - 38 | 60 | 29 | 5 | 3 | 3 | clay | - |
| 38 - 60 | 62 | 29 | 5 | 2 | 2 | clay | - |
| 60 - 93 | 66 | 25 | 4 | 3 | 2 | clay | - |
| 93 -120 | 60 | 25 | 9 | 4 | 2 | clay | - |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 24 | 5.4 | 4.5 | 2.15 | 8 | 8.4 | 15.6 |
| 24 - 38 | 5.4 | 4.5 | 1.36 | 5 | 8.2 | 13.8 |
| 38 - 60 | 5.7 | 4.7 | 0.12 | 4 | 7.8 | 10.6 |
| 60 - 93 | 5.9 | 4.8 | 0.70** | 4 | 4.6 | 7.4 |
| 93 -120 | 6.0 | 4.9 | n.d | 4 | 6.4 | 12.8 |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 24 | 0.76 | 0.11 | 0.06 | T | 1.04 | 9.0 | 15 | 3.4 | 10 | 53 |
| 24 - 38 | 0.24 | 0.04 | 0.02 | 0.03 | 1.01 | 7.0 | 12 | 2.2 | 5 | 75 |
| 38 - 60 | 0.23 | 0.03 | 0.01 | T | 0.96 | 6.5 | 11 | 2.2 | 4 | 72 |
| 60 - 93 | 0.23 | 0.04 | 0.01 | T | 0.57 | 4.8 | 7 | 1.3 | 6 | 67 |
| 93 -120 | 0.29 | 0.03 | 0.01 | T | 0.79 | 4.6 | 8 | 1.3 | 7 | 70 |

*derived from soluble Al figures
** data suspect

| | |
|---|---|
| Profile no.: | NWP/ADF/39/82 |
| Soil name : | Chafuguma series |
| Int. classification : | acric ferralsol(FAO); haplic acrustox (USDA) |
| Soil map unit : | 17 |
| Date of description : | 23-11-1982 |
| Described by : | G.M. Ngosa and Wen Ting-tiang |
| Location : | along the track from Chief Mulonga's village to the Zairen border, 0.4 km S of the border track; UTM grid 4823-6744 (sheet 1126 D4) |
| Elevation : | 1425 m a.s.l. |
| Landform : | plateau, interfluve of a saddle shaped connection between two dolines, close to the interfluve between Congo and Zambezi watersheds, slope 2% (S) |
| Vegetation and land use : | pit sited in medium to dense miombo woodland with Isoberlinia angolensis and Brachystegia boehmii as dominant species, tree growth is moderate, the area is not cultivated |
| Anthills : | combined mound and pinnacle type, both having a red colour, the mounds having an average base of 7 m, an average height of 5 m and on average 50 m apart, the pinnacles are $1\frac{1}{2}$ m high an have a diameter of 1 m, common small 50 cm high anthills with a diameter of 20 cm |
| Human influence : | burning of undergrowth |
| Climate : | tropical savannah with an unimodal rainfall of circa 1350 mm/year |
| Parent material : | according to the Geological Map of Zambia carbonaceous shale, but indications are that the soil has formed over limestone |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderately rapid throughout |
| Moisture state : | 0 - 73 cm moist, just moist below |
| Groundwater : | not reached |
| Surface stones : | nil |

Rock Outcrops : nil

Erosion : no visible evidence

LUB code: $\frac{1\ D\ F\ F\ F}{A - - (2.5YR\ 3/6)}$

Land capability class: C1(LUB),2

Remarks: - no clear clay cutans have been observed

PROFILE DESCRIPTION.

| | | |
|---|---|---|
| Ah | 0 - 12cm | dark reddish brown (slightly redder than 5YR 3/4, moist, and 5YR 4/6, dry) clay loam with a weak fine subangular blocky structure, slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine and fine, common medium inped pores; many very fine and fine, common medium roots; transition smooth and gradual. |
| BA | 12 - 30cm | dark reddish brown (2.5 to 5YR 3/4 , moist and 2.5 to 5YR 4/6, dry) clay loam with a weak fine to medium subangular blocky structure; slightly hard (dry), very friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine, few medium inped pores; common very fine and fine, few medium and coarse roots; transition smooth and diffuse. |
| Bws1 | 30 - 73cm | dark reddish brown (2.5YR 3/6, moist) clay with a moderately coherent porous massive structure; friable (moist), slightly plastic and sticky (wet); common very fine and fine, few medium and coarse pores; common very fine and fine, few medium and coarse roots; transition smooth and diffuse. |
| Bws2 | 73 - 275cm | dark reddish brown (slightly redder than 2.5YR 3/7, moist) clay with a moderately coherent porous massive structure; friable (moist), slightly plastic and sticky (wet); possibly few thin patchy cutans; common very fine and fine, few medium pores; common very fine and fine, few medium and coarse roots; very few small (± 2 mm) black ironstone gravel. |
| Bws3 | 275 - 300 cm | similar to Bw2, but with very few angular quartz gravel and frequent small (± 2mm) black ironstone gravel. |

ANALYTICAL DATA

Profile no. NWP/ADP/39/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 12 | 34 | 24 | 31 | 8 | 3 | clay loam | - |
| 12 - 30 | 30 | 29 | 33 | 5 | 3 | clay loam | - |
| 30 - 73 | 42 | 28 | 22 | 5 | 3 | clay | - |
| 73 -125 | 42 | 32 | 18 | 5 | 3 | clay | - |
| 125 -160 | 44 | 38 | 12 | 3 | 3 | clay | - |
| 230 -280 | 48 | 35 | 11 | 3 | 3 | clay | - |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | micronutrients Cu (ppm) | Zn (ppm) | Mo (ppm) | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 12 | 5.1 | 4.1 | 2.46 | 12 | 8.4 | 55.4 | 8.3 | 8.2 | 2.5 | 0.12 |
| 12 - 30 | 5.1 | 4.2 | 0.97 | 7 | 7.4 | 49.8 | 4.1 | 2.3 | 1.8 | 0.05 |
| 30 - 73 | 5.5 | 4.4 | 0.20 | 4 | 2.4 | 50.2 | 2.7 | 1.2 | 0.2 | 0.05 |
| 73 -125 | 5.8 | 4.4 | 0.27 | 2 | 1.8 | 37.8 | n.d | n.d | n.d | n.d. |
| 125 -160 | 5.8 | 4.5 | n.d. | 2 | 1.8 | 23.6 | n.d | n.d | n.d | n.d. |
| 230 -280 | 5.8 | 4.4 | n.d. | 2 | n.d | n.d | n.d | n.d | n.d | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil | | | | | ) | (meq/100 g clay) | | (% | ) |
| 0 - 12 | 0.22 | 0.23 | 0.38 | T | 2.90 | 11.7 | 35 | 11.0 | 7 | 78 |
| 12 - 30 | 0.18 | 0.09 | 0.18 | T | 1.80 | 7.8 | 26 | 7.5 | 6 | 80 |
| 30 - 73 | 0.13 | 0.05 | 0.23 | T | 0.88 | 5.7 | 13 | 3.7 | 7 | 68 |
| 73 -125 | 0.17 | 0.04 | 0.17 | T | 0.54 | 5.2 | 12 | 2.2 | 7 | 59 |
| 125 -160 | 0.12 | 0.02 | 0.12 | 0.10 | 0.35 | 4.9 | 11 | 1.4 | 7 | 57 |
| 230 -280 | 0.11 | 0.02 | 0.08 | 0.10 | n.d | 4.8 | 10 | n.d | 6 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/40/82 |
| Soil name : | Mwinilunga series |
| Int. classification : | humic gleysol (FAO); aeric tropaquept (USDA) |
| Soil map unit : | 27 |
| Date of description : | 24-11-1982 |
| Described by : | V. Mbita and Wen Ting-tiang |
| Location : | along Solwezi - Mwinilunga road, approximately 40.5 km E of the bridge over the Lunga; UTM grid 2576 - 7013 (sheet 1124D2) |
| Elevation : | 1470 m a.s.l. |
| Landform : | undulating plateau, made up of gently undulating woodland areas and relatively deep incised grassland areas; upper slope, near crest; slightly convex slope 1 - 3% (S) |
| Vegetation and land use : | thin grassland, used for extensive grazing |
| Anthills : | nil |
| Human influence : | burning of grasses |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | Kalahari sand |
| Soil depth : | very deep |
| Drainage : | poorly drained |
| Permeability : | rapid throughout |
| Moisture state : | 0 - 85 cm moist, wet below (after rains) |
| Groundwater : | 105 cm; the groundwater level fluctuates from several metres deep during the dry season to near or at the surface in the rainy season |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 A A B X / A - W3 (10YR 5/3) |
| Land capability class : | Gw (LUB); 5 |
| Remarks : | no clay cutans have been observed |

PROFILE DESCRIPTION (NWP/ADP/40/82)

| | | |
|---|---|---|
| Ah | 0 - 24 cm | very dark grayish brown (10YR 3/2,moist and 10YR 5/2,dry) very fine sand with a weak crumb structure, tending to single grain; loose (moist); many very fine and fine pores; many fine, few medium roots; transition smooth and clear |
| AC | 24 - 37 cm | dark brown (10YR 3/3,moist) very fine sand; single grain; loose (moist); many fine pores; common very fine and fine roots; transition smooth and clear |
| Cg1 | 37 - 85 cm | brown (10YR 5/3,moist) very fine sandy loam to loamy sand; single grain; common faint fine and medium light brownish mottles (10YR 5/4, moist); loose (moist); many fine pores; common very fine, fine and medium roots; transition smooth and gradual |
| Cg2 | 85 - 100 cm | yellowish brown (10YR 5/6,moist) very fine loamy sand; single grain; common faint to distinct medium bright brown mottles (10YR 6/6,moist); loose (moist); many fine pores; common fine roots; transition smooth and clear |
| Cg3 | 100 - 230+ cm | brownish yellow (10YR 6/6,moist) very fine sandy loam; single grain; loose (moist); many distinct coarse reddish mottles (5YR 5/8, moist); many fine pores; few fine roots |

ANALYTICAL DATA

Profile no. NWP/ADP/40/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 24 | 2 | 12 | 59 | 24 | 3 | very fine sand |
| 24 - 37 | 2 | 10 | 58 | 27 | 3 | very fine sand |
| 37 - 85 | 6 | 20 | 53 | 19 | 2 | very fine sandy loam |
| 85 -100 | 5 | 17 | 57 | 19 | 2 | very fine loamy sand |
| 100 -130 | 12 | 15 | 48 | 21 | 4 | very fine sandy loam |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 24 | 5.4 | 4.2 | 1.02 | 15 | n.d. | n.d. |
| 24 - 37 | 5.4 | 4.5 | 0.64 | 15 | n.d. | n.d. |
| 37 - 85 | 5.6 | 4.7 | 0.45 | 15 | n.d. | n.d. |
| 85 -100 | 5.7 | 4.8 | 0.27 | 11 | n.d. | n.d. |
| 100 -130 | 5.8 | 5.2 | n.d. | 6 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 24 | 0.17 | 0.06 | 0.03 | T | n.d. | 2.6 | 130 | n.d. | 10 | n.d. |
| 24 - 37 | 0.13 | 0.03 | 0.01 | T | n.d. | 1.6 | 80 | n.d. | 11 | n.d. |
| 37 - 85 | 0.15 | 0.02 | 0.01 | T | n.d. | 1.2 | 20 | n.d. | 15 | n.d. |
| 85 -100 | 0.15 | 0.02 | T | T | n.d. | 0.8 | 16 | n.d. | 22 | n.d. |
| 100 -130 | 0.14 | 0.02 | T | T | n.d. | 0.6 | 5 | n.d. | 27 | n.d. |

| | |
|---|---|
| Profile no.: | NWP/ADP/42/82 |
| Soil name : | Mulobolq series |
| Int. classification: | orthic ferralsol (FAO); ultic haplustox (USDA) |
| Soil map unit : | 38 |
| Date of description : | 25-11-1983 |
| Described by : | Wen Ting-tiang |
| Location : | along Kabompo Gorge track, 13 km south of the main road, UTM grid 2978 - 6804 (sheet 1125C3) |
| Elevation : | 1450 m a.s.l. |
| Landform: | moderately, dissected plateau, upper slope, uniform slope 1% (NE) |
| Vegetation and land use : | light to medium miombo woodland with Marquesia macroura as dominant species, also Brachystegia boehmii, Monotes species, Uapaca kirkiana and Parinari curatellifolia, moderate growth |
| Anthills : | mound type anthills, with an average height of 3 m, an average base of 6 m and on average 30 m apart, common 40 cm high yellow brown small anthills |
| Human influence : | burning of undergrowth |
| Climate : | tropical savannah with an unimodal rainfall of circa 1100 mm/year |
| Parent material : | muscovite schist and biotite gneiss of the Basement complex |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | 0 - 62 cm moderately rapid, rapid below |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code | 1 B C F F / A - - (10YR 6/6) |
| Land capability class : | S1 (LUB); 3 |
| Remarks : | - no clay cutans have been observed |

PROFILE DESCRIPTION (NOP/ADP/42/82)

| | | |
|---|---|---|
| Ah | 0 - 10 cm | very dark brown (10YR 2/2, moist and 10YR 5/2, dry) sandy loam with a weak medium and coarse crumb structure; slightly hard (dry), friable (moist); many very fine and fine, few medium inped pores; many very fine and fine, few medium roots; transition smooth and clear |
| AB | 10 - 35 cm | yellowish brown (10YR 5/4, moist and 10YR 6/3, dry) sandy clay loam (field texture sandy loam) with a weak fine and medium subangular blocky structure; slightly hard (dry), friable (moist); many very fine, common fine and few medium inped pores; many very fine, common fine and medium roots; transition smooth and gradual |
| BA | 35 - 62 cm | brownish yellow (10YR 6/6, moist) clay (field texture sandy clay loam ) with a weak medium and coarse subangular blocky structure; slightly hard (dry), friable (moist), slightly plastic and non-sticky (wet); many very fine, few fine and medium inped pores; common very fine, few fine, medium and coarse roots; transition smooth and gradual |
| Bws1 | 62 - 116 cm | brownish yellow (slightly redder than 10YR 6/7, moist) clay (field texture light sandy clay) with a moderately coherent porous massive structure; friable (moist), slightly plastic and slightly sticky (wet); many very fine, common fine and few medium pores; common very fine, few fine, medium and coarse roots; transition smooth and diffuse |
| Bws2 | 116 - 175 cm | brownish yellow (slightly redder than 10YR 6/7, moist) clay (field texture sandy clay) with a moderately coherent porous massive structure; few distinct fine red (2.5YR 5/8, moist) mottles friable (moist), slightly plastic and slightly sticky (wet); many very fine, few fine and medium pores; few very fine and medium roots; transition wavy and abrupt |
| Bms | 175 + cm | strongly cemented ironstone gravel (sheet laterite) |

ANALYTICAL DATA                                        Profile no. NWP/ADP/42/82

<u>Particle size distribution (%)</u>

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 10 | 8 | 18 | 44 | 24 | 6 | sandy loam | - |
| 10 - 35 | 34 | 19 | 31 | 13 | 3 | sandy clay loam | - |
| 35 - 62 | 46 | 21 | 20 | 9 | 4 | clay | 0.6 |
| 62 - 116 | 46 | 17 | 27 | 7 | 3 | clay | 0.7 |
| 116 - 160 | 48 | 20 | 23 | 6 | 3 | clay | 0.7 |

<u>Chemical data</u>

| depth | pH | pH | org. C | avail. P | sol. Al | sol. Mn |
|---|---|---|---|---|---|---|
| (cm) | ($H_2O$) | ($CaCl_2$) | (%) | (ppm) | | |
| 0 - 10 | 5.2 | 4.2 | 1.72 | 28 | 6.0 | 3.8 |
| 10 - 35 | 5.1 | 4.1 | 0.76 | 8 | 6.2 | 2.4 |
| 35 - 62 | 5.3 | 4.1 | 0.34 | 5 | 6.2 | 2.0 |
| 62 - 116 | 5.6 | 4.2 | 0.25 | 2 | 8.6 | 15.2 |
| 116 - 160 | 5.6 | 4.2 | n.d | 1 | 8.0 | 17.2 |

| depth | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al* | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| (cm) | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 10 | 0.65 | 0.54 | 0.18 | T | 0.74 | 5.9 | 74 | 25.1 | 23 | 37 |
| 10 - 35 | 0.14 | 0.26 | 0.14 | T | 0.77 | 4.3 | 13 | 3.9 | 13 | 59 |
| 35 - 62 | 0.20 | 0.21 | 0.19 | T | 0.77 | 4.5 | 10 | 3.0 | 13 | 56 |
| 62 - 116 | 0.12 | 0.06 | 0.18 | T | 1.06 | 4.3 | 9 | 3.1 | 8 | 75 |
| 116 - 160 | 0.14 | 0.04 | 0.20 | T | 0.99 | 3.4 | 7 | 2.9 | 11 | 72 |

| | |
|---|---|
| Profile no. : | NWP/ADF/43/32 |
| Soil name : | Shilenda series |
| Int. classification : | xanthic ferralsol (FAO), ultic haplustox (USDA) |
| Soil map unit : | 35 |
| Date of description : | 25-11-1983 |
| Described by : | Wen Ting-tiang |
| Location : | along the road to Chowe school, 3.4 km south of the junction to Ntambu; UTM grid 3029 - 6427 (sheet 1225A3) |
| Elevation : | 1170 m a.s.l. |
| Landform : | gently undulating plateau, crest, slope 0 - 1% (SW) |
| Vegetation and land use : | medium dense miombo woodland with Isoberlinia angolensis and Brachystegia boehmii as dominant species, also Diplorhynchus condylocarpon, Parinaria curatellifolia and Uapaca species; although the area is presently uninhited it has probably been under chitimene cultivation and the forest is largely regrowth, elsewhere chitemene cultivation with cassava as main crop |
| Anthills : | mound type anthills, grey, with an average height of 4 m and an average base of 8 m, pinnacle type anthills, yellow brown, with an average height of 1.5 m and an average diameter of 1 m, both types on average 50m apart, common grey 30 cm high small anthills |
| Human influence : | none at present, except for fuelwood gather- gathering and burning of undergrowth |
| Climate : | tropical savannah with an unimodal rainfall of circa 1075 mm/year |
| Parent material : | biotite schist of the Basement complex |
| Soil depth : | very deep to deep |
| Drainage : | well drained |
| Permeability : | 0 - 34 cm moderately rapid, 34 - 142 cm rapid, moderately rapid below |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |

Erosion : no visible evidence

LUB code : $\frac{1\ B\ C\ D\ F}{A\ -\ -\ (10YR\ 6/6)}$

Land capability class : S1 (LUB); 3

Remarks : - no clay cutans have been observed

PROFILE DESCRIPTION (NWP/ADP/43/82)

| | | |
|---|---|---|
| Ah | 0 - 8 cm | dark grayish brown (10YR 4/2,moist and 10YR 7/3,dry) sandy loam with a weak medium and coarse crumb structure; very friable (moist); many very fine, common fine and few medium inped pores; many very fine and fine, few medium roots; transition smooth and clear |
| AB | 8 - 34 cm | yellowish brown (10YR 5/5,moist and 10YR 7/4, dry) sandy clay loam (field texture sandy loam) with a weak fine subangular blocky structure; friable (moist); many very fine, few fine, medium and coarse pores; common very fine, fine and medium, few coarse roots; transition smooth and gradual |
| BA | 34 - 55 cm | brownish yellow (10YR 6/6,moist) clay to clay loam with a weak fine and medium subangular blocky structure; friable (moist), slightly plastic and non-sticky (wet); few fine, medium and coarse pores; few very fine, fine, medium and coarse roots; transition smooth and diffuse |
| Bws1 | 55 - 142 cm | brownish yellow (slightly redder than 10YR 6/6, moist) clay loam to clay with a moderately coherent porous massive structure; friable (moist), slightly plastic and non-sticky (wet); few very fine and medium pores; few very fine, fine and medium roots; few small ironstone gravel; transition wavy and clear |
| Bws2 | 142 - 150+ cm | similar to Bws1, but with very frequent small ironstone gravel |

ANALYTICAL DATA Profile no. NWP/ADP/43/82

## Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 8 | 14 | 16 | 43 | 23 | 4 | sandy loam | - |
| 8 - 34 | 32 | 16 | 19 | 27 | 6 | sand caly loam | - |
| 34 - 55 | 40 | 19 | 26 | 10 | 5 | clay loam to clay | 1.1 |
| 55 - 95 | 38 | 26 | 21 | 9 | 6 | clay loam | 2.2 |
| 95 -135 | 44 | 23 | 20 | 7 | 6 | clay | 7.4 |

## Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 8 | 5.1 | 4.1 | 1.10 | 10 | n.d. | n.d. |
| 8 - 34 | 4.5 | 4.1 | 0.51 | 7 | n.d. | n.d. |
| 34 - 55 | 5.1 | 4.1 | 0.42 | 6 | n.d. | n.d. |
| 55 - 95 | 5.2 | 4.1 | 0.29 | 3 | n.d. | n.d. |
| 95 -135 | 5.1 | 4.1 | n.d. | 3 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 8 | 0.22 | 0.12 | 0.08 | T | n.d | 3.3 | 24 | n.d. | 13 | n.d. |
| 8 - 34 | 0.23 | 0.09 | 0.08 | [illegible] | n.d | 4.3 | 14 | n.d. | 9 | n.d. |
| 34 - 55 | 0.17 | 0.07 | 0.06 | T | n.d | 3.5 | 9 | n.d. | 9 | n.d |
| 55 - 95 | 0.13 | 0.06 | 0.06 | 0.01 | n.d | 7.0 | 18 | n.d. | 4 | n.d |
| 95 -135 | 0.12 | 0.06 | 0.06 | 0.01 | n.d | 3.8 | 9 | n.d. | 7 | n.d |

| | |
|---|---|
| Profile no.: | NUP/ADP/46/83 |
| Soil name : | Ntambu series |
| Int. classification : | gleyic ferralsol (FAO); epiaquic haplustox (USDA) |
| Soil map unit : | 25 |
| Date of description : | 14-3-1983 |
| Described by : | V. Mbita and Wen Ting-tiang |
| Location : | along eastern branch of Ntambu road, 1.1 km S of the turnoff towards the Chavuma road; UTM grid 2983 - 6443 (sheet 1225A3) |
| Elevation : | 1140 m a.s.l. |
| Landform : | river terrace, slope 0 - 1% |
| Vegetation and land use : | medium dense secondary miombo woodland with Brachystegia boehmii and Anisophyllea boehmii as dominant species, also Brachystegia spiciformis, Hymenocardia acida, Parinari curatellifolia and Erythrophleum africanum; local land use is shifting cultivation with cassava, maize and rice as main crops |
| Anthills : | mound type, light grey, with an average height of 1.5 m, an average base of 4 m and on average 40 m apart |
| Human influence : | previously cultivated by hoe |
| Climate : | tropical savannah with an unimodal rainfall of circa 1075 mm/year |
| Parent material : | Kalahari sand, possibly reworked |
| Soil depth : | very deep |
| Drainage : | moderately well drained |
| Permeability : | 0 - 71 cm rapid, moderate below |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| LUB code : | 1 B B C C / 0 W1 - (10YR 4/6) |
| Land capability class : | S2w (LUB); 3 |
| Remarks : | - texture variations of this soil rather large<br>- heavier sandy clay subsoil occurs mostly within 90 cm |

- no clay cutans have been observed

Erosion : no visible evidence

PROFILE DESCRIPTION (NWP/ADP/46/82)

| | | |
|---|---|---|
| Ah1 | 0 - 11 cm | dark gray (10YR 4/1,moist and 10YR 6/2,dry) sandy loam with a weak fine subangular blocky structure; very friable (moist); many very fine and few fine roots; many very fine and fine, common medium inped and exped pores, transition smooth and clear |
| Ah2 | 11 - 25 cm | dark grayish brown (10YR 4/2,moist and 10YR 7/2,dry) sandy loam with a weak fine and medium subangular blocky structure; very friable (moist); many very fine, few fine and medium mostly inped pores; many very fine, common fine and few medium and coarse roots, transition smooth and gradual |
| AB | 25 - 41 cm | grayish brown (10YR 5/2,moist) sandy loam with a weak medium subangular blocky structure; many very fine, few fine and medium inped pores; common very fine, few fine, medium and coarse roots; transition smooth and gradual |
| Bws | 41 - 71 cm | very pale brown (slightly yellower than 10YR 7/3, moist) sandy clay loam; common faint fine and medium yellow (10YR 7/6,moist) mottles; weak medium and coarse subangular blocky structure; friable (moist); slightly plastic and non-sticky (wet); many very fine, few fine and medium inped pores; common very fine, few fine, medium and coarse roots; transition smooth and gradual |
| BCg | 71 - 185 cm | light yellow (slightly browner than 2.5Y 7/3, moist) sandy clay loam; common fine faint to distinct yellow (10YR 7/6,moist) mottles, and common faint medium light gray (2.5Y 7/1,moist) mottles; weakly coherent porous massive structure; friable (moist), slightly plastic and non-sticky (wet); many very fine and few fine pores; few very fine, fine and medium roots |
| Cg | 185 - 220+ cm | white (2.5Y 8/2,moist) sandy clay with few, locally common, prominent medium dark red (2.5YR 3/6,moist) mottles |

ANALYTICAL DATA

Profile no. NWP/ADP/46/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 11 | 12 | 8 | 19 | 50 | 11 | sandy loam | - |
| 11 - 15 | 15 | 8 | 35 | 35 | 7 | sandy loam | - |
| 25 - 41 | 13 | 17 | 16 | 44 | 10 | sandy loam | - |
| 41 - 71 | 32 | 20 | 9 | 30 | 9 | sandy clay loam | - |
| 71 - 120 | 25 | 15 | 15 | 26 | 19 | sandy clay loam | - |
| 120 - 185 | 38 | 10 | 31 | 15 | 6 | sandy clay | - |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 11 | 4.8 | 4.2 | 0.97 | 11 | n.d. | n.d |
| 11 - 25 | 5.7 | 4.6 | 0.28 | 3 | n.d. | n.d |
| 25 - 41 | 5.5 | 4.3 | 0.06 | 9 | n.d. | n.d |
| 41 - 71 | 5.1 | 4.2 | 0.27 | 5 | n.d. | n.d |
| 71 - 120 | 5.0 | 4.1 | 0.17 | 7 | n.d. | n.d |
| 120 - 185 | 5.2 | 4.0 | n.d. | 4 | n.d. | n.d |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil | | | | ) | (meq/100 g clay) | | | (%) | |
| 0 - 11 | 0.52 | 0.57 | 0.13 | 0.05 | n.d | 2.6 | 22 | n.d | 49 | n.d |
| 11 - 25 | 0.13 | 0.13 | 0.11 | 0.04 | n.d | 1.7 | 12 | n.d | 32 | n.d |
| 25 - 41 | 0.07 | 0.07 | 0.15 | 0.05 | n.d | 2.0 | 16 | n.d | 25 | n.d |
| 41 - 71 | 0.08 | 0.08 | 0.18 | 0.05 | n.d | 2.4 | 7 | n.d | 24 | n.d |
| 71 - 120 | 0.12 | 0.12 | 0.16 | 0.07 | n.d | 2.3 | 9 | n.d | 30 | n.d |
| 120 - 185 | 0.28 | 0.28 | 0.19 | 0.05 | n.d | 2.8 | 7 | n.d | 33 | n.d |

| | |
|---|---|
| Profile no.: | NWP/ADP/047/82 |
| Soil name : | Shilenda series |
| Int. Classification : | xanthic ferralsol (FAO); ultic haplustox (USDA) |
| Soil map unit : | 35 |
| Date of description : | 27-11-1982 |
| Authors : | Wen Ting-tiang and G.M. Ngosa |
| Location : | about 300 m N of the Solwezi-Mwinilunga road just W of the Shilenda turn-off, UTM grid 3754-6389 (sheet 122584) |
| Elevation : | appxox. 1450m a.s.l. |
| Landform : | plateau, upper slope, slope < 1% (N) |
| Vegetation and land use : | pit sited in medium dense miombo woodland with Brachystegia boehmii, Marquesia macroura and Monotes spp. as dominant species, also Anisophyllea boehmii, the tree growth is moderate; the area N of the road is uninhibited (protected fores |
| Anthills : | mound type with a dark grey colour, an average base of 8 m, an average height o 5 m and on average 70 m apart; few small greyish anthills, with an average diamet of 20 cm and an average height of 30 cm |
| Human influence : | burning |
| Climate : | tropical savannah with an unimodal rainfall of circa 1250 mm/year |
| Parent material : | probably musovite-kyanite schist of the Basement complex |
| Soil depth : | very deep |
| Drainage : | well drained, tending to moderately well drained |
| Permeability : | rapid in the top two horizons, moderate rapid below |
| Moisture state : | 0 - 68 moist, 68+ just moist (after rain |
| Groundwater : | not reached |
| Surface stone : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 B B C C / 0 - - (7,5YR 4/6) |
| Land cap. class : | S1 (LUB), 3 |
| Remarks : | - moderate termite activity<br>- no cutans have been observed |

- 0 - 150 cm pit, 150 - 270 cm augering
- sand grains in surface layer uncoated

PROFILE DESCRIPTION (NWP/ADP/47/82)

| | | | |
|---|---|---|---|
| Ah | 0 - | 13 cm | greyish yellow brown (10YR 4/2,moist and 10YR 6/1 dry) sandy loam with a weak medium crumb structure; slightly hard, tending to soft (dry), very friable (moist), non plastic and non sticky (wet); many very fine, few fine inped pores; many very fine and fine, few medium roots; transition clear and smooth |
| AB | 13 - | 38 cm | dull yelowish brown (10YR 4/3,moist and 10YR 6/3 dry) sandy loam with a weak medium subangular blocky structure, slightly hard (dry), very friable (moist), non plastic and non sticky (wet); many very fine and few fine inped pores; many very fine, common fine and few medium roots; transition smooth and clear |
| Bws1 | 38 - | 68 cm | bright brown (7.5YR 4/6,moist) sandy clay loam with a weak medium subangular blocky structure; hard (dry), friable (moist), slightly plastic and slightly sticky (wet), many very fine, common fine and few medium inped pores; common very fine and few fine roots; transition smooth and gradual |
| Bws2 | 68 - | 150 cm | orange (7.5YR 6/6,moist) sandy clay loam with a moderately coherent porous massive structure structure; hard to very hard (dry), friable (moist), slightly plastic and slightly sticky (wet); many very fine and few fine pores; few very fine, fine, medium and coarse roots; few small krotovinas; transition smooth and gradual |
| Btg | 105 - | 270+ cm | orange (7.5YR 6/6,moist) sandy clay loam with a moderately coherent porous massive structure; common fine faint pale yellow (2.5Y 8/4,moist) and few fine distinct bright brown (7.5YR 5/8, moist) mottles; friable (moist), slightly plastic and slightly sticky (wet); common very fine, few fine and medium pores; common patchy thin cutans common fine and few very fine and few very fine roots; between 190 and a1 210 cm grequent small soft Fe concretions, elsewhere few small soft Fe concretions |

ANALYTICAL DATA  Profile no. NWP/ADP/47/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0 - 13 | 10 | 14 | 24 | 13 | 9 | sandy loam | - |
| 13 - 38 | 10 | 14 | 42 | 19 | 5 | fine sandy loam | - |
| 38 - 68 | 26 | 14 | 34 | 12 | 4 | sandy clay loam | - |
| 68 - 105 | 34 | 14 | 28 | 17 | 7 | sandy clay loam | - |
| 105 - 150 | 30 | 16 | 29 | 12 | 3 | sandy clay loam | - |
| 150 - 200 | 34 | 26 | 21 | 8 | 11 | clay loam | - |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | micronutrients Cu (ppm) | Zn (ppm) | Mo (ppm) | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 13 | 5.3 | 4.1 | 1.04 | 13 | n.d | n.d. | 2.3 | 10.1 | 0.3 | 0.35 |
| 13 - 38 | 5.4 | 4.2 | 0.37 | 9 | 6.8 | 0.6 | 0.8 | 9.9 | 1.5 | 0.57 |
| 38 - 68 | 5.2 | 4.0 | 0.19 | 7 | 13.4 | 0.6 | 0.5 | 18.8 | 0.1 | 0.05 |
| 68 - 105 | 5.4 | 4.1 | 0.60* | 5 | 11.0 | 0.4 | n.d | n.d | n.d | n.d |
| 105 - 150 | 5.6 | 4.2 | n.d | 4 | 8.4 | 0.6 | n.d | n.d | n.d | n.d |
| 150 - 200 | 5.5 | 4.1 | n.d | 5 | 8.0 | 0.6 | n.d | n.d | n.d | n.d |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 13 | 0.22 | 0.43 | 0.18 | - | 1.28 | 4.3 | 43 | 21.1 | 22 | 61 |
| 13 - 38 | 0.11 | 0.20 | 0.18 | T | 1.03 | 2.7 | 27 | 15.2 | 18 | 68 |
| 38 - 68 | 0.13 | 0.12 | 0.23 | - | 1.63 | 3.8* | 15 | 8.1 | 15 | 77 |
| 68 - 105 | 0.18 | 0.10 | 0.27 | - | 1.47 | 5.1 | 15 | 6.8 | 13 | 72 |
| 105 - 150 | 0.21 | 0.15 | 0.20 | - | 1.38 | 4.7 | 16 | 6.5 | 14 | 71 |
| 150 - 200 | 0.23 | 0.20 | 0.21 | - | 1.24 | 4.7 | 14 | 5.5 | 16 | 66 |

* data suspect

| | |
|---|---|
| Profile no.: | NWP/ADP/51/83 |
| Soil name : | Chimbwi series |
| Int. classification : | dystric fluvisol (FAO), typic tropaquept (USDA) |
| Soil map unit : | 40 |
| Date of description : | 23-1-1983 |
| Described by : | Wen Ting-tiang and R.N. Magai |
| Location : | along the Kalulushi road, about 16 km E of the Lunga river, UTM grid 4652-5726 (sheet 1226D3) |
| Elevation : | approximately 1180 m a.s.l. |
| Landform : | flat floor of very large dambo, several km in length and about 500 m wide |
| Vegetation and land use : | open grassland, probably not being used agriculturally |
| Anthills : | few mound type, about 3 m high |
| Human influence : | none other than burning and gathering of thatch grass |
| Climate : | tropical savannah with an unimodal rainfall of circa 1275 mm/year |
| Parent material : | alluvial deposit |
| Soil depth : | very deep |
| Drainage : | poorly drained |
| Permeability : | not assessed |
| Moisture state : | upper 60 cm moist, wet below, at several places the surface is soggy |
| Groundwater : | at about 80 cm |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 D D D F / 0 W3 (10YR 4/1) |
| Land capability class : | Gw (LUB), 3 |
| Remarks : | - samples obtained by augering |

SUMMARY PROFILE DESCRIPTION (NWP/ADP/51/83)

| | | |
|---|---|---|
| Ah | 0 - 15 cm | very dark gray (10YR 3/1,moist and 10YR 5/2, dry) clay loam |
| Au | 15 - 60 cm | dark gray (10YR 3/1,moist and 10YR 6/2,dry) clay loam |
| 2Cg1 | 60 - 90 cm | light brownish gray (10YR 6/2,moist) clay |
| 2Cg2 | 90 - 120+ cm | pale brown (10YR 6/3,moist) clay with common brown mottles, laterite gravels below 100 cm |

ANALYTICAL DATA

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class | gravel |
|---|---|---|---|---|---|---|---|
| 0- 30 | 30 | 31 | 37 | 1 | 1 | clay loam | - |
| 30- 60 | 32 | 34 | 32 | 1 | 1 | clay loam | - |
| 60- 80 | 50 | 31 | 17 | 1 | 1 | clay | - |
| 80-120 | 51 | 27 | 20 | 1 | 1 | clay | - |

Chemical data

| depth (cm) | pH ($CaCl_2$) | pH ($H_2O$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0- 30 | 5.0 | 6.0 | 2.22 | 7 | n.d. | n.d. |
| 30- 60 | 5.5 | 6.4 | 0.51 | 6 | n.d. | n.d. |
| 60- 80 | 5.7 | 6.5 | 0.40 | 4 | n.d. | n.d. |
| 80-120 | 5.9 | 6.5 | 0.31 | 1 | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil | | | | | ) | (meq/100 g clay) | | (% | ) |
| 0- 30 | 3.90 | 0.82 | 0.01 | T | n.d. | 9.8 | 33 | n.d. | 48 | n.d. |
| 30- 60 | 2.35 | 0.74 | 0.01 | 0.01 | n.d. | 5.6 | 18 | n.d. | 55 | n.d. |
| 60- 80 | 4.00 | 1.65 | 0.01 | 0.01 | n.d. | 9.3 | 19 | n.d. | 61 | n.d. |
| 80-120 | 4.20 | 1.65 | 0.01 | 0.01 | n.d. | 12.6 | 25 | n.d. | 47 | n.d. |

APPENDIX III — Profile descriptions and analytical data from pits other than those opened during the survey of the project area

Soil profile descriptions with their accompanying analytical data of two previous surveys in the project area have been used in this report. They have been taken from Heilmann's Exploratory Soil Map of Mwinilunga and Solwezi district (Heilmann 1977) and the semi-detailed survey of part of the Solwezi dome south of Solwezi boma (Broekhuis 1983). In the text these profile pits are identified by their full pit number.

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| | |
|---|---|
| Profile no.: | MWP/15/77 (RRLMWP 15/77) |
| Soil name : | Samfya series |
| Int. classification : | xanthic ferralsol (FAO); typic haplustox (USDA) |
| Soil map unit : | 21 |
| Date of description : | 19-10-1977 |
| Described by : | P. Heilmann |
| Location : | along road from Ikelenge to Angolan border, approx. UTM grid JT 8868 (sheet SC 35-13 |
| Landform : | plateau, slope 0 - 3% |
| Vegetation : | degraded woodland |
| Climate : | tropical savannah with an unimodal rainfall of circa 1425 mm/year |
| Parent material : | granite |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | moderate |
| LUB code : | 1 E F F F / A - - (7.5YR 6/5) |
| Land capability class : | C1 (LUB); 2 |
| Remarks : | description based on augering only |

BRIEF PROFILE DESCRIPTION

| | | |
|---|---|---|
| A | 0 - 10 cm | very dark grayish brown (10YR 3/2, moist) sandy clay with a very weak structure; sticky and plastic (wet) |
| AB | 10 - 40 cm | brown (10YR 5/3, moist) sandy clay to clay with a very weak structure; sticky and plastic (wet) |
| Bw | 40 - 90 cm | light brown (7.5YR 6/5, moist) clay without any macro structure; very sticky and plastic (wet); rather compact |

ANALYTICAL DATA

Profile no. NWP/15/77

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 20 | 37 | 9 | 33 | 16 | 5 | sandy clay |
| 20 - 40 | 48 | 8 | 28 | 12 | 4 | clay |
| 40 - 60 | 48 | 6 | 32 | 10 | 4 | clay |
| 60 - 90 | 50 | 5 | 32 | 9 | 4 | clay |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | total N (%) |
|---|---|---|---|---|---|---|---|
| 0 - 20 | n.d. | 4.4 | 1.48 | 7 | n.d. | n.d. | 0.07 |
| 20 - 40 | n.d. | 4.2 | 0.94 | 3 | n.d. | n.d. | 0.05 |
| 40 - 60 | n.d. | 4.2 | n.d. | n.d. | n.d. | n.d. | n.d. |
| 60 - 90 | n.d. | 4.3 | n.d. | n.d. | n.d. | n.d. | n.d. |

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq/100 g clay) | | (%) | |
| 0 - 20 | 0.60 | 0.40 | 0.28 | 0.04 | n.d. | 10.0 | 27 | n.d. | 13 | n.d. |
| 20 - 40 | 0.20 | 0.10 | 0.14 | 0.04 | n.d. | 6.4 | 13 | n.d. | 7 | n.d. |
| 40 - 60 | 0.20 | 0.05 | 0.12 | 0.04 | n.d. | 5.8 | 12 | n.d. | 7 | n.d. |
| 60 - 90 | 0.10 | 0.10 | 0.14 | 0.04 | n.d. | 4.2 | 8 | n.d. | 6 | n.d. |

---

Profile no.: NWP/27/77 (RRNWP 27/77)
Soil name : Misamfu series
Int. classification : rhodic ferralsol (FAO); tropeptic haplustox (USDA)
Soil map unit : 15
Date of description : 20-10-1977
Described by : P. Heilmann
Location : near Lwawu mission, Mwinilunga district, approx. UTM grid JT 8212 (sheet SC 35-13)
Landform : plateau, slope 0 - 3%
Vegetation : open woodland with many bamboos
Anthills : many large mound type
Climate : tropical savannah with an unimodal rainfall of circa 1350 mm/year
Parent material : basic igneous rock and Kalahari sand
Soil depth : very deep

profile NWP/27/77 continued

| | |
|---|---|
| Drainage : | well drained |
| Permeability : | moderately rapid |
| LUB code : | 1 C C C E / A - - (5 to 2.5YR 4/6) |
| Land capability class : | C1 (LUB), 3 |
| Remarks : | description based on augering only. |

BRIEF PROFILE DESCRIPTION

| | | |
|---|---|---|
| A | 0 - 20 cm | reddish brown (5YR 4/4, moist) sandy clay loam with a weak structure; friable (moist), sticky and slightly plastic (wet) |
| AB | 20 - 40 cm | reddish brown (5 to 2.5YR 4/4, moist) sandy clay loam with a weak structure; porous; friable (moist), sticky and slightly plastic (wet); transition very gradual |
| BA | 40 - 60 cm | yellowish red (5 to 2.5YR 4/6, moist) sandy clay loam ; structure and consistence as in AB; transition very gradual |
| Bws | 60 - 90 cm | dark red (2.5YR 3/8, moist) sandy clay with a weak to moderate structure; possibly some clay cutans; friable (moist); slightly sticky and plastic (wet) |

ANALYTICAL DATA — Profile no. NWP/27/77

Particle size distribution (%)

| Depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 20 | 26 | 8 | 51 | 14 | 1 | sandy clay loam |
| 20 - 40 | 32 | 7 | 51 | 8 | 2 | sandy clay loam |
| 40 - 60 | 32 | 10 | 46 | 9 | 3 | sandy clay loam |
| 60 - 90 | 36 | 18 | 36 | 9 | 1 | sandy clay |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | total N (%) |
|---|---|---|---|---|---|---|---|
| 0 - 20 | n.d. | 4.2 | 0.94 | 7 | n.d. | n.d. | 0.04 |
| 20 - 40 | n.d. | 4.1 | 1.13 | 6 | n.d. | n.d. | n.d. |
| 40 - 60 | n.d. | 4.1 | n.d. | n.d. | n.d. | n.d. | n.d. |
| 60 - 90 | n.d. | 4.1 | n.d. | n.d. | n.d. | n.d. | n.d. |

profile NWP/27/77 continued

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (---------- meq/100 g soil | | | | | ---------) | (meq / 100 g clay) | | (---- % | ---) |
| 0 - 20 | 0.60 | 0.65 | 0.16 | 0.00 | n.d. | 4.3 | 17 | n.d. | 33 | n.d. |
| 20 - 40 | 0.35 | 0.30 | 0.06 | 0.00 | n.d. | 5.6 | 18 | n.d. | 13 | n.d. |
| 40 - 60 | 0.40 | 0.30 | 0.04 | 0.04 | n.d. | 4.7 | 15 | n.d. | 17 | n.d. |
| 60 - 90 | 0.40 | 0.30 | 0.02 | 0.04 | n.d. | 3.9 | 11 | n.d. | 19 | n.d. |

---

Profile no.: NWP/42/77 (RRNWP 42/77)

Soil name : Ndakale series

Int. classification : xanthic ferralsol (FAO); typic haplustox (USDA)

Soil map unit : 22

Date of description : 3-11-1977

Described by : P. Heilmann

Location : along road from Mwinilunga to Kakoma, approx. UTM grid KT 2131 (sheet SC 35-13)

Landform : plateau

Vegetation : open woodland

Climate : tropical savannah with an unimodal rainfall of circa 1350 mm/year

Parent material : Kalahari sand

Soil depth : very deep

Drainage : excessively drained

Permeability : very rapid

LUB code : 1 X X X B / A - - (10YR 5/4)

Land capability class : S2t (LUB); 4

Remarks : description based on augering only

BRIEF PROFILE DESCRIPTION

A 0 - 20 cm dark grayish brown (10YR 4/2, moist) loamy sand; loose (dry)

BA 20 - 40 cm pale brown (10YR 6/3, moist) loamy sand; loose (dry); very porous%

Bw 40 - 90 cm light yellowish brown (10YR 5½/4, moist) loamy fine sand grading into fine sandy loam; no macro structure

ANALYTICAL DATA  Profile no. NWP/42/77

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 20 | 9 | 7 | 49 | 31 | 4 | loamy sand |
| 20 - 40 | 11 | 7 | 49 | 29 | 4 | loamy sand |
| 40 - 60 | 12 | 5 | 53 | 28 | 2 | loamy fine sand |
| 60 - 90 | 14 | 6 | 55 | 23 | 2 | fine sandy loam |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) | total N (%) |
|---|---|---|---|---|---|---|---|
| 0 - 20 | n.d. | 4.4 | 0.90 | 16 | n.d. | n.d. | 0.07 |
| 20 - 40 | n.d. | 4.3 | 0.50 | 5 | n.d. | n.d. | 0.04 |
| 40 - 60 | n.d. | 4.4 | n.d. | n.d. | n.d. | n.d. | n.d. |
| 60 - 90 | n.d. | 4.6 | n.d. | n.d. | n.d. | n.d. | n.d. |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 20 | 0.45 | 0.25 | 0.04 | 0.04 | n.d. | 2.0 | 22 | n.d. | 39 | n.d. |
| 20 - 40 | 0.10 | 0.10 | 0.03 | 0.04 | n.d. | 2.2 | 20 | n.d. | 12 | n.d. |
| 40 - 60 | 0.10 | 0.10 | 0.02 | 0.04 | n.d. | 2.0 | 17 | n.d. | 13 | n.d. |
| 60 - 90 | 0.10 | 0.30 | 0.02 | 0.04 | n.d. | 2.0 | 14 | n.d. | 23 | n.d. |

Profile no.: NWP/2/82

Soil name : Kado series

Int. classification : gleyic cambisol (FAO); aquic ustochrept (USDA)

Soil map unit : 19

Date of description : 9-2-1982

Described by : J.F. Broekhuis and Wen Ting-tiang

Location : Kisalala area, Solwezi district, UTM grid MS 445334 (sheet 1226A4)

Elevation : about 1300 m a.s.l.

Landform : gently undulating plateau, slightly dissected, lower slope, with dambo like features; slope 1-3%

Vegetation and land use : tree savannah with a sparse tree cover consisting mainly of Combretum and Uapaca nitida species, with Hypperrhenia grasses in between

Climate : tropical savannah with an unimodal rainfall of cirça 1300 mm/year

Parent material : colluvial deposit derived from upland soil formed over granitic gneiss

Soil depth : the depth varies from moderately shallow (25 cm) to deep, occassionally very deep

Drainage : imperfectly drained

Permeability : rapid in upper 40 cm, moderate in lower part of soil

Moisture state : moist throughout (after rains)

Groundwater : not reached

Surface stones : nil

Rock outcrops : nil

Erosion : sheet erosion is likely to occur

LUB code : $\frac{\text{1 B C C C}}{\text{A E1 W2 (10YR 7/3)}}$

Land capability class : S3w (LUB); 4

Remarks : no cutans have been observed

PROFILE DESCRIPTION

| | | |
|---|---|---|
| A | 0 - 10 cm | dark grayish brown (10YR 4/2, moist) sandy loam with a weak medium crumb structure; friable (moist); many very fine, fine and medium, common coarse inped and exped pores; many fine and few medium roots; transition smooth and clear |
| AB | 10 - 23 cm | grayish brown (10YR 5/2, moist) fine sandy loam with a weak medium subangular blocky structure; weak rusty root channels; very friable (moist); many very fine and fine, common medium and few coarse mostly inped pores; common fine and few medium roots; transition smooth and clear |

| | | |
|---|---|---|
| BA | 23 - 40 cm | very pale brown (10YR 7/3, moist) sandy clay loam with a weak medium subangular blocky structure; friable (moist) common very fine and fine, few medium inped pores; few fine, medium and coarse roots; transition smooth and gradual |
| Bw1 | 40 - 73 cm | very pale brown (10YR to 2.5Y 7/3, moist) sandy clay loam with a massive porous, moderately coherent structure; few fine distinct bright yellowish red (5YR 5/8, moist) mottles; friable (moist); common very fine and fine pores; few fine, medium and coarse roots; transition smooth & clear |
| Bw2 | 73 - 88 cm | pale yellow (2.5Y 7/4, moist) sandy clay loam with a massive porous, moderately coherent structure; friable (moist); few small soft reddish brown Fe/Mn concretions; very few fine, medium and coarse roots; few very fine and common medium pores; transition smooth and clear |
| Bw3 | 88 - 110 cm | pale yellow (2.5Y 8/3, moist) sandy clay loam with a massive porous, strongly coherent structure; friable (moist); frequent small and large hard reddish brown Fe/Mn concretions, with a soft mottle like rim; few very fine and common fine pores; very few fine roots; transition smooth and clear |
| Cg | 110 - 125 cm | light gray (2.5Y 7/2, moist) sandy clay loam with a massive porous, strongly coherent structure; firm (moist); few small and large hard reddish brown Fe/Mn concretions, with a soft mottle like rim; few very fine and fine pores; transition wavy and abrupt |
| Csm | 125+ cm | strongly cemented ironstone |

ANALYTICAL DATA — Profile no. MWP/2/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 10 - 23 | 18 | 11 | 51 | 14 | 6 | fine sandy loam |
| 23 - 40 | 24 | 12 | 44 | 17 | 3 | sandy clay loam |
| 40 - 73 | 32 | 14 | 41 | 10 | 3 | sandy clay loam |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 10 - 23 | 4.4 | 4.2 | n.d. | n.d. | n.d. | n.d. |
| 23 - 40 | 5.1 | 4.2 | n.d. | n.d. | n.d. | n.d. |
| 40 - 73 | 5.1 | 4.3 | n.d. | n.d. | n.d. | n.d. |

| depth (cm) | exch. Ca (meq/100 g soil) | exch. Mg (meq/100 g soil) | exch. K (meq/100 g soil) | exch. Na (meq/100 g soil) | exch. Al (meq/100 g soil) | CEC (meq/100 g soil) | CEC (meq/100 g clay) | ECEC (meq/100 g clay) | base sat. (%) | Al sat. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 - 23 | 0.01 | 0.01 | 0.02 | 0.01 | n.d. | 2.2 | 12 | n.d. | 2 | n.d. |
| 23 - 40 | 0.01 | 0.04 | 0.01 | 0.01 | n.d. | 2.2 | 9 | n.d. | 3 | n.d. |
| 40 - 73 | 0.01 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |

| | |
|---|---|
| Profile no. : | NW/3/82 |
| Soil name : | Chifwesa seies |
| Int. classification : | xanthic ferralsol (FAO); ultic haplustox (USDA) |
| Soil map unit : | 35 |
| Date of description : | 10-2-1982 |
| Described by : | Wen Ting-tiang and J.F. Broekhuis |
| Location : | Kisalala area, Solwezi district, UTM grid MS 437290 (sheet 1226A4) |
| Elevation : | about 1300 m a.s.l. |
| Landform : | gently undulating plateau, slightly dissected, middle slope, slope 1 - 3% |
| Vegetation and land use : | miombo woodland with Brachystegia boehmii as dominant species, the area is largely uninhibited |
| Climate : | tropical savannah with an unimodal rainfall of circa 1300 mm/year |
| Parent material : | gneiss |
| Soil depth : | very deep |
| Drainage : | well drained |
| Permeability : | rapid, but Bt1 moderately rapid |
| Moisture state : | moist throughout (after rains) |
| Groundwater : | not reached |
| Surface stones : | nil |
| Rock outcrops : | nil |
| Erosion : | no visible evidence |
| LUB code : | 1 B C C C / A - - (7.5YR 5/6) |
| Land capability class : | S1 (LUB); 3 |
| Remarks : | - 0 - 200 cm pit, augering below<br>- similar profiles with a predominantly sandy clay texture occur as well<br>- the depth of the laterite varies from 150 to 250 cm<br>- firld texture subsoil (BA, Bt1 and Bt2) is sandy clay loam |

PROFILE DESCRIPTION

| | | |
|---|---|---|
| Ah | 0 - 7 cm | very dark gray (10YR 3/1, moist and 10YR 5/2, dry) fine sandy loam with a weak medium subangular blocky structure; friable (moist); many very fine, fine and medium, common coarse inped and exped pores; many fine and common medium roots; transition smooth and clear |
| AB | 7 - 30 cm | dark brown (7.5 to 10YR 4/4, moist and 7.5 to 10YR 6/3, dry) sandy clay loam with a weak medium subangular blocky structure; friable (moist); many very fine and fine, common medium and few coarse inped pores; many fine, common medium and few coarse roots; transition smooth and gradual |

| | | |
|---|---|---|
| BA | 30 - 55 cm | strong brown (7.5YR 5/6, moist) sandy clay with a massive porous, moderately coherent structure; firm (moist); few white (10YR 8/1, moist) mostly faint colourations, roundish (up to 1.5 cm) in cross section and mostly a few cm long (infillings of root channels and/or animal burrows); few yellowish red (5YR 5/8, moist) fine faint mottles; many very fine, common fine and few medium and coarse pores; few fine, medium and coarse roots; transition smooth and diffuse |
| Bt1 | 55 - 145 cm | reddish yellow (7.5YR 6/8, moist) clay with a massive porous, moderately coherent structure, firm (moist); white colourations as in BA; many very fine, common fine and few medium pores; few fine, medium and coarse roots, transition smooth and diffuse |
| Bt2 | 145 - 215 cm | reddish yellow (7.5YR 6/7, moist) clay (slightly lighter than Bt1) with a massive porous, moderately coherent structure; firm (moist); few fine distinct white (N 8.5/0, moist) mottles with a relatively sandy texture; pores as in Bt1; few fine roots |
| Bw | 215 - 250 cm | yellow (10YR 7/6, moist) clay with few fine distinct white (N 8.5/0, moist) relatively sandy mottles in upper part of the horizon, firm (moist); plastic and slightly sticky (wet) |
| Bms | 250+ cm | strongly cemented ironstone |

ANALYTICAL DATA — Profile no. NMP/3/82

Particle size distribution (%)

| depth (cm) | clay | silt | fine sand | medium sand | coarse sand | textural class |
|---|---|---|---|---|---|---|
| 0 - 7 | 13 | 11 | 56 | 18 | 2 | fine sandy loam |
| 7 - 30 | 24 | 14 | 44 | 16 | 2 | sandy clay loam |
| 30 - 55 | 39 | 11 | 38 | 10 | 2 | sandy clay |
| 55 - 105 | 47 | 11 | 31 | 9 | 2 | clay |
| 105 - 145 | 45 | 13 | 34 | 7 | 1 | clay |
| 145 - 200 | 43 | 12 | 37 | 7 | 1 | clay to sandy clay |
| 200 - 250 | 47 | 16 | 30 | 5 | 2 | clay |

Chemical data

| depth (cm) | pH ($H_2O$) | pH ($CaCl_2$) | org. C (%) | avail. P (ppm) | sol. Al (ppm) | sol. Mn (ppm) |
|---|---|---|---|---|---|---|
| 0 - 7 | 6.3 | 5.6 | 1.58 | 15 | n.d. | n.d. |
| 7 - 30 | 5.3 | 4.7 | 0.39 | 5 | n.d. | n.d. |
| 30 - 55 | 5.3 | 4.4 | 0.21 | 3 | n.d. | n.d. |
| 55 - 105 | 5.0 | 4.4 | 0.05 | 2 | n.d. | n.d. |
| 105 - 145 | 5.2 | 4.3 | n.d. | 1 | n.d. | n.d. |
| 145 - 200 | 4.9 | 4.3 | n.d. | 2 | n.d. | n.d. |
| 200 - 250 | 5.2 | 4.3 | n.d. | 2 | n.d. | n.d. |

Profile NWP/3/82 continued

| depth (cm) | exch. Ca | exch. Mg | exch. K | exch. Na | exch. Al | CEC | CEC | ECEC | base sat. | Al sat. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (meq/100 g soil) | | | | | | (meq / 100 g clay) | | (%) | |
| 0 - 7 | 0.18 | 0.21 | 0.17 | 0.03 | n.d. | 3.5 | 27 | n.d. | 17 | n.d. |
| 7 - 30 | 0.11 | 0.58 | 0.18 | 0.01 | n.d. | 3.7 | 15 | n.d. | 24 | n.d. |
| 30 - 55 | 0.10 | 0.41 | 0.15 | 0.03 | n.d. | 4.3 | 11 | n.d. | 16 | n.d. |
| 55 - 105 | 0.10 | 0.25 | 0.08 | 0.01 | n.d. | 4.6 | 10 | n.d. | 10 | n.d. |
| 105 - 145 | 0.10 | 0.58 | 0.07 | 0.02 | n.d. | 8.3 | 18 | n.d. | 9 | n.d. |
| 145 - 200 | 0.11 | 0.66 | 0.07 | 0.02 | n.d. | 3.9 | 9 | n.d. | 22 | n.d. |
| 200 - 250 | 0.28 | 0.41 | 0.15 | 0.01 | n.d. | 6.1 | 13 | n.d. | 14 | n.d. |

## APPENDIX IV Laboratory numbers of profile pits

All the laboratory numbers belonging to the samples from which data have been used in this report are given below. Except where indicated otherwise, all the samples were analyzed in 1982.

NWP/ADP/2/82

0- 6 2875
10- 20 2876
40- 50 2877
70- 80 2878
100-110 2879
130-140 2880
160-170 2881

NWP/ADP/3/82

0- 5 3363
5- 25 3364
25- 60 3365
60- 90 3366
90-135 3367
135-180 3368

NWP/ADP/4/82

0- 6 3369
6- 20 3370
20- 60 3371
60-110 3372
110-160 3373
160-200 3374

NWP/ADP/5/82

20- 60 3375
60- 90 3376
90-165 3377

NWP/ADP/7/82

0- 6 3384
6- 30 3385
30- 69 3386
69-130 3387
130-190 3388

NWP/ADP/8/82

0- 10 3389
10- 37 3390
37- 76 3391
76-106 3392
106-190 3393

NWP/ADP/10/82

0- 15 3399
15- 35 3400
35- 55 3401
55-100 3402
130-150 3403

NWP/ADP/11/82

0- 11 3404
11- 26 3405
26- 82 3406
82-123 3407
123-190 3408

NWP/ADP/12/82

0- 10 3409
10- 30 3410
30- 60 3411
60- 85 3412
85-115 3413
115-165 3414
165-190 3415

NWP/ADP/15/82

0- 9 3426
9- 17 3427
17- 31 3428
31-100 3429
100-155 3430

NWP/ADP/16/82

0- 5 3431
5- 25 3432
25- 55 3433
55-100 3434
100-150 3435
150-170 3436

NWP/ADP/19/82

0- 10 3491
10- 25 3492
25- 40 3493
40-100 3494
100-150 3495
150-200 3496

NWP/ADP/20/82

0- 6 3497
6- 20 3498
20- 62 3499
62-110 3500
110-150 3501
150-200 3502

NWP/ADP/22/82

0- 7 3861
7- 15 3862
15- 58 3863
58- 78 3864
78-130 3465

NWP/ADP/23/82

0- 11 3866
11- 73 3867
73-110 3868
110-155 3869
155-165 3870

NWP/ADP/25/82

0- 5 3845
5- 18 3846
18- 32 3847
32- 53 3848
53-100 3849
100-160 3850

NWP/ADP/26/82

0- 8 3851
88- 22 3852
22- 50 3853
50-100 3854
100-150 3855

NWP/ADP/27/82

0- 15 3871
15- 35 3872
35- 70 3873
70-125 3874
125-180 3875

NWP/ADP/28/82

0- 10 3876
10- 22 3877
22- 34 3878
34- 90 3879

NWP/ADP/29/82

0- 12 3880
12- 45 3881
45- 70 3882
70-120 3883

NWP/ADP/30/82

0- 10 3884
10- 30 3885
30-880 3886

| NWP/ADP/31/82 | |
|---|---|
| 0- 10 | 3887 |
| 10- 20 | 3888 |
| 20- 45 | 3889 |
| 45- 75 | 3890 |
| 75-125 | 3891 |
| 125-175 | 3892 |

| NWP/ADP/32/82 | |
|---|---|
| 0- 9 | 4192 |
| 9- 35 | 4193 |
| 35-100 | 4194 |
| 100-150 | 4195 |
| 150-170 | 4196 |

| NWP/ADP/33/82 | |
|---|---|
| 0- 10 | 3856 |
| 10- 45 | 3857 |
| 45-100 | 3858 |
| 100-150 | 3859 |

| NWP/ADP/34/82 | |
|---|---|
| 0- 15 | 4196 |
| 15- 30 | 4197 |
| 30- 80 | 4198 |
| 80-130 | 4199 |

| NWP/ADP/37/82 | |
|---|---|
| 0- 10 | 4390 |
| 10- 26 | 4391 |
| 26- 75 | 4392 |
| 75-149 | 4393 |
| 149-186 | 4394 |

| NWP/ADP/38/82 | |
|---|---|
| 0- 24 | 4395 |
| 24- 38 | 4396 |
| 38- 60 | 4397 |
| 60- 90 | 4398 |
| 90-120 | 4399 |

| NWP/ADP/39/82 | |
|---|---|
| 0- 12 | 4370 |
| 12- 30 | 4371 |
| 30- 73 | 4372 |
| 73-125 | 4373 |
| 125-160 | 4374 |
| 230-280 | 4375 |

| NWP/ADP/40/82 | |
|---|---|
| 0- 24 | 4400 |
| 24- 37 | 4401 |
| 37- 85 | 4402 |
| 85-100 | 4403 |
| 100-130 | 4404 |

| NWP/ADP/42/82 | |
|---|---|
| 0- 10 | 4405 |
| 10- 35 | 4406 |
| 35- 62 | 4407 |
| 62-116 | 4408 |
| 116-160 | 4409 |

| NWP/ADP/43/82 | |
|---|---|
| 0- 8 | 4410 |
| 8- 34 | 4411 |
| 34- 55 | 4412 |
| 55- 95 | 4413 |
| 95-135 | 4414 |

| NWP/ADP/46/82 | |
|---|---|
| 0- 11 | 83/1164 |
| 11- 25 | 83/1165 |
| 25- 41 | 83/1166 |
| 41- 71 | 83/1167 |
| 71-120 | 83/1397 |
| 120-185 | 83/1398 |

| NWP/ADP/47/82 | |
|---|---|
| 0- 13 | 4380 |
| 13- 38 | 4381 |
| 38- 68 | 4382 |
| 68-105 | 4383 |
| 105-150 | 4384 |
| 150-200 | 4385 |

| NWP/ADP/51/82 | |
|---|---|
| 0- 30 | 83/632 |
| 30- 60 | 83/633 |
| 60- 90 | 83/634 |
| 90-115 | 83/635 |

| NWP/15/77 | |
|---|---|
| 0- 20 | 77/5279 |
| 20- 40 | 77/5280 |
| 40- 60 | 77/5281 |
| 60- 90 | 77/5282 |

| NWP/27/77 | |
|---|---|
| 0- 20 | 77/4218 |
| 20- 40 | 77/4219 |
| 40- 60 | 77/4220 |
| 60- 90 | 77/4221 |

| NWP/42/77 | |
|---|---|
| 0- 20 | 77/5291 |
| 20- 40 | 77/5292 |
| 40- 60 | 77/5293 |
| 60- 90 | 77/5294 |

| NWP/2/82 | |
|---|---|
| 10- 23 | 82/712 |
| 23- 40 | 82/713 |
| 40- 73 | 82/714 |

| NWP/3/82 | |
|---|---|
| 0- 7 | 82/715 |
| 7- 30 | 82/716 |
| 30-55 | 82/717 |
| 55-105 | 82/718 |
| 105-145 | 82/719 |
| 145-200 | 82/720 |
| 200-250 | 82/721 |

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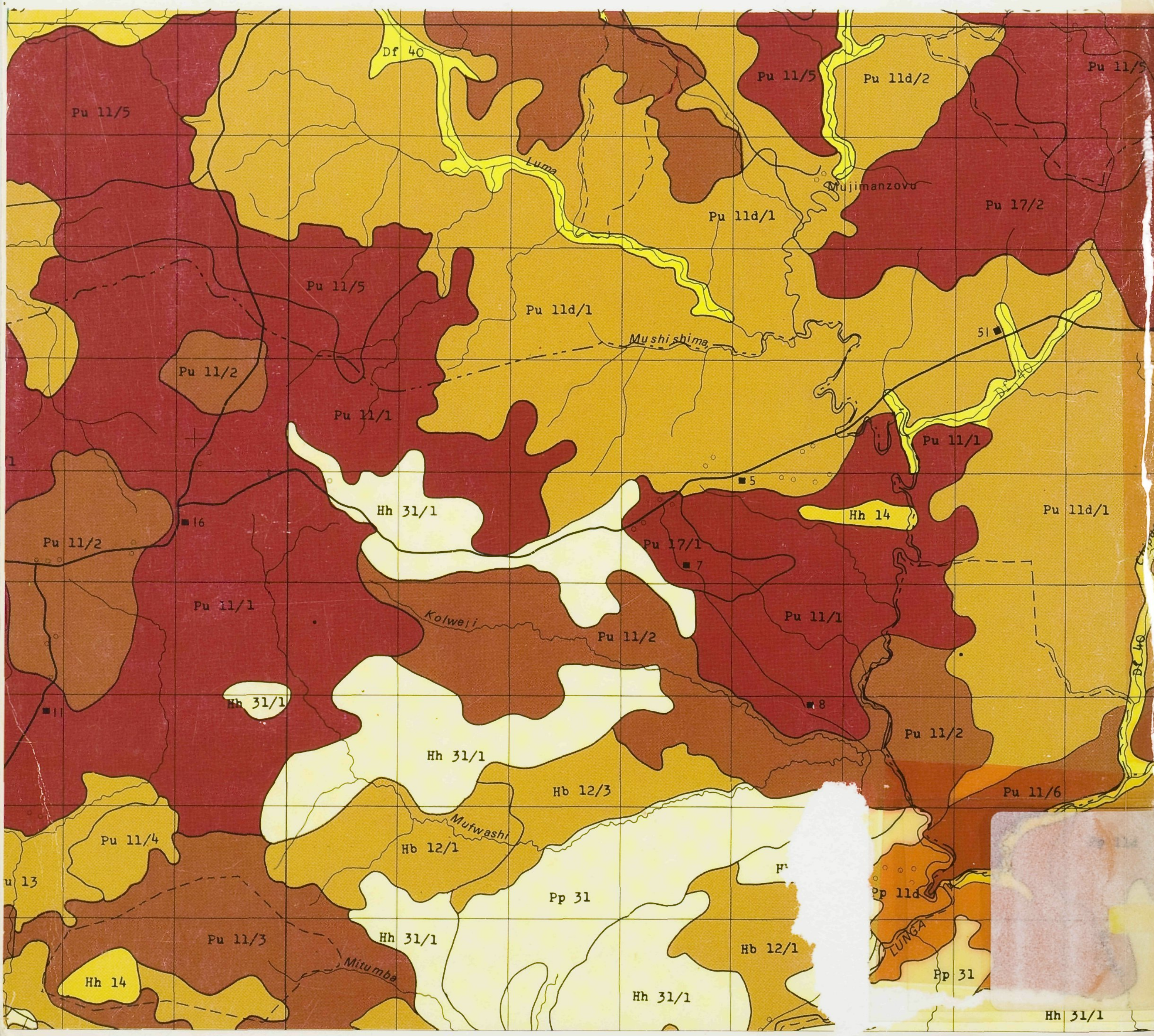
The map overleaf shows land capability for the area around Kawana, north of the Kasempa District Headquarters in the North-Western Province of Zambia. Land with highest potential is shown in a red-brown colour and land with lowest potential is shown in pale yellow. The map was compiled using soils information based in part on satellite data.

Scale: 1:500,000

Produced by the
Regional Remote Sensing Facility, Nairobi, Kenya



Df 40
Pu 11/5
Pu 11/5
Pu 11d/2
Pu 11/5
Luma
Mujimanzovu
Pu 11d/1
Pu 17/2
Pu 11/5
Pu 11d/1
Mushishima
51
Df 40
Pu 11/2
Pu 11/1
Pu 11/1
5
Hh 31/1
16
Hh 14
Pu 11d/1
Pu 11/2
Pu 17/1
7
Pu 11/1
Pu 11/1
Pu 11/2
Hh 31/1
8
11
Pu 11/2
Df 40
Hh 31/1
Hb 12/3
Pu 11/6
Pu 11/4
Mufwashi
Hb 12/1
Pp 31
Pp 11d
Pu 11/3
Hh 31/1
Mitumba
Hb 12/1
LUNGA
Hh 14
Hh 31/1
Pp 31
Hh 31/1